# Influence of the Mixture of Xanthate Collectors on the Flotation of Difficult Copper Oxide Ore to Float- Case of Minerals Fill 18 Deposit Shangulowe

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**ABSTRACT**
This paper presents the results of a study conducted to highlight the influence of the mixture of xanthate collectors on the flotation of copper oxide ores. The Shangolowe deposit sample assayed 3.22% copper and 0.08% cobalt, and by means of mineralogy and chemical analysis the gangue appears dolomitic. Test optimization ratio and the main sulfudizing collector were performed, testing after which the dosage rates of 4000g NaSH / dT ore and 400g KAX /dT ore were used as a reference for further testing. Xanthate collectors namely: KAX, KEX, SIBX and SNPX were tested alone and their specific behaviors were reported. The study showed that KAX increase the recovery and three other collectors improved concentrates quality. They were then taken two to two mixed in the proportions of 25% -75% 50% -50% 75% -25%. It appears from these tests that the mix-KAX/SIBX taken in ratios of 75 and 25%, stood out all tests because it offered good selectivity and improved metallurgical performance. Comparative testing of cleaning under standard conditions and the best test mixture, also confirmed an improvement in the selectivity of 7 points compared to the usual KAX. A comparison of the collector's costs, helped highlight a desired gain per ton contained copper with the use of mixed collectors which was about 13% compared to the use of KAX alone. Operating conditions and flotation scheme on the test which offered the best metallurgical performance subsequently proposed to the operator, who was consolidating the results obtained previously with cyclic tests in laboratory and pilot plant.

**Keywords:** Xanthate, Shangulowe, Flotation, Collector.

## 1. Introduction

The deposit is located at Shangulowe open pit mine, approximately 15 km from the mining town of Kambove. It is surrounded by other fields such as Kamfundwa, Kamoya, etc. Mineralization as average of 2 to 3% copper and a cobalt content lower than 1%. The Kambove concentrator feed consists of ores from different deposits, which include also the Shangulowe deposit. The observation made at Kambove Concentrator is that feeding alone this ore has an overall efficiency of copper recovery less than 70% and an overall grade in the concentrate less to 15%Cu, leading to a decrease in economic performance process. The structural complexity of the ore minerals spread with malachite in the matrix is the basis for this decline. It is in this context that a study was initiated in order to improve the buoyancy of Shangulowe ore.

This work's main objective is to highlight the influence of mixture collectors to improve the buoyancy of minerals fill 018 deposit Shangulowe and perform a cost analysis on the part of collectors.

## 2. Materials and Methods

### 2.1. Comminution Operation

Screening and weighing of large blocks throughout a jaw crusher, cylinder crusher, ball mill, vibrating sieve of 1/4 mesh and 10mesh, and a 1ton scale.

### 2.2. Laboratory Grinding Operation

- A laboratory ball mill with length L = 285 mm, diameter D = 183 mm and speed of 123 revolutions per minute
- A Vibrating pulverizer
- A sieve "Rotap" with a series of 11 sieves American brand TYLER
- A brand Statorius electronic scale, maximum capacity of 4200g with an accuracy of 0.01 g.

### 2.3. Other Equipments

- A range of flotation cells 1 and 2.5 liters - stopwatch - pH meter - a palette - a syringe for handling foaming - a manual agitator - a laboratory flotation machine type Denver.
- A laboratory stereoscopic microscope for mineralogical analysis.

### 2.4. Chemical Analysis

Absorption spectrophotometric method is used for chemical analysis of the samples.

### 2.5. Reagents Used

- SIBX: Isobuthyl xanthate Sodium collector - the SNPX: Normal Propyl Xanthate Sodium, collector - the KAX: Amyl Xanthate Sodium, collector - The KEX: Potassium Ethyl Xanthate, collector - The mixture diesel and X rinkalore used as extra collector - Sodium silicate ($Na_2SiO_3$), which plays both the role of dispersant and depressing - The senfroth (G41), foaming agent - The sodium hydrosulfide (NaSH), sulfudhizing agent, - sodium carbonate ($Na_2CO_3$), which stabilizes the emulsion of diesel-X rinkalore in water.

