



Evaluation of different adsorbents for copper removal from cobalt electrolyte

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Synopsis

Ion exchange is considered to be an effective technology for the removal of various impurities from cobalt advance electrolytes. With the correct choice of resin, ion exchange can consistently remove the required impurities to the levels for the production of high-grade cobalt metal. Although ion exchange was in the past used primarily for nickel removal, more recently it has been also considered for the removal of copper, zinc, and cadmium. Generally, granular ion exchange products are used, but Mintek is currently evaluating ion exchange fibres for a number of applications, including the removal of copper from cobalt advance electrolytes. Fibrous ion exchangers have major advantages compared to granular resins in that they have significantly higher reaction rates, and wash water volumes could be limited.

Granular and fibrous ion exchangers were evaluated and compared for the removal of copper from cobalt advance electrolyte. A synthetic electrolyte containing 50 g/L cobalt and 50 mg/L copper was used for the test work. Equilibrium isotherms, mini-column tests, and split elution tests were done. The results were used to size a full-scale operation to treat 100 m³/h of electrolyte. The potential cobalt losses or recycle requirements were estimated, and data to calculate indicative operating costs for each adsorbent was generated. This information was used for a techno-economic comparison of granular and fibrous ion exchange systems for the removal of copper from cobalt advance electrolyte.

Keywords

ion exchange, impurity removal, copper, cobalt electrolyte.

Introduction

Mintek conducted a significant amount of work on the development of ion exchange fibres (IXFs) during the 1980s and 1990s. Scale-up of production of these materials was, however, not feasible at that stage. Similar development work was done at the Institute of Physical and Organic Chemistry (IPOC) in Belarus, who have commercialized the production of these materials more recently (Shunkevich *et al.*, 2004; Soldatov *et al.*, 2004; Vatutsina *et al.*, 2007). This provided Mintek with the opportunity to resume its development on the use of IXFs for metallurgical processes.

An important feature of fibrous ion exchangers is their extremely high osmotic stability, which allows multiple cycles of drying and moistening as well as conversion

from one ionic form to the other without destruction of the filaments. The filtering layers of ion exchange fabrics do not significantly change their volume and permeability due to swelling of the filaments, which occurs as ion exchange proceeds and ionic state changes.

This paper demonstrates the possibility of using fibrous ion exchangers for hydrometallurgical applications such as copper removal from cobalt electrolyte. A comparison is presented of the design parameters and indicative costs for impurity removal using fibrous ion exchangers and granular resins having similar functionality.

Experimental procedures

A number of IXFs were tested for their selectivity, maximum copper capacity, and equilibrium behaviour in order to choose the most suitable fibre for the subsequent investigations, which consisted of split elution, mini-column, and mini-pilot plant tests. A similar test programme was carried out on a granular resin having the same functionality as the selected fibre, namely a resin containing imino-diacetic acid groups.

Maximum loading capacities for divalent metals

A maximum loading capacity test was performed in order to determine the maximum capacity of the fibres at different pH values for divalent metals using copper. A fibre-to-solution ratio was used that would provide an excess of metal in solution with respect to the

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amount of fibre used. This was done to ensure that there was adequate copper available, so that there were no equilibrium constraints during the determination of the maximum loading capacity. The tests were done by contacting air-dried fibre (in the H⁺ form) with the calculated volume of a 1.3 g/L copper feed solution at pH values of 2, 2.5, 3, 3.5, 4, and 4.5. Fibre samples were removed from the solution by filtration after the pH stabilized, washed with water, and stripped with an excess of 2 M HCl solution.

'S-curves'

The effect of pH on the extraction of metals from an equimolar mixture of Cu²⁺, Mg²⁺, Mn²⁺, Ca²⁺, Ni²⁺, Zn²⁺, and Co²⁺ was determined to evaluate the relative affinity of each material tested for the metals of interest.

The mass of fibre used was sufficient (in capacity) to adsorb all the metals from solution. A feed solution was prepared from metal sulphate salts. One batch test was carried out for each fibre, and samples were taken at pH values of 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, and 7. The contact period for each batch test was dictated by the time required for the pH to stabilize at the level at which it was controlled. The test was stopped when the pH had been stable for at least 1 hour. A solution sample was taken and the loaded fibre was filtered out of the barren solution. The loaded fibre was washed and stripped by contacting it with 300 mL of 2M HCl solution in a beaker while stirring using a magnetic stirrer for approximately 1 hour.

Similar experiments were done with the resin, but the feed solution did not contain Mn since it started to precipitate (as MnO₂) in the presence of the resin at a pH of 3. The contact period for each pH point was 24 hours. The loaded resin was separated from the solution, washed, and eluted using 10 bed volumes (BVs) of 2 M H₂SO₄.

