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ANION EXCHANGE RESIN

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## ABSTRACT

Tri-n-butyl phosphate (TBP) diluted with a suitable diluent is commonly used for solvent extraction in Purex process for the recovery of uranium and plutonium from irradiated nuclear fuels. This solvent gets degraded due to various factors, the main degradation product being dibutyl phosphoric acid (HDBP). A solvent cleanup step is generally incorporated in the process for removing the degradation products from the used solvent. A liquid-liquid cleanup system using sodium carbonate or sodium hydroxide solution is routinely used. Considering certain advantages, like the possibility of loading the resin almost to saturation capacity and the subsequent disposal of the spent resin by incineration and the feasibility of adopting it to the process, a liquid-solid system has been tried as an alternate method, employing various available macroreticular anion exchange resins in OH- form for the sorption of HDBP from TBP. After standardizing the various conditions for the satisfactory removal of HDBP from TBP using synthetic mixtures, resins were tested with process solvent in batch contacts. The parameters studied were (1) capacity of different resins for HDBP sorption (2) influence of acidity, uranium and HDBP on the sorption behaviour of the latter (3) removal of fission products from the solvent by the resin and (4) regeneration and recycling of the resin.

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Descriptors

FUEL REPROCESSING

PUREX PROCESS

TRI-n-BUTYL PHOSPHATE (TBP)

DIBUTYL PHOSPHORIC ACID (HDBP)

MACRORETICULAR ANION EXCHANGE

SOLVENT CLEANUP

PURIFICATION OF DEGRADED TBP SOLVENT USING MACRORETICULAR  
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1. INTRODUCTION

Tri-n-butyl phosphate (TBP) diluted with shell-sol-T or n-dodecane is used as extractant in Purex process for the reprocessing of irradiated fuels. The intense radiation field encountered at various stages of reprocessing degrades both TBP as well as the diluent. The degradation is further enhanced by the presence of nitrous acid and nitric acid used in the process. Utilization of high temperatures in the extraction process also contributes to the generation of degradation products.

The adverse effects of these degradation products on the overall performance of the process are given in various publications (1-8). If the solvent is to be recycled, it is necessary to reduce the concentration levels of these degradation products. Normally, for this purpose, the solvent is given a treatment with sodium carbonate solution. While this method is effective, it has the following major disadvantages.

1. It generates large quantities of active aqueous waste.
2. It is not fully effective in removing all the contaminants from the degraded solvent.(9)

3. It is difficult to achieve a good phase separation during sodium carbonate treatment. Due to this, when the treated solvent undergoes acid scrubbing, a portion of the degradation products get extracted back into the solvent from the entrained aqueous phase.

To overcome some of these disadvantages, liquid-solid solvent cleanup systems using a variety of solid sorbents have been proposed and these have been discussed by Healy (10). Wallace Schultz (11,12) had studied the use of Amberlyst A-26, a strong base macroreticular anion exchanger, for the purification of used solvents from fuel reprocessing plant. He found that Amberlyst A-26 removes traces of fission products, dibutyl phosphoric acid (HDBP) and diluent degradation products from used solvents. Novak (13) had reported similar studies using the same resin. Even though, Schultz had studied extensively the sorption of fission products like Zr<sup>95</sup>-Nb<sup>95</sup> and Ru<sup>106</sup>-Rh<sup>106</sup>, no data is given on the sorption of HDBP and uranium. In the latter work, the entire data is collected using synthetic solutions.

In the present study, which was prompted by the encouraging results obtained by the above authors, an effort has been made to assess the performance of Amberlyst A-26 resin for the removal of HDBP from the actual Purex plant solvents, for its possible application in a batchwise solvent cleanup step in the process. Further, the performance of a few other resins, both of imported as well as of indigenous origin has been checked and compared with A-26 for their suitability to this task.



## 2. EXPERIMENTAL

### 2.1 MATERIALS

#### 2.1.1 Ion Exchange Resins

A list of the anion exchange resins used with the relevant details are given in Table 1. Exchange capacities of these resins were determined under comparable conditions using standard procedures and these values are included in the same Table.

The resin in (as received)  $\text{Cl}^-$  form was converted to  $\text{OH}^-$  form by treatment with sodium hydroxide solution. About 250 gms. of the resin in  $\text{Cl}^-$  form was taken in a separating funnel and converted to  $\text{OH}^-$  form by passing 1M NaOH. Then the resin was washed free of  $\text{OH}^-$  by distilled water and left for air-drying. This air-dried resin was used for sorption experiment.

