THE SUCCESSFUL COMMERCIAL IMPLEMENTATION OF THE COMBINED LEACH – ION EXCHANGE – SOLVENT EXTRACTION - ELECTROWINNING PROCESS AT THE BUCIM COPPER PROJECT

By

[1]Todor Angelov, [1]Georgi Savov, [1]Aleksander Tsekov and [2]Ivan Nishkov

[1]Iontech 2000 JSC, Bulgaria
[2]University of Mining and Geology "St. Ivan Rilski", Bulgaria

Presenter and Corresponding Author

Todor Angelov
todor_ang@abv.bg

ABSTRACT

Bucim Copper Project is situated near the village of Bucim and in the south borders of Plachkovitsa Mountain in the Republic of Macedonia. Territorially and administratively the Project belongs to the municipality of Radovis. It is 95 kilometers away from the Skopje capital, and 170 kilometers from the nearest port Thessaloniki (Republic of Greece) at an altitude of 620 m above sea level.
Commissioned in January 2012 and reached steady copper production in August 2012, Bucim Copper Project, became the first commercial operation using combined Iontech's hydrometallurgical process to treat low grade and higher grade oxide copper ores and to produce LME grade copper cathodes. The Iontech's Leach-Ion Exchange–Solvent Extraction-Electrowinning process combines ion exchange and solvent extraction to extract and concentrate the copper from pregnant leach solution, before the final product - copper cathodes is obtained by electrowining. The process is suitable for recovery of copper from PLS with metal concentrations, varying on a broad range as well as for treatment of solutions in the decommissioning of spent copper heaps and dumps, acid mine drainage /AMD/ and ammoniacal etch solutions. Furthermore, combining the ion exchange and solvent extraction allows (1) winter operation without troubles - solvent extraction work properly i.e. with good phase disengagement times, even at low temperatures (this is due to high temperatures of ion exchange regenerate used as a solvent extraction feed), (2) strongly reduces organic losses and crud formation, (3) control of metal/acid ratio, which is very important for solvent extraction process and (4) lead to solvent extraction plant sizes reduction.

In order to improve the whole plant performance, to expand the production capacity and to provide proper management of the excess drainage waters in 2014 was decided to expand the Bucim Copper Project. The expansion will be completed in 2015, with the commissioning of newly constructed leach fields, the expanded ion exchange circuit as well as with total replacement of extractant originally used in solvent extraction circuit.

This paper highlights the successful implementation of Combined Leach-Ion Exchange–Solvent Extraction-Electrowinning process at the Bucim Copper Project, while providing the original operations description as well as the changes and additions within the plant, which will lead to improved overall performance.

INTRODUCTION

Bucim Copper Project started to operate in January 2012 at the Bucim Mine Site in the Republic of Macedonia by applying combined Iontech's hydrometallurgical process with heap leaching, ion exchange, solvent extraction and electrowinning at a small scale of 2400 tons of copper cathodes per year. The combined Iontech's Leach-Ion Exchange–Solvent Extraction- Electrowinning (ION/L-IX-SX-EW) process was selected as the best available technology for the site not only due to the fact that the final product is with extremely high quality, but also due to its ability to achieve the stringent environmental demands.

Based on a successful start up, despite the extended commissioning, related largely to mechanical issues, a decision to expand production to a rate of 3000 tons of copper cathode per year was taken in the 2014.

The Bucim Copper Project comprises a leach operations for treatment of oxide copper ore, together with associated ion exchange, solvent extraction, and electrowinning circuits to separate and recover copper dissolved from the ores. New developments, changes and additions to a number of the original operations like new leach fields construction, ion exchange circuit expansion and SX reagent replacement has led to project recovery and availability levels routinely above 95%.

IONTECH/ LEACH-ION EXCHANGE-SOLVENT EXTRACTION-ELECTROWINNING (ION/L-IX-SX-EW) PROCESS

Development Hystory

Iontech began developing the combined process in 2002, with the main purpose of developing a new hydrometallurgical process to recover copper from copper pregnant leach solutions.