## 3. Results and Discussion

### 3.1. Chemical and Mineralogical Analysis

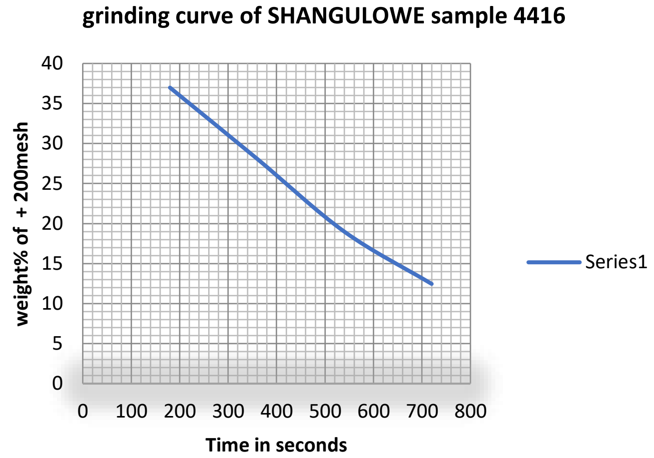
**Table 1: Chemical analysis of the sample 4416 Shangulowe deposit**

| Element | Assay (%) | Element | Assay (%) | element | Assay (%) |
|---|---|---|---|---|---|
| $Cu^{Total}$ | 3,22 | $MgO^{Total}$ | 2,62 | $MnO_2$ | 0,24 |
| $Cu^{oxydé}$ | 2,41 | $MgO^{Soluble}$ | 0,10 | $Fe^{Total}$ | 4,85 |
| $Co^{Total}$ | 0,08 | $CaO^{Soluble}$ | 0,27 | $P_2O_5$ | 0,18 |
| $Co^{oxydé}$ | 0,07 | $Al_2O_3$ | 14,23 | Ni | 0,01 |
| $CaO^{Total}$ | 0,34 | $SiO_2$ | 49,17 | | |

The results in Table 1 indicate that: The minerals fill 18 Shangulowe essentially contains copper as material to be recovered for Gécamines, which is about 75% oxidized form; Cobalt is the state of traces about 0, 08%. The matrix is formed by the major part of silica, with little dolomite. According to the standards Gécamines, in fact, the following relationship can confirm the account held ratio value $Cu^{tot}/CaO^{soluble}$ thus 3.22 / 0.27 = 11.9 which is less than 15.
The Mineralogical examination of the sample stereoscopic binocular microscope allowed us to detect the presence of the following minerals: Malachite: it is not rough, rather scattered in the matrix; Chrysocolla: in small quantities; Heterogenite in state of traces; Quartz: it is dominant; minor presence of Clay and Limonite.

### 3.2. Determination of Optimal Grinding Time

**Figure 1: Determination of the optimal grinding time**




It appears from the examination of these results that the grinding time giving a pulp with a d80 at 75 microns is 8 minutes 35 seconds.

