

## TREATMENT OF Cu-BEARING LIQUID EFFLUENTS BY NON-DISPERSIVE SOLVENT EXTRACTION WITH STRIP DISPERSION MEMBRANE TECHNOLOGY

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### Abstract

The removal of copper (II) from acidic liquid effluents had been investigated using non-dispersive solvent extraction with strip dispersion (NDSXSD) membrane technology and oxime derivative Acorga M5640 as ionophore. Several variables which influenced the transport of the metal had been studied.

**Keywords:** *Copper (II), Acorga M5640, non-dispersive solvent extraction with strip dispersion, liquid membranes*

### INTRODUCTION

Aqueous streams contaminated with heavy metal ions may be produced as effluents either from industrial plants or during attempts to remediate solid materials bearing hazardous metal ions, such as contaminated soils.

Increasingly more stringent environmental regulations lead to the need of the treatment of such solutions, which also results in the recycling and reuse of targeted heavy metals to the corresponding process.

Several methods for these purposes are currently available, among them liquid membrane technologies had attracted considerable attention in the past. One of the most advanced liquid membrane operation mode is non-dispersive solvent extraction with strip dispersion (NDSXSD) technique, which integrates the advantages of the various liquid membrane technologies [1]. Though copper has not the adverse effect on humans as other metals (chromium (VI), arsenic (V), etc.), its ingestion results in nausea and other gastrointestinal disorders, thus, its removal from liquid effluents is also needed in order to avoid contamination of natural and drinking waters[2].

The present investigation deals with the removal of copper (II) from acidic aqueous solution using the oxime derivative Acorga M5640 and NDSXSD technology in a conventional supported liquid membrane cell to obtain data prior to the scaling-up of the system to a continuous operation mode using a hollow fiber device.

### EXPERIMENTAL

The characteristics of both the extractant (Acorga M5640) and organic diluent (Iberfluid) used in the present work had been given elsewhere [3]. All other chemicals were of AR grade.

Also, the characteristics of the cell, membrane support (Durapore GVHP 4700) and operation mode were similar to those described in a previous publication [4]. Copper in the aqueous solutions was analyzed by AAS.

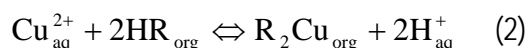
The overall mass transfer coefficient  $K$  was computed using

$$\ln \frac{[Cu(II)]_t}{[Cu(II)]_0} = -\frac{A}{V} \cdot K \cdot t \quad (1)$$

where  $A$  is the effective membrane area,  $V$  is the volume of feed solution,  $[Cu(II)]_t$  and  $[Cu(II)]_0$  are the copper concentrations in the feed solution at an elapsed time and time zero, respectively, and  $t$  is the time.

### RESULTS AND DISCUSSION

The extraction of Cu(II) by oxime derivatives (i.e. Acorga M5640) in acidic aqueous media can be represented by the next equation [5]



where  $aq$  and  $org$  represented the corresponding aqueous and organic solutions and HR represented the active substance of the extractant. Figure 1 schematically represented the transport of Cu(II) using NDSXSD technology, which is related to a counter-transport mechanism.

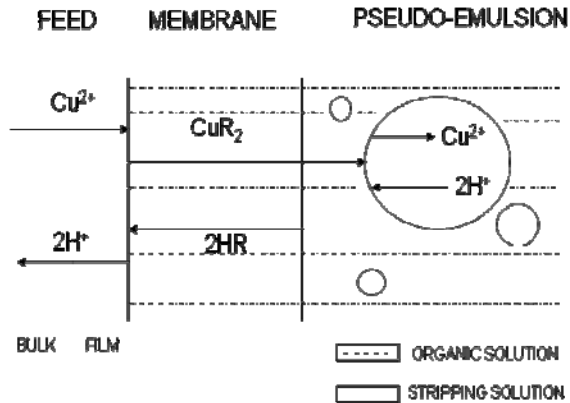


Figure 1. Schematic view of the active transport of Cu(II) by Acorga M5640 and NDSXSD.

### 1. Influence of stirring speed of the feed phase

The influence of the stirring speed of the feed phase was investigated in order to optimize uniform mixing of aqueous feed and to minimize thickness of the aqueous boundary layer with the feed and pseudo-emulsion phases conditions being maintained as follows: feed phase (0.02 g/L Cu(II) at pH 3.0±0.1), pseudo-emulsion phase (organic solution: 5% v/v Acorga M5640 in Iberfluid), stripping solution: 180 g/L H<sub>2</sub>SO<sub>4</sub>).

The results obtained are shown in Table 1; the overall mass transfer coefficient becomes virtually independent of the stirring speed in the range 1200-1400 min<sup>-1</sup>, indicating a first decrease in the aqueous boundary layer thickness (up to 1200 min<sup>-1</sup>), and then a minimum value of thickness is reached in this range.

