The Complementary Aspects of Ion-Exchange Resins and Solvent Extraction in Copper Recovery Processes

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A complementary ion exchange/solvent extraction process for the recovery of copper from low-grade ores developed by Iontech Engineering Ltd. is described. It has successfully been implemented on a full-scale plant level at the Buchim Copper Mine in Macedonia, yielding a maximum copper cathode production of 2400 tonnes per year. Technical and economic aspects of three years of operational experience are comprehensively compared with the Asarel Medet copper plant in Bulgaria, which is utilizing conventional solvent extraction in the enrichment/purification step.

INTRODUCTION

The concentration and separation of copper from primary leachates is one of the key operations in the hydrometallurgical processing of oxide ores (Langner, 2011). Conventionally, this basic operation is conducted by submitting the pregnant leach solution (PLS), with a 1–5 g/L Cu content, from the initial sulfuric acid leach to a solvent-extraction (SX) process in which copper reports to the organic phase (see Figure 1). After phase separation, the metal is stripped from the extractant/diluent mixture employing sulfuric acid to furnish a concentrated metal solution, usually containing 40–50 g Cu/L. The final products of the overall process are copper cathodes, which are obtained from a terminal electrowinning step.

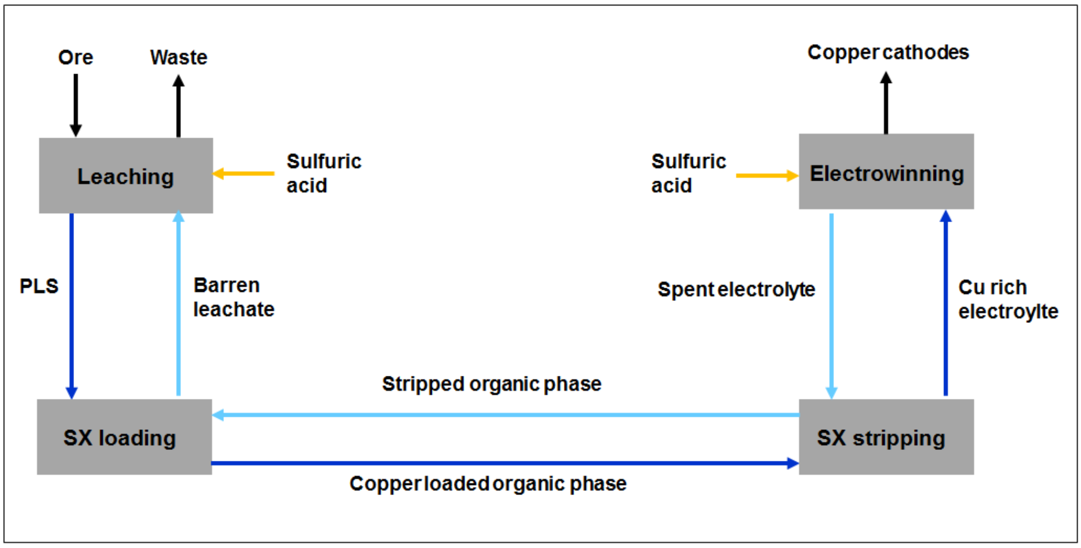

Figure 1. Simplified flowsheet for the recovery of copper through electrowinning.

Although considered as "technology of choice", SX to date is still suffering from several drawbacks, such as the risk of poor phase disengagement and the high capital costs of solvent-extraction plants. Especially, the processing of leachates with lower copper tenors (< 1 g/L) is often economically less attractive. As a result, tremendous efforts have been dedicated to the evaluation of alternative technologies to address these challenges.

IX/SX PROCESSES

To date, selective chelating IX resins are being implemented at different stages of the copper processing flow sheet, i.e., (Streat & Naden, 1987; Zaganiaris, 2013): (i) the primary extraction/separation of copper from leachates to yield concentrates; (ii) the removal of trace impurities from electrolytes during copper cathode production (Halle *et al*., 2008; Ruiz *et al*., 2013); (iii) the elimination of heavy metals from mine waste waters to reduce the ecological footprint of a mine and to comply with local regulations; and (iv) the recovery of trace amounts of copper from residual ores in order to increase the overall efficiency of the process.

Being both used in the same applications (selective removal/concentration of particular metals), IX and SX are often considered as competitive technologies and their utilization within the same flow-sheet is seldom realized. However, a combined process, amplifying the strengths of each technology, would be desirable.