#### 2.1.2 TBP in Dodecane

TBP (Fluka AG) and n-dodecane (Fluka AG) were used as received. A solution of 30% V/V of TBP in dodecane was used as solvent.

#### 2.1.3 Dibutylphosphoric Acid (HDBP) in Benzene

The commercially available HDBP (Fluka AG) was diluted with benzene and washed with 1M HCl to remove monobutylphosphoric acid. Then the HDBP was stripped by 2% sodium carbonate solution. This aqueous layer was acidified and the HDBP was extracted into fresh benzene phase from acid medium. The HDBP was estimated by titration with NaOH.

#### 2.1.4 Preparation of HDBP in 30% TBP/dodecane

250 ml of 0.1M HDBP in benzene was stripped thrice with 2% sodium carbonate solution (100 ml, 100 ml and 50 ml lots of

sodium carbonate solution was used). The aqueous phase from each of the steps was collected, mixed together, acidified by the addition of 40 ml of concentrated hydrochloric acid and extracted into 30% TBP/dodecane (100ml+100ml+50ml).

#### 2.1.5 Degraded Purex Process Solvent

The degraded process solvent was withdrawn from the appropriate stream of the plant from time to time, depending on the experimental requirements. The solution was left undisturbed for 3-4 days for settling of the suspended impurities, if any.

The required volume of the above solution was shaken with water at 1:1 volume ratio. The aqueous phase was discarded and the water-washed solvent was left undisturbed for one day to allow for the separation of traces of water. The clear organic phase was taken for ion exchange sorption experiments. In few experiments, sodium carbonate washed process solvent was used to study the feasibility of using the ion exchange procedure for final purification of the alkali treated solvent.

### 2.2 ANALYTICAL METHODS

#### 2.2.1 Analysis of Dibutyl Phosphoric Acid

##### (a) Titrimetric Procedure

5 ml of the 30% TBP solution containing HDBP was stripped with 2% sodium carbonate solution (5ml+5ml+5ml lots of sodium carbonate). The aqueous phase from each of the steps was collected and was given a scrub with benzene. The aqueous phase was acidified by the addition of 4 ml of concentrated hydrochloric acid and the HDBP was extracted into benzene (5ml+5ml+5ml lots of benzene). The centrifuged benzene phase from all the three contacts was collected together and HDBP wa

estimated by titrating with standard sodium hydroxide solution in alcohol medium using methyl red and bromocresol green as indicators.

Samples containing appreciable quantity of uranium were washed with 1 M sulphuric acid and then HDBP was analysed by the above procedure. Samples containing very low concentrations of HDBP were analysed by starting with 25 ml or 50 ml of the sample and proceeding with the same method as described above after minor modifications.

#### (b) Spectrophotometric Procedure

Samples containing very low concentrations of HDBP were analysed by converting the separated HDBP into inorganic phosphate by repeated fuming with perchloric acid and estimating the resultant phosphate by ammonium molybdovanadate method.

#### 2.2.2 Analysis of Other Components

Uranium was analysed by alcoholic thiocyanate method.

Acidity of the solution was estimated by complexing uranium with pre-neutralised potassium oxalate and then titrating the free acid with standard sodium hydroxide to potentiometric end point.

The fission product assay was carried out by gamma spectrometry using a high purity germanium detector connected to 4K multi channel analyser.

### 2.3 ION EXCHANGE STUDIES

#### 2.3.1 Column Experiments for Capacity Determination

Glass burette of 10 ml capacity was used as column. 1.0 g of each resin was filled in the burette. Initially, the column

was conditioned with methanol (4 bed volume) and then with benzene (4 bed volume). DBP in benzene was passed through the column at a uniform flow rate of 4 bed volume per hour. The effluent was collected in 5 ml volumetric flasks and the concentration of HDBP was estimated. The column was loaded to almost 100 % breakthrough capacity. Then it was washed with benzene (3-4 bed volume) to remove unadsorbed and trapped feed solution.

Finally, the DBP loaded on the column was eluted with 4 N NaOH solution. The eluted product solution was acidified and HDBP was extracted into benzene for its estimation.

Similar experiments were carried out by using HDBP in 30 % TBP/dodecane as the feed solution.

### 2.3.2 Batch Equilibration Experiments for Capacity Determination

#### (a) HDBP Sorption from Synthetic Mixture of TBP and HDBP

To determine the capacity of the resin under batch equilibrium conditions, appropriate volume of the process solvent, usually 50 ml, was shaken with weighed amount of air-dried resin in conical flask for 4 hours on a mechanical shaker having horizontal to and fro motion. The organic phase before and after equilibration was analysed for the relevant components using the methods given in 2.2.

