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Improvement of Extraction Efficiency at Kamoto Copper Company's High Grade Train 1 KCC SA

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Abstrat: This study seeks to resolve a practical problem encountered in solvent extraction. This problem relates to the copper extraction yield in the high-grade circuit. Between July and September 2024, constraints related to increased production and increased demand for HG raffinate led to an increase in feed flow, which increased transfer but resulted in a decrease in copper extraction yield to average values of 80%.

Low extraction yield would mean potentially lower copper recovery at the stripping stage, raffinate richer in residual copper and, in addition, low overall plant productivity. The main objective of this research was therefore to improve copper extraction efficiency, taking into account the increase in feed flow rate, in order to ensure an optimal amount of copper transfer, which would enable the plant to meet its annual production targets.

To do this, a sample of the discharged organic phase and another of the solution from the PLS leaching process were taken at the plant and then characterised for use in laboratory extraction tests. Thirty extraction tests were carried out, varying four parameters in turn to the following values: pH (1.2; 1.4; 1.6; 1.8; 2; 2.2 and 2.4), the O/A ratio (1/3, 1/2, 1, 2/1, 3/1, 4/1, 5/1), the residence time (1; 2; 3; 4 and 5 min) and agitation speed (400; 600; 800; 1000; 1200; 1500 and 1700 rpm). The optimum values for these parameters will be used to establish simulation isotherms in order to adapt the flow rate to the flowsheet.

At the end of this study, the results obtained when applied to a simulation with ISOCALC showed that an efficiency of 84.76% could be achieved by feeding 900m³/h into a series-parallel circuit with a flow rate of 500m³/h on the series stages and 400m³/h on the parallel stage, with a parallel O/A ratio of 2.8, a pH of 1.28, a residence time of 3 minutes and an agitation speed of 100 rpm.³/h on the parallel stage at an O/A ratio of 2.8; a pH of 1.28; a residence time of 3 minutes with an agitation speed of 800 rpm for an organic extractant of 23.12%. These conditions would also minimise the co-extraction of iron to 31.32%.

An extractant was added up to 28% under the same conditions and we obtained an extraction yield of 92.32% and a transfer of 277.15 tonnes/day.

Keywords: *Solvent Extraction, Copper Extraction Efficiency, Hydrometallurgy, High Grade Circuit, Kamoto Copper Company (KCC), Process Optimization, Organic/Aqueous Ratio (O/A), LIX 984N, ISOCALC Simulation, Iron Co-Extraction, Series–Parallel Configuration, Feed Flow Rate, Loaded Organic, PLS, Copper Stripping.*

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I. INTRODUCTION

Solvent extraction is a key process in hydrometallurgical plants due to its ability to purify and concentrate post-leaching solutions (Habashi, 1999). This is the case at the Luilu plants, which use oxidised copper and cobalt ores to produce copper in cathode form and cobalt in the form of high-purity hydroxide (MWEMA, 2016). This process is very important for maximising yields and minimising production costs (DAVENPORT et al., 2011).

Various constraints have highlighted the importance of this work, such as an increase in the feed rate to train 1 in order to maximise transfer and increase production, and high downstream operating costs due to the addition of 300 m^3/h of high-grade (HG) raffinate to the low-grade (LG) circuit, which increases the copper content in the cobalt circuit. This increases the use of lime and sulphuric acid due to the low copper recovery in the PLS during extraction (SOLE & HISKEY, 2005).

The objective of this study is therefore to identify the optimal operating conditions for achieving extraction yields of over 80%, with a particular focus on improving yield by maximising transfer while controlling iron co-extraction (RITCEY, 2006; FLETT, 2019).

In order to meet this objective, laboratory tests were carried out according to an experimental plan based on one parameter at a time. These tests made it possible to study the evolution of copper extraction yield as a function of four essential parameters: pH, O/A ratio, phase separation time and agitation speed (MOYO & KIME, 2014; BABA et al., 2013).

Simulations using ISOCALC software were also carried out to adapt the mass balance to the flowsheet and optimise yields, taking into account the specific characteristics of the previously characterised industrial PLS and discharged organic phase samples (OUTOTEC, 2018; TUTU & MANDA, 2017; SCHLESINGER et al.,2013).