Equilibrium isotherms

Adsorption equilibrium isotherms were generated for the loading of Cu and Co onto the adsorbents by batch contact of portions of the fibre/resin in the H⁺ form and synthetic solution (100 mg/L of Cu and 50 g/L of cobalt in a sulphate media) at different fibre to solution volume ratios. The pH values for the individual experiments were controlled at 3, 4, 4.5, and 5 for Fiban X-1 fibre, Lewatit TP 207 resin, Fiban K-3, K-4, and AK-22 (3) fibres respectively.

Efficiency of fibres in numerous operational cycles

The objective of this experiment was to establish the efficiency of selected materials in numerous adsorption/elution cycles. A small column was packed with a fibre sample in the di-sodium form and synthetic solution simulating cobalt electrolyte containing 50 mg/L Cu as impurity was passed through the column to fully load the fibre. After loading, the fibre in the column was washed with excess water prior to elution with sulphuric acid. Eluate samples were analysed for their Co and Cu concentrations. After elution, the fibre was converted back into the di-sodium form for the next adsorption cycle. These adsorption and elution cycles were repeated from 10 to 20 times.

After the last cycle, a portion of the stripped fibre was dried and analysed for any residual copper and cobalt.

Mini-column tests

Breakthrough tests for TP 207 resin and X-1 fibre

For the purpose of a techno-economic comparison between the FIBAN X-1 fibre and granular TP 207 resin, mini-column breakthrough tests were conducted employing the conditions presented in Table I.

Optimization of fibre column operating parameters

Adsorption within a packed-bed column is a process in which continuous mass transfer occurs between two phases (the mobile phase containing the solution and the solid phase of the packed bed). The solution concentration in both phases is a function of the contact time and the depth of the adsorption zone. The mass balance of the packed-bed reactor can be described by the Thomas model (Thirunavukkarasu *et al.*, 2002):

$$\frac{C_e}{C_0} = \frac{1}{1 + \exp\left[\frac{k}{Q}(q_0 m - C_0 V)\right]} \quad [1]$$

where:

- C_e is the effluent adsorbate concentration (mg/L)
- C_0 the influent adsorbate concentration (mg/L)
- k the Thomas rate constant (L/min-mg)
- q_0 the maximum solid phase concentration of solute (mg/g)
- m the mass of the adsorbent (g)
- V the throughput volume (mL)
- Q the volumetric flow rate (mL/min).

According to the mass balance of a specific packed bed, the determining factors of the mass balance for a given bed depth of the column are the volumetric flow rate and the initial solution concentration. For fibres it was also necessary to check the impact of fibre packing density because while this parameter changes, the filtering layer resistance also varies and this can influence the column efficiency. Therefore, in order to optimize the adsorption process in a packed-bed fibre column, the following parameters were examined and their influence on the column efficiency was estimated:

- Flow rate, which translated to an increase in the linear velocity for the specific experimental set-up
- Packing density.

Input	Lewatit TP 207	Fiban X-1
Material form	di-sodium	
Density, g/cm ³ (dry)	0.42	0.23
Absolute dry mass, g	119	5
Flow rate, mL/h BV/h	100	90
	2	4
Aspect ratio of resin bed (height:diameter)	4.1	1.8
Volume of adsorbent (H ⁺ form), mL	50	22
pH	4.5	
Cu feed, mg/L	100	
Co feed, g/L	50	

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While studying the influence of a certain parameter the values of the other parameters were kept constant. For all the tests 4 cm diameter columns were used. The tests were conducted on synthetic solution containing Cu at approximately 50 mg/L and Co at approximately 50 g/L. The feed solution pH was adjusted to a value of approximately 3 by the addition of 1 M NaOH solution. Input parameters for these tests are presented in Table II.

Mini-pilot plant

The operational sequence for a lead-lag-lag configuration of columns is illustrated in Figure 1. Initially, all three columns are in adsorption. Transfer (loaded or lead resin/fibre column leaves adsorption circuit for elution) occurs when the bulk of the mass transfer zone (MTZ) has moved through the lead column (C1) into the lag columns (C2 and C3). The feed is transferred from the lead column (C1) to column C2, which then becomes the lead column. Column C1 is stripped and/or regenerated and returned to the adsorption circuit in the lag (or last) position. The solution is passed downflow through the resin bed, but upflow through the fibre bed. The main parameters of the process employing the fibre are presented in Table III.

