

# PROCESSING OF HALCOPYRITE LOW GRADE ORE - ENHANCING GOLD RECOVERY BY LEACHING AND BIOLEACHING

**Boris KRSTEV, Alexandar KRSTEV**

Faculty of Mining&Geology  
32000 STIP  
Republic of Macedonia  
borisk@rgf.ukim.edu.mk

## ***Abstract***

The conventional flotation technologies cannot provide fair results when applied to very low grade ores or to "refractory" ores. This class includes intimate and nonuniform mineral associations, with partially oxidized minerals and high secondary mineral content and also high soluble salt content, pre-activated minerals because of the excessive permeability of the deposit and of the intense circulation of waters with heavy metal ions etc. Bacterial oxidation as a means to the recovery of metals from sulphidic deposits has been used for thousands of years. One of the major uses of biooxidation is the leaching of copper or the liberation of refractory gold where this is encapsulated in pyrite. In the Bucim copper mine Macedonia, porphyritic type, the final product from flotation is the copper concentrate consisting 20% Cu, 21g/t gold and 25g/t silver, with recoveries: 88-90% for copper, 60% for gold and 40% for silver. The carried out investigations of the leaching in the agitated tank involve micro-organisms, thiobacillus ferro-oxidans and thiobacillus thio-oxidans. The achieved results are following: Copper recovery 95%, gold recovery from 70-85% and silver recovery from 70-80%.

**Key words:** Bioleaching, gold, silver, thiobacillus ferrooxidans, leptospirillum ferrooxidans,

## **Introduction**

Bucim copper and gold mine is the unique mine in the Republic of Macedonia located in the southern part of country on the south-west slopes of the Plackovica mountain. The mine is situated 130 km from the Republic capital-Skopje, 13 km from Radovis, and 2,5 km from the road connecting Stip with Strumica. The unique copper mineralization of a porphyritic type is occurring in the gneisses to their contact with the andesites. The mineral content decreases gradually with increasing distance from the contact and occurs principally as fillings and coatings on fracture planes. Andesites are barren in general, however, copper mineralization associated with fractures and joints is found in the andesites as well.

After 1979 the first tonnes of the copper concentrate are produced. Since that time to nowadays the Bucim mine permanently has realised a good production - financing results including itself in the leader country company. Mine of the open type is the basis characteristic of the Bucim mine. The mine is equipped with modern mechanisation making possible about the high productivity and good operating conditions for the operators. The process includes drilling and blasting, then blasted ore is transported towards primary crushing while the tailing on the mine disposal. The Mineral Processing and ore concentration cover the following operations: primary, secondary and tertiary crushing, screening and storing, grinding and classification, flotation, regrinding, thickening and filtering and finally the tailing removal in tailing pond. Final product is the copper concentrate consisting 20% Cu, 21 g/t Au and 25 g/t Ag, with following recoveries: 88% for copper, 60% for Au and 35-40% for silver.

## Developments in Gold processing

Recovery techniques for gold have progressed in line with new ore discoveries in recent years, while basic methods also remain essential for profitable production. Various new developments are mentioned, such as oxidation, cyanidation, CGA (coal gold agglomeration), carbon technologies: CIP (carbon-in pulp), CIL (carbon-in-leach), CILO (carbon-in-leach with Oxygen), bioleaching and other alternatives.

The cyanidation or cyanide process depends on the dissolution of exposed gold particles to dilute alkaline cyanide solution - usually sodium cyanide, NaCN, - in the presence of oxygen. The gold is then usually concentrated from the cyanide solution by precipitation on zinc or by adsorption on activated carbon, with further treatment to produce saleable gold. The gold in the ore must be exposed to the leaching action of the cyanide solution to dissolve it. Some ores are sufficiently porous for the solution to percolate through them without fine grinding; many of these are amenable to percolation leaching in vats or heaps. Others are impervious, and require fine grinding before being leached in suspension in agitators.