The successful results of the initial bench scale tests initiated the design and construction of a fully integrated pilot plant at the Tzar Asen Copper Project /TACP/, with production capability of 960 tpy (or 2.6 tpd) of copper cathode. The TACP is located adjacent to the mining village of Tzar Asen in Bulgaria's central parts at an elevation of about 300 m above sea level, approximately 120 km southeast of Sofia, the country's capital city. The TACP involves treatment of the PLS stream, originating from the dump leach operation with the ion exchange facility for copper extraction and concentration, and the subsequent recovery of the copper as a high purity cathode product by solvent extraction and electrowinning, to produce sheets of 99.99%-pure copper cathodes(1).

Operations of the TACP pilot plant confirmed the metallurgy of the ION/L-IX-SX-EW process and gave enough engineering, design and operational data to minimize the scale-up risk in order to implement the combined process in fully commercial operations for copper recovery(2).

Process Description

The ION/L-IX-SX-EW process is very succesful in the recovery of copper from different copper containing solutions. Figure 1 depicts the overall process. As the name suggests the process involves four major stages:

- Leaching - the process by which copper is removed from the ore using chemical agents called lixiviants, mostly sulfuric acid solution. When lixiviant solution is applied to the ore, it dissolves the present copper to produce a pregnant leach solution(PLS);

- Ion Exchange - the processin which the copper containing PLS is passed trough the resin laid in the columns and copper is adsorbed on the resin. The column is then regenerated with sulfuric acid solution to obtain highly purified copper solution, suitable for the further treatment via solvent extraction process;

- Solvent Extraction – the process in which an organic extractant that binds copper but not impurity metals is dissolved in an organic solvent (diluent) and is mixed with the copper containing aqueous solution. The copper-loaded organic solution is separated from the aqueous solution in a settler tank. The barren aqueous solution, called raffinate is sent back to the leaching. Sulfuric acid solution, mostly spent electrolyte returned from the EW tankhouse is then added to the loaded organic mixture, which strips the copper into an electrolytic solution ready for electrowinning;

- Electrowinning - the process by which copper ions within strong electrolyte solution, produced in SX process are plated onto the cathode to produce copper sheets with 99.999% purity.