The entire operation could be divided into three parts:

- (1) Conversion of stripped fibre into the di-sodium form. The dry X-1 staple was packed into the columns. Regenerant (2 BVs of 1 M NaOH) was passed through the column at a flow rate of 10 BV/h (to convert fibre to the di-sodium form), followed by 1 L of wash water (upflow) to remove entrained base.
- (2) Adsorption. Feed solution was passed through the adsorption column in an upflow direction. Once the fibre bed was filled with solution, the piston was pushed down to adjust the packing density to that required for the specific test (a sketch of the adsorption column with fibrous ion exchanger is presented in Figure 2). Solution was passed through at a flow rate of 4 L/h. Solution samples were taken

from the first and last columns every 15 minutes. The first column was removed from the adsorption circuit to be eluted once the barren had reached 80% breakthrough, and the second column was transferred to the lead position.

- (3) Elution. Air was pumped through the column to remove entrained solution from the fibre, then 200 mL of 0.2 M H₂SO₄ was passed downflow through the column at 14.2 mL/min (10 BV/h) to elute any Co loaded onto the fibre. After Co elution, 100 mL of 1 M H₂SO₄ was passed downflow through the fibre column at 14.2 mL/min (10 BV/h) to elute any remaining metals loaded on to the fibre. The stripped fibre was washed with 500 mL of water (upflow,

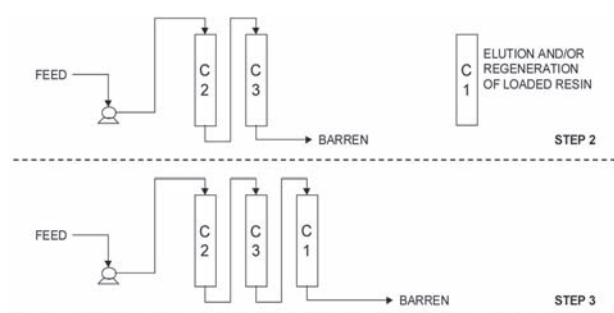


Figure 1—Illustration of the operating sequence of a lead-lag-lag ion exchange circuit

Material	Fiban X-1					
Fibre form	Di-sodium					
Parameter to be optimized	Solution flow rate					
Flow rate	BV/h	11	16	22	34	44
Fibre volume	mL	95	95	95	95	95
Mass of absolute dry fibre,	g	26.6	25.7	25.7	25.7	25.7
Packing density	g/cm ³	0.28	0.27	0.27	0.27	0.27
H/D		2	2	2	2	2
Parameter to be optimized	Packing density*					
Packing density	g/cm ³	0.37	0.43	0.53		
Flow rate	BV/h	24	24	26		
Fibre volume	mL	88	63	60		
Mass of absolute dry fibre,	g	32.3	25.7	32.1		
H/D		1.8	1.3	1.2		

*Fibre with different capacity was used

Feed flow rate	L/h	4
Cu loading	g/kg	25
Packing density	g/cm ³	0.4
Cu feed	mg/L	50
Number of columns	#	3
Fibre volume per column	mL	83
Mass fibre per column	g	33

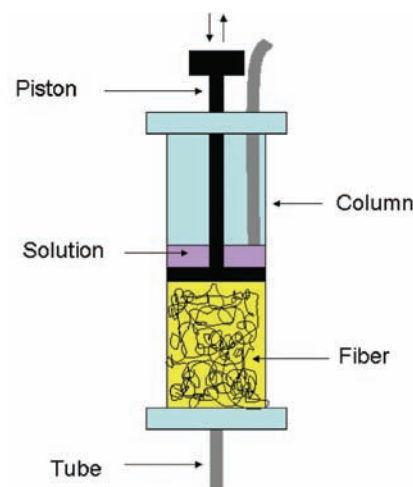


Figure 2—Ion exchange fibre column for adsorption

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50 mL/min) after elution. The piston compressing the fibre was lifted up and 200 L of 1 M NaOH was passed upflow through the column at 20 mL/min (the colour of the fibre became bright orange) to convert the fibre to the di-sodium form. The converted fibre was washed with 1 L of water to remove entrained NaOH (upflow, 67 mL/min). The entire elution and regeneration procedures of the fibre took 1 hour. The column was returned to the system as the lag column in the third position, as shown in Figure 1. The fibre was compressed until the required volume was attained only after it was filled with solution. This was necessary because the fibre swelled in the base form and the resistance of the fibrous layer was high enough to block the solution flow through the column.

Results and discussion

Characteristics of materials tested

Four fibrous ion exchange materials (FIBAN®) were tested in comparison with a conventional granular ion exchanger. The imino-diacetic acid resin tested, Lewatit TP207, is a product from Lanxess. Functional groups and backbone structures of these materials are presented in Figure 3.