➢ *Historical Overview of Solvent Extraction*

Liquid-liquid extraction or solvent extraction is a separation method that has been used industrially for several years. It has seen considerable growth, particularly with the development of nuclear energy. It was first used during the Second World War to enrich the elements used in the manufacture of the first atomic bomb. It remains the most widely used method for uranium enrichment to this day.

➢ *Principle and Purpose of Solvent Extraction*

- *Principle*

Solvent extraction is a process based on the principle of distributing a dissolved substance between two immiscible organic liquid phases and the affinity of the two for extracting the solute. When brought into contact with each other, this allows the transfer of a solute initially contained in one liquid phase to another liquid phase that is immiscible with the first. In general, one of the phases is aqueous and the other phase is an organic solution containing an extractant and a diluent.

Traditionally, solvent extraction involves two main steps: extraction and stripping. Extraction involves transferring the solute from the aqueous phase to the organic phase. Conversely, stripping (also known as elution or re-extraction) involves transferring the solute from the organic phase to the aqueous phase (TSHIPESHI, 2019).

- *Objectives*

Solvent extraction plants play a role very similar to that of a concentrator. They normally process impure, low-grade feedstock and convert it into a pure, high-grade product suitable for obtaining the desired metal product. The objectives of a solvent extraction plant are :

- ✓ purification, which is an operation in which the useful mineral is extracted while the other anions and cations are rejected.
- ✓ concentration of a liquor typically containing a certain concentration of 1-10 g/l of the mineral to approximately 50 g/l for good production or unit efficiency;
- ✓ conversion, which consists of changing the aqueous phase matrix in which the desired metal is found is found. For example, from a hydrochloric and sulphuric acid leaching solution to a sulphuric acid stripping solution, or from an ammoniacal leaching solution to a sulphuric acid stripping solution.

➢ *Extraction Parameters*

The key extraction parameters are mainly the sharing, distribution and selectivity coefficients and the efficiency of an extraction.

- Partition coefficient
- Distribution coefficient
- Extraction efficiency
- Selectivity coefficient

Depending on the nature of the interactions involved in the extractant, extraction types can be classified into four categories:

- solvation extraction ;
- Cation exchange extraction ;
- chelation extraction ;
- Anion exchange extraction.

➢ *Chemical Aspects of Solvent Extraction of Copper*

- *Chemical Equilibrium of Solvent Extraction*

As mentioned above, solvent extraction is based on the distribution of the metal to be extracted between the aqueous phase and the organic phase. To extract a metal from the aqueous phase, an extractant with a strong affinity for that metal is brought into close contact with the aqueous phase. The passage of the solute into the organic phase theoretically results in an equilibrium as described by the following equation (Hossein, 1999):

$$Me^{n+}\,(aq) + n\,RH\,(org) \leftrightarrow Rn\,Me\,(org) + nH^{+}\,(aq)$$

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Where :

- ✓ Me^{n+}: the metal ion in aqueous solution
- ✓ RH (org) the extractant dissolved in the organic phase;
- ✓ RnMe the metal/extractant complex in the organic phase.

In the case of solvent extraction of copper in a sulphate medium, copper is extracted from the aqueous phase by a typical "RH" extractant according to the equation:

$$[Cu^{2+} + SO_4^{2-}]\ (aq) + 2RH(org) \rightarrow R_2Cu(org) + [2H^+ + SO_4^{2-}](aq)$$

In accordance with LE CHATELIER's principle of chemical equilibrium, which states that "if we tend to modify the conditions of a system, it reacts in such a way as to partially oppose the changes imposed on it until a new state of equilibrium is established".

The previous reaction leading to copper extraction is favoured by a low acid concentration in the aqueous phase, implying a relatively high pH. Furthermore, this reaction results in the generation of H^+protons, which combine with sulphate ions in solution to form sulphuric acid.

On the other hand, copper stripping involves re-extracting it into a new aqueous phase according to the equation:

$$R_2Cu(org) + [2H^+ + SO_4^{2-}](aq) \rightarrow [Cu^{2+} + SO_4^{2-}](aq) + 2RH(org)$$

Similarly, LE CHATELIER's principle of chemical equilibrium indicates that the above reaction is favoured by a high acid concentration in the aqueous phase, implying a relatively low pH. On the other hand, this reaction leads to regeneration of the organic phase, which is generally recycled at the extraction stage.

➢ *Typical Copper Extractants*

Solvent extraction is a chemical process in which the chemical extractant can exchange hydrogen ions and specific metal ions at the organic-aqueous interface. The organic liquid phase is composed of the chemical extractant and the diluent (COGNIS, Practical Guide to Solvent Extraction Plant Operation, 2005).