Coal gold agglomeration CGA process ingeniously combines one of the classic mineral separations with established coal preparation technology. Gold surfaces are generally hydrophobic, and therefore gold can be recovered by surface chemically-based processes such as flotation or amalgamation. Similarly, the selective recovery of hydrophobic gold particles from an aqueous slurry into an oil phase. The process involves mixing gold ore slurry with oil in the form of coal/oil agglomerates. Oleophilic (oil loving) gold particles are incorporated into the coal/oil agglomerates, which can then be separated easily from the slurry by screening or flotation. High gold recovery independent of particle size, no cyanide or mercury is used, therefore the process has environmental attractions. Silver (native or argentite) and platinum group metals also recoverable.

Using high oxygen concentrations in carbon-in-leach gold extraction can give shorter residence times, enhanced recoveries and a reduction in plant size. The developers of CILO are confident that the technology can be applied in both new and retrofitted plants seeing the principal advantages of the system as:

- A reduction in capital and operating costs of a CIP plant by effectively eliminating the entire leaching section;
- A reduction in the capital and operating costs of a CIL plant by substantially reducing the size of the leaching tanks by a factor estimated at 4,8;
- An improvement in gold extraction and a reduction in costs as compared to the operation of conventional CIP and CIL plants;
- The possibility of maximising gold recovery by the utilisation of similar retention times as in present systems;
- In the case of retrofitting, benefits would comprise increased capacity, reduced per-ton costs, or improved gold extraction, or a proportionate combination of these parameters;
- In the case of ores containing oxygen-consuming materials, for example, from tailings dams, the use of oxygen enrichment has been shown to give significantly increased recoveries.

The characteristic of the bioleaching of copper sulphides is following:

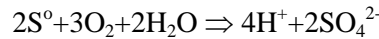
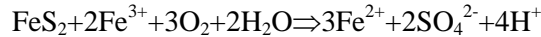
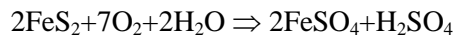
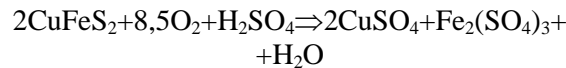
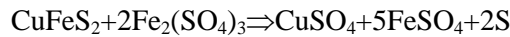
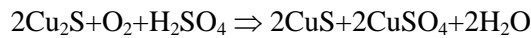
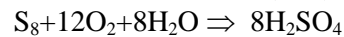
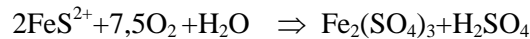
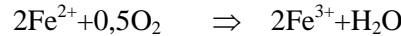
- The minerals being leached are copper sulphides;
- The mine and plant have been using the leaching/cementation process for more than a century;
- The leaching of sulphides is enhanced by bacteria of the thiobacillus genus;

The bacterium usually encountered in metal sulphide oxidation is *Thiobacillus ferrooxidans*. It's versatile and oxidises both iron and sulphur under acid conditions. It grows readily on pyrite, arsenopyrite and chalcopyrite, to mention but a few mineral sources of nutrition. A variety of micro-organisms, some as yet unknown, are associated with the bacterial leaching of minerals. Of these, the best known types are:

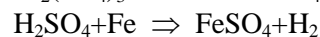
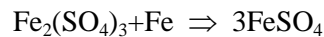
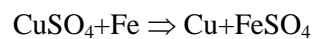
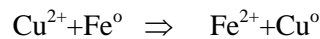
- *Thiobacillus ferro-oxidans* and *thio-oxidans* which thrive in extreme environments of high acidity and heavy metal concentrations, and temperatures up to 35°C;
- *Leptospirillum ferro-oxidans* - a group of microbes which oxidise iron and metal sulphides in media at temperatures up to 50°C;

- The extreme thiophiles, such as *Sulfolobus* and *Acidianus*, which thrive at temperatures as high as 50°-70°C.