To study the effect of uranium on the sorption of HDBP by resin, 10 g/l of uranium was extracted into 30% TBP containing 2 g/l of HDBP. The uranium bearing organic phase was stripped twice with equal volumes of 0.01 N nitric acid. 50 ml of the resultant organic phase was equilibrated with 1 g of air-dried

resin.

To study the effect of acidity on the sorption of HDBP by resin, the uranium loaded organic phase obtained as above was stripped twice with 0.01N nitric acid and the resultant organic phase was equilibrated with 2N nitric acid in one case and 4N nitric acid in the other. The acidity of the organic phase was estimated and 50 ml from each of the lots was taken and equilibrated with 1 g of air-dried resin.

(b) HDBP Sorption Studies Using Water-Washed Process Solvent

Most of these experiments were carried out in 50 ml batches. In a few experiments, 250 ml and 500 ml of the washed process solvent mentioned earlier was used. The batch equilibration experiments were conducted in a similar way as given in the case of synthetic solution.

In some equilibration experiments, resin pre-soaked in water was used which are indicated in appropriate Tables.

In some experiments, resins were used in repeated cycles to test their efficiency under such conditions. In these cases the resin used in one equilibration experiment was collected after filtration and was regenerated by washing with 2% sodium carbonate followed by 1 N NaOH and finally with water. These resins were used in subsequent experiments in water soaked condition only.

### 3 RESULTS AND DISCUSSION

#### 3.1 Loading Capacity from Column Experiments

The typical HDBP break-through curves for the column experiments conducted with resins using HDBP in benzene as feed

organic are given in Fig.1, as examples. The capacities of the respective resins as calculated from the elution data of the above experiments are given in Table 2. Similar data obtained with HDBP in 30% TBP are also included in Table 2.

To prepare the resin for use in non-aqueous systems, it is a general practice to pass methanol prior to conditioning with hydrocarbon or other solvent miscible with alcohol. An effort was made to see if methanol washing step can be avoided. The results obtained from the loading experiments in which water conditioned and methanol conditioned resins were used are presented in Fig 2. From the data, it can be seen that methanol conditioning of the resin is not necessary. The material balance values obtained using the data from these experiments are given in Table 3, from which it can be seen that the performance of these resins for the sorption of HDBP and its subsequent elution is very satisfactory.

### 3.2 Sorption Studies With Simulated Solutions

The results of the batch experiments on the sorption of HDBP in presence of uranium are given in Table 4. It can be seen that a satisfactory sorption of HDBP could be achieved even in the presence of 3g/l of uranium in the solution. From the data it is seen that uranium is also sorbed by the resin to a considerable extent. In the experimental results reported by Novak (13) a solution of 30 % TBP/dodecane having HDBP concentration of 0.076M (~16 g/l) and uranium concentration of 10 mg/l was used. Using this as the feed solution for column experiments, he found that HDBP was getting sorbed on the column in preference to uranium. The conclusions from the present work,

which are based on batch experiments, are somewhat different from those of Novak (13) Even at considerably high concentration of HDBP (~5 g/l), a good sorption of uranium is noticed, at lower acidities (Table 5).

It has been noticed that HDBP and uranium are present in almost the same concentration level in thoroughly water washed spent solvent from Process. This approximate 1 : 1 correspondence in mole ratio of HDBP and uranium in washed solvent has been used to assess the quality of the solvent (14). Thus, the solvent to be treated is generally expected to contain uranium and HDBP at comparable concentration levels and is to be taken into account while treating the solvent. From the data given in Table 4, it can be seen that the combined capacity due to uranium and HDBP does not exceed the total capacity of resin given in Table 2. Since the uranium species being sorbed by the resin are not known, much significance need not be attached to the combined capacity.

The results of the batch experiments to study the effect of the organic phase acidity on the sorption of HDBP are given in Table 5. It can be seen that the organic phase acidity has to be low for achieving good HDBP sorption. Even at an organic phase acidity of 0.3 M the sorption of HDBP gets reduced to as low as 11 % from about 98 % achievable at lower acidities. This effect is more pronounced in the case of uranium, as at 0.3 M acidity, there is practically no uptake of uranium by the resin. In the case of spent process solvents, to be treated by the resin, it passes through either a strip column for the removal of excess

uranium where very dilute acid/water is used as strip or an alkaline wash route. Under these circumstances the resultant organic phase acidity is expected to be very low.

### 3.3 Sorption Experiments with Process Solvent Samples

The performance of different ion exchangers for the removal of HDBP was studied with Purex process solvent. In these experiments, water-washed solvent was used. The results of the experiments conducted are given in Table 6. It can be seen that A-26 resin gives a satisfactory sorption of HDBP.

