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USE OF TECHNIQUES COMBINING LIXIVIATION IN TAS AND L SOLVENT EXTRACTION FOR THE VALORIZATION OF MINERALS POOR OF THE MUKONDO DEPOSITION

Ph. CHISUNKA KAMPOLOBWE, W. KITOBO SAMSONI, S. NGOY DIYAMBI, A. KADIAT et MUDEKEREZA

Polytechnic Faculty of the University of Lubumbashi (UNILU) in the **D**emocratic
Republic**C**ongo

A. ABSTRACT

The Mukondo deposit located in the vicinity of the mining town of Kakanda(10 to 15km) is a very important deposit of Lualaba which contains oresCuprocobaltifères. The present study initiated by the mining company Boss Mining injoint venture with Gécamines. the minerals of Cellular and Individuals Cobalt Silicates 'PCS' shifting to Cobalt poor ores the study is about the tests ofvaluation of this deposit containing approximately 1.3% copper and 0.7% cobalt, the optimization of heap leaching of this conventional ore already operational and Solvent extraction of Copper and Cobalt from PLS (Pignan Leach Solution) prepared laboratory experiments have shown that the copper content is leaching with dissolution yields of about 70% irrespective of the acidic medium used,however, Cobalt partially leaches at about 17% when using the acid only. Cobalt is leached with good yields (greater than 95%) by adding in the reaction medium a chemical agent such as sodium metabisulfite which facilitates the reduction of trivalent cobalt. Heap leach tests have shown that the leaching takes place with slow kinetics compared to stirred tank leaching and that the dissolution rate of metals could be increased by playing on the percolation rate. To promote subsequent solvent extraction operations Copper and cobalt, percolations with recirculation of PLS were conducted at an optimal pH of extraction of copper by the LIX 984N and the recirculation was carried out until PLS containing 4 to 5 g / l Cu and about 2 g / l Co. are obtained,extraction tests indicated as in most literatures and as observed in some factories of the place that Copper s extracts easily and selectively using the LIX 984N. The residual concentration of copper in the refining is less than 100ppm. On the other hand, to extract the Cobalt, whatever the type of exterminator used (D2EHPA, CYANEX 272 or LIX 272), it is necessary to raise the pH around 5. At this pH is observed precipitation of some metals (iron, Cu), which requires prior to their elimination. These experimental findings demonstrate the possibility to valorize the minerals of the Mukondo deposit using the techniques Combining ore leaching and solvent extraction of copper and copper Cobalt.

KEY WORDS: Mukondo, Co, Heap leaching, PLS, Electrolysis.

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RESUME

Le gisement de Mukondo situé dans les environs de la cité minière de Kakanda (10 à 15km) est un gisement très important du Lualaba qui contient des minerais Cuprocobaltifères. La présente étude initiée par la société minière Boss Mining en joint-venture avec la Gécamines. Les minerais de Cellulaires et 'Particulates' Cobalt Silicates 'PCS' enmutation vers Cobalt minerais pauvres l'étude porte sur les tests de valorisation de ce gisement titrant environ 1,3% en Cuivre et 0,7% en Cobalt ,l'optimisation de la lixiviationen tas de ce minerais classique opérationnel déjà et l'extraction par solvant du Cuivre et du Cobalt des PLS (Pignan Leach Solution) préparé les expérimentations en laboratoire ont montré que le Cuivre contenu se lixivie avec des rendements de dissolution d'environ 70% quel que soit le milieu acide utilisé, mais par contre le Cobalt se lixivie partiellement a environ 17% lorsqu'on utilise l'acide seul. Le Cobalt est lixivié avec des bons rendements (supérieurs à 95%) en ajoutant dans le milieu réactionnel un agent chimique comme le Métabisulfite de sodium qui facilite la réduction de Cobalt trivalent. Les tests de lixiviation en tas ont montré que la lixiviation se déroule avec une cinétique lente comparée à la lixiviation en cuve agitée et que la vitesse de dissolution des métaux pouvait être augmentée en jouant sur le débit de percolation. Pour favoriser les opérations ultérieures d'extraction par solvant du Cuivre et du Cobalt, les percolations avec recirculation des PLS ont été menée à un pH optimal d'extraction du Cuivre par le LIX 984N et la recirculation a été menée jusqu'à a l obtention des PLS contenant 4 à 5 g/l de Cu et environ 2 g/l de Co. Les tests d'extraction ont indiqué comme dans la plupart des littératures et comme observé dans certaines usines de la place que le Cuivre s extrait facilement et sélectivement en utilisant le LIX 984N. La concentration résiduelle du Cuivre dans le raffinant est de moins 100ppm. Par contre, pour extraire le Cobalt, quel que soit le type d'ex tractant utilisé (D2EHPA, CYANEX 272 ou LIX 272), il faut remonter le pH autour de 5. A ce pH on assiste à des précipitations de certains métaux (fer, Cu), ce qui exige au préalable leur élimination. Ces constatations expérimentales démontrent la possibilité de valoriser les minerais du gisement de Mukondo en utilisant les techniques combinant la lixiviation en tas des minerais et l'extraction par solvant du Cuivre et du Cobalt.

Mots clefs: Mukondo, Co, Heap leaching, PLS, Electrolyse.

0. GENERAL

The Lualaba province DR Congo has many Cuprocobalt mines, but the Mukondo mine was exploited at the beginning of 2002 by Boss Mining.so cited is a significant reserve of Cobalt as well as another of the reserves Tenke Fungurume. The Mukondo deposit is located in the vicinity of the city Kakanda mine (10 to 15km). Geographically, the mine has its deposits located at 10 46 South latitude, 26 28 East longitude and 1300m above sea level. These latter are of the Cuprocobaltifere sedimentary type whose mineralization is on a set of 'SDB' basic schists and 'RSC' siliceous cell rocks.

Many offices and the social infrastructure that is to say houses workers city, schools, hospital and others are from the mother Gécamines environment DR Congo.