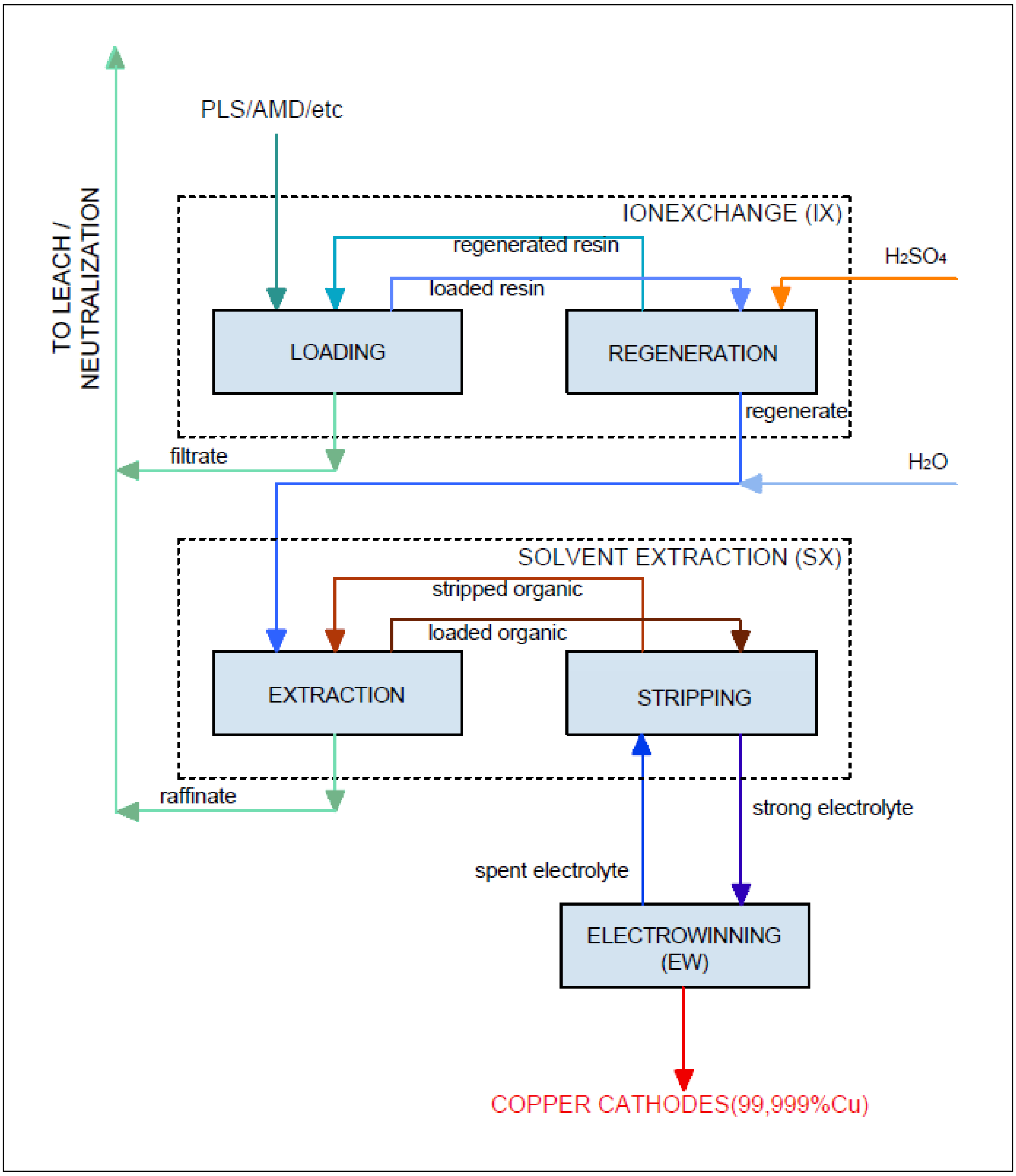

Figure 1: ION/L-IX-SX-EW Process basic flowsheet

Key Findings

The key findings of the ION/L-IX-SX-EW process are:

1. The Process is suitable for recovery of copper from solutions with metal concentrations, varying on a broad range;

2. The Process is capable to operate effectively with very low-graded copper-bearing solutions. This results in prolonged projects life, compare to solvent extraction recovery only;

3. The construction of large ponds for pre-filtration of the PLS is not necessary. In this case, very sensitive solvent extraction process can be work properly even at intensive rainfalls and with turbid solutions and solutions containing large quantities of suspended solids;

4. Winter operation without troubles. SX can be work properly i.e. with good phase disengagement times, even at low temperatures. This is due to high temperatures of IX regenerate used as a SX feed;

5. Combining of ion exchange and solvent extraction strongly reduces organic losses and crud formation;

6. Integration of the IX process in SXEW scheme can be used for control of metal/acid ratio as well as Cu/Fe ratio, which are very important for SX process;

7. Combining of ion exchange and solvent extraction reduces EW organic problems and thence improved copper cathodes quality;

8. Ion Exchange - Solvent Extraction - Electrowinning technological approach lead to SX plant sizes reducing. Thus, minimizes the floor space requirements for SX “footprint“;

9. The IX-SX combination is characterized with similar capital cost and lower operating cost compare to solvent extraction process only;

10. The Process generates no effluents and minimal emissions;

11. The Process offers short construction times.

Possible Applications

The objective of the ION/L-IX-SX-EW process development was to provide an economically attractive and environmental friendly alternative for copper recovery from different process streams in order to produce high quality final product.