#### Sorption of HDBP

Studies on sorption of HDBP from process solvent of varying HDBP concentrations were carried out with A-26 resin in batch experiments. The results of these studies are given in Table 7. These results show the applicability of this method for sorbing HDBP present at various concentration levels in the solvent. Most of these experiments were conducted by treating the process solvent with air-dried resin in OH<sup>-</sup> form in the ratio of 1 litre of solution to 10 g of resin. When relatively higher concentrations of HDBP (approximately 5 g/l) are involved, the HDBP sorption is found to be poor. Subsequently, experiments were carried out by taking double the quantity of the resin (ie., 1000ml of solution/20 g of resin).

Under the organic to resin ratios (V/W) tested, it is seen that the quantity of the resin to be utilised for solvent treatment would vary depending on the concentration of HDBP in the feed solvent and the purity required in the treated solvent. In general, a maximum capacity of 0.5 meq HDBP per gram is observed under these conditions. If the organic to be treated has



an HDBP concentration of 2 g/l, then the quantity of the resin to be used should be so chosen that its exchange capacity does not exceed 0.5 meq/g for obtaining a treated solvent with less than 0.2 g/l HDBP. The presence of uranium in the organic phase would influence considerably this treatment step. Tables 6 and 7 also include the sorption values obtained for A-72 resin and the results indicate that the resin is slightly inferior to A-26 resin in its performance, with respect to the process solvents. A-161 is found to be much inferior to A-26 and A-72 resins in its performance as can be seen from the data in Table 6.

#### Sorption of Uranium

It was observed that when the uranium concentration was of the order of 2 to 3 g/l, the sorption of uranium on the resin followed similar pattern as observed in the case of batch experiments with simulated solution (vide Table 4). The data is presented in Tables 6 & 7.

The most important advantage reported (15) for solvent cleanup by ion exchange resins and other solid sorbents is the relatively efficient removal of fission products. The data on the sorption of fission products by A-26 resin from process solvent are shown in Table 8. It can be seen that removal of >95 % of Zr95 and Nb95 and about 85 % of Ru106 are possible provided extra amount of resin is used. Otherwise, lower levels of sorption may result.

#### 3.4 Resin Conditioning

From the present studies, it is observed that conditioning of resin prior to use plays an important role in the sorption of

HDBP by the resin. In the earlier work ( 11,12) the resin was conditioned with TBP/n-dodecane solution. The differences in resin capacities observed by pre-treating the resin with TBP/n-dodecane and water can be seen from the data given in Table 9. It is observed that pre-soaking of the resin in water leads to good sorption of HDBP. TBP conditioning of the resin is not required.

### 3.5 Experiments with reconditioned resins

From economic considerations, recycling of the resin for repeated operations was contemplated. Keeping this in view, the reconditioning procedures for the resin were standardised and reconditioned resin was recycled several times for solvent treatment. The used resin after reconditioning was employed for further sorption experiments. The results of these experiments are given in Table 10. It can be seen that one lot of A-26 resin can be reused upto 5 times without any appreciable decrease in its performance.

Table 8 also contains results on the sorption behaviour of fission products on a reconditioned resin. It is seen that the sorption of fission products by the wet reconditioned resin is substantially lower than those obtained with fresh air-dried resin. This behaviour is in contrast to that observed in the case of HDBP and uranium. The fission products are mainly bound by the degradation product of diluent and these are difficult to remove by alkali wash. Hence, their sorption by the resin in OH-form might be lowered by water which would hinder the direct contact between the resin and organic phase.

In the earlier studies, (12) the resin in organic medium has

been used mainly for the removal of fission products from degraded solvent. In the present studies, the emphasis has been on the removal of HDBP.

### 3.6 Experiments with Sodium Carbonate Treated Process Solvent

It is reported (16, 17) that the solid sorbents are better suited for the secondary clean up i.e. for removing the contaminants which are remaining in the solvent after sodium carbonate treatment. Hence, ion exchange sorption of HDBP and fission products from sodium carbonate treated process solvent was also studied. In this case, it would be possible to treat more solvent per gram of the resin from exchange capacity considerations. The results of these experiments, given in Table 11, indicate that even at such low concentration levels of HDBP and fission products, the solvent cleanup is effective with resins. It is found that the performance of A-26 and A-72 resins are comparable.

