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ABSTRACTS

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PERTRACTION OF SOLUTES IN DOUBLE HOLLOW-FIBER MEMBRANE PERTRACTORS

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The membrane extraction process itself shows certain advantages over classical solvent extraction (a smaller amount of extracting agent, negligible loss of organic solvents, impossible stable emulsion formation). Very large surface area per unit volume can be achieved using microporous hollow-fiber extractors, which enables high separation factors, although the mass transfer coefficient is not unusually high in hollow fibers (1,2). Moreover, in hollow fibers the two fluids flow are almost completely independent which unable flooding, loading or channeling (3,4). Besides, the mass transfer rate can be enhanced using reversible and irreversible chemical reaction.

Simultaneous membrane extraction and reextraction process using hollow fiber contained liquid membranes (5,6) has further advantages over corresponding consecutive steps since fewer moving parts are used, resulting in less maintenance cost. Compact and modular hollow fiber devices can be used with exceptionally high mass transfer area per unit equipment volume. Incomparably smaller amount of agent is necessary. Yet, despite such obvious advantages, these liquid membranes have very important disadvantage due to the membrane instability. The probable causes of membrane instability are: loss of membrane by solubility in the mobile feed and strip phase; progressive wetting of the support pores by surface-active carrier molecules; pressure differential across the membrane; osmotic flow of large quantities of water across the membrane.

In the present work a new concept of simultaneous membrane extraction and reextraction process (pertraction) was analyzed and experimentally checked, using the double hollow-fiber separators ("fiber in fiber" type). Two types of modules were designed using microporous polysulphone hollow fibers. Parallel flow module is made of seven parallel large hollow fibers (ϕ 2.00/1.00mm, 150mm long). One thinner hollow fiber (ϕ 0.80/0.40 mm 200mm long) is placed inside each large fiber (Fig 1). The fibers are glued in place with epoxy, so that three independent flows are enabled. The analysis of hydrodinamical characteristics of the module shows that the pressure drop in the module is directly proportional to the flow rate for all three streams. Values obtained for Reynold's number (Re) indicate that in all cases the flow regime is laminar.

This type of module is used for simple pertraction of phenol, copper and indium analysis. The pertraction of metal ions from the binary mixture is also analyzed. In all cases the feed solution (aqueous solution of the solute) flows around the large fibers. Extractants (consume oil and gasoline 1:1 for phenol, 10 vol.% of LIX 84 in gasoline for copper and 20 % of DEHPA in gasoline for indium) flow counter currently through annular space between the fibers. Stripping solutions (0.1M NaOH for phenol, 0.05M H_2SO_4 for copper and 6M HCl for indium) flow through the thin fibers. Effects of the flow rate and the initial feed concentration on the pertraction efficiency for solutes under study are analyzed. Mass transfer coefficients of the solutes are determined.

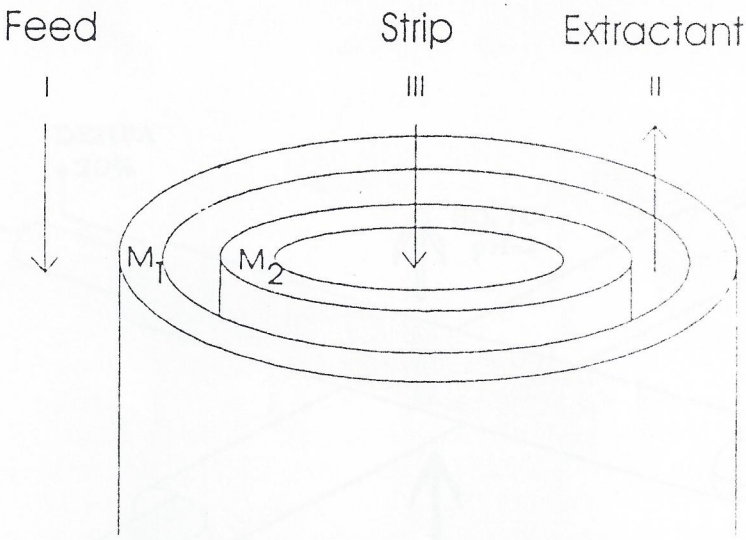
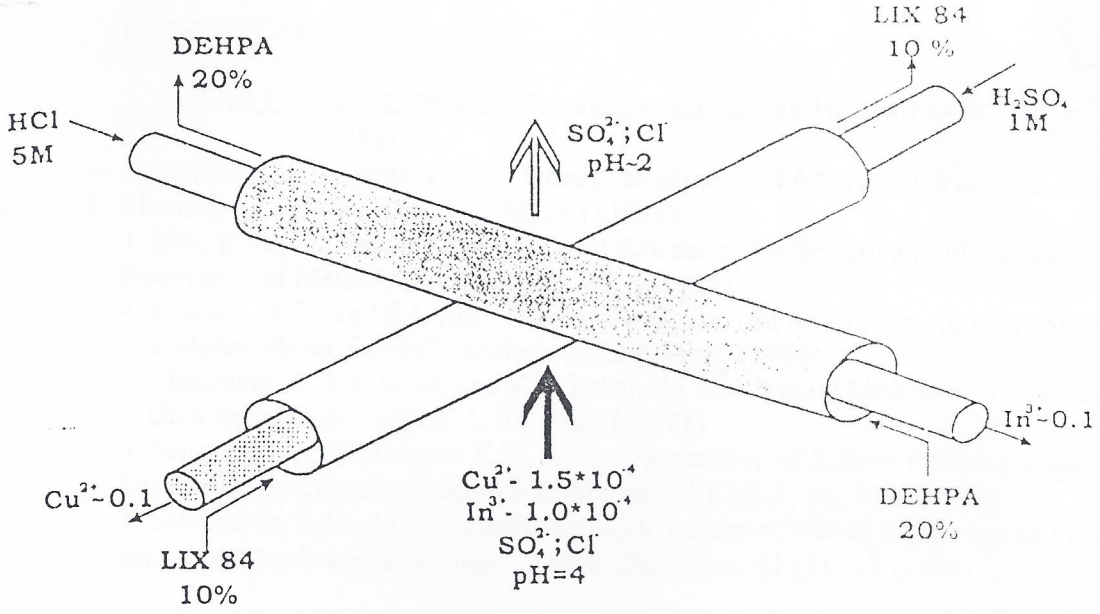