The ION/L-IX-SX-EW process:

- is capple to treating variety of pregnant leach solutions originating from:
  - dump leach operations
  - heap leach operations
  - agitation leach operations
  - vat leach operations

- allows the economic treatment of low-grade copper containing streams like:
  - solutions from the decommissioning of spent copper dumps and heaps
  - acid mine drainage (AMD)
  - other contaminated waters and process streams

COMMERCIAL IMPLEMENTATION OF IONTECH/ LEACH - ION EXCHANGE - SOLVENT EXTRACTION - ELECTROWINNING (ION/L-IX-SX-EW) PROCESS

The Iontech/Leach-Ion Exchange-Solvent Extraction-Electrowinning (ION/L-IX-SX-EW) Process has been under development for over 9 years. In the late 2010 the construction of an industrial

scale plant, with start-up scheduled for early 2012, began at the Bucim mine site in the Republic of Macedonia. This was the beginning of the Bucim Copper Project - the first operation commercially using the ION/L-IX-SX-EW Process.
The Bucim Copper Project is situated near the village of Bucim and in the south borders of Plachkovitsa Mountain, in Republic of Macedonia. Dominating top in the immediate surrounding is Versnik, on 720 meters above the sea level, while 620 meters is the average above the sea altitude of the ore deposit[3].

Figure 2: Bucim Copper Project Location

Bucim Copper Project territorially and administratively belongs to the municipality of Radovis. It is 95 kilometers away from the Skopje capital, and 170 kilometers from the nearest port Thessaloniki (Republic of Greece).

Copper production at the Bucim Copper Project started at a level of 2400 tons of copper cathodes per year, treating oxide ore to recover copper and to produce LME grade copper cathodes.The downstream processing of the copper-rich solutions, produced by the leach process includes ion exchange and solvent extraction circuits to extract and concentrate the copper, before the final product-copper cathodes is obtained by electrowining. The project includes heap leach facilities with separate pregnant leach solution ponds, events pond, sediment control ponds, copper recovery plant, roads, man camp, and miscellaneous facilities to support the main operations.

The Bucim Copper Project has been successful in achieving its production goal, obtaining high quality cathodes since start up. However, after twelve months of operation was desided to increase its production to 3000 tons of copper cathodes per year by the commissioning of new leach fields and the ion exchange circuit expansion.

Bucim Copper Project Original Operations

The Buchim Copper Project includes the following operations: Heap Leaching, Ion Exchange, Solvent Extraction and Electrowining[4]. The process flowsheet is shown in Figure 3.
The piping network for heap leaching comprises main lines at ground level and heap supply header pipes along the heaps, which distribute solution over the surface through a series of dripper lines. All piping networks are HDPE throughout, and are installed manually using special equipment.In the leaching operation the barren solution from the ion exchange facility (“filtrate”) and solvent extraction plant (“raffinate”) which has a high acid concentration is applied to the surface of the dump at rates of eight litters per square meter each hour. Pregnant leach solution (PLS) forms as the solution percolates through the pile and dissolves copper minerals into the aqueous solution as copper sulphate. The PLS flows down through the entire heap until it reaches the drainage layer where it enters the lined PLS pond. A highly permeable material separates the two liners and leak, if detected is removed by a pump. Control-emergency pond, designed to accommodate the excess flow from leaching and the runoff from major storms is also constructed at the site.