### 3.7 Behaviour of Gel Type Resin

The performance of two locally available gel-type anion resins (Tulsion A-33 and A-35) were tested for solvent clean up purpose and the results are given in Table 12. It can be seen that the sorption of HDBP and uranium is somewhat comparable to that achieved by macroreticular resins. However, the fission products sorption is found to be less. The results of the experiments where reconditioned resins were used are given in Table 13, which shows the extremely poor performance of these resins after one cycle of use. Hence no further tests were

carried out with gel-type resin. A detailed study would be required to find out a suitable technique for recycling these resins.

Similarly, the performance of a cation exchange resin (Dowex 50 W X 8) was tried. This was done mainly to see whether a good sorption of fission products is possible. The data in Table 12 indicates no significant uptake by the resin.

#### 4 CONCLUSIONS

The results of the present study demonstrate a practical application of these resins in the clean-up of spent solvents from a nuclear fuel reprocessing plant.

This work shows the satisfactory performance of Amberlyst A-26 resin even in recycling tests. For HDBP sorption, the performance of water-soaked resin is comparable with that of air-dried resin. Locally available A-72 resin can also serve the purpose, but with lesser efficiency. As the resin is used in OH-form, any acidic impurity would affect the solvent purification adversely. This problem can be solved by washing the solvent with water prior to ion exchange sorption. These resins can be used for further purification of the used solvent which has been treated with sodium carbonate solution.

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Table 1

## Details of Ion Exchange Resins Used

- A-26 : Amberlyst A-26, Macroreticular strong base anion exchanger  
Rohm and Hass Co. USA.
- A-72 : Tulsion A-72, Macroreticular strong base anion exchanger  
Thermax Pvt. Ltd., India.
- A-161: Duolite A-161, Macroreticular strong base anion exchanger  
Henkel Chemicals, India.
- XE-270: Amberlite XE-270 (IRA-97) Macroreticular weak base  
anion exchanger  
Rohm and Hass Co., USA.
- A-21 :Amberlyst A-21, Macroreticular, weak base anion exchanger  
Rohm & Hass Co., USA.
- A-33 : Tulsion A-33, Gel type strong base anion exchanger  
Thermax Pvt. Ltd. India.
- A-35 : Tulsion A-35, Gel type, Strong base anion exchanger  
Thermax Pvt. Ltd. India.

## Total Capacity of Resins

(meq/g of dry resin)

Resin	A-26	A-72	A-161	XE-270	A-21	A-33	A-35
Capacity	3.74	4.02	3.20	4.20	3.96	3.15	3.00

Table 2

## Capacity of the Ion Exchange Resins : Column Runs

Feed solution	Capacity (meq/g of dry resin)		
	A-21	XE-270	A-26
0.13 M HDBP in benzene	1.61	1.80	1.58
0.13 M HDBP in 30%TBP/ n-dodecane	-	1.50	1.40

Table 3

Ion Exchange Sorption of HDBP

Material Balance Data

Flow Rate : 2 bed volume per hour

Resin used : Amberlite XE-270

Experiment stage	Concentration of HDBP in meq.	
	Water conditioned	Methanol conditioned
Effluent column volume		
4	-	0.002
5	0.033	0.132
6	0.305	0.241
7	0.480	0.400
8	0.510	0.486
9	0.510	0.510
Washings	0.644	0.490
Eluate	2.130	2.254
Total	4.518	4.515

Total HDBP passed through the ion exchange bed = 4.90 meq.

Table 4

## Sorption of HDBP in Presence of Uranium

Feed : [HDBP] = 1.63 g/l

[U] = 3.26 g/l

Acidity = &lt;0.01 M

volume = 50 ml

Weight of the resin = 1 g (air-dried)

Resin	Concentration in treated solvent (g/l)		% sorbed		meq/g of resin	
	HDBP	U	HDBP	U	HDBP	U
A-26	0.21	0.18	87.1	94.5	0.34	0.65
A-72	0.31	0.18	81.0	94.5	0.31	0.65
A-15*	1.67	0.92	NIL	71.8	NIL	0.49

\* Macroreticular cation exchanger

Table 5

## Effect of Acidity on the Sorption of HDBP and Uranium

Feed : [HDBP] = 4.68 g/l

[U] = 0.21 g/l

volume = 50 ml

Weight of the resin (A-26) = 1 g (air-dried)

Feed acidity (M)	HDBP			U		
	in the treated solvent (g/l)	% sorbed	meq/g	in the treated solvent (g/l)	% sorbed	meq/g
0.02	0.10	97.8	1.09	0.005	97.6	0.03
0.30	4.14	11.5	0.13	0.21	-	-
0.60	4.14	11.5	0.13	0.21	-	-



