Available online at www.sciencedirect.com

jmr&t
Journal of Materials Research and Technology

www.jmrt.com.br

Original Article

Clarification and solvent extraction studies of a high talc containing copper aqueous solution

Bienvenu Ilunga Mbuya[a], **Méschac-Bill Kime**[b,*], **César Muteba Kabeya**[a], **Arthur Tshamala Kaniki**[c]

[a] Université de Likasi, The Democratic Republic of the Congo
[b] University of Johannesburg, South Africa
[c] Université de Lubumbashi, The Democratic Republic of the Congo

ARTICLE INFO

ABSTRACT

Effects of different flocculants on the clarification of a copper aqueous solution destined for solvent extraction were investigated. The test work was conducted on the pregnant leaching solution (PLS) of a high talc containing copper ore that had a high propensity of bearing a large amount of suspended solids. The clarification test work was conducted using three commercial high molecular anionic polyacrylamide polymer flocculants: rheomax® DR 1050, brontë 103, and senfloc® 2660. Solvent extraction tests were done using 30% (v/v) LIX 984N at pH 1.8. The parameters of clarification and solvent extraction were the flocculant dosage (0, 58.14, 116.28, 232.56 and 348.84 g/t) and the ratio O/A (1/5, 1/2, 2/3, 1/1, 3/2, 2/1, and 5/1), respectively. The analysis results of the PLS showed it contained 2000 ppm of solids in suspension. The optimal conditions for clarification and solvent extraction were a dosage of 116.28 g/t and an O/A of 1.5, respectively. Under optimal conditions, the residual total suspended solids (TSS) in the clarified solutions were 1196 ppm, 954 ppm, and 928 ppm; the phases disengagement time (PDT) for organic continuous dispersion were 70 s, 80 s and 60 s; the percent TSS entrained in the organic phase were 26.76%, 28.93% and 25.32%; copper recoveries were 97.63%, 98.98% and 95.13%, with rheomax® DR 1050, brontë 103 and senfloc® 2660, respectively.

1. Introduction

The Congolese Copperbelt once very rich in copper and cobalt has seen its depletion increasing in the last decades [1–3].

Low-grade deposits that were previously not treated are nowadays processed one after the other thanks to the development of metallurgical techniques like solvent extraction. Leaching techniques used to dissolve minerals are mainly heap leaching and agitation leaching. Heap leaching processes

generally yield clear PLSs compared to agitation leaching processes that give leach solutions containing substantial amounts of suspended solids. This situation is far more aggravated if the ore treated has a high talc content that causes serious problems in downstream processes like solvent extraction [4]. Clarification is a crucial step after the leaching process because it eliminates the suspended solids that are detrimental to downstream processes [5]. However, the dosage of flocculants and coagulants used needs to be appropriately monitored as any excess negatively affects the solvent extraction efficiency [6,7]. Ruashi mining is a hydrometallurgical plant located in the Katanga province of the Democratic Republic of the Congo (DRC). It treats various oxidised ores of copper and cobalt and produces pure copper cathode (99.99%) and cobalt salts (30.00%), by means of a simplified circuit: leaching–solid/liquid separation–solvent extraction–electrowinning for copper or selective precipitation for cobalt. The plant receives the copper–cobalt ore mainly from Etoile mine. The ore sourced from this mine is characterised by a high talc content that makes hydrometallurgical treatments very drastic. This is mainly due to the physical characteristics of talc, which is very frangible and generates large amounts of TSS, around 2000 ppm after the settling process and 1000 ppm after clarification. The counter current decantation (CCD) train clarification at Ruashi mining comprises two stages; a primary settling and a secondary settling. The primary settling is constituted of a single thickener, whereas, the secondary settling comprises four thickeners. The leaching aqueous solution comes in the first thickener in which after decanting, the overflow that is the high grade (HG) PLS is directly into a storage tank, the HG basin through the HG clarifier. The underflow of the primary thickener is fed to the secondary stage. After settling, the overflow represents a low grade (LG) PLS that is directly fed into the LG storage basin through the LG clarifier. The underflow of the secondary stage represents the settling reject that is neutralised before disposal. The HG solution is treated at the "SX–HG" and produces a high acid grade raffinate that is recycled to the mill and leach plant while the LG solution is treated at the "SX–LG" that produces a low acid grade raffinate. The extracted copper from SX–HG and SX–LG are mixed and sent to the electrowinning unit for copper deposition at 99.99% purity. The aim of this work was to investigate the removal of solids in suspension from the PLS by flocculation, and solvent extraction for copper recovery. Firstly, the optimal flocculation conditions were established (dosage of flocculants) for the complete removal of solids in suspension. Secondly, solvent extraction was tested and optimised (O/A ratio) for copper recovery.