Although FIBAN® K-3 and K-4 have the same carboxylic functionality, their matrices are different. FIBAN® K-3 was synthesized from a polyacrylonitrile (PAN) backbone, while K-4 is a product of radiation grafting of acrylic acid to a polypropylene (PP) backbone (Shunkevich *et al.*, 2004). Generally, the difference in matrices of ion exchangers has an impact on their physical properties, and not their chemical properties. The main distinctive feature of the fibres synthesized on the PAN backbone is possible hydrolysis of the nitrile groups of the matrix over a period of time, resulting in the formation of additional carboxylic acid groups (Soldatov *et al.*, 2004; Vatutsina *et al.*, 2007).

Maximum copper loading capacities

Maximum copper loading capacities as a function of pH for the various fibres indicated that the fibres function optimally at relatively high pH values. However, Cu could start precipitating at pH 5, so the maximum Cu loadings were done at pH 4.5. The results for the maximum copper loading capacities for the various fibres and the TP 207 resin tested are presented in Table IV.

Loading capacities found experimentally were somewhat lower than the metal loading capacities that would have been

predicted from the theoretical exchange capacities. This suggests that not all the functional groups within the structure of the fibres and the resin are available for the extraction of copper at lower pH values. Fiban AK-22(3) showed a higher capacity than was expected, which presumably was caused by complexation of copper by the polyamine groups on the fibre.

pH vs extraction isotherms

The 'S-curves' (pH vs extraction) were constructed under conditions whereby the fibres/resins had sufficient capacity within one batch test in order to adsorb all the metals from solution (i.e. excess fibre/resin and limited metals in solution). The results of 'S-curve' tests can be used to establish the metal selectivity order, and the aim of this test work was to select the fibre that would provide the best copper selectivity over cobalt. The metal loading capacities increased with pH, and the S-curves achieved for Fiban X-1 are presented in Figure 4 as an example.

Results indicated that TP 207 and Fiban X-1 would appear to function optimally at about pH 3 for Cu removal from Co electrolyte. The other fibres generally would require somewhat higher pH values. The order of selectivity for the various fibres and TP 207 were determined as follows:

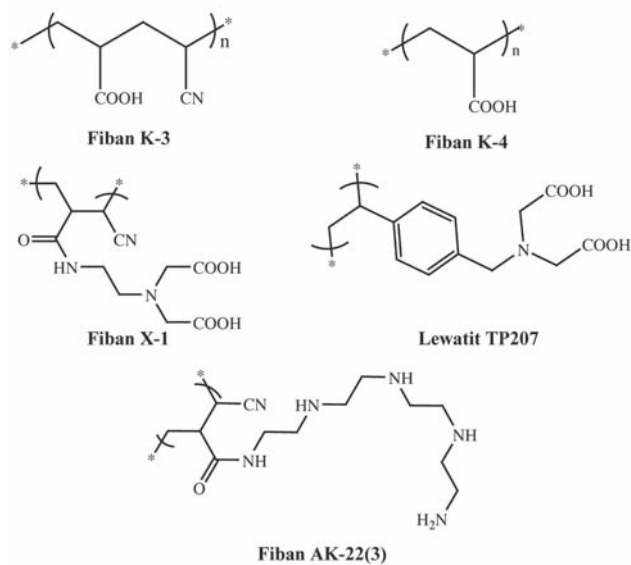


Figure 3—Chemical structures of materials tested

Table IV

Copper maximum loading capacity (pH 4.5)

Adsorbent	Maximum theoretical capacity, meq/g*	Theoretical Cu maximum loading, mmol/g	Cu maximum loading, mmol/g
Fiban AK- 22(3)	1.0	0.5	1.3
Fiban K-3	5.4	2.7	1.9
Fiban K-4	5.0	2.5	2.0
Fiban X-1**	3.7	1.9	1.8
Lewatit TP207	5.2	2.62	2.57

*Based on content of -COOH groups

**In some tests X-1 with 3.2 meq/g maximum theoretical capacity was used, namely, for the mini-pilot plant, re-usability testing and design

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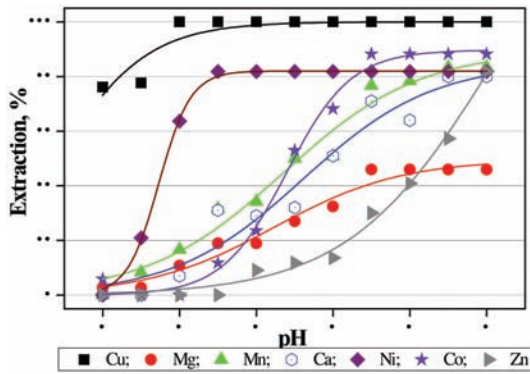