To date, copper extractants have been marketed by several international companies. One example is BASF, which has launched volume mixtures on the equal ketoximes-aldoximes under the general name of "LIX" and SOLVAY, which launched modified aldoximes on the market under the general name "ACORGA". Some of the advantages and disadvantages of different families of extractants are listed in the table below. The criteria for choosing an extractant are broadly based on the properties listed in this table. All reagents used to extract copper from sulphate solutions in an acidic environment are based on the functionality of hydroxy oxime. Two types of oximes are used of oximes are used: ketoximes and aldoximes.

Ketoximes (ketone and hydroxylamine) are the first oxime-based copper extractants to have been commercialised. They have excellent physical properties such as low entrainment, rapid phase separation and relatively high tolerance to "crud" generating elements such as soluble silica, polymer-based flocculants and "stray" organic compounds. They strip easily and have good net transfer and very good selectivity for copper over iron. They have slightly lower kinetics than aldoximes, particularly at low temperatures, and they have relatively lower chemical stability than aldoximes.

Aldoximes (aldehyde and hydroxylamine) have fast copper transfer kinetics and good copper selectivity over iron. They are very strong copper extractants, so strong that they are always used in combination with equilibrium modifiers or a ketoxime to increase stripping efficiency.They are these equilibrium-modifying agents often increase the risk of sludge formation and entrainment.

Aldoximes are less stable than ketoximes.

Unmodified ketoxime-aldoxime mixtures combine the strong extracting power and fast kinetics of aldoximes with the good physical properties and stripability of ketoximes; they have good selectivity for copper over iron and are more stable in leach liquors containing chloride and nitrate ions than modified aldoximes. Ketoxim-aldoxime mixtures allow more copper to be recovered than any other reagent formulation. The reaction mechanism of a ketoxim-aldoxime mixture is illustrated by the following equations:

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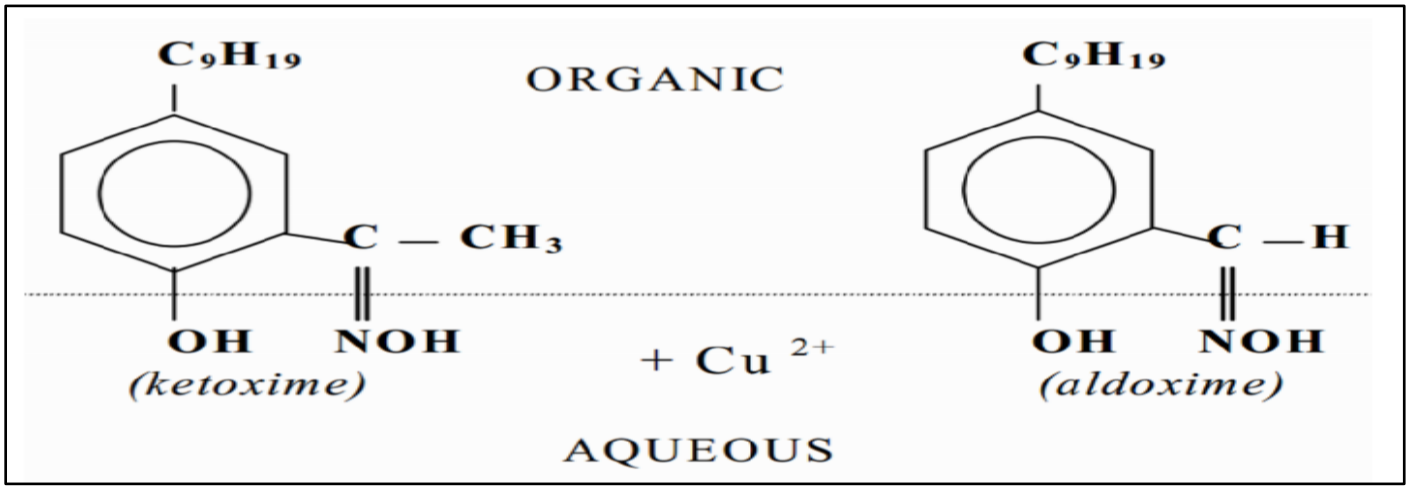

Fig 1 Reaction Mechanism of a Ketoxime-Aldoxime Mixture