Table 6

Performance of Various Resins with Process Solvent

Feed : [HDBP] : 1.56 g/l

[U] : 1.03 g/l

volume : 50 ml

Weight of Resin : 1.0 g (air-dried)

Resin	Conc. of HDBP in treated solvent (g/l)	% HDBP sorbed	meq/g	Conc. of U in treated solvent (g/l)	% U sorbed	meq/g
A-26	0.33	78.8	0.29	NIL	100	0.46
A-72	0.31	80.1	0.30	NIL	100	0.46
A-161	0.56	64.1	0.24	0.26	74	0.32

Table 7

## Sorption Behaviour of HDBP with Process Solvent

Resin : A-26 (air-dried)

Volume of solvent (ml)	Wt. of resin (g)	Conc. of HDBP		% of HDBP sorbed	meq/g	Conc. of U		% of U sorbed	meq/g
		feed (g/l)	treated (g/l)			feed (g/l)	treated (g/l)		
500	5.0	0.58	0.07	87.9	0.24				
500	5.0	2.83	0.58	79.5	1.07				
500	5.0	4.90	2.83	42.2	0.99				
10	0.2	2.05	0.21	90.0	0.44	2.6	0.26	90.0	0.50
50	1.0	4.5	0.96	78.7	0.84	4.28	2.45	43.0	0.40
Resin: A-72 (air-dried)									
50	1.0	4.5	1.60	64.4	0.69	4.28	1.60	62.6	0.56

Table 8

Sorption of Fission Products from Process Solvent

Feed : [Ru 106] : 330 uc/l, [Zr 95] : 1030 uc/l  
 [Nb 95] : 810 uc/l, [HDBP] : 4.9 g/l  
 [U] : 3.9 g/l  
 volume : 500 ml  
 Resin : A-26 (air-dried)

Wt of resin (g)	Ru 106		Zr 95		Nb 95	
	con. in treated solvent (uc/l)	% sorbed	con. in treated solvent (uc/l)	% sorbed	con. in treated solvent (uc/l)	% sorbed
5	112	66.1	407	60.5	282	65.2
10	75	77.3	80	92.2	46	94.4
15	50	85.0	46	95.5	19	97.7
<u>Reconditioned resin</u>						
10 (reconditioned)	210	36.4	810	21.4	410	49.4

Table 9

Sorption of uranium and HDBP by Water or TBP Soaked Resins

Feed : 50 ml (Process solvent)

Resin : A-26 (1 g)

Resin	Conc. of HDBP		% HDBP sorbed	meq/g	Conc. of U		% U sorbed	meq/g
	Feed (g/l)	Treated solvent (g/l)			Feed (g/l)	Treated solvent (g/l)		
Air-dried	3.1	1.5	50.0	0.37	-	-	-	-
Water-soaked	3.1	0.2	93.2	0.69	4.3	1.5	65.0	0.59
Water-soaked	4.5	1.2	73.6	0.80	-	-	-	-
TBP-soaked	4.5	1.9	58.1	0.63	5.6	3.4	39.3	0.46

Table 10

## Behaviour of the Reconditioned Resin

Resin : A-26 (5 g)

No. of recyc- ling	Volume of process solvent (ml)	HDBP			
		conc. in feed (g/l)	conc. in treated solvent (g/l)	% sorbed	meq
1	250	1.83	0.26	85.8	0.37
4	250	1.83	0.19	89.6	0.39
5	250	1.83	0.11	94.0	0.41

Table 11

Ion Exchange Clean-up of Sodium Carbonate-Treated  
Process Solvent

Feed : [HDBP] : 0.16 g/l  
 [Ru 106] : 37.4 uc/l  
 [Cs 137] : 3.5 uc/l  
 volume : 50 ml

Weight of the resin : 1 g (water soaked)

Resin	HDBP		Ru 106		Cs 137	
	Conc. in treated solvent (g/l)	% sorbed	Conc. in treated solvent (uc/l)	% sorbed	Conc. in treated solvent (uc/l)	% sorbed
A-26	0.08	46.9	24.2	35.3	2.8	20.0
A-72	0.08	46.9	25.0	33.2	2.3	34.3

Table 12

Behaviour of Gel-Type Resins

Feed : [HDBP] : 2.44 g/l

[U] : 2.73 g/l

Beta activity : 97 uc/l

Gamma activity : 37.9 uc/l

volume : 50 ml

Weight of the resin : 1 g (water-soaked)