2. Experimental

The high talc containing PLS used was taken from the overflow of the primary thickener in the CCD clarification chain of Ruashi mining. In order to get a representative sample, a systematic sampling of small volumes was conducted each 2 h over two days. The overall volume was homogenised and well kept away from pollutants.

Batch clarification tests were performed on the high talc PLS using three commercial high molecular anionic

Table 1 – Chemical composition of the PLS.

Element	Cu [g/L]	Co [g/L]	Fe [g/L]	Mn [g/L]	TSS [ppm]
Concentration	10.10	2.89	2.48	2.81	2146

polyacrylamide polymer [[–CH$_2$–CH(–CONH$_2$)–]$_n$] flocculants: rheomax® DR 1050 (BASF, South Africa), brontë 103 (Axis House, South Africa), and senfloc® 2660 (Senmin, South Africa). These flocculants were primarily selected because of their availability and frequent use for base metal clarification processes. They were all received in powder form and were prepared using the same procedure. The flocculants were dissolved in deionised water for a final concentration of 0.1% (w/w). As soon as the deionised water was stirred in glass beaker (IDc90 mm) at 750 rpm, the flocculant was poured into it and the mixture was allowed to homogenise for 4 h in order to get all the grains of the flocculant dissolved. Mixtures were kept for 24 h before use.

Actual clarification tests were conducted in stirred beakers. For each test, a 1000-mL sample of the PLS was placed into a 2000 mL glass beaker (IDc90 mm). Similarly, mixing was achieved using a 25 mm octagon magnetic bar with pivot ring. The mixing speed was kept at 750 rpm in all tests. Different flocculant dosages (58.14, 116.28, 232.56, and 348.84 g/t) were then added in a single stage to the PLS under continuous mixing. Starting from the volume of flocculant prepared at 1 g/L, flocculant dosage was calculated as follows:

$$D = \frac{V_f \times C_f}{W_f} \times 10^3 \tag{1}$$

where D [g/t] is flocculate dosage, V_f [L] is flocculant volume, C_f [g/L] is flocculant concentration, W_f [g] is flocculant weight, and 10^3 is a conversion factor.

The sample was kept stirred at the same speed for 1 h. This time was long enough to allow the flocculants to form sufficient and strong enough flocs with solids suspensions. After that, the flocs were allowed to settle for 25 min. Finally, the solution was poured on 125 mm diameter, 22 μm pore sizes Whatman filter paper. The solids retained on the filter were dried and weighted. Determination of the TSS was conducted on the aqueous solutions before and after clarification.

Solvent extraction experiments were carried out at room temperature (±27 °C) on the clarified and non-clarified solutions. The extraction was performed using 30% (v/v) LIX 984N (BASF, USA) at pH 1.8 at different O/A (1/5, 1/2, 2/3, 1/1, 3/2, 2/1, and 5/1). The mixtures were shaken until equilibrium was reached (20 min) using mechanical shakers. The phases were allowed to separate, followed by filtration on respective filter papers (Whatman 541 for aqueous phase and Whatman 1PS for organic phase) and the aqueous phases were saved for analysis. The solids retained on the filter papers were dried and weighted.

