

HEAP LEACHING OF AFRICAN COPPER-COBALT ORES

Lewis G., Bastin D., Alvayai C. & Frenay J.
University of Liege, Chemin des Chevreuils B52/-1, 4000 Liege, Belgium
E-mail: J.Frenay@ulg.ac.be

ABSTRACT

Heap leaching is now largely applied to recover copper from oxidized ores. However it is not yet applied in central Africa. Laboratory tests have been carried out in order to study the feasibility of the process to valorize the copper-cobalt oxidized ores from Katanga, DR Congo.

Laboratory percolation tests studied the main parameters such as flow-rate, acid curing, acid concentration, copper recovery, acid consumption, concentrations in the pregnant leach solution.

Results show a high and fast leaching of copper and a rather low and slow kinetic of cobalt leaching, due to the majority of Co(III) species.

A property of these ores is to generate a great quantity of fine particles which considerably limit the permeability of the heap. Different ways to improve the permeability were investigated : elimination of the finest particles or agglomeration of the overall ore with or without sulfuric acid curing.

KEY-WORDS : heap leaching ; cobalt ; copper ores ; permeability ; desliming ; agglomeration.

1 INTRODUCTION

Hydrometallurgy of oxidised copper ores is now a well experienced process. For deposits of medium size –saying around a capacity of 20 000 t Cu per year – the process consists in a sequence of three main steps : heap leaching – solvent extraction – electrowinning.

Heap leaching is now of very common practice, low capital intensive and carried out on the mine site, allowing a satisfactory management of the residues. Solvent extraction is needed to concentrate the pregnant solution – usually between 1 to 5 g/L Cu – up to values required by the electrowinning, typically 30 to 45 g/L Cu.

However specific ore deposits may require adapted flowsheet. It could be the case of oxidised Cu-Co deposits which only exist in central Africa, D.R.Congo and Zambia. Moreover the use of heap leaching has been until recently considered as hazardous in some regions of the world, particularly in central Africa where an alternance of dry and wet seasons occurs with storms of high intensity.

The purpose of this research was to assess the feasibility of the heap leaching – solvent extraction – electrowinning treatment to DRC Cu-Co ore deposits. It has been carried out on some deposits processed by societies of the Forrest Group, mainly CMSK.

2 MATERIALS AND METHODS

2.1 The Cu-Co Oxidised Ores

Samples of two ore deposits of Katanga, DRC, have been studied. Their chemical analysis are given in table 1.

Table I – Chemical analysis of Cu-Co oxidised ores, %.

sample	Cu	Co	Fe	SiO ₂	Al ₂ O ₃
A	4.05	1.15	1.0	65.1	8.7
B	3.20	0.11	3.0	56.3	28.2

As received, sample A contained 27 % of –20mm. It has been crushed in our lab under 20mm. The particle size analyse of the crushed sample is given in table 2.

Table II – Particle size analysis of a crushed –20mm ore sample (sample A).

	Sieve opening [mm]	Medium-size [mm]	Ore distrib. [%]	Cumul. smaller [%]
-20+15mm	20	17.5	12.3	100.0
-15+10mm	15	12.5	17.2	87.7
-10+5mm	10	7.5	17.7	70.5
-5+2mm	5	3.5	17.7	52.8
-2+1mm	2	1.5	9.4	35.0
-1+0.5mm	1	0.75	6.1	25.6
-0,5+0.25mm	0.5	0.375	2.4	19.6
-0,25+75µm	0.25	0.1625	5.0	17.2
-75µm	0.075	0.038	12.2	12.2

As received, sample B was composed of a huge amount of fine particles, characterized by a muddy appearance. Its particle size analysis is given in table 3. This is explained by the strong meteoric alteration undergone by these old ore piles. It has been crushed in our lab under 30 mm.

Table III – Particle size analysis of a uncrushed ore sample (sample B).

	Sieve opening [mm]	Medium-size [mm]	Ore distrib. [%]	Cumul. smaller [%]
+100mm	-	-	9.0	100.0
-100+50mm	100	75	10.4	91.0
-50+30mm	50	40	6.0	80.6
-30+20mm	30	25	3.8	74.6
-20+10mm	20	15	8.8	70.8
-10+5mm	10	7.5	7.3	62.0
-5+2mm	5	3.5	10.5	54.7
-2+1mm	2	1.5	6.8	44.2
-1+0.5mm	1	0.75	5.9	37.4
-0,5+0.25mm	0.5	0.375	2.8	31.5
-0.25+0.15mm	0.25	0.2	3.2	28.7
-0,15+75µm	0.15	0.1125	5.0	25.5
-75+43µm	0.075	0.059	1.1	20.5
-43µm	0.043	0.0215	19.5	19.5

It is evident that sample B contains a very great proportion of material of fine and very fine particle size. Crushing of this material can obviously increase this amount as shown in table 4.