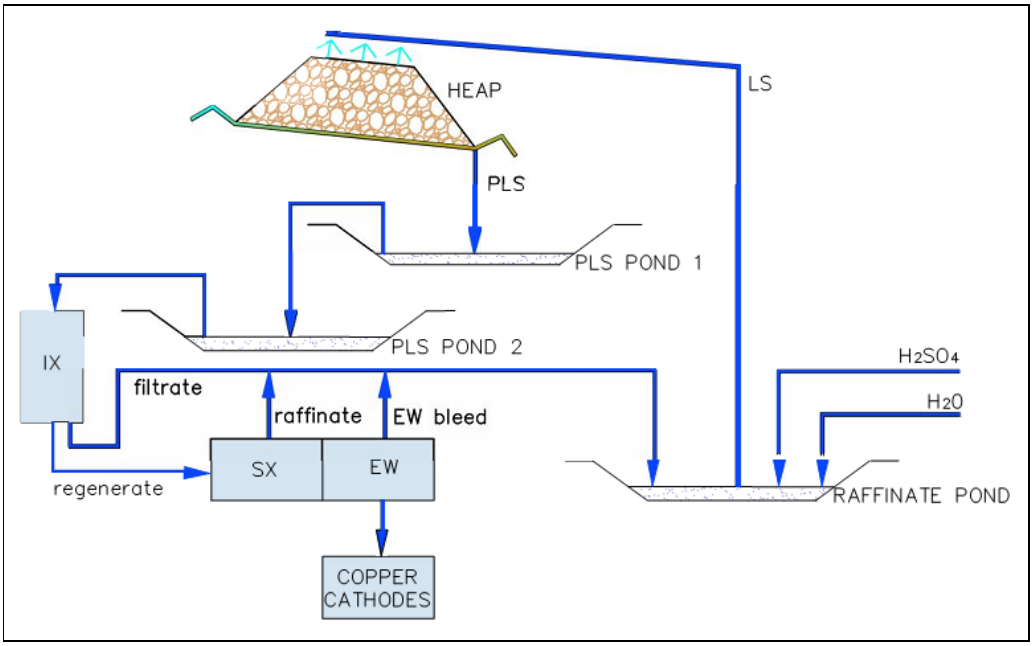

Figure 3: Bucim Copper Project flowsheet

From the PLS ponds, solutions are directed to IX facility with a design feed flow rate of approximately 650 m^3/h. The facility consists of 8 ion exchange columns - 4 IONTIX units (Iontech Design)(5). The obtained IX regenerant is pumped to plant feed pond, where it is mixed with pregnant leach solution from the leach operation. Feed solution from the plant feed pond flows into a conventionally designed solvent extraction plant (SX) at around 30 m^3/h. The SX plant using a 3E x 2S configuration, with "conventional flow" design. The feed is depleted of copper and returned to leaching as a raffinate solution along with the filtrate from IX facility, thus forming a very environmentally responsible process by not allowing any discharge into the environment. The use of a selective copper extractant (LIX 84-I), which operates in a closed circuit inside the plant, allows the copper to be transferred to an electrolyte operating in a closed circuit with the electrowinning plant.

The copper is captured from the strong electrolyte in the electrowinning plant. The electrowinning process uses a common design. Cells are connected in series to a current transformer rectifier with hydraulic feeding of electrolyte to cells connected in parallel. Scavenger cells are not included. The operation uses stainless steel permanent cathodes and Pb/Ca/Sn alloy anodes, assembled in combinations of 25 and 26 units per cell, respectively, contained in a total of 24 cells.

The cathodes are removed from the cells and transported for manually stripping by hammer and chisel in order to separate the deposited copper from the mother plate. The copper cathodes with 99.999% purity are weighed and banded and the mother plates are rinsed and returned to the cells for the next loading cycle.

The main operational parameters are summarized in Table 1.

Table 1: Bucim Copper Project original operational parameters

Leaching	Application Rate - 8 l/h/ m^2
PLS Flowrate	650 m^3/h
PLS Copper Grade	0.5 - 0.6 g/l Cu
IX resin	64 m^3(H^+ form); Lewatit TP 207 M+
SX feed	28 m^3/h; 7-8 g/l Cu, 15-20 g/l H^+
Organic	45 m^3/h; 20 v/v% LIX 84-I diluted in ShellSol D100
Lean Electrolyte	22,5 m^3/h, 37 g/l Cu ,175 g/l H^+
Strong Electrolyte	110 m^3/h, 49 g/l Cu,160 g/l H^+
Electrowinning	Permanent cathodes, 280A/ m^2, 24 cells, 92%Current efficiency
Product Quality	LME (High Purity Grade) Copper