Mukondo Mining a reserve of quality and quantity of Gécamines.These days, these cell ores by flotation at KDC Concentrator Gecamines kakanda and some of the Cobalt Silicates 'PCS' individuals by the DMS process (concentration in dense media) getting around 15% cobalt on average after initially the raw laundering of the ore by simply washing the rich ores around 2% cobalt from the mine for production around 25% more cobalt. To one given period, this ore was sent to Luita where the hydro plant is located Boss Mining metallurgical plant for the extraction of copper and cobalt. Copper being pure electrolysis extract after heap leaching of ores, and, recovered cobalt as salt after precipitation. A small progressive story of Mukondo.After Mining the production in the factories in total of 5000 TCo per year resumed at annual budget around the years 2008-2009 respectively at a total return of 75% discounted. The Kababamkolé Mining Company journey, KMC in acronym, is a private company born of a partnership contract signed on January 11, 2001 with kambove-Kakanda to Kakanda and Congo Cobalt Corporation 'C.C.C' factory Electrolysis with Heap leaching then in common became Savannah Mining with a buyout at the end of 2006 by Eurasian Natural Resources Corporation 'ENRC' denomination Mining boss B.M Mining in acronym joint venture with Gécamines dynamic a multinational ERGAFRICA now we also talked about 'CAMEC' a partner multinational a moment before ENRC.

Several projects for the treatment of Cupro-cobaltiferous ores by hydrometallurgical processes with solvent extraction are initiated by Boss Mining the valorization of minerals from the Mukondo deposit. Minerals treated with concentrator are the Cells and PCS in the

DMS section which are ores extracted from the deposits of copper-rich (2.5-3%) and cobalt (1.5-2%) deposits. touch of the classic Heap leaching already in place and, added solvent extraction perceptive of the already active era now, the pen of co-authors is strong modesty, a publication on the annals of the Faculté Polytechnique 2010 to Lubumbashi University Press now with positive adjustments readers of this.

1. INTRODUCTION

The present theme in the context of a study initiated by the same companyof the problem concerning the valorization of copper and cobalt from the poor veins of thesame deposit shifting from rich to cobalt ores poor grading about 1.3%in copper and 0.7% in cobalt. The interest of this subject is to make viable its exploitationas long as possible for society. The valorization envisaged passes by Industrially, the leaching of the oxidized ores the most carried out is theacid leaching in sulfate medium. Sulfuric acid dissolves many oxides:CuO, CoO, ZnO, Fe2O3 natural or obtained by the attack of the corresponding sulfides.

It does not attack silica the siliceous gangue of many minerals. We realizea separation between the constituents of an ore.

$CuO_{(s)}+H_2SO_4 \rightarrow CuSO_4 + H_2O$ (1.1)

$Cu_2O+H_2SO_4 \rightarrow Cu + CuSO_4 + H_2O$ (1.2)

$CuCO_3.Cu(OH)_2 + 2\ H_2SO_4 \rightarrow 2CuSO_4+CO_2+3H_2O$ (1.3)

$Cu_3(OH)_2(CO_3)_2 + H_2SO_4 \rightarrow 3C_uSO_4 + 2CO_2 +4H_2O$ (1.4)

$CuSiO_3.2H_2O + H_2SO_4 \rightarrow CuSO_4 + SiO_2 + 3H_2O$ (1.5)

$CoO_{(s)} + H_2SO_4 \rightarrow CoSO_4 + H_2O$ (1.6)

The trivalent Co-oxide (Co2O3) present in the mineral heterogenite does notlixive not in the presence of sulfuric acid alone. By cons presence of reducerlike Fe (II), it leaches according to the reaction:

$Co_2O_3 + FeSO_4 + 3H_2SO_4 \rightarrow 2CoSO_4 + Fe_2(SO_4)_3 + 3H_2O$ (1.7)

Sodium metabisulfite is also used as a reducing agent and acts onferric ions present in solution when dissolved in sulfuric acid:

$Na_2S_2O_5 + H_2SO_4 \rightarrow Na_2SO_4 + 2SO_2 + H_2O$ (1.8)

$SO_2 + Fe_2(So_4)_3 + H_2O \rightarrow 2FeSO_4 + 2H_2SO_4$(1.9)

$2FeSO_4 + Co_2O_3 + 3H_2SO_4 \rightarrow 2CoSO_4 + Fe_2(SO_4)_3 + 3H_2O$ (1.10)

In conventional metallurgy, tank leaching techniques are used agitated, but in recent years some companies like the Boss Mining dealing poor ores have developed the heap leaching technique. In these types of operation, the material extracted from the mine is placed on a surface previously cleaned is rendered impervious, having a certain slope to allow the flow of the rich solution to the outside of the pile. The leaching solution is sprayed (perforated pipes or sprinklers) above the pile is then percolated to

through the latter, while solubilizing the valuable metal. The rich solution is collected

at the lower end of the surface to be pumped to the recovery basin (Villar, 2006).

Ore grain size varies from -5mm to -20mm is the choice of this grain size depends on the ore itself is from its response to leaching.The existence of a large number of ultra fine particles can cause migration vertical fines during leaching causing drainage problems of solution (Meruane, 1999). The presence of more than 8% of the particles-212µm increases strongly the probability of encountering this kind of problem. An agglomeration of particles before leaching can then be imposed. Agglomeration is a process aiming to fix fine particles around large ones, acting as nuclei, using water and an agglomerating agent, most often sulfuric acid is used ; we are talking about "curing". From a chemical point of view, a sulphation fast and energetic copper oxides occurs, which generates solutions highly concentrated in Copper. Solubilising "curing" attacks usually more iron, at the base of the ferric ion necessary for the dissolution of Copper sulphide. It also stabilizes the silica avoiding the formation of colloidal silicthe sintering and curing process would be inconvenient to recommend so to improve the permeability of the pile, decreased the leaching time, decreased the lixiviant consumption and increase the concentration of PLS (allowing decrease the size of the extraction facilities by saving). Watering cycles are more efficient and increase the percentage of extraction.The height of the heap is an important parameter is depends on the permeability, and the desired concentration of the solution. Sometimes a bunch of small dimensions has a better recovery, but it requires a larger operating area. Heap leaching has developed with the industrial application of extraction solvent, a technique for separating and concentrating metal ions into aqueous solution even accepting solutions low in metal, for example for Copper 2 to 5 g / l.