Table IV - Proportion of fine material, %.

	-250µm	-75µm	-43µm
Received sample	28.7	20.5	19.5
Crushed -30mm	30.7	21.9	20.7
Crushed -15mm	38.6	29.5	28.0

The chemical analysis made on fractions of the different particle sizes showed a rather regular distribution of Cu and Co except in the fine fractions (-250µm) of both samples which are more than two times less concentrated in copper.

Mineralogical observations (optical microscopy and X-Rays Diffraction) carried out on sample A highlighted:

- The main phases containing Cu are malachite $\text{Cu}_2\text{CO}_3(\text{OH})_2$ and pseudomalachite $\text{Cu}_5\text{PO}_4(\text{OH})_4$ and a small quantity of chrysocolla, copper silicate;
- The main phase containing cobalt is heterogenite $\text{CoO}(\text{OH})$ under different cristallinity states;
- The main components of the gangue are quartz, silica and phyllosilicates, in decreasing order: clinocllore, muscovite and talc.

Similar observations on sample B showed roughly the same mineralogy with a larger amount of copper silicate, phyllosilicates and iron oxy-hydroxide, mainly goethite.

The chemical leachability has been determined by agitation leaching in Erlenmeyer of -150µm samples at various pH.

Results showed for sample A:

- A very fast leaching of copper: 95 % after 30 minutes;
- A very low leaching of cobalt: 5 % after 30 minutes;
- A low acid consumption by the gangue.

And for sample B:

- A lower leaching of copper: 80 % after 3 hours;
- A very low leaching of cobalt: 10-13 %;
- Acid consumption depends on the leaching duration.

2.2 Percolation Leaching Tests

Percolation tests were carried out in laboratory columns. Different particle sizes were tested : minus 10mm, minus 15mm and minus 20mm.

The influence of main parameters has been studied : particle size, acid concentration, flowrate. The impact of the amount of fine particles has also been investigated on the highly weathered sample B.

Table V – Percolation device

	Height [m]	Diameter [m]	Ore processed [kg]
Small column (s)	0.5	0.086	4
High column (h)	1.8	0.100	22

3 RESULTS AND DISCUSSION

Some significant results of the percolation tests are given in figures 1 and 2.

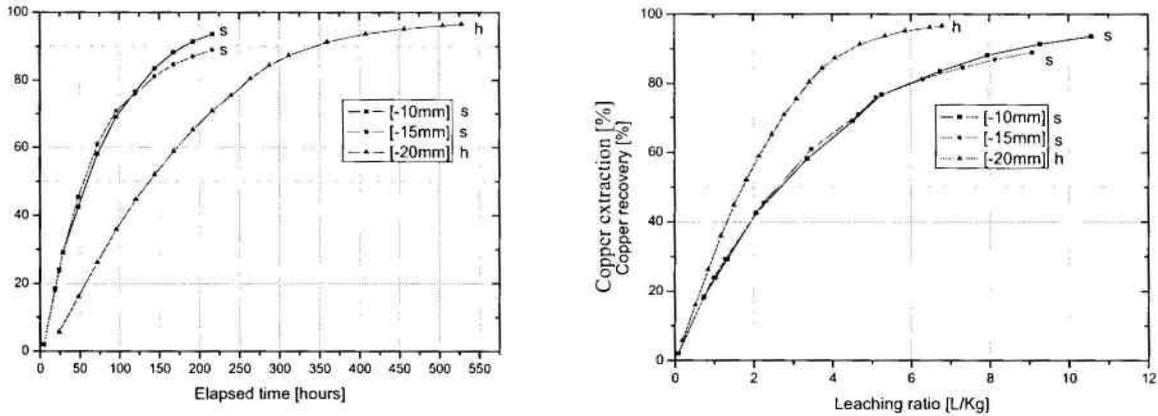


Figure 1 – Influence of particle size on copper leaching kinetic. Sample A; 20 g/L H₂SO₄; Flowrate 30 L/h.m²; s=small column – h=high column

Very high recovery rates, over 90 %, are obtained with both samples A and B in rather short time for this kind of operations. With a 1.8 meter high column typical results are : 90 % copper recovery within 15 days when feeding the leaching solutions 20 g/L H₂SO₄ at a flowrate of 40 L/h.m².