**Table 2: Size distribution analysis of 4416 sample**

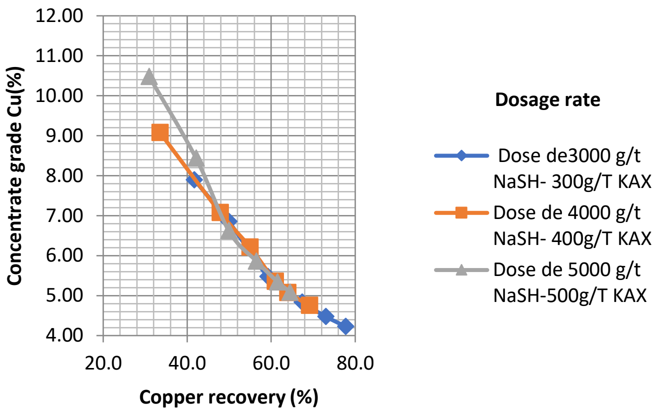
| Screen (#) | Fractions | | | Copper | | | |
|---|---|---|---|---|---|---|---|
| | (g) | (%) | (% refus cum) | Assay (%) | (g) | Rép (%) | Rép cum (%) |
| **+48** | 5,50 | 0,46 | 0,46 | 3,35 | 0,18 | 0,47 | 0,47 |
| **-48 + 65** | 23,00 | 1,92 | 2,4 | 3,23 | 0,74 | 1,90 | 2,37 |
| **-65 + 100** | 56,64 | 4,73 | 7,1 | 3,52 | 1,99 | 5,10 | 7,47 |
| **-100 +150** | 113,63 | 9,49 | 16,6 | 3,7 | 4,20 | 10,75 | 18,21 |
| **- 150+200** | 243,20 | 20,32 | 36,9 | 3,28 | 7,98 | 20,39 | 38,60 |
| **-200+270** | 89,54 | 7,48 | 44,4 | 2,95 | 2,64 | 6,75 | 45,36 |
| **-270+325** | 135,59 | 11,33 | 55,7 | 2,96 | 4,01 | 10,26 | 55,62 |
| **-325+400** | 7,00 | 0,58 | 56,3 | 2,99 | 0,21 | 0,54 | 56,15 |
| **-400** | 522,99 | 43,69 | 100,00 | 3,28 | 17,15 | 43,85 | 100,00 |
| **Total** | 1197,09 | 100,00 | | 3,27 | 39,12 | 100,00 | |

In view of the results shown in Table 2, it appears that: - Approximately 38% copper are contained in the fraction greater than 200 mesh, 17% copper is found in the fraction 325 -200 Mesh, 44% copper is included in the fraction -325 Mesh. Shangulowe ore deposit 18 has a tendency to produce significant fine particles.

### 3.3. Influence of Sulfudizing ratio

Optimization tests of NaSH and KAX respectively at dosage rates of 3000,4000 and 5000 g / t NaSH where KAX being taken to a tenth of the dose of NaSH have been made.

**Figure 2: Influence of the ratio of sulfidizing**

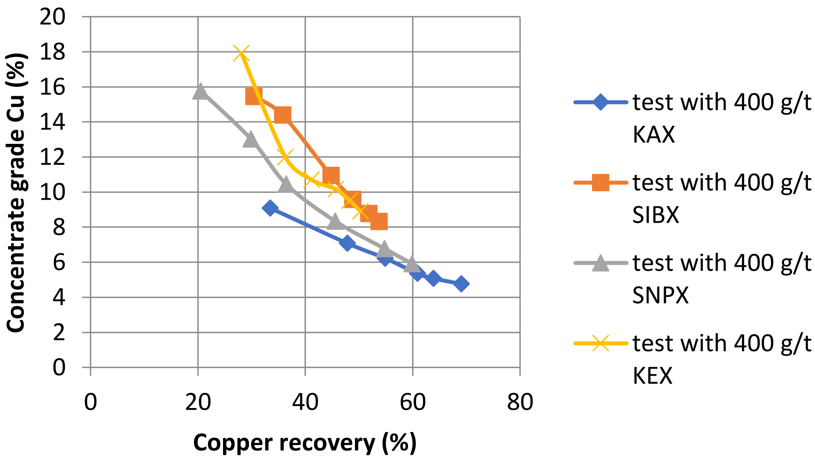



It appears from the examination results as: optimal dosage rate of the sulfidizing agent is 4000 g / t since at low dosage selectivity is relatively low, although the recovery is the best of the series and this is probably the result of the inadequacy of sulfidisation having led the collection of gangue minerals, high-dosage rates against the results reflect an excess of sulfidisation with a considerable depression of useful minerals of copper.

### 3.4. Comparative Tests of Collectors Selected.

The flotation dosage rates of reagents were equal to those of the optimal test variation in the consumption of sulfidhizing, only the nature of the collector has been these trials.