The mechanisms through which micro-organisms oxidize sulphide minerals are complex and are not fully understood. Nonetheless, two mechanisms, termed direct oxidation and indirect oxidation, have been identified. Direct oxidation refers to reactions which are directly catalysed by micro-organisms. Indirect oxidation, on the other hand, refers to reactions which utilize the oxidation properties of ferric iron. It's evident that the leaching systems involved are complex with regard to the micro-organisms present (normally more than one type in natural systems), interactions between the micro-organisms populations present, and the oxidative processes which lead to the eventual extraction of the metals. The reaction of the bacteria:



The reaction of cementation:



Biobleaching of copper minerals in dump and heap leaching operations is the most common industrial scale application of bio-hydrometallurgy and is used in several countries including USA, Russia, Australia, Canada etc.

- With adaption of the bacteria and optimisation of the various process variables, the residence time could be reduced to about four days to give similar gold extraction;
- The process is simple to operate with the key control variables being temperature, pH dissolved oxygen and ferric iron;
- Bacteria are extremely hardy, and can withstand mishaps normally experienced in industrial plant operations;
- Engineering is significantly less sophisticated than for pressure leaching or roasting.

### Existing industrial flotation investigations

The investigations for ore samples from the Bucim mine are carried out by flotation in the standard and new reagent regime. In rougher selective chalcopyrite concentrate are obtained the following results for recoveries of copper, gold and silver:

**Table No 1.** Results of flotation

Conditions	R e c o v e r y (%)		
	Cu	Au	Ag
Standard	89.85	57.50	40.50
New-Orfom C0800	91.18	82.66	45.43
New-Penflot - 3	92.50	77.26	48.71
Varied	90.35	85.82	42.20

## Experimental Examinations

The laboratory investigations from bioleaching for the presence precious metals - gold and silver are carried out by *Thiobacillus ferro-oxidans* and *Leptospirillum ferro-oxidans* in "short" treatment time (for week) on the temperature from 35°. The reaction for cementation is carried out with scrap iron. The cumulative recoveries are given on the following table:

**Table No 2.** Results of bacterial leaching

	Cu (%)	Au (%)	Ag (%)
Leaching ( $H_2SO_4$ )	92.4	81.5	75.5
Leaching ( $NH_3$ )	93.0	84.5	80.5
Leaching ( $H_2SO_4 + H_2O_2$ )	93,0	82,5	78,5
<i>Thiobacillus ferrooxidans</i>	96.5	86.8	81.2
<i>Leptospirillum ferrooxidans</i>	95.4	84.7	85.0

## Conclusions

It's evident advantage of the achieved results by "short" term bioleaching on the standard conditions for the porphyritic type of ore relating to the conventional selective chalcopyrite flotation using standard (KEX or NaIPX) or new reagent regime ( Orfom and Penflot).

## References:

1. C.C.Mwaba (1991), Biohydrometallurgy: An Extraction Technology for the 1990s, *Mining Magazine*, September 1991.
2. Brewis T. (1995), Metal extraction by Bacterial oxidation, *Mining Magazine*, October 1995.
3. Ralph, B.J., (1985), Biotechnology Applied to Raw Minerals Processing, in *Comprehensive Biotechnology, volume 4, edited by Robinson, C.W. and Howell, J.A.*, Pergamon Press, Oxford (UK).
4. Harris, L. and Brierley. J.A., (1989), Biotechnology, *Mining Magazine*, Oct. 1989, 301-304.
5. Smith, E.E. and Shumate, K.S., (1970), Sulphide to Sulphate Reaction Mechanism: A Study of the Sulphide to Sulphate Reaction Mechanism as it Relates to the Formation of Acid Mine Waters, Water Pollution Control Research Series, Ohio State University Research Foundation, Ohio, USA.
6. Brierley, J.A., (1990), Biotechnology for the Extractive Metals Industry, *J. Metals*, 42(1), 28-30.
7. Brown, J., (1989), Developments in Bio-Oxidation Leaching, in *Contemporary Gold-Bendigo: A Workshop for the Gold Extraction Industry, 27-29 September 1989*, Bendigo, Australia.
8. Demopoulos, G.P. and Papangelakis, V.G., (1989), Recent Advances in Refractory Gold Processing, *CIM Bull*, 82(931), 845-91.