Figure 4—Extraction versus pH for Fiban X-1

Fiban X-1: Cu > Ni > Zn Co > Mn > Ca > Mg
 Fiban K-3: Cu > Zn > Mn Ni Co > Ca > Mg
 Fiban K-4: Cu > Zn > Ni Co Ca > Mn > Mg
 Fiban AK-22(3): Cu > Ni > Co Zn > Mg Mn Ca
 Lewatit TP 207: Cu > Ni > Zn > Co > Ca > Mg

The selectivity orders observed for Lewatit TP 207 and fibre Fiban X-1 were similar, which could be expected due to the similarity of their functional groups (Figure 3).

Equilibrium isotherms

Equilibrium isotherms were constructed using synthetic cobalt electrolyte solution containing 100 mg/L Cu. The pH values for the individual experiments were controlled at 3, 4, 4.5, and 5 for Fiban X-1 and TP 207, K-3, K-4, and AK-22(3) respectively. Results are presented in Figure 5.

The Langmuir equilibrium model (Soldatov *et al.*, 2004) was fitted to the equilibrium data obtained and selectivity coefficients were calculated. The main results of the equilibrium tests are presented in Table V.

Fiban AK-22(3) provided the highest loading of copper and the lowest co-loading of cobalt, while Fiban X-1, K-3, and K-4 had lower copper loadings and significantly higher Co co-loadings. Unnecessarily high Co co-loadings would generally increase the reagent amounts required to load and strip the fibre, and might cause a higher Co loss.

Langmuir parameters indicate that the resin had a higher maximum copper loading (the value of parameter *a* characterizes the saturation adsorption capacity). The highest affinity between the ion exchanger and copper was shown by AK-22(3) ($b = 0.38$ L/mg).

Based on these results the various adsorbents tested could be arranged in the following order with regard to their selectivity for copper over cobalt:

Fiban AK-22(3) > Fiban X-1 > Lewatit TP207 >
 Fiban K-4 > Fiban K-3

Fibres with a selectivity for copper over cobalt higher than that of the Lewatit TP 207 resin were chosen for further test work.

Re-usability of Fiban X-1 and AK-22(3)

Fiban AK-22(3) was noticed to change colour from white to pinkish, which indicated the possibility of cobalt poisoning of the fibre. Following this observation, Fiban X-1 and AK-

22(3) were selected and subjected to numerous cycles of adsorption/elution to establish if any poisoning was evident.

The results of loading and elution cycles of Fiban X-1 and AK-22(3) are presented in Figures 6 and 7 respectively. Analysis of residual Cu/Co at termination of the tests is listed in Table VI.

Results indicate that Fiban AK-22(3) was poisoned with cobalt and completely lost its capacity within only 10 cycles of adsorption and elution. Hence, this material was excluded from further test work.

Fiban X-1 retained its selectivity and capacity over 20 cycles of adsorption and desorption (on average 0.82 mmol/g of divalent metals was loaded with only 4% variation in the

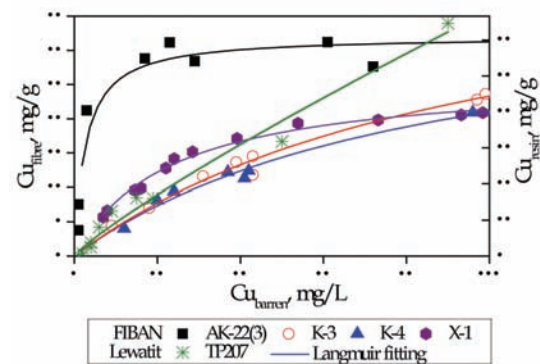


Figure 5—Copper adsorption equilibrium isotherms

Materials		X-1	K-3	K-4	AK-22(3)	TP 207
Langmuir	a	26	47	39	32	164
	b	0.04	0.01	0.01	0.38	0.01
	RSQ	0.99	0.98	0.98	0.92	0.95
Maximum copper loadings	mg/g	20	24	21	31	97
Cobalt co-loading		10	72	55	13	82
Selectivity Cu/Co*		1000	175	197	1304	591

$$\frac{Cu}{Co} = \frac{Cu_{resin}/Cu_{barren}}{Co_{resin}/Co_{barren}} \quad \text{where}$$

Cu_{resin}, Co_{resin} - metal loaded onto the material; mg/g
 Cu_{barren}, Co_{barren} - metal concentration in solution, mg/L.