Being

$$K_{lim} = \frac{D_{aq}}{d_{aq}} \quad (3)$$

where  $D_{aq}$  is the average aqueous diffusion coefficient of the metal-containing species and  $d_{aq}$  is the thickness of the aqueous boundary layer, and assuming a value of  $D_{aq}$  in the 10<sup>-5</sup> cm<sup>2</sup>/s range and

$K_{lim}$  equal to 5.5x10<sup>-3</sup> cm/s, the value of  $d_{aq}$  is estimated as 1.8x10<sup>-3</sup> cm, this value is the minimum thickness of the stagnant aqueous diffusion layer. The stirring speed of 1200 min<sup>-1</sup> in the feed phase was kept constant throughout the experimented conducted.

Table 1. Variation of the overall mass transfer coefficient with the stirring speed

| Speed (min <sup>-1</sup> ) | K (cm/s)             |
|----------------------------|----------------------|
| 400                        | 9.9x10 <sup>-4</sup> |
| 800                        | 3.4x10 <sup>-3</sup> |
| 1200                       | 5.5x10 <sup>-3</sup> |
| 1400                       | 5.4x10 <sup>-3</sup> |

### 2. Influence of initial copper (II) concentration in the feed phase

Studying the effect of the initial concentration of copper (0.02-0.2 g/L) in the feed phase of pH 3.0±0.1, when the pseudo-emulsion phase remained similar as above, it was shown (Table 2) that the overall mass transfer coefficient decreases with the increasing initial copper concentration in the feed phase.

The copper (II) concentration in the organic phase is higher at higher initial copper concentration in the feed phase, this leads to the saturation of the liquid

membrane and the pore liquid by the metal-carrier complex molecule, and thus this increases the resistance of de-complexation or stripping at the strip interface since the value of the stripping distribution coefficient is usually lower than that of the extraction.

Table 2. Influence of initial Cu(II) concentration on the overall mass transfer coefficient

| [Cu] <sub>0</sub> (g/L) | K (cm/s)             |
|-------------------------|----------------------|
| 0.02                    | 5.5x10 <sup>-3</sup> |
| 0.1                     | 2.1x10 <sup>-3</sup> |
| 0.2                     | 1.6x10 <sup>-3</sup> |

### 3. Influence of pH on the overall mass transfer coefficient

In order to investigate the effect of pH in the feed phase during the transport process of copper by NDSXSD, experiments were conducted at different pH values in the ranges of 1.0-4.0. Other experimental conditions were maintained as in subsection 3.1.

Results obtained were shown in Table 3. The overall mass transfer coefficient increases with increasing pH, and reaching a maximum in the 3.0-4.0 range.

Table 3. Effect of pH on K

| pH±0.1 | K (cm/s)             |
|--------|----------------------|
| 1.0    | 9.9x10 <sup>-4</sup> |
| 2.0    | 2.1x10 <sup>-4</sup> |
| 3.0    | 5.5x10 <sup>-4</sup> |
| 4.0    | 5.5x10 <sup>-4</sup> |

#### 4. Influence of Acorga M5640 concentration on the overall mass transfer coefficient

A NDSXSD system having no carrier in the organic phase results in no transport of copper ions through the membrane. Table 4 shows the results concerning to the transport of Cu(II) from a feed phase of 0.02 g/L Cu(II) at pH 3.0±0.1 using a pseudo-emulsion phase of variable concentrations of Acorga M5640 in Iberfluid and a stripping solution of 180 g/L sulphuric acid. As can be seen from the Table, the overall mass transfer coefficient increases with extractant concentration until a maximum is reached, then levels off and further, the transport of the metal decreases.

Table 4. Effect of carrier concentration on K value

| Acorga M5640 (% v/v) | K (cm/s)             |
|----------------------|----------------------|
| 1                    | 2.2x10 <sup>-3</sup> |
| 2.5                  | 4.1x10 <sup>-3</sup> |
| 5                    | 5.5x10 <sup>-3</sup> |
| 10                   | 5.5x10 <sup>-3</sup> |
| 20                   | 5.0x10 <sup>-3</sup> |

This behaviour is attributable to the fact that at low Acorga M5640 concentrations, diffusion of Cu(II) complex across the membrane is the rate-determining step. While at higher carrier concentrations (in the 5-10% v/v range) diffusion of the metal ion across the feed phase boundary layer is the rate-determining step. The decrease of the value of K at 20% v/v extractant concentration is attributable to an increase of the viscosity of the organic solution filling the micropores of the membrane which results in a decrease of metal transport since the diffusion coefficient of the metal-carrier complex in the organic solution is inversely proportional to the viscosity of the organic phase.

## 4. CONCLUSIONS

NDSXSD studies were carried out with a permeation cell for simultaneous extraction and stripping of Cu(II) from acidic solutions using Acorga M5640 as carrier. From the results obtained, it can be concluded that the experimental conditions, i.e. using a pseudo-emulsion of 5% v/v Acorga M5640 in Iberfluid and 180 g/L H<sub>2</sub>SO<sub>4</sub> is suitable for the efficient extraction (exceeding 95%) and stripping of Cu(II) under optimum conditions. This technology is a promising alternative to conventional methods and these results can be improved by the use of a more efficient operational device such as hollow fiber modules.

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