The method is based on the use of a diluted extractant in an organic solvent brought into contact by mixing and stirring with the phase aqueous which contains the desired metal. When mixing two immiscible phases,the metal ion binds to the extractant, by complex formation and is transferred into the organic phase. After this extraction, the two phases are separated by decanting. The desired metal is then transferred to a new aqueous phase in a refined and concentrated form. This second operation is named stripping. Extraction and stripping are two equilibrium chemical reactions that are mainly controlled by the pH of the medium:

Extraction

$$M(aq)^{++} + 2RH(org) \rightleftarrows R2M(org) + 2H(aq)^{+} \qquad (4.30)$$

Stripping or:

1. M (aq) ++ is the metal ion of the aqueous solution;
2. 2RH (org) is the extractant dissolved in the organic phase;
3. R2M (org) is the metal / extractant complex loaded into the organic phase;
4. 2H (aq) + is the acidity in the refining.

The solvent extraction technique is used in hydrometallurgy for purification of solutions and separation of a very large number of different metals combined with electrolysis, it has been highly developed for the production of copper

cathode of high purity. Today solvent extraction is adopted in almost all modern hydro-metallurgical plants for the purification of many metals (Cu, Co, Ni, U, Ta, Nb) and there are more than 30 installations. Existing worldwide (Gerald and Jergensen 1999, Kathryn et al.gorgon, 2006) in the former Katanga, this technique is used by mining companies such as Somika, Ruashi Mining, Chemaf and Tenke Fungurume Mining to extract Copper direct leaching solutions of oxidized orescobalt and zinc, they are extracted by organophosphoric products which are derivatives of phosphoric acid with which they form stable complexes: D2HPA, CYANEX 272, ... the most commercialized is di (2-ethylhexyl) phosphoric acid (D2EHPA).

There is not yet in the world a factory in Cobalt that uses its separation with other metals by solvent extraction with D2EHPA. By against, this extraction is very developed for the elimination of zinc during thepurification of solutions eg Cobalt, the case at Kasese Knightsbridge Cobaltin South Africa. The complex is stable at pH above 2.5. A problem thatlimit the use of these acid extractants is their limited selectivity for manymetals and their high affinity for Fe3+ extraction. Extraction with these compounds organophoric requires the prior elimination of these ions in solution (Owusu,1998; kongolo et al., 2003).Today, the Boss Mining company installed in Kakanda in Lualaba province is trying to develop this technology to valorize the poor Cupro ??? cobaltiferes ore from Mukondo. In this work, the experiments were conducted to show this possibility.

2. MATERIALS AND METHODS

2.1 Exchanging and characterization

The sample of the classic operational Ore Mukondo ore claimanthas been used for experiments has been collected and prepared by the Geology Department ofthe Boss Mining company. Its chemical characterization indicated that the sample would titrateabout 1.3% Copper and 0.7% Cobalt. the analysis also indicates a highsilica (Table 1).

Table 1- Elemental chemical composition of the Mukondo sample.

Content elements	Teneur
Cu total	1,30%
Cu oxyde	1,18%
Co	0,70%
Fe	0,83%
Mn	0,05%
Zn	38ppm
Ni	20ppm
P_2O_5	0,17%
Al_2O_3	3,41%
SiO_2	77,6%

Neither 20ppm1. Malachite:: $CuCO_3Cu(OH)_2$;

1. heterogenite : $aCoO.bCo_2O_3.nH_2O$;
2. Silica: SiO_2(gangue mineral).

The mineralogical analysis also indicated the presence of the traces of chrisocolla($CuSiO_{3.2H2O}$), goethite (FeO.OH) and dolomite ($CaCO_3.MgCO_3$).

Granulometric characterization of the sample showed that it contains about 64% particle larger than 425 µm, with about 37% particles of dimensions greater than 3mm. As in the subsequent test, we perform heaped leaches, we washed out the fraction of less than 425 µm,bring us closer to the condition currently used by the factory (Boss Mining) for the leaching of the Cupier ore, that is, washing the ore fed for eliminate fractions of less than 600 µm, which may clog the pile and prevent thus the percolation of solutions.

2.2 lixiviation test in stirred tank

A first series of leaching tests was carried out in stirred tanks. Goals of these tests were:

1.determine the maximum amount of copper is cobalt that is leachate in medium
acid alone in reducing acidic medium (ie in the presence of metabusifite
sodium $Na_2S_2O_5$);

2. appreciate the kinetics with which this leaching takes place;
3. determine the acid consumption by the gangue.

2.3 Heap leach tests

The reagents used during these tests are:

1. Sulfuric acid (H_2SO_4) prepared at a concentration 8 times molar;
2. sodium metabulsifite ($Na_2S_2O_5$);
3. iron powder.2.3 heap leaching

Heap leach tests were conducted using columns Polypropylene and PVC as shown in the photographs in Figure 1.

Figure 1 - Experimental mounting of heap leach columns

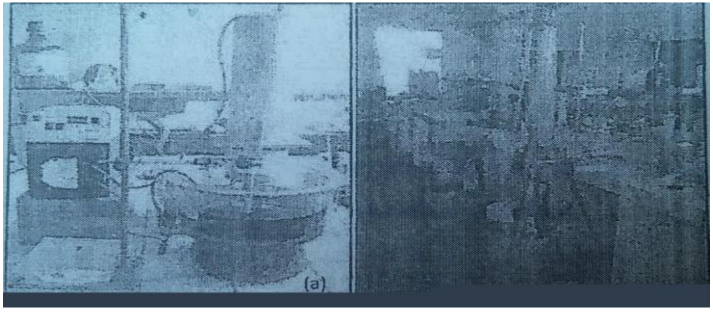


Table 2- characteristics of the columns used

column	Column Matter	Diameter column	Height column	Height of the bed
A	Polypropylene	20	40	20
B	PVC	40	100	40

Heap leach tests were conducted with recirculation of solutions.The target copper concentration for a good extraction is 4 to 5 g / l. We determined the amount of acid to use is the volume of solution starting the weight of the leached ore.
For small columns taking 2kg of ore (size> 425µm), the volume of solution being 5 l, the amount of concentrated acid used for a final Ph favorable for solvent extraction of copper (1.7 to 1.8) was 143ml.