Percolation tests carried out on samples crushed under various mesh (10, 15 and 20mm) didn't display any significant influence on the leaching kinetics nor acid consumption. It has been attributed to the high accessibility of the copper mineralization.

In the case of sample B, percolation gives lower copper recoveries than agitation. It is most probably due to the presence of copper silicate species characterized by a lower leaching kinetic, increasing its leaching time. The influence of copper mineralogy is important in a short duration test by agitation but disappears in percolation tests requiring longer leaching cycle of several days.

For both samples, the cobalt leaching is rather low. However recoveries strongly exceed those achieved by agitation tests : 25 % by percolation compared to 10 % by agitation and do not show the limitation of the cobalt leaching linked to the valence state of cobalt. Co(III) is leached only at a very low kinetic and only Co(II) is leached in agitation tests. Addition of a reducing agent (divalent iron or sodium metabisulfite) in the leaching solution increases the kinetic of cobalt leaching.

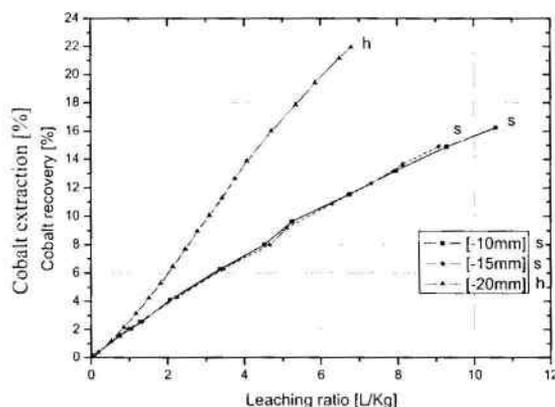


Figure 2 – Influence of particle size on cobalt leaching kinetic. Sample A; 20 g/L H₂SO₄; Flowrate 30 L/h.m²; s=small column – h=high column

An important difference between the two samples is the acid consumption. Sample A displays rather low acid consumption : 1.85 kg H₂SO₄ per kg copper while the stoichiometric value is 1.54. However with sample B which is deeply weathered and is composed of more phyllosilicate and iron oxy-hydroxide minerals, consumptions of 3 kg H₂SO₄ per kg copper are observed. The elimination of the finest particles, mainly composed of clayey minerals, induces a significant reduction of acid consumption (2.4 kg H₂SO₄ per kg copper).

In the first step of the leaching, up to around 60 % Cu recovery, the leaching is rather fast and more concentrate acidic solution (20 g/L H₂SO₄ per kg copper) with high flowrate (up to 75 L/h.m²) can be easily used. That first step of leaching requires only several days.

After that first step, less acidic solutions and possibly a lower flowrate are suggested for leaching. So an optimal use of the dissolving potential of the acid can be obtained. The realization of the leaching on the basis of a two-step process provides a fast copper recovery, a reduction of the amount of pregnant leaching solution for the subsequent treatment (SX – EW) and a lower acid consumption.

The percolation through sample B is more difficult due to its high content in fine and very fine materials. The flowrate through that sample is very limited (<5 L/h.m²) and thus very long leaching time would be needed for a satisfactory copper recovery.

Several procedures were tested to overcome this low permeability, such as agglomeration or removal of fine particles.

Agglomeration would be the most appropriate way to improve the permeability as it allows the treatment of the whole ore. Moreover, so doing, good copper recoveries can be achieved with a single leaching operation. Several agglomeration tests were carried out with various agents such as water, concentrate sulphuric acid solutions, sodium silicate solutions or with some additives (anhydrite, coarse particles). Moreoften the pressure resistance of the resulting pellets is not high enough to avoid crushing under the weight of a heap of several meters high. That low resistance has been attributed to the high content of fine and very fine particles composing the ore of sample B.

The effect of a desliming has been investigated. Percolation tests highlight the importance to keep a part of the fine particles in order to ensure a sufficient flowrate of leaching solutions. A washing out of particle size under 40µm induces a large increase of permeability without lowering the leaching kinetic. Our tests have pointed out that higher desliming would give too high a permeability and, as a consequence, a lower residence time of the leaching solution in the heap, which considerably lowers the leaching kinetic. Figure 3 illustrates these considerations.