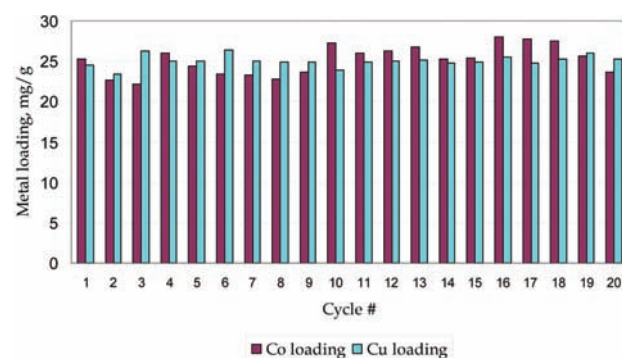


Figure 6—Cobalt and copper loading of FIBAN X-1 over 20 adsorption/elution cycles based on elution data

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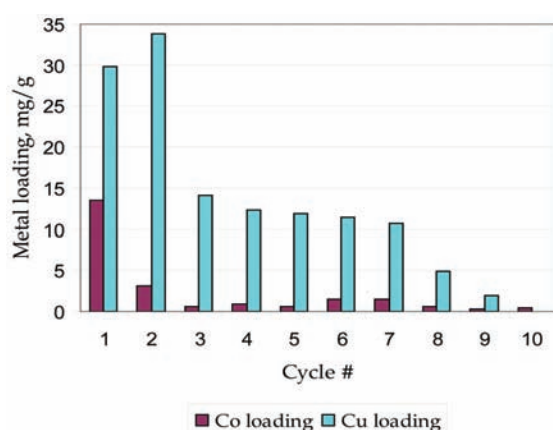


Figure 7—Cobalt and copper loading of FIBAN AK-22(3) over 10 adsorption/elution cycles based on elution data

FIBAN®	Co, %	Cu, %
X-1	<0.05	<0.05
AK-22(3)	2.26	<0.05

loading capacity, average selectivity coefficient obtained was 996), and no residual copper/cobalt was found in the fibre after the final stripping cycle, as shown in Table VI.

Mini-column tests

Comparison of breakthrough curves for TP 207 resin and X-1 fibre

Mini-column breakthrough tests were done to allow a techno-economic comparison between FIBAN X-1 fibre and the granular TP 207 resin. Synthetic solution containing 100 mg/L Cu and 50 g/L Co at pH 4.5 was passed downflow through the column containing fibre/resin at a flow rate of 2 BV/h. Results obtained are presented in Table VII and Figure 8.

Results indicated that the fibrous ion exchanger had a considerably shorter mass transfer zone compared to the resin, which would reduce the size of the plant significantly. It also had a higher selectivity coefficient for Cu over Co, which should result in lower operating costs.

Influence of column parameters on performance

Column parameters, including flow rate, packing density, and aspect ratio, were varied in order to optimize the design parameters for the fibre ion exchange column.

Fiban X-1 loading efficiency was tested at five different flow rates, and three different packing densities or aspect ratios. Results are depicted in Figure 9.

An increase in the linear flow rate increased the height of the MTZ, but decreased its residence time and therefore decreases the service time of the bed. However, the total

Table VII

Mini-column breakthrough results

	TP 207 resin	Fiban X-1 fibre
Cu loading, g/kg	97	35
Co loading, g/kg	82	28
Selectivity for Cu/Co	588	638
Flowrate, BV/h	2 ^a	4.7 ^b
Linear velocity, mm/sec	0.057	0.051
Height of MTZ, cm	8.2	2.8

^a Resin volume was measured via tapped wet-volume method

^b Fibre volume was controlled by pressing with a piston and could be varied depending on desired packing density