Bucim Copper Project New Developments

After approximately two years of successful leaching operations, in the second quarter of 2014 the pregnant leach solution chemistry has changed dramatically - solution copper grade decreased (from 0.5-0.6 g/l to below 0.3 g/l) and acidity inreased. In order to improve the overall performance of leaching operations and to increase copper grade in pregnant leach solutions new leach fields at the oxide heap leach are designed, constructed and commissioned in the middle of 2014 with total area for leach of 73 664 m^2. Moreover, an orderly leach management plan, which includes properly, designed application periods followed by rest periods, during which aeration and oxidation of copper minerals will continue and application rates are developed and enforced. Compliance with the plan has lead to the restoration of copper grade and the pH of solution to the optimal levels - 0.7 g/l Cu and pH 2.5-3.0.

In November 2014 Bucim Copper Project improved its ion exchange operation at plant scale by applying two new ion exchange colums, within the existing ion exchange facility. The new ion exchange columns have the same design and bigger size as the original ones.

In the meanwhile new flow configuration for maintaining the optimal pressure loss in the columns and to give more flexibility to treat feed solutions with variable copper concentrations was applied successfully at the ion exchange facility. The original flow configuration was kept. The new flow configuration differs from the original flow configuration, as the exiting the first column solution enters the top, instead of the bottom of the second column. As a result approximately 25 percent in the copper production rate was reached.

The solvent extraction plant started to operate with ketoxime reagent LIX 84-I. For the purpose of make up only this reagent had been used in its standard version LIX 84-I.

In 2013 a solvent extraction reagent called Acorga M5640 was successfully tested and the replacement of LIX 84-I reagent inventory gradually through make up quantities of Acorga M5640 was decided in the middle of 2013. In October 2013 Bucim started to use Acorga M5640 as make up reagent to the solvent extraction plant. The main characteristics of the new reagent are increased reagent stability, higher organic loading as % of maximum load and improved copper net transfer.

The conversion of the Bucim Copper Project plant organic from a ketoxime LIX 84-I reagent to a strong ester-modified aldoxime Acorga M5640 reagent, has directly resulted in significant improvement in the overall performance of the solvent extraction circuit as well as in the plant organic health.

The main operational parameters after new developments at the Bucim Copper Project are summarized in Table 2.

Table 2: Bucim Copper Project new developments operational parameters

Leaching	Total area for leach - 122 000 m^2 Application Rate – 8-10 l/h/ m^2
PLS Flowrate	650 m^3/h
PLS Copper Grade	0.7 g/l Cu
IX resin	84 m^3(H^+ form); Lewatit TP 207 M+
SX feed	42 m^3/h; 8-10 g/l Cu, 15 g/l H^+
Organic	46 m^3/h; 21 v/v% Acorga M5640 diluted in ShellSol D100
Lean Electrolyte	25 m^3/h, 35 g/l Cu, 180 g/l H^+
Strong Electrolyte	110 m^3/h, 50 g/l Cu, 160 g/l H^+
Electrowinning	Permanent cathodes,300 A/ m^2, 24 cells, 92% Current efficiency
Product Quality	LME (High Purity Grade) Copper

CONCLUSIONS

Successful commercial operations at the Bucim Copper Project using Iontech/Leach-Ion Exchange-Solvent Extraction-Electrowinning (ION/L-IX-SX-EW) process have shown that copper can be recovered selectively into saleable high-grade product from low grade leach solutions and that no effluents are produced for environmental discharge, because all streams are returned to the site where they originated, namely the heap.

In general the Buchim Copper Project provides a valuable case study in all aspects of plant operations for future implementations of this type of technology. There are a number of copper deposits worldwide that are amenable to treatment by this type of circuit and the lessons learnt will be valuable in eliminating some of the issues that will be “fact of life” during the design, commissioning and operation.

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