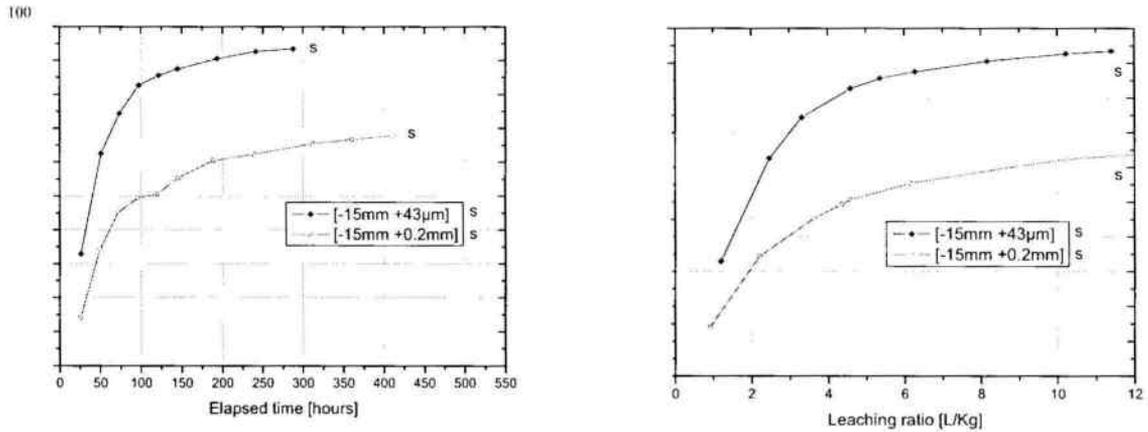


Figure 3 – Copper leaching of two deslimed samples. Sample B; Column height 0.5m; 20 g/L H₂SO₄; Flowrate 27 L/h.m²; s=small column – h=high column

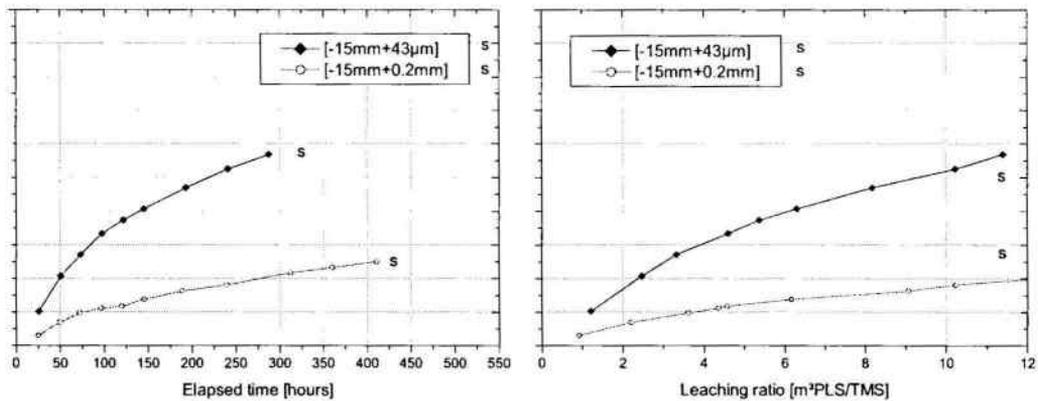


Figure 4 –Cobalt leaching of two deslimed samples. Sample B; Column height 0.5m; 20 g/L H₂SO₄; Flowrate 27 L/h.m²; s=small column – h=high column

Our tests show that with a desliming at 43µm a good permeability is achieved, allowing the application of high flowrate (40 L/h.m²). Desliming displays another main advantage that is an important reduction of acid consumption : 2.4 kg H₂SO₄ per kg copper with a solution at 20 g/L H₂SO₄ compared to 3 kg with a non-deslimed sample. Obviously the main disadvantage of desliming consists in the inherent loss of the copper contained in the fine particles when there is no slime recovering treatment. These losses are quantified in table 6.

Table VI – Ore and copper losses induced when desliming « sample B ».

Desliming	1mm	250µm	75µm	43µm
Ore losses [%]	47.2	38.6	29.5	28.0
Copper losses [%]	34.0	24.0	19.5	18.9

4 CONCLUSIONS

The laboratory leaching tests carried out show the very fast leaching of copper. Kinetic of the cobalt leaching is much lower but can be increased by addition of some reducing agents such as divalent iron or sodium metabisulfite.

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High recoveries of copper, over 90 %, are obtained in rather short times compared with usual practice of heap leaching. Due to that high reactivity, the pregnant solutions also have rather high copper concentration.

A difficult problem of permeability has to be overcome with weathered samples which contain a huge amount of very fine particles. Our tests show that a washing out of the 43 μ m particles allows very good leaching rates.

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