For the large column taking 4kg of ore samples, the volume of acidconcentrate and solution were doubled, the procedure included the following operations:

1.prepare the etching solution in a basin; Solvent extraction of copperThe copper extraction tests were carried out with diluted LIX 984N in the ESCAID 100. These tests were carried out discontinuously (in stirred tanks in the batch).

2.4. Solvent extraction of Copper.

These tests were carried out in two main stages:
1. The contacting of the extractant (organic phase) with the aqueous phase containing the metal (copper) to extract, with stirring at 700 rpm;
2. decantation using a separating funnel, which facilitates the separation of 2 phases.The reagents used were LIX 984N as extractant and ESCAïD 100 as diluent.

The operations for this test were conducted according to the following procedure:

1. Pour 50ml aqueous phase an 800ml beaker;

2. add 250ml of organic phase (LIX 984N at 15% v/ v in ESCAID 100) that is ratio PO / PA = 5/1;

3. start the agitator (rotation speed 800rpm);

4. maintain the pH constant with 10N NaOH solution using a burette;

5. Shake until pH stabilizes and separate the two phases with aseparating funnel then recover the raffinate;

6. measure the pH of the raffinate and then analyze it;

7. Repeat the operations for different phase reports with 150, 100, 75 and 50 ml of aqueous phase for respectively 50, 100, 150, and 200 of phaseorganic

The copper extraction tests were carried out with LIX 984N diluted in ESCAID 100. These tests were performed discontinuously (batch stirred tank).

2.5. Solvent extraction of Cobalt.

The purpose of these tests, carried out with three different extractants, was determination of the optimal conditions of the extraction. The influence of pH on the Extraction yield has been studied. These tests were also carried outdiscontinuous, in stirred tank.

The reagents used in these tests are:
Separation of the phases in a separating funnel, the so-called aqueous phase (raffinate Cobalt) was analyzed.These tests were performed with D2EHPA; the CYANEX 272 as well only with the LIX 272 .all these extractants were prepared as a solution to15% in ESCAID 100.
separation of the phases in a separating funnel, the so-called aqueous phase (raffinate Cobalt) was analyzed.These tests were performed with D2EHPA; the CYANEX 272 as well only with the LIX 272 .all these extractants were prepared as a solution to 15% in ESCAID 100.

The experimental procedure is repeated below:

1. Pour 100ml of aqueous phase into an 800ml beaker;
2. add 100ml of organic phase (D2DEHPA at 15% v/ v in ESCAID 100) that is, ratio PO / PA = 1/1;
3. start the agitator (rotation speed 800rpm);
4. maintain the pH constant by adding the 10N NaOH solution using aburette;
5. Shake until pH stabilizes and separate the two phases with aseparating funnel then recover the raffinate;
6. measure the pH of the raffinate and then analyze it;
7. repeat the operations for different pH values as well as with the differentextractants.

3. Results and discussion

3.1. Results of lixiviation tests in stirred tank

The results of the first Mukondo ore leaching trials,in stirred tank at pH = 1.5 indicated that copper and cobalt leach under the action of sulfuric acid. In acidic medium alone, about 85% of copper and 18% cobalt in the presence of sodium metabisulfite (Na2S2O5) as reducing Co (III), about 88% copper and 83% cobalt are dissolved. Using the iron in powder form as a reducing agent, the dissolution yield of cobalt increases substantially up to 98% while that of copper drops to 61%. Same by first dissolving the iron powder in sulfuric acid before adding the ore, we note that the dissolution rate of copper always drops (about 67%) while that of Cobalt rises to 91%. The addition of a Co reducer (III) should not in principle influence the leaching of copper but curiously its yield drops even when the iron is dissolved beforehand.

From the point of view of acid consumption we note that by working in the middle acid alone, gangue consumes about 330kg of H_2SO_4 / t of minerals. On the other hand reducing acid medium with sodium metabusilfite the acid consumption is estimated at a value of about 267kg / t of ore Figure 2-Evolution of the leaching yield of Co during stirred tank leaching, Figure3-Evolution of the leaching yield of Co during stirred tank leaching :

Figure 2-Evolution of the leaching yield of Co during stirred tank leaching.

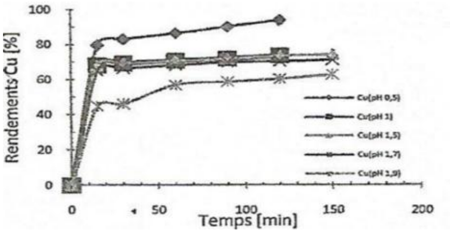
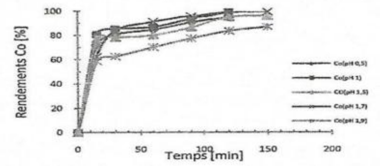


Figure3-Evolution of the leaching yield of Co during stirred tank leaching



From the analysis of the curves presented in Figures 2 and 3, we note that the curves are divided into two zones: a first zone between 0 and 15 minutes or can see that the slope is very large (fast kinetics) and a second zone or the slope is weak (slow kinetics). in the first zone, have already dissolved 90 to 95% of all copper and cobalt dissolved after two hours and thirty minutes leaching. We also note that the best copper yield is achieved at pH = 0.5

whereas at pH = 1.7 we reach only 70% this can always be explained by the presence of chrysocolla found during the mineralogical analysis. The decrease in kinetics is explained by the rapid solubilization of malachite present in the treated minerals, followed by that of chrysocolla, which has slow kinetics.

There is better solubilization of copper at low pH because the medium is very acidic, which promotes kinetics. The solubilization of cobalt depends more of the reducer than the pH since the result of table 14 indicates that there is no longerCo (III) than Co (II) in the ore treated.