Fig. 1 Scheme of "fiber in fiber" type of membranes

On the basis of experimental results it is concluded that in the case of phenol pertraction the flow rate of the extractant does not effect the pertraction efficiency. Unlikely, the increase of flow rate of feed solution causes the decrease of the pertraction efficiency of phenol. The increase of the flow rate of stripping solution causes the increase of the pertraction process. The results obtained analyzing 27 different combinations of flow rates of all three independent flows shows that the highest values for pertraction efficiency are obtained for the same flow rates of feed and stripping solutions and the higher flow rate of extractant (about 64%). Obviously, it is important to have mobile extracting solution since it diminishes the pressure differential across the membrane. In the pertraction process of phenol the mass transfer resistance of organic extractant controls, since it is the system with low distribution coefficient. Extraction step seams tobe the slower one. On the other hand, for copper and indium as the systems with high distribution coefficients (m>>1) the aqueous boundary layer resistances seam to control. Stripping step seams to be the slower one.

It is demonstrated that the hollow-fiber membrane pertraction process can be applied to practical dual separation of metal ions from binary mixtures. Stevanovic at al.(7) analyzed and experimentally checked a concept of dual membrane extraction of cupric and indium ions, using a two-membrane cell. They showed that much greater separation factors could be obtained in dual membrane extraction process than those obtained in single membrane extraction of metal ions from binary mixtures, one by one. Using this concept of dual membrane separation, we made a laboratory double hollow-fiber pertractor ("fiber in fiber type),with transversal flows (Fig. 2).



Cu/In ≥ 140
In/Cu ≥ 4500

Fig. 2 Scheme of the laboratory double hollow-fiber pertractor ("fiber in fiber type), with transversal flows

The same hollow fibers and glue are used. The fibers are glued in a way to enable five independent flows. Around the large fibers runs the feed solution (binary mixture of aqueous solutions of cupric and indium ions). Through the two independent annular spaces run two different extracting solutions for metal ions. Through the two independent thin fibers run two different stripping solutions for each metal. The kinetics of metal ion pertraction is analyzed. The degree of metal ion separation is calculated as follows:

$$S = [M_1]_s * [M_2]_f / [M_1]_f * [M_2]_s$$

were the symbol S denotes the separation factor, $[M_1]$ and $[M_2]$ the steady state metal concentration, and subscripts f and s denote feed and stripping solutes, respectively. The obtained results show that high, even absolute selectivity of the complexing agents for the corresponding ions is attained by dual pertraction process, unlike the single pertraction or solvent extraction processes where this selectivity is only partial for the same pair of metal ion - complexing agent. This can be explained from the system equilibrium point as follows: In single pertraction process, when one component is extracted from a two- or multicomponent mixture, the concentration of the component extracted decreases, while concentrations of other present components remain essentially constant, so that, even when their affinities for the complexing agent are small, relatively higher driving forces produce substantial mass transfer of these components and, as a result, separation factors are not very large. In the case of simultaneous dual or multiple pertraction processes, concentrations decrease for all components extracted, and, therefore, the driving force ratio remains nearly constant, so, very high separation factors are possible (over 4000 for In/Cu separation)

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