**Figure 3: Metallurgical results of comparative tests of collectors selected.**



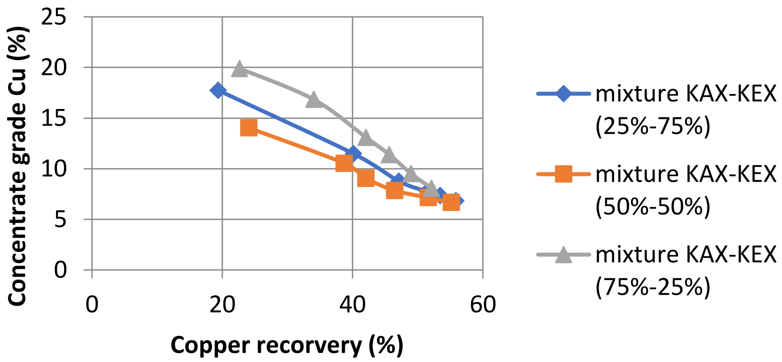
These flotation tests, we have noted the following highlights:

- The KAX is less selective, but relatively strong since, leading to a significant recovery
  Leading three other flotation collectors have the same recovery of 20 to 30%. Compared to KAX the three collectors are more selective with powers somewhat lower, resulting in yields roughing weak recovery ranging from 50-60%.
  Comparing the results obtained with the three collectors except KAX shows that:
- The SNPX present a great power collector resulting in a high-performance roughing
- Seems to be the KEX the most selective of the three with a head grade of about 18% Cu. As for SIBX it seems to be the compromise of KEX and SNPX.

**3.5.** Trials with Mixtures of Collectors

### 3.5.1. Flotation tests with the mixture KAX-KEX

**Figure 4: Flotation results with the mixture KAX – KEX**

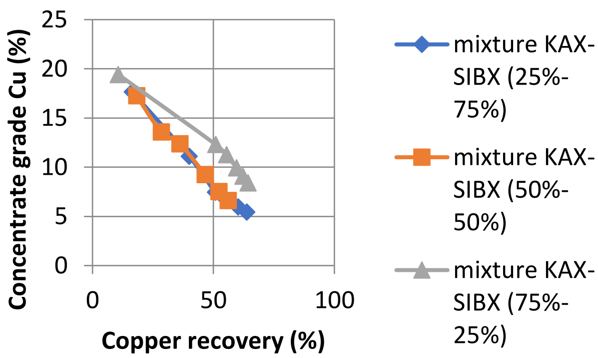



Examination of these results shows that the proportions of 75% and 25% KAX/KEX gave the best performance with a head metal content of 19.73%, and roughing concentrate as 8.41% Cu with a recovery of 52%.

These proportions of concentrate mixtures give good quality with low recovery of this series but located in the same margins than other mixtures.

### 3.5.2. Flotation tests with the mixture KAX-SIBX

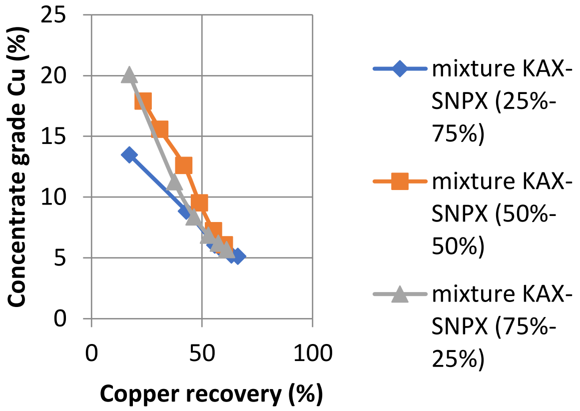
**Figure 5: Flotation results with the mixture KAX- SIBX**




- Examination of these results shows that the proportions of 75% and 25% KAX/SIBX gave the best performance with a head concentrate of 19.43%Cu, and roughing concentrate as 8.41% Cu with a recovery 64.2%. The results obtained with the other proportions are comparable with a rough content of about 6% Cu with a recovery of approximately 60%.