From all that proceeds we retain that we must work in an acid environment in the presence of sodium metabusifite as reducing agents to dissolve copper and Cobalt. For Copper, as for Cobalt, the best results are obtained at pH 0.5 but since it is envisaged in the following the solution treatment obtained by solvent extraction, the pH must be close to 2 in order to favor the extraction of the Copper.

The dissolution yields of copper at pH 1.9 being slightlybelow those obtained at pH 1.7, we have retained this last value forperform heap leach tests. moreover, guided by literature we envisionedthe preparation of 4-5 g / l copper solutions in recirculation batch testssolutions. Tests carried out in stirred tanks at pH = 1.7 (pH retained) indicated thatsodium metabisulfite could be leached approximately 70% copper anddissolve almost all Cobalt (about 99%) after 2:30 'but onenotes however that for Copper, one reaches almost the same result as in the tankagitated. while for Cobalt, the kinetics are slower in heaps than in agitated tanks.

These results can be explained by the fact that in a pile, only the fluid (the acidic solution) is moving while the pile is static, the contact between the ore and the Sulfuric acid solution is therefore low in stirred tank.It should be noted, however, that the reasons for limiting the performance of lixiviation of copper around 70% are the same as those evoked during the analysis of the results of kinetic lixiviation tests in agitated tanks. As to Cobalt, the yield is capped at 50% which is much lower than what was observed in a stirred tank, this can be explained by the loss of reagent (Metabisulfitesodium) which is caused by percolate before it acts on the ore. This hypothesis is true by adding an extra dose of sodium metabisulfite to leach all the cobalt contained in the Mukondo ore.

kinetically, leaching (copper and cobalt) is rapid in thefirst 24 hours as indicating the slopes of the curves giving the amount of metals leached as a function of time. These curves each have a branch slope indicating a first phase of rapid leaching in the first 24 hours and a second branch of weak slope (second phase plus slow). These slopes decrease very significantly after 48 hours of leaching. This can be explained by the nature of the minerals present; the minerals easily treatable such as malachite leachate quickly while minerals such as the chrysocolla, leach very slowly.

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3.2 Results of heap leach tests.

The results of the tests with percolate recirculation but very low flow rates different sizes (250 l / hm2 for test 1 and 6110 l / hm2 for test 2) shows us that these two leachings were done with very fast kinetics after six hours. The curves of FIGS. 4 to 5, however, indicating that after 24 hours the leaching (test 1) continued but with slower kinetics. In both cases (test 1 and test 2) dissolution yields are achieved about 90% for Cobalt while for Copper, 73% is achieved in Test 1 and more than 90% in test 2.

The reasons for the cap on the dissolution yield of the Copper at about 70% for Test 1 are the same as those cited for testing in Agitated copper. In principle, the landing is not reached, the second slope branch the "Copper" curve only indicates that the leaching is very slow and that therefore, it takes a long time to reach a leach yield of copper from more than 90%.

The rapid kinetics observed however in test 2 (FIGS. 6 and 7) is favored by the very significant increase in the percolation rate. We reach about 3.8 g / l Cu after only eight hours of leaching. The leaching of the ore from Mukondo is therefore with good kinetics when the flow is high.

Figure 4- Evolution of the concentration of metals during heap leaching in the small column (Flow = 250 l / hm2).

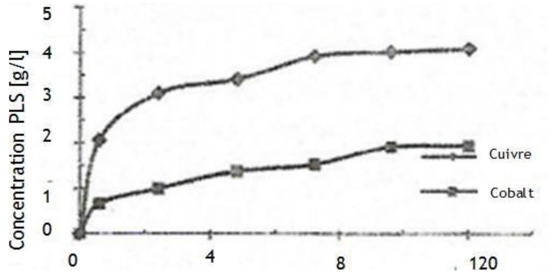
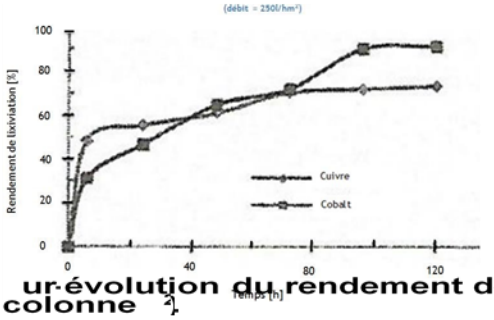


Figure 5 - evolution of the concentration of metals during heap leaching in the small column (Flow = 250 l / hm2). (Column (flow 6100l / hm), Time (h)).



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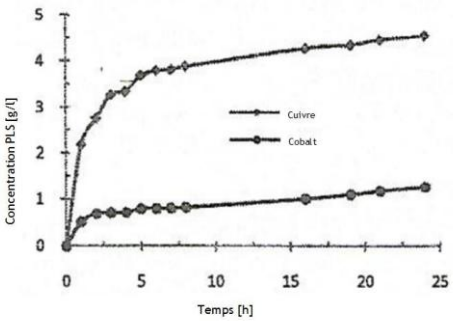
Tests carried out in stirred tanks at pH = 1.7 (pH retained) indicated thatsodium metabisulfite could be leached approximately 70% copper anddissolve almost all Cobalt (about 99%) after 2:30 'but one notes however that for Copper, one reaches almost the same result as in the tank agitated.Whereas for Cobalt, the kinetics are slower in heaps than in stirred tanks.

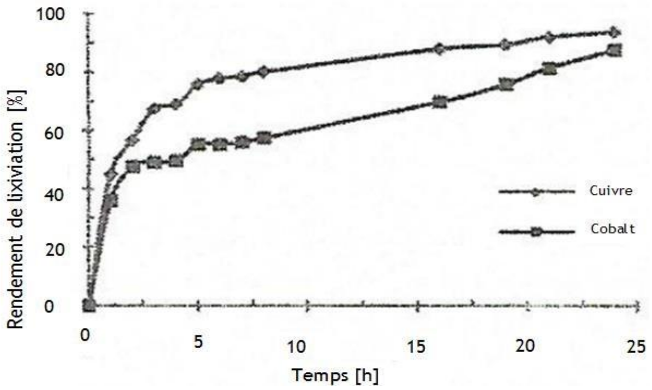
These results can be explained by the fact that in a pile, only the fluid (the acidic solution) is moving while the pile is static, the contact between the ore and the Sulfuric acid solution is therefore low in stirred tank.