Resin	HDBP			U			Beta activity		Gamma activity	
	conc. in treated solvent (g/l)	% sorbed	meq/g	conc. in treated solvent (g/l)	% sorbed	meq/g	conc. in treated solvent (uc/l)	% sorbed	conc. in treated solvent (uc/l)	% sorbed
A-33	0.44	82.0	0.48	1.04	61.9	0.36	69.6	23.2	32.7	13.7
A-35	0.46	81.1	0.47	1.04	61.9	0.36	78.4	19.2	30.7	19.0
50 W X8	2.34	4.1	0.02	2.34	14.3	0.08	80.4	17.1	35.3	6.9

Table 13

## Sorption Behaviour of Gel-Type Resins (Reconditioned)

Feed : [HDBP] : 2.52 g/l

[U] : 2.34 g/l

Beta activity : 80.7 uc/l

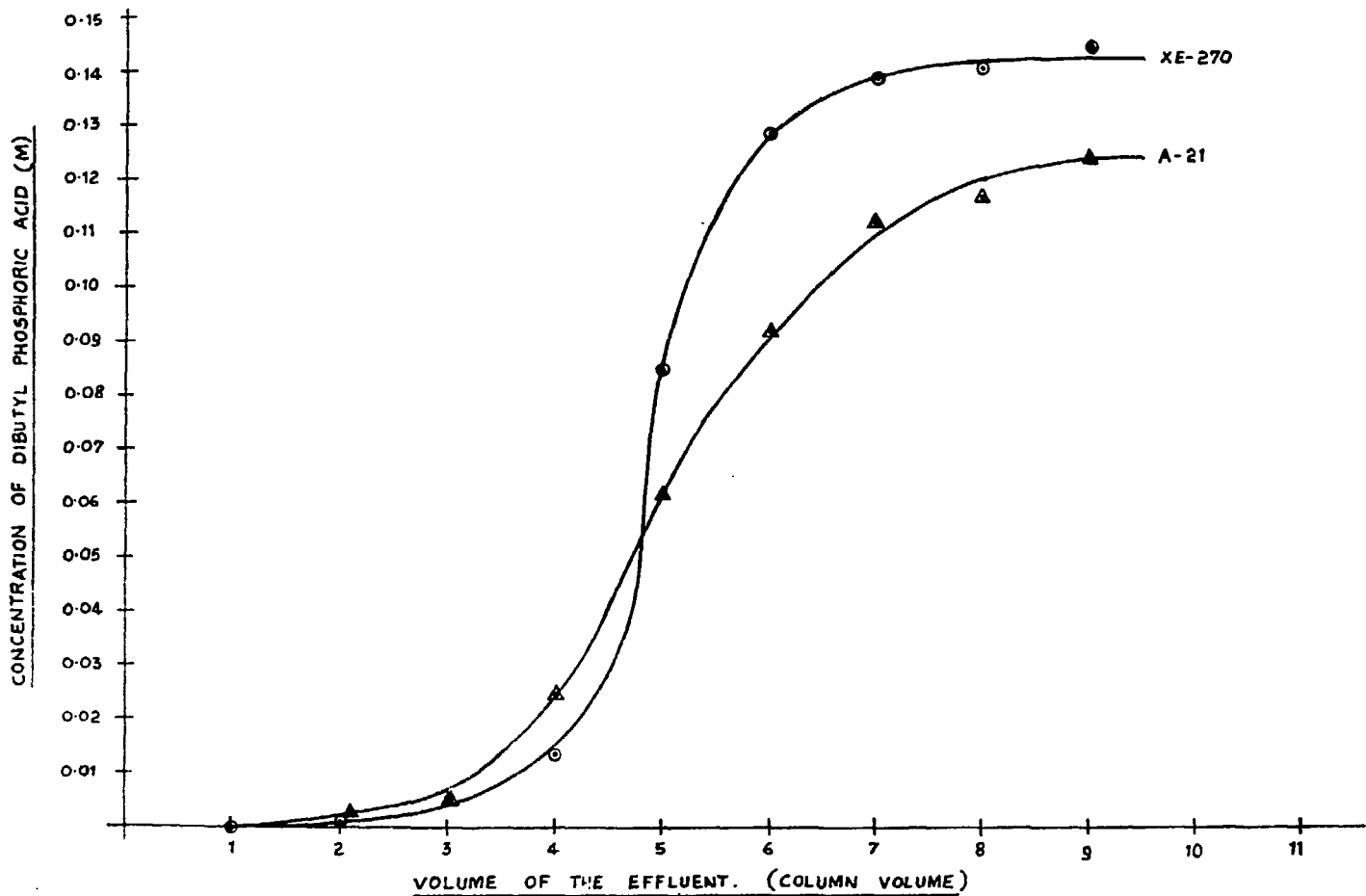
Gamma activity : 49.1 uc/l

volume : 50 ml

Weight of the resin : 1 g

Resin	HDBP		U		Beta activity		Gamma activity	
	conc. in treated solvent (g/l)	% sorbed	Conc. in treated solvent (g/l)	% sorbed	Conc. in treated solvent (uc/l)	% sorbed	conc. in treated solvent (uc/l)	% sorbed
A-33	1.31	48	1.82	22.2	80.1	nil	49.0	nil
A-35	1.55	40	1.82	22.2	72.0	10.8	44.1	10.2