3. Results

Table 1 presents the analysis of the collected PLS. To determine the particle size distribution of the as-received PLS, it
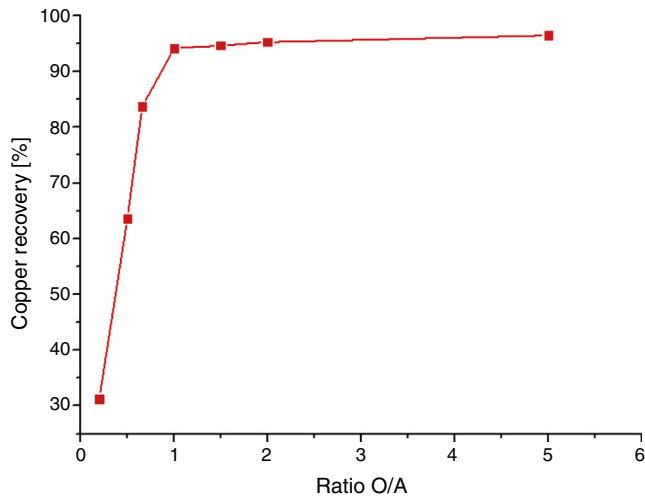
Fig. 1 – Evolution of copper extraction performance on the non-clarified solution as a function of O/A.

Fig. 3 – Evolution of copper extraction performance on the solution clarified with rheomax® 1050 as a function of O/A.

was filtered sequentially through a series of filter papers. Optimum TSS retention was obtained with filter paper 125 mm in diameter, with pore sizes of 22 μm (Whatman™ 1541-125 Ashless).

Fig. 1 shows the effect of O/A on the recovery of copper using 30% (v/v) LIX 984N at pH 1.8. The test work was done on a non-clarified PLS. It can be seen that copper recovery increased with increasing ratio O/A. The optimum copper recovery was 90.00% and the PDT was 180 s. The raffinate yielded a TSS of 1650 ppm.

Fig. 2 shows the effect of flocculant dosage on the clarification of the PLS. It can be seen that the TSS decreased with increase in the flocculant dosage, reaching about 322 ppm (rheomax), 307 ppm (brontë) and 285 ppm (senfloc® 2660) at 232.56 g/t; beyond, the clarification efficiency decreased with increase in the dosage and the TSS reached 848 ppm (rheomax), 650 ppm (brontë) and 620 ppm (senfloc® 2660) at 348.84 g/t.
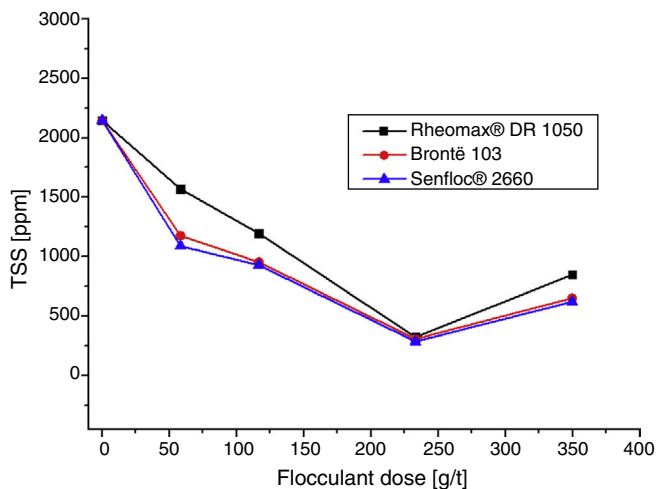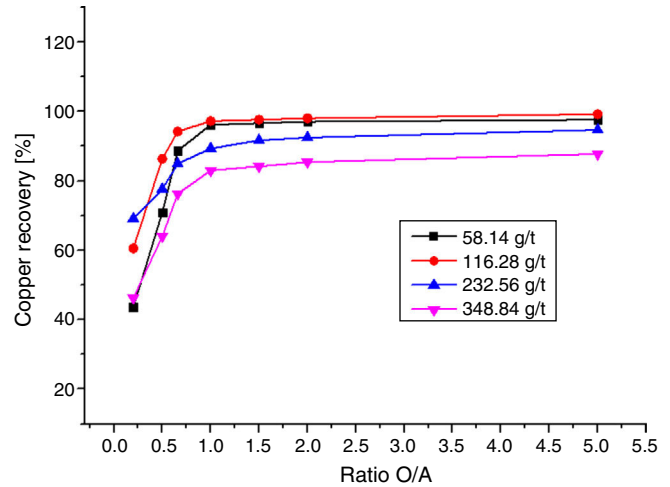
Fig. 3 shows the effect of O/A on the recovery of copper from the PLS clarified using rheomax® DR 1050. It can be seen that copper recovery increased with O/A. The PLS clarified with 116.5 g/t rheomax® DR 1050 gave the best results at O/A = 1.5 (97.63%) followed by the PLS clarified with 58.14 g/t rheomax® DR 1050 (96.61%). In turn, the PLS clarified with 232.56 g/t and 348.84 g/t gave relatively low results, 92.48% and 84.19%, respectively.