FFigure 6. Evolution of the leaching performance of metals during heap leaching in the large column (flow=6100l/hm^2)

FFigure 7-Evolution of the leaching performance of metals during heap leaching in the large column (6100l / hm flow).

Figure 7 -



It should be noted, however, that the reasons for limiting the performance of lixiviation of copper around 70% are the same as those evoked duringthe analysis of the results of kinetic lixiviation tests in agitated tanks. As toCobalt, the yield is capped at 50% which is much lower than what wasobserved in a stirred tank, this can be explained by the loss of reagent (Metabisulfitesodium) which is caused by percolate before it acts on the ore. This hypothesisis true by adding an extra dose of sodium metabisulfite to leach all the cobalt contained in the Mukondo ore.

Kinetically, leaching (copper and cobalt) is rapid in the first 24 hours as indicating the slopes of the curves giving the amount ofmetals leached as a function of time. these curves each have a branchslope indicating a first phase of rapid leaching in thefirst 24 hours and a second branch of weak slope (second phase plusslow). These slopes decrease very significantly after 48 hours of leaching. Thiscan be explained by the nature of the minerals present; the minerals easilytreatable such as malachite leachate quickly while minerals such asthe chrysocolla, leach very slowly.

The results of the tests with percolate recirculation but very low flow rates different sizes (250 l / hm2 for test 1 and 6110 l / hm2 for test 2) shows us thatthese two leachings were done with very fast kinetics after six hours. Thecurves of FIGS. 4 to 5, however, indicating that after 24 hours the leaching (test1) continued but with slower kinetics.In both cases (test 1 and test 2) dissolution yields are achievedabout 90% for Cobalt while for Copper, 73% is achieved in Test 1and more than 90% in test 2.
The reasons for the cap on the dissolution yield of the Copper at about 70% for Test 1 are the same as those cited for testing in agitated copper. In principle, the landing is not reached, the second slope branchthe "Copper" curve only indicates that the leaching is very slow and thattherefore, it takes a long time to reach a leach yield of copper frommore than 90%.

The rapid kinetics observed however in test 2 (FIGS. 6 and 7) isfavored by the very significant increase in the percolation rate. We reach about3.8 g / l Cu after only eight hours of leaching. The leaching of the ore from Mukondo is therefore with good kinetics when the flow is high.The flow rate set for test 2 makes it possible to quickly obtain very good resultsbut the latter being very large, it can be at the base of the increase in the cost ofproduction, it is therefore very important to find a compromise between this flow anthat of test 2 to obtain results of leaching of the ore from Mukondogiving a good kinetics of dissolution of Copper and Cobalt with a flowacceptable industrially (economically speaking).4. Results of copper and cobalt extraction tests.In this paragraph are presented the results of the copper extraction tests by theLIX 984N and those of Cobalt extraction by D2EHPA, CYANEX 272 and LIX272.

The solution used for these tests, obtained during the experiments of theheap leaching, had the chemical composition given in Table 3.

Table 3-chemical composition of the solution used for solvent extraction tests.

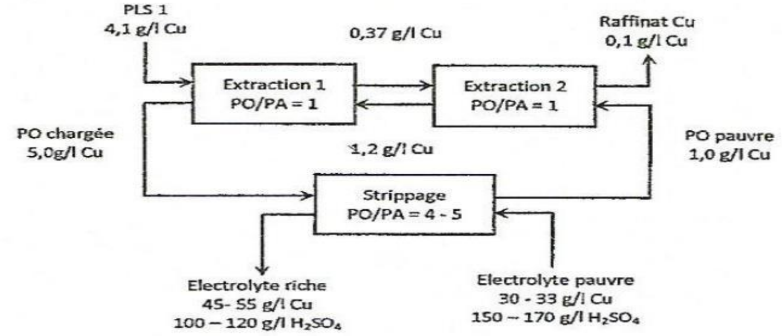
Element	Cu(g/l)	Co(g/l)	Fe(g/l)	Mn(g/l)	Ni(g/l)	Zn(g/l)
composition	4.1	1.1	0.61	0.13	0.031	0.161

4.1 Extraction of Copper by LIX 984N

The results of the copper extraction tests by LIX 984 confirmed thevery high selectivity of this extractant. The extractions went well with astarting solution at a pH of 1.7 and a Cu concentration of about 4g / l, the raffinateequilibrated with the loaded organic phase at a pH of about 1.3 with a yield of about 96%. For an aqueous phase / organic phase ratio (PA / PO) of 1/1, the raffinate obtained titrated less than 100 mg /l.

In copper.By conducting the extractions at different phase ratios, we determined equilibrium isothermal extraction of copper by LIX 984N at 15% by volume inESCAID 100 and McCabe and Thiele diagrams. this last diagram forCopper extraction indicated that this extraction can be conducted in two stageswith a PA / PO ratio of 1/1. The balance sheet drawn from these diagrams is reproduced inFigure 8.

Figure 8- General diagram of extraction and stripping of copper.



4.2. Cobalt extraction tests.

Cobalt extraction was tested with three extractants: D2EHPA, CYANEX272 and LIX 272. The extraction tests at constant pH gave the results that are presented in curves 9, 10 and 11 giving the influence of pH on the extraction of metals (copper and cobalt) as a function of pH.Figure 11- LIX 272 metal extraction efficiency variation (15% v / v in ESCAID 100) pH function.

Figure 9- Variation of the metal extraction yield by D2EHPA (15% v / v in ESCAID 100) As a function of pH.