### 3.5.3. Flotation tests with the mixture KAX - SNPX

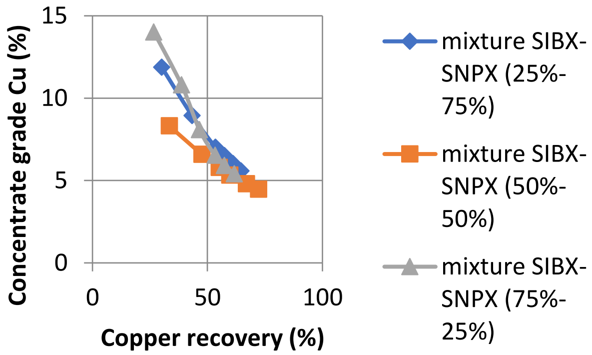
**Figure 6: Flotation results with the mixture KAX - SNPX**




The mixture KAX-SNPX in the respective proportions of 50 and 50% gave good metallurgical performance, with a concentrate grading 17.9% Cu, an overall concentrate grading 6.08% Cu and an overall efficiency of copper recovery of 60.1%.

### 3.5.4. Flotation tests with the mixture SIBX-SNPX

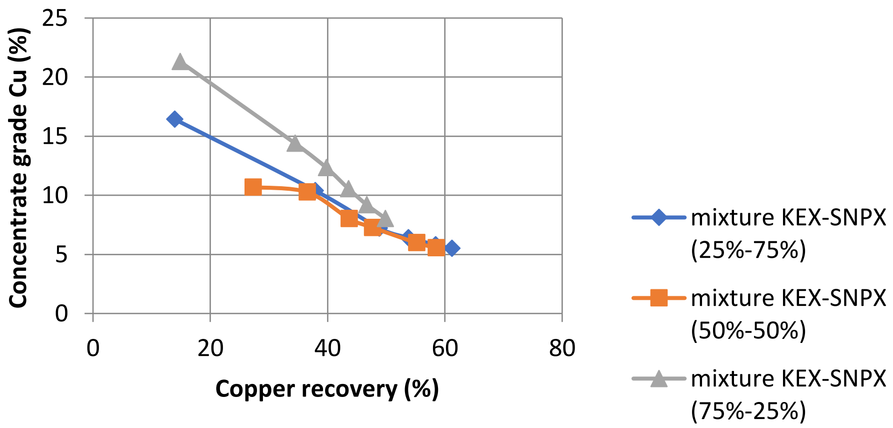
**Figure 7: Flotation results with the mixture SIBX – SNPX**




The mixture SIBX-SNPX in the respective proportions of 25% and 75% has good selectivity and yield to copper roughing of 5.69% Cu with a recovery of 64.6%. These results are acceptable compared to other mixtures.

### 3.5.5. Flotation tests with the mixture KEX-SNPX

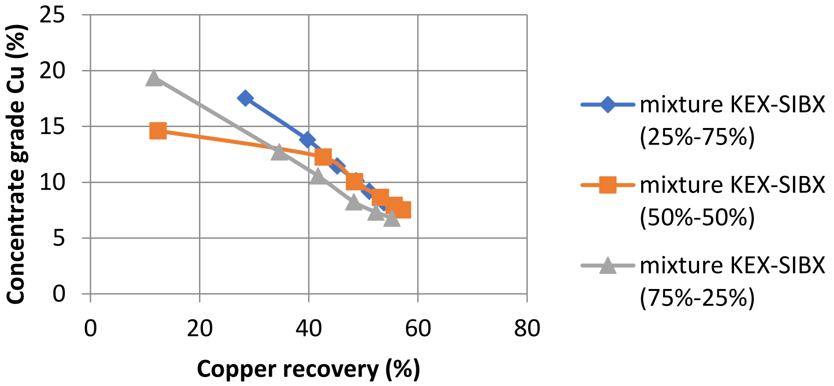
**Figure 8: Flotation results with the mixture KEX - SNPX**



Analysis of the results shows that the mixture KEX-SNPX respectively in the proportions of 25% and 75% gave acceptable metallurgical performance of the series with a head grade of 16.4% Cu and a roughing concentrate of 5.49 %Cu with an overall recovery of 61.2%.