THE BUCHIM MINE PROJECT

The Buchim DOOEL Radovish Mine in Macedonia went online in 1979 after a construction time of three years (Solway Group, 2015). It is an open pit mine which produces copper, gold and silver concentrates by means of floatation. Thereby, 4 million tons of ore are converted into 40 000 tons of copper concentrate. After more than 30 years of operation, significant amounts of residual ores have been accumulating on site. Since this stockpiled overburden still bears a copper content of 0.2–0.3%, efforts were dedicated to recover this "lost" value. However, PLS originating from the sulfuric acid treatment of these low content ores typically exhibited a copper concentration of less than 1 g/L. Thus, a simple SX step for metal enrichment seemed to be economically unattractive due to the footprint of the resulting SX plant.

In order to overcome this shortfall, Iontech Engineering Ltd. developed a combined SX/IX process which is depicted in Figure 2 (Savov *et al*., 2012). The main difference, compared with a conventional hydrometallurgical copper recovery flowsheet, is the implementation of an IX step prior to SX.

In the primary IX circuit, copper is selectively removed from the PLS and accumulates on the ion-exchange resin. The feed is split between four trains, each consisting of two filters operated in a lead–lag configuration (see Figure 3). Once the first filter is exhausted, it is switched to the elution mode while the second is still in operation. Once the column is regenerated, it is placed back in operation at the lag position. The usual operating capacities are *ca*. 35 g of copper per litre of resin, depending on the fluctuating feed concentration of 0.5–1.0 g/L. The regeneration of the resin is accomplished with 15–20% sulfuric acid and furnishes an eluate with a copper tenor of 15–18 g/L which is unsuitable for direct EW. Thus, the concentration of the IX eluate is further upgraded in the subsequent SX step to achieve the desired copper content. The final EW step yields LME Grade A copper cathodes.

The IX/SX/EW plant at Buchim Mine has been successfully running since 2012 without any interruptions. The key operating figures are summarized in Table I.

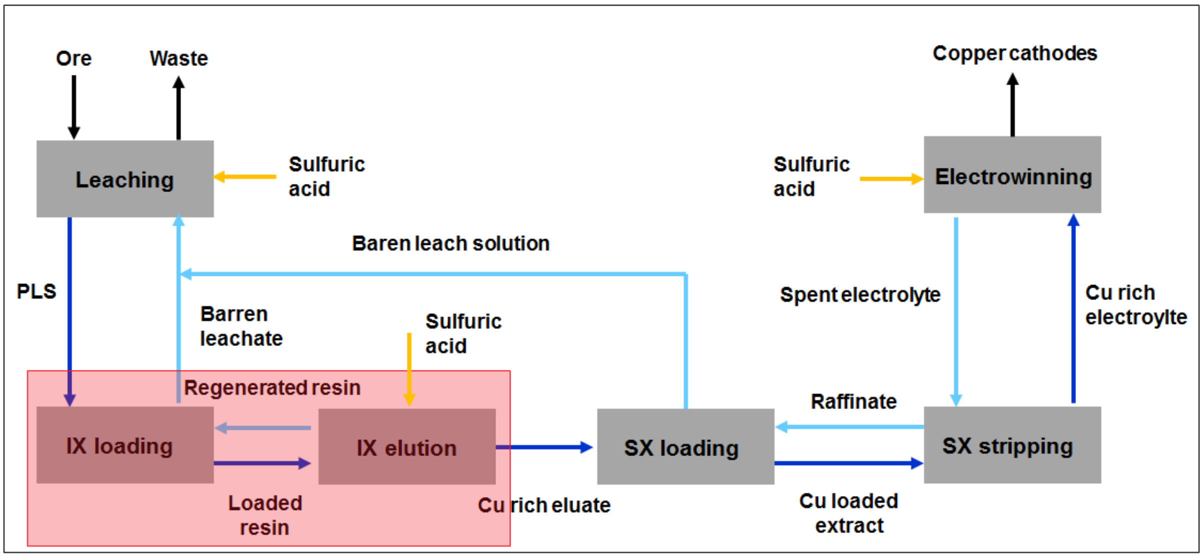

Figure 2. Flowscheme of the Buchim Mine copper recovery plant.
The combined IX/SX process has been running successfully for three years.