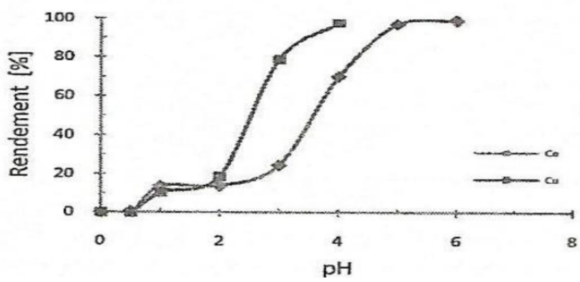


Figure 10- Variation in CYANEX 272 metal extraction efficiency (15% v / v in ESCAID) as a function of pH.

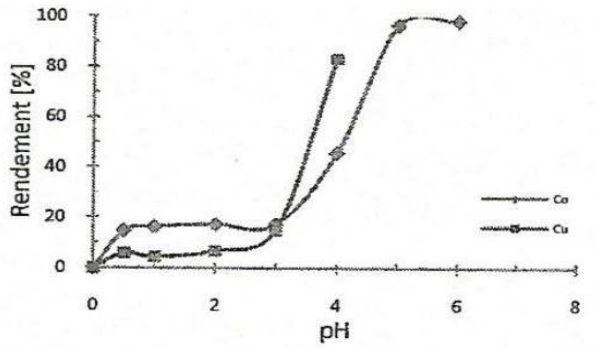
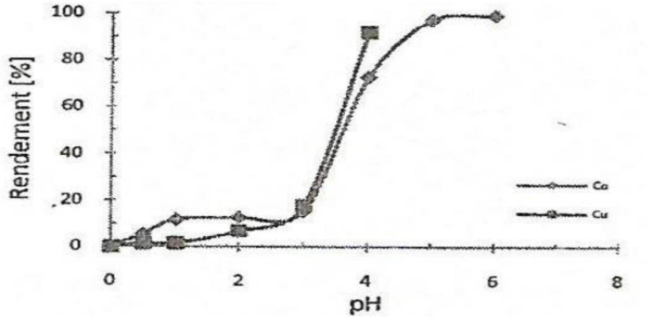


Figure 11- variation of the extraction efficiency of the metals by the LIX 272 (15% v / v in ESCAID 100) According to the pH.



The above results indicate that Cobalt is extracted with high yields (99%) at such high pH (pH> 5) regardless of the type of extractant used. During these tests we noticed the precipitation of iron from pH2 and that of copper from pH 4. Below pH = 2 it is noted that for the D2EHPA the order of separation is Fe-Co-Cu. For CYANEX 272 the order ofseparation is the same as that of D2EHPA.

So we note that whatever the type of extractant used here (D2EHPA, CYANEX272, LIX 272) the iron was extracted before Cobalt and Copper. Between pH 2 and 4, the curves of Figures 9 and 11 shows that copper is extracted before Cobalt. these results thus indicating that theCobalt separation by solvent extraction using the three extractants tested impregnating solutions produced by leaching is only possible after the extraction or elimination of Iron and Copper. Whatever the type of extractant, the pH. The minimum cobalt extraction (i.e where the yield is about 95%) is 5.

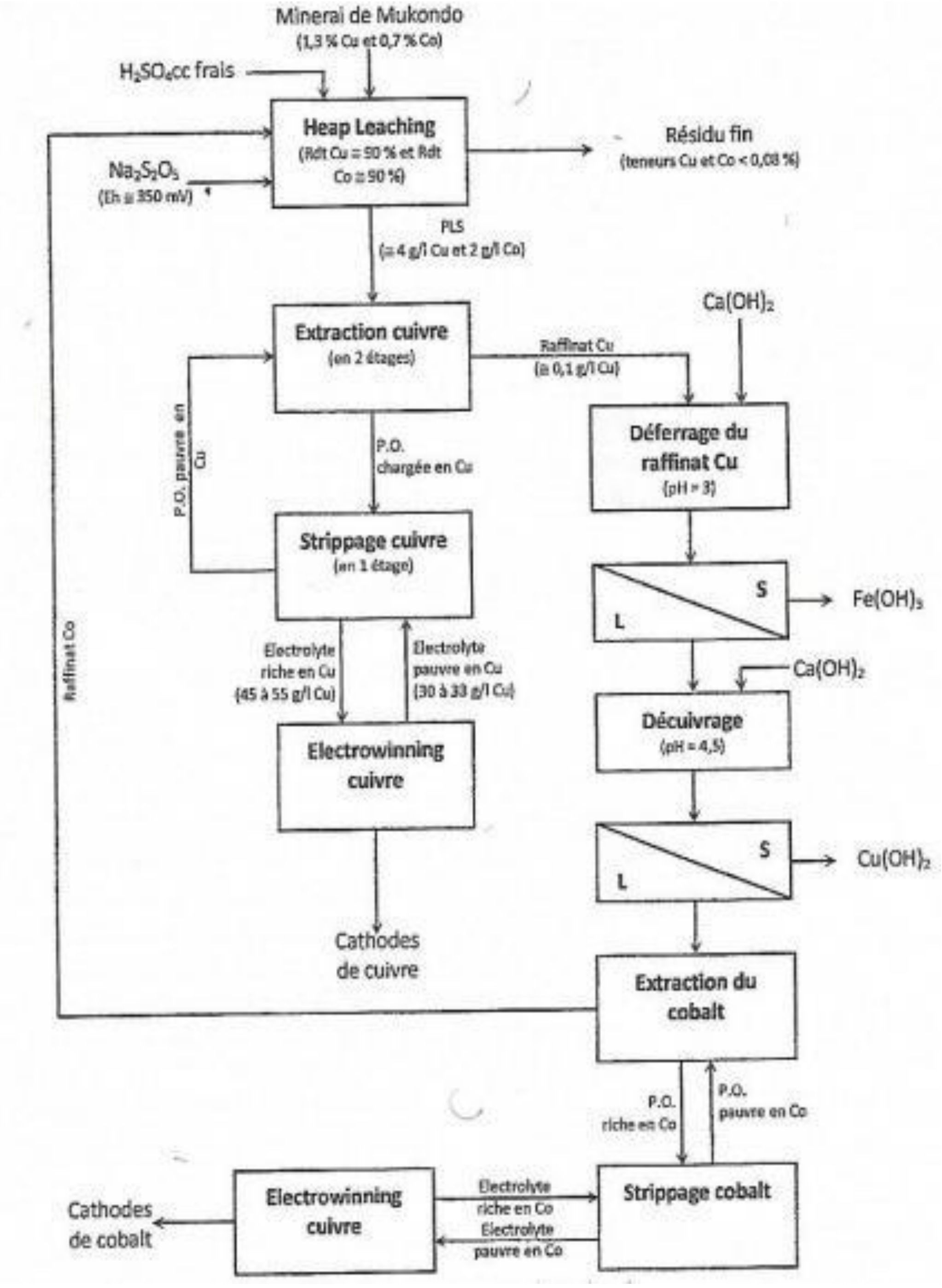
Our test solvant extraction in this schemework :