Fig. 4 shows the effect of O/A on the recovery of copper from the PLS clarified using brontë 103. It can be seen that copper recovery increased with O/A. The PLS clarified with 58.14 g/t and 116.5 g/t brontë 103 gave the best results at O/A = 1.5 of about 97.55%. In turn, the PLS clarified with 232.56 g/t and 348.84 g/t gave relatively low results, 80.20% and 76.28%, respectively.

Fig. 5 shows the effect of O/A on the recovery of copper from the PLS clarified using senfloc® 2660. It can be seen that copper recovery increased with O/A. The PLS clarified with 58.14 g/t and 116.5 g/t brontë 103 gave the best results
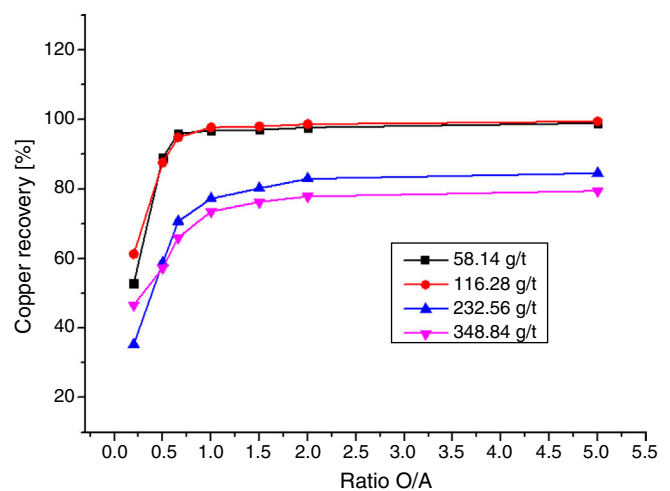

Fig. 2 – Effect of flocculant dosage on the flocculation efficiency of the clarified PLS.

Fig. 4 – Evolution of copper extraction performance on the solution clarified with brontë® 103 as a function of O/A.
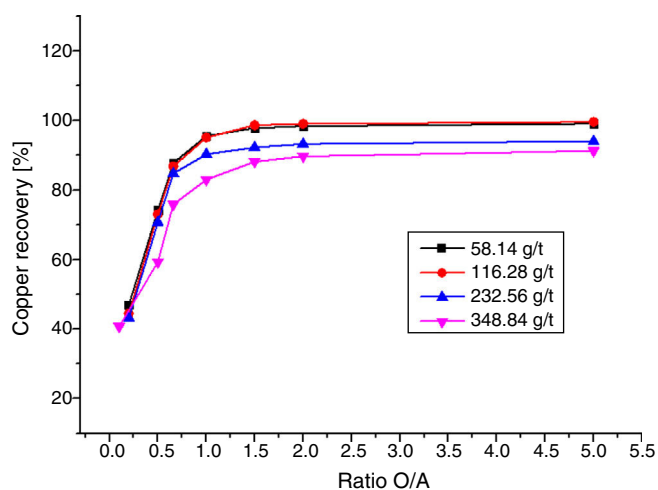
Fig. 5 – Evolution of copper extraction performance on the solution clarified with senfloc® 2660 as a function of O/A.

at O/A = 1.5 of about 98.28%. In turn, the PLS clarified with 232.56 g/t and 348.84 g/t gave relatively low results, 92.28% and 88.14%, respectively.

Fig. 6 shows the effect of flocculant dosage on the entrainment of the suspended solids in the loaded organic phase. It can be seen that the TSS entrained in the organic phase decreased with increase in the flocculant dosage, reaching about 8.96% (rheomax), 5.38% (brontë) and 4.03% (senfloc® 2660) at 348.84 g/t.