**3.5.6. Flotation tests with the mixture KEX – SNBX**

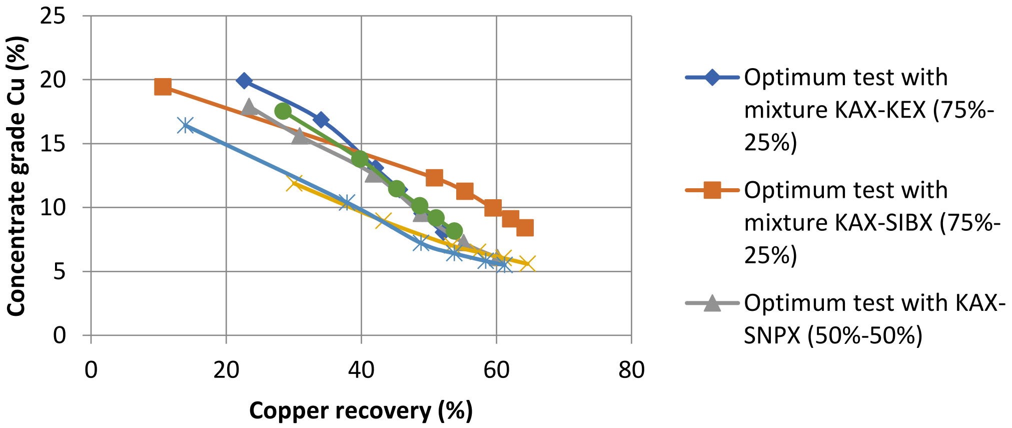
**Figure 9: Flotation results with the mixture KEX - SNBX**




The mixture KEX-SIBX in the respective proportions of 25 and 75% has good selectivity and gave acceptable metallurgical results with 17.54% Cu head concentrate, and a roughing concentrate grading 8.16% Cu with an overall copper recovery of 53.8%. This test has the merit of being the most selective of the series roughing.

**3.5.7. Conclusion flotation tests carried out with the mixture of collectors**

**Figure 10: Comparative results of tests with the optimal mix of collectors**

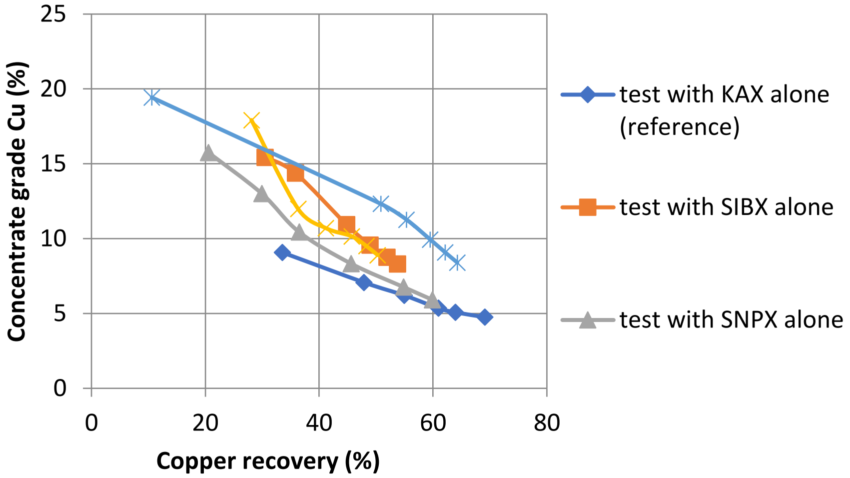



The best test with the mixture of collectors has summers compared them, and these results show that:

- The combination of KAX 75% with other collectors 25% causes a significant improvement in the selectivity head with an average grade of concentrates 20% Cu with an average recovery of 20%, otherwise in the roughing process the association with the SIBX is interesting given the acceptable quality of concentrates obtained with the best recovery;
- The results obtained with the other mixtures are less satisfactory than those achieved with the combination KAX-SIBX.