**FIG-1. BREAK THROUGH CURVES FOR THE SORPTION OF HDBP WITH RESINS.**

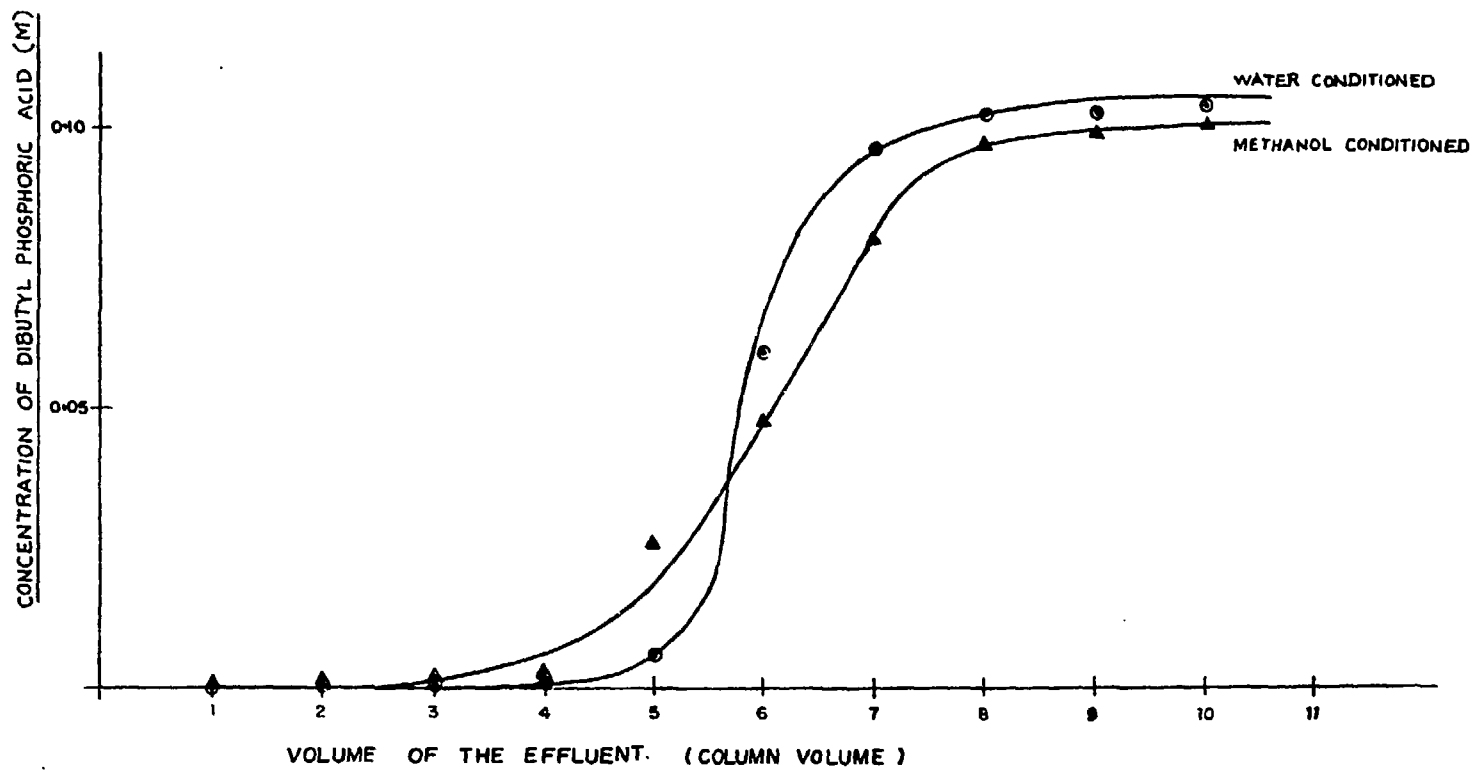


FIG 2 BREAK THROUGH CURVES FOR THE SORPTION OF HDBP WITH XE-270 RESIN - EFFECT OF PRE-CONDITIONING.