Fig. 7 shows the effect of flocculation dosage and type on the PDT. The O/A used was 1.5. All the curves exhibited the same trend with the flocculation with senfloc® 2660 yielding the smaller PDT while rheomax® DR 1050 yielded the larger time. The PDT slightly decreased from about 80 s with 58.14 g/t of the flocculant dosage to about 70 s with 116.5 g/t of the flocculant dosage. However, for dosages beyond, the PDT increased with increase in the flocculant dosage.
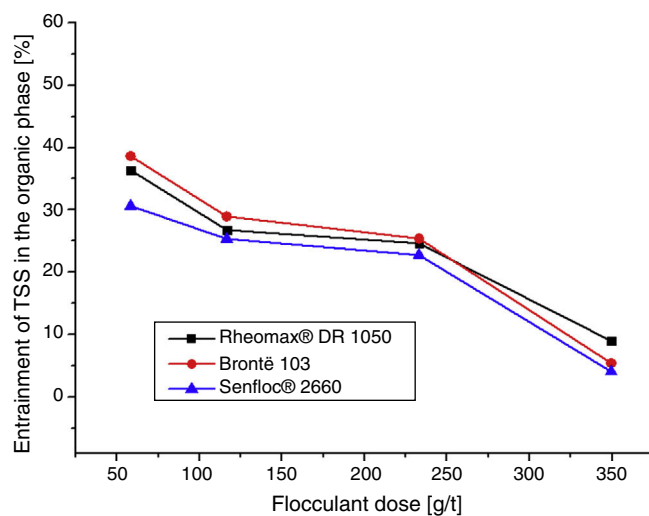
4. Discussions

As can be seen from Fig. 1, the recovery of copper using 30% (v/v) LIX 984N at pH 1.8 increased with increase in the O/A ratio and reached a plateau at 90.00%. This relatively low recovery was attributed to the presence of cruds. In fact, the un-clarified PLS contained a TSS of over 2000 ppm that led to forming intermediate phases which caused the loss of the organic phase and hence resulted in low utilisation of the strength of the organic extractant.

As can be seen from Fig. 2, for all the flocculant types, the TSS decreased with increase in the flocculant dosage up to 232.56 g/t, but quickly started increasing beyond. The first three dosages stabilised efficiently the suspensoids that decanted due to their weights. This led to the diminution of the TSS in the PLS treated. However, one can notice that for dosages over 232.56 g/t, the TSS increased as a result of the destabilisation of the flocs formed. This can be explained in that any flocculant excess can lead to a compression of the macromolecular chain thereby reducing the numbers of active sites where the suspensoids are adsorbed.

Figs. 3–5 show the effect of O/A on the recovery of copper from the PLS clarified using the different types of flocculants. It can be seen that all the curves presented similar trends. The extraction of copper from the solutions clarified with first two dosages (58.14 g/t and 116.5 g/t) yielded recoveries around 98.00% at O/A = 1.5. However, this tendency reversed for the solutions clarified with 232.56 g/t and 348.84 g/t dosages and their relating extraction yields were below 80.00%. This was due to contamination of the organic extractant by the flocculants that acted as surfactants in lowering the interfacial tension between the aqueous and organic phases. This translated in the PDT observed of 200 s for the high dosage, compared to about 70 s for the dosage of 58.25 g/t using senfloc® 2660.

Examination of Fig. 6 shows that the entrainment of solids in the organic phase decreased with increase in the flocculant dosage, with senfloc® 2660 giving the lowest entrainment percentage (30.61%) at 58.25 g/t, compared to rheomax
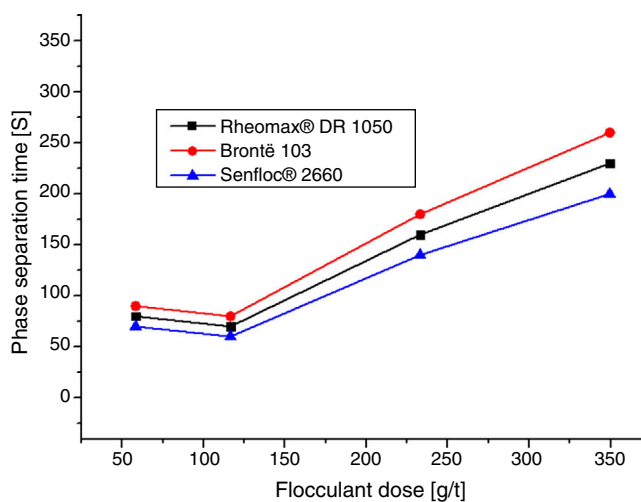