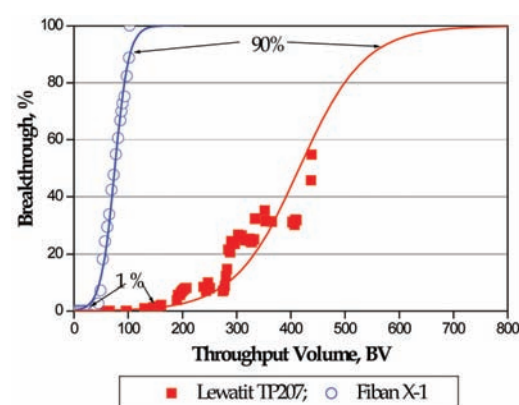


Figure 8—Copper breakthrough curves for TP 207 and Fiban X-1

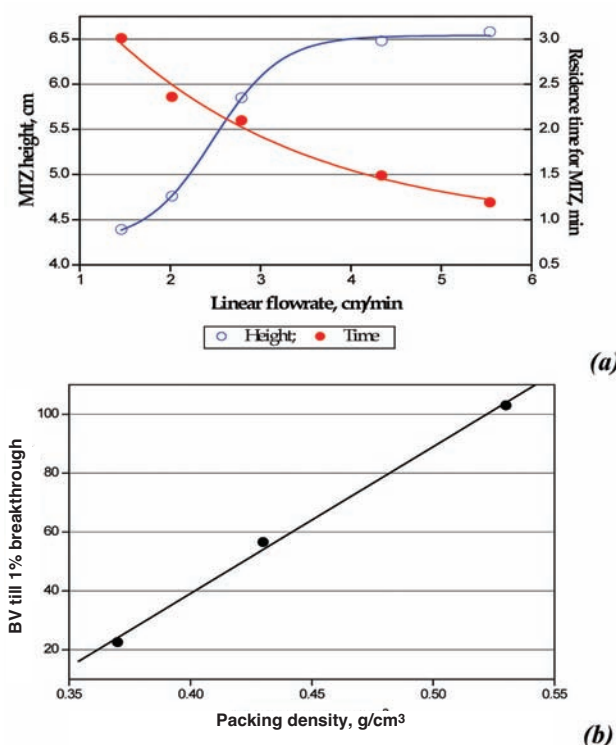


Figure 9—Influence of the column parameters on bed volumes that can be treated for 1% Cu breakthrough: (a) flow rate at 0.27 g/cm³ fibre density; (b) packing density at 24 BV/h flow rate

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loading capacity of the fibre bed was constant (20 mg/g of Cu, 8 mg/g of Co). The choice of the optimum flow rate would then be dictated by design requirements.

Increasing of fibre packing density leads to an increase in the hydrodynamic resistance of the filtering layer to solution flow. At a packing density $>0.4 \text{ g/cm}^3$ a problem with the filtering layer resistance was observed. After conversion of the fibre into the basic form the fibre swells and blocks the free flow of solution at a high packing density. This is typical for carboxylic ion exchange fibres. Thus, the optimum packing density (taking into account the need to convert the fibre into basic form during current tests) was 0.4 g/cm^3 for the laboratory equipment.

The following conclusions were drawn based on the results obtained during these tests where the parameters were varied:

- The influence of flow rate on fibre efficiency was described by exponential decay with variation of residence time for the mass transfer zone from 1.2 to 3 minutes
- The optimum packing density, where the pressure drop was reasonable, was 0.4 g/L . However, it was necessary to maintain a lower packing density during conversion of the stripped fibre into the basic form, rinsing of excess NaOH, and the initial adsorption phase. This was required as the resistance of the fibre bed hampered solution flow under these conditions. The fibre should be pressed to a higher density only after adsorption has started.

Mini pilot-plant campaign results

The results of the countercurrent process are presented in Figure 10 and Table VIII. A lead-lag-lag fixed bed arrangement was used. Synthetic solution containing 50 mg/L Cu and 50 mg/L Co at pH 3 was passed through the system at 4 L/h flow rate (total mass of absolute dry fibre was 94.5 g , total volume per 3 columns was around 240 mL).

As can be seen from the graph at the bottom of Figure 10, no copper breakthrough ($> 0.5 \text{ mg/L}$ in effluent stream) after the last column was observed during the mini-pilot plant tests. Ten transfers (of the lead columns) were done.

The average cobalt loss per column with respect to the delta between cobalt advance and spent electrolytes was $0.14 \pm 0.05 \%$. This could probably be lowered during optimization of the technique to selectively strip co-loaded Co prior to Cu stripping, to achieve the levels that were obtained during the mini-column test work.

Comparison between fibre and resin plant designs

Based on the results of the mini pilot-plant campaign, and equilibrium and mini-column tests, the plant sizing, reagent consumption, and Co recycle/loss for TP207 resin and fibre Fiban X-1 were compared in order to establish the advantages or disadvantages of fibrous ion exchanger for hydrometallurgical applications. The results of calculations for plants using resin or fibre are presented in Table IX.

In spite of the fact that the loading capacity of TP207 for copper is double that of the fibre, the use of Fiban X-1 has advantages compared with the resin:

- Somewhat better selectivity for copper over cobalt
- Shorter mass transfer height allows an increase in the productivity of the adsorbent
- It would allow a decrease in the total volume of fibre used per column; faster fibre regeneration also allows a decrease in fibre volume per column
- The total volume of the plant can be reduced by more than 90% using fibre, reducing the costs of the adsorbent as well as CAPEX
- Backwash might not be necessary
- Cobalt losses per annum are around 50% less for the fibre plant
- Various shapes and sizes of columns can be used.