### 3.5.8. Comparison of results of the best test mixtures with those of tests taken with collectors one on one.

**Figure 11: Flotation results of best test mixture with those of tests taken with collectors alone**

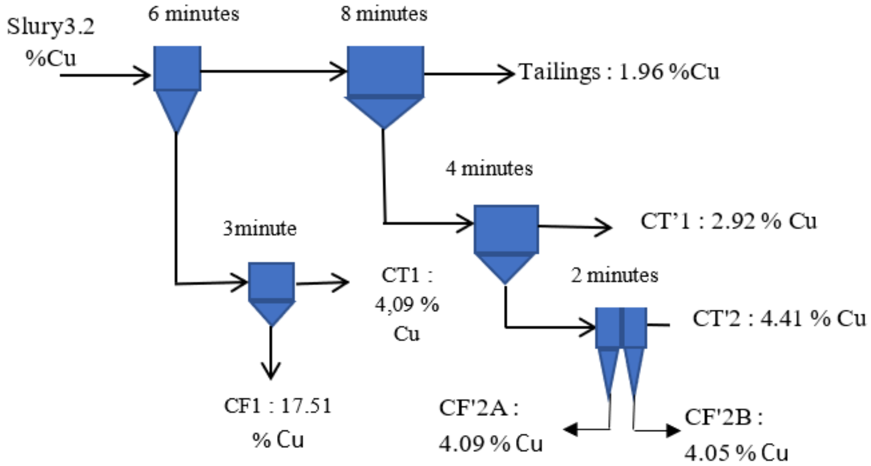



These results demonstrate the positive effect of the synergistic mixture KAX-SIBX with the production of a head concentrate of satisfactory quality, although the recovery is relatively low, but in the roughing the use of this mixture leads to the best quality of the concentrate with a recovery comparable to the best performance obtained with collectors one on one taken in the case of KAX.

### 3.6.Test Results With Cleaning Rougher Concentrates

### 3.6.1. Test under standard or reference

**Figure 12: Cleaning Test results with standard conditions.**

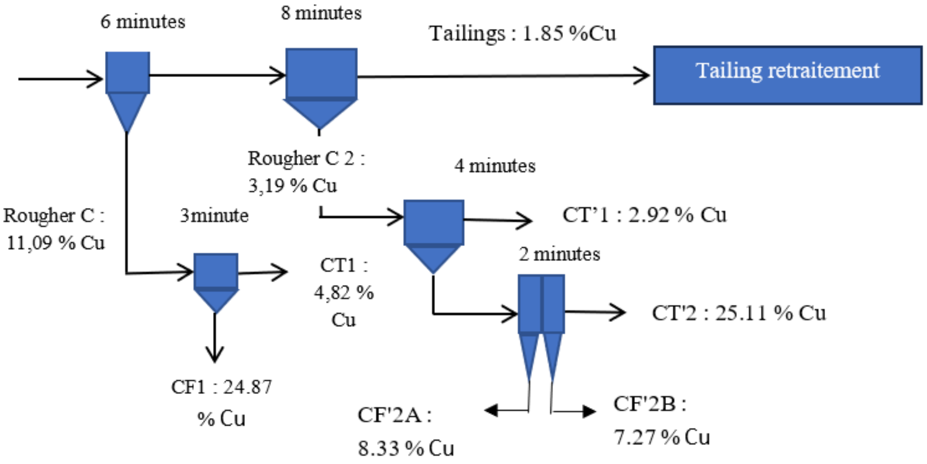



Plan of cleaning the roughing concentrate at dosage rates of 4000 g/t NaSH and 400 g/t KAX. The test results show that:

- A cleaner concentrate (CF1) grading 17.51% Cu was obtained with an associated recovery of about 30%, which leads to a concentration ratio of 5.2;
- The cleaning steps of roughing tails concentrates proved unsatisfactory with an equivalent concentration rate of around 1.3.