Fig. 6 – Effect of flocculant dosage on the entrainment of the suspended solids in the organic phase from the clarified PLS (O/A = 1.5).

Fig. 7 – Effect of flocculation dosage on the phase separation time (O/A = 1.5).

(36.35%) and brontë (38.61%). With the highest dosage (348.84 g/t), the entrainment percentages reduced to 8.96% (rheomax$^®$ DR 1050), 5.38% (brontë) and 4.03% (senfloc$^®$ 2660). This is a clear indication that the reactivity of flocculant is directly related to their chemistry and molecular weights; it is recommended that further work investigate these aspects.

5.   Conclusions

This work was aimed at studying the effect of three types of flocculants used for treating a high talc containing copper aqueous solution on the extraction yield of copper. It is worth noting that in industrial practices it is common to increase the flocculant dosage in order to optimise the PLS clarity. This does not necessarily result in the increase in the clarification efficiency. It should be indicated that though low dosages are not very efficient in reducing the TSS, they are often opted because of the high operational costs incurred by the use of large volumes of flocculants. The clarification tests revealed that the dosage of 232.56 g/t gave the best clarification performance for all the flocculants considered, and senfloc$^®$ 2660 proved to be the flocculant that gave good clarification compared to the other flocculants. However, in conjunction with the solvent extraction tests, the optimum recovery was obtained for solutions treated with the dosage of 116.28 g/t. For O/A = 1.5, the recovery obtained was 95.13% and the PDT was 60 s.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

[1] Burlet C, Vanbrabant Y, Dupin L, Goethals H, Thys T. Raman spectrometry as a tool to characterise cobalt secondary ore: the TRACE project. Brussels, Belgium: Royal Belgian Institute for Natural Sciences, Geological Survey of Belgium; 2010.

[2] Kime MB, Kanoa EK, Mulaba–Bafubiandi AF, Diyambi SN. Value recovery from Mukondo mine low–grade cobalt ore by heap leaching and solvent extraction. In: Hydrometallurgy Conference 2016: Sustainable Hydrometallurgical Extraction of Metals Cape Town, 1–3 August 2016 Southern African Institute of Mining and Metallurgy. 2016.

[3] Mbuya BI, Kime MB, Tshimombo AMD. Comparative study of approaches based on the Taguchi and ANOVA for optimising the leaching of copper–cobalt flotation tailings. Chem Eng Commun 2017;204:512–21, http://dx.doi.org/10.1080/00986445.2017.1278588.

[4] Kime MB, Kaniki AT. Determination of the milling parameters of a pear-shaped ball mill for grinding a high-talc oxidized copper–cobalt ore. CIM J 2017;8, http://dx.doi.org/10.15834/cimj.2017.13.

[5] Das K. Mineral particles: flocculation in encyclopedia of surface and colloid science. 2nd ed; 2009, 10.1081/E-ESCS-120012926.

[6] Virnig MJ, Olafson SM, Kordosky GA, Wolfe GA. Crud formation: field studies and fundamental studies. In: Riveros PA, Dixon DG, Dreisinger DB, Collins MJ, editors. Copper, Toronto, Canada, 26–29 August 2007. Montreal, Quebec: Canadian Institute of Mining Metallurgy and Petroleum; 2007. p. 291–303.

[7] Readett DJ, Miller GM. The impact of silica on solvent extraction: Girilambone Copper Company case study. In: Cooper WC, Dreisinger DB, Dutrizac JE, Hein H, Ugarte G, editors. Copper, Santiago, Chile, 26–29 November 1995. Montreal, Quebec: Canadian Institute of Mining Metallurgy and Petroleum; 1995. p. 679–90.