CAPEX requirements

The data presented in Table IX was used to size an ion exchange plant using either TP207 resin or the Fiban X-1 fibre as the adsorbent. An 'order-of-magnitude' mechanical equipment cost was then calculated for each scenario.

The lower volume of fibre required results in considerably smaller columns, while the shorter cycle time reduces the volumes of all related tankage. The result is that the mechanical equipment cost required for the fibre plant is about 25% of that required for a resin-based plant.

Adsorbent cost can generally form a significant portion of the total capital cost of an ion exchange plant, especially where chelating resins such as the iminodiacetic acid resins are used. Because the adsorbent volume/mass is far lower for the fibre plant, further savings will be achieved in the cost of the 'first fill'.

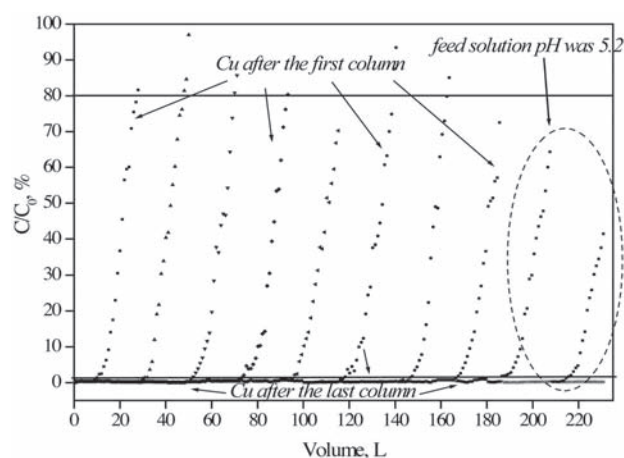


Figure 10—Cu adsorption profiles (lead-lag-lag system)

Table VIII

Mini pilot-campaign results

Average height of MTZ	cm	5
Average cobalt loss per column	%	0.14 ± 0.05
Average copper loading	mg/g	24

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Table IX

Comparison of TP 207 resin with Fiban X-1 fibre

Parameter		Fibre			Resin		
		Input					
Feed flow rate	m ³ /h	100					
Cu loading	g/L	10			20		
Co loading	g/L	10			45		
Res time MTZ	min	1.6			30		
Cu in feed	mg/L	50					
Co in feed	g/L	50000					
# columns		2	3	4	2	3	4
Elution time	h	1.5			10		
		Output					
Upgrade		200			400		
Transfer time	h	6.8	3.4	2.3	210	105	70
Fibre flow rate	m ³ /h	0.5			0.25		
Fibre for MTZ	m ³	2.7			50.0		
Fibre for elution	m ³	0.75			2.5		
Fibre/column	m ³	3.4	1.7	1.1	52.5	26.3	17.5
Total fibre volume	m ³	6.8	5.1	4.6	105.0	78.8	70.0
No. of transfers/year		1218	2436	3654	40	79	119
Time/year	h	8322					
		Co loss/recycle					
Co treated (based on 5 g/L delta)	kg/a	4161					
Co loaded per cycle	kg/cycle	34	17	11	2363	1181	788
	%	20					
Co loss/recycle per cycle (of the Co loaded)	kg/cycle	6.8	3.4	2.3	472.5	236.3	157.5
Co loss/recycle per annum	kg/a	8322			18725		

Conclusions

Several fibrous ion exchangers were investigated. Fiban X-1 with iminodiacetic acid groups proved to be the best adsorbent for copper removal from cobalt electrolyte. Test results obtained during evaluations of FIBAN® X-1 fibrous ion exchanger and granular ion exchanger Lewatit TP 207 were compared to assess the potential cost implications of a fibrous ion exchanger. This comparison established that the fibrous ion exchanger FIBAN® X-1 could be suitable for hydrometallurgical processes. Preliminary indications are that it could offer major cost savings compared to conventional granular iminodiacetic acid resin. Further work on Cu removal is focused on evaluation of the fibre and resin with limited or no regeneration included. Ultimately, the form in which the fibre or resin is to be employed will be an economic decision. Removal of entrained and co-loaded cobalt from the fibre is being optimized to further limit cobalt loss/recycle.

Other fibres investigated have promising characteristics for selective Zn and Ni removal from cobalt electrolyte. FIBAN® X-1 could also be used as a substitute for TP 207,

and for nickel-cobalt separation when these metals are present in solution in similar orders of concentration.

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