### 3.6.2. Test with 75% KAX and 25% SIBX

**Figure 13: Results of the cleaning test of mixture SIBX25%- KAX75%.**




Plan of cleaning the roughing concentrate with mixture KAX 75% - SIBX 25%. The test results show that:

- A cleaner concentrate (CF1) grading 24.87% Cu was obtained with an associated recovery of about 39%, which leads to a concentration ratio of 7.7;
- Flotation cleaning steps to roughing tails concentrate is characterized by a concentration level equivalent 2.4.
- The scavenger concentrate depletion may be recirculated to the feed,
- As the final tails are loaded, it's recommended to put a reprocessing plant discharge.

### 3.6.3. Conclusion trials with cleaning

According to the analysis of test results with cleaning steps:

- The mixture KAX-SIBX taken respectively in the ratios of 75% and 25% is more selective with respect to the use of KAX only as a collector, the quality of the concentrates obtained with cleaning steps shown;
- The copper recoveries seem slightly improved with the mixture of collectors but they remain in the same order of magnitude.

## 3.7.Comparison of collector's costs in the production of concentrate

The calculation of comparative cost collectors will be a monthly concentrate feed of 120,000 dry ton of ore grading 3.22% Cu with a consumption ratio of collector 400 g / t and considering the results obtained in the roughing stage tests with cleaning. The comparative calculations are shown in Table 3.

**Table 3: Indicative cost of production concentrates**

| Process | Concentrate | | Collector | | Prod cost |
|---|---|---|---|---|---|
| | %Cu | TCu | Ratio g/t | Unit cost $/T | $/TCu |
| KAX alone | 6.45 | 2231 | 400 | 2750 | 59,17 |
| 75%KAX-25%SIBX | 8.71 | 2505 | 400 | SIBX: 2550 | 51,49 |

The analysis of comparative calculation cost collectors showed that:

- The total cost of the mixture of collectors is lower than KAX despite a cost per dry ton produced greater for the mixture depends on a low recovery weight;
- The expected gain per ton copper contained with the use of the mixture of the collectors is of the order of 13% compared to the use of KAX. This has an impact on the cost of production.

## 4. Conclusion

The present study is part of all channels to improve the buoyancy of minerals fill 18 Shangulowe compared to usual results. It is in this context that a study of the influence of mixtures of xanthate collectors was initiated. The sample has been the study titled 3.22% copper and 0.08% cobalt. In order to highlight the influence of the mixture of collectors namely Amylxantate KAX potassium, potassium ethyl xanthate KEX, the isobutylxanthate SIBX sodium and sodium SNPX Propylxanthate normal, rough tests of optimizing the consumption ratio of sulfiding, the comparative roughing tests with the mixtures of collectors selected taken in pairs at varying proportions and finally cleaning tests with comparative test carried out under the standard conditions of the concentrator have been achieved.

Roughing and cleaning tests with the mixture KAX- SIBX taken respectively in the proportions of 75% and 25% showed an improvement in the selectivity of 7 points for cleaning tests with a copper recovery of the same order of magnitude as that of KAX, around 60%.

A comparison of the collectors’ costs, helped highlight a desired gain per ton contained copper with the use of mixed collectors which was about 13% compared to the use of KAX.

We therefore suggest to the operator to use the formulation of reagents at different stages of roughing, the reprocessing of tail, according to the scheme proposed flotation.

This work does not end the search for improved flotation of Shangulowe ore difficult to float. we also suggest the future researcher - to make manifolds mixed with xanthates- dithiophosphates which are powerful and also mix collectors xanthates with the fatty acids

## 5. Conflict of interest

Authors do not have any conflict of interest to declare.

## 6. Acknowledgements

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