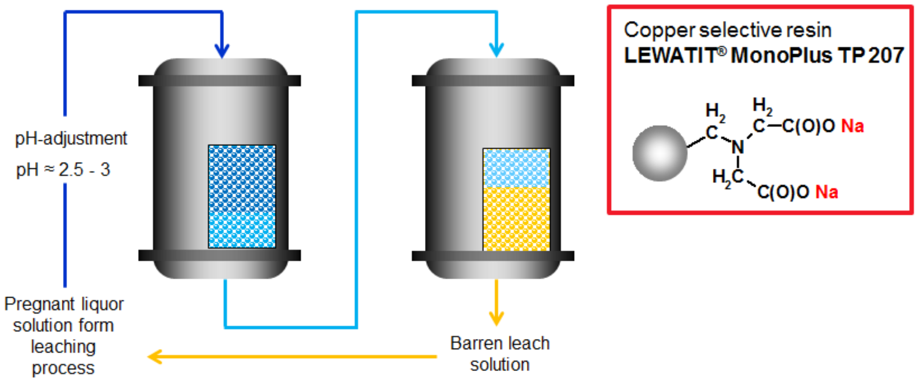

Figure 3. Lead and lag IX filter arrangement and the chemical structure of the copper-selective resin, LEWATIT® MonoPlus TP 207 from LANXESS.

Table I. Key design data for the SX/IX/EW process at Buchim Mine, Macedonia.

Leaching	Feed flow rate (m^3/h)	650
	pH of feed solution	2.5 – 3.0
	Copper PLS concentration (g/L)	0.7
	Iron feed concentration, max. (g/L)	0.3
IX	Feed flow rate (m^3/h)	648
	Copper loading capacity (g/L of resin)	35 – 40
	Copper concentration in the eluate (g/L)	15 – 18
	Concentrated copper eluate (CCE) (m^3/h)	40
SX	Flow rate of CCE to SX plant (m^3/h)	40
EW	No. of cells	24
	Total cathode area (m^2)	900
	Current density (A/m^2)	280
	Total flow rate of electrolyte (m^3/h)	110
	Copper electrolyte conc. (g/L)	38

A COMPARISON WITH A "CLASSICAL" SX/EW PROCESS – THE ASAREL MEDET PROJECT

The Asarel Medet Project in Panagjurishte, Bulgaria, was also successfully completed by Iontech Engineering Ltd. and reveals many parallels with the Buchim Mine (see Table II, Tsekov *et al.*, 2003). However, the copper cathode production follows the established hydrometallurgical flowsheme, consisting of sulfuric acid leach, solvent extraction and electrowinning. Due to similar ore copper contents, copper concentrations in the PLS and, likewise, annual copper cathode production levels, this reference can be used to compare this conventional SX/EW process with the complementary IX/SX/EW at Buchim Mine (Table III).

Table II. Key design data at Asarel Medet, Panagjurishte, Bulgaria.

Leaching	Feed flow rate (m^3/h)	500
	pH of feed solution	1.5–2.5
	Copper PLS concentration (g/L)	0.6
	Iron feed concentration, max. (g/L)	<5.0
SX	Flow rate of CCE to SX plant (m^3/h)	422
EW	No. of cells	10
	Total cathode area (m^2)	736
	Current density (A/m^2)	300
	Total flow rate of electrolyte (m^3/h)	100
	Average copper electrolyte conc. (g/L)	38

Table III. Comparison of the IX/SX/EW and the SX/EW processes.

		Buchim	**Asarel Medet**
IX	Resin type	Lewatit ® MonoPlus TP 207	–
	First fill of IX resin (m^3)	80	–
	Top-up (m^3/a)	7	–
SX	First diluent fill (m^3/a)	60	440
	Diluent consumption (m^3/a)	38	140
	Initial fill of extractant (m^3)	15	40
	Solvent extractant consumption	4	10
Summary	Maximum Cu cathode production (t/a)	2400	2000
	Plant footprint (m^2)	1500	3000

Strikingly, the integration of an additonal IX circuit lead to a reduction of both the initial diluent as well as extractant fill by 86% and 63%, respectively. In addition, the smaller volumes of organic liquids employed on the SX stage help to reduce the annual losses of these chemicals by 73% for the diluent and 60% for the solvent extractant. The resulting cost savings overcompensate the expenditures for the first resin fill, as well as the annual top-up (usually <10%), and ultimately lower the operational expenses.

Finally, the significantly diminshed quantities of liquids for the SX operation have a tremendous effect on the footprint of the whole plant (*ca.* 50% less). Anticipating that the building area corresponds, at least to some extent, with the costs for facilities and equipment, a reduction of the capital expenditures can be expected.

CONCLUSION

A new IX/SX/EW concept has been developed that capitalises on the complementary strengths of solvent extraction and ion exchange. This technology has been utilised for the recovery of copper from residual ores at the Buchim Mine in Macedonia for three years at full scale. Compared with conventional SX/EW operations, this technology makes the exploitation of low-grade copper ores econmically attractive, due to reduced operational and capital expenditures. Furthermore, the additional ion-exchange installations diminsh the volumes of harmful organic substances in the following SX step and minimise the risks associated with the handling/usage of these chemicals, such as environmental pollution or fires.

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