1. For its selective extraction with good yields to LIX 984N.le pH des PLS(pH=1.7) (see copper extraction condition in most factories of the place a table 8);
2. the precipitation of ferric iron at pH3 in the copper raffinate;
3. the precipitation of residual copper at pH 4.5 in the raffinate after de-ironing;

4. cobalt extraction by LIX 272 as the slope of the curvegiving the yield as a function of the pH that was obtained with the LIX 272 isgreater than the slopes obtained with the other two attractants.

Using the results above, we proposed a treatment scheme**Figure 12**:

Figure 12- Proposed scheme for the treatment of Mukondo ore



5 Conclusions.

The objective of this study was the variation of Cupro-cobaltiferous ores Mukondo poor by heap leaching followed by solvent extraction of copper and cobalt titrating approximately 1.3% Cu and 0.7% Co. to achieve this goal, several tests lixiviation in stirred tank and heap were carried out. PLS that have been prepared under optimal conditions during the first tests were treated by extraction in the goal of extracting Copper and Cobalt. The results of all experiments that have been conducted in this work, inform us as follows.

Copper contained in the poor ore of Mukondo easily leaches in an acidic medium alone and dissolution yields of about 83% are attained. By against cobalt is only leached in acidic medium with dissolution of about 18%. To achieve high dissolution yields, it The leachate must be added by adding reducing agents ($Na_2S_2O_5$).

By leaching the ore in piles (particle size greater than 425µm)it has been observed that copper and cobalt leach as in a stirred tank but with slow kinetics. By varying the flow, we found that the increase in this parameter makes it possible to increase the dissolution kinetics of copper and cobalt. It has also been found that most copper and cobalt are leached less than 20:00 'and the other party continues to leach slowly. We concluded that this second part would not be in the form of malachite but of chrysocolla.
The consumption of acid by gangue, working around pH = 1.7 which has been selected to favor subsequent solvent extraction operations of approximately 90Kg / t of minerals; this consumption is not very important to increase substantially the cost of production if the process that was studied in this work is Heap leaching with recirculation of PLS has shown that 4 to 5 g / l Copper are easily reached after a few days (4 to 5 days of leaching) with a reasonable recirculation flow of about 250l / hm^2.
These solutions contain about 2g / l Cobalt, tests indicated that copper is extracted easily to PLS that have been produced by the LIX 984N with yieldsgreater than 95% without the pH of the PLS being maintained to avoid stripping of the extracted part. This extraction is easily done in 2 stages using aPO / PA ratio = 1/1 producing aaffinate containing less than 100 ppm Cu.
Cobalt extraction tests carried out with 3 different types of extractants (D2EHPA, CYANEX 272 and LIX 272) indicated that this metal is extracted with good yields at high pH (pH> 5); which first requires the elimination ofFe^{3+} ions and Cu^{2+} ions. The results above have shown that it is possible to valorize ores Mukondo poor using heap leach technology combined with Solvent extraction scheme proposal before conclusion. The dynamics of BM Mining Joint Management Gecamines a word taken up in the AppendicessManagement T.D Lessons Learned from the University of Lubumbashiby P.O KALUNGA MAWAZO of the CHISUNKA Assistant on secondment of B.M Mining Mixed Gecamines Assistant Production Management at Control of Production uses and customs in DR Congo Absences Authorized to the service of the Nation the meaning of the Republic, an achievement very soon, the Verbal Trial of the Provincial Inspectorate of Labor ex-Katangasuspension of

Contract without prejudice Art.60 litera b of the Labor Code, the Government a word on this dispute,non-compliance with Art.100 of the Labor Code to Art.321…rubish contract Gecamines don't for people first adjustement must be done to respect DR Congo Constitution and low's country usus.

6. Appendices :

Departure, in a joint venture with Gécamines a Gécamines Agent detachment the Director Production Department is a contact of Gécamines and the reports then came the Deputy General Manager of B.M already now is an Agent gecamines; the partner a multinational company Eurasian Natural Resources ERGAFRICA Corporation (ENRC) currently undergoing transformation.Management T.D Lessons Learned from the University of Lubumbashiby P.O KALUNGA MAWAZO of the CHISUNKA Assistant on secondment of B.M Mining Mixed Gecamines Assistant Production Management at Control of Production uses and customs in DR Congo Absences Authorized to the service of the Nation the meaning of the Republic, an achievement very soon, the Verbal Trial of the Provincial Inspectorate of Labor ex-Katanga No. 445/2011 says that the claim is well-founded and admissible, suspension of Contract without prejudiceArt.60 litera b of the Labor Code, the Government a word on this dispute,non-compliance with Art.100 of the Labor Code to Art.321. RTA 1710 Court of Appeals toLubumbashi the plaintiff to Court of Cassation in Kinshasa. Respect for constitution Art.97 and Art.62, no one is supposed to ignore the law. BM Collective Agreement

Mining 2006 Art.29 availability → on request, payment of fees housing by the company BM Mining mixed Gecamines quid put on secondment!

ASLIC trade union notice to the Ministry of Mines locally, said administrative defects B.M Mining not reply to the letters to his Agent and still to the Chief, the Governor of Province of Former Katanga Management : **Shakespeare** to say 'To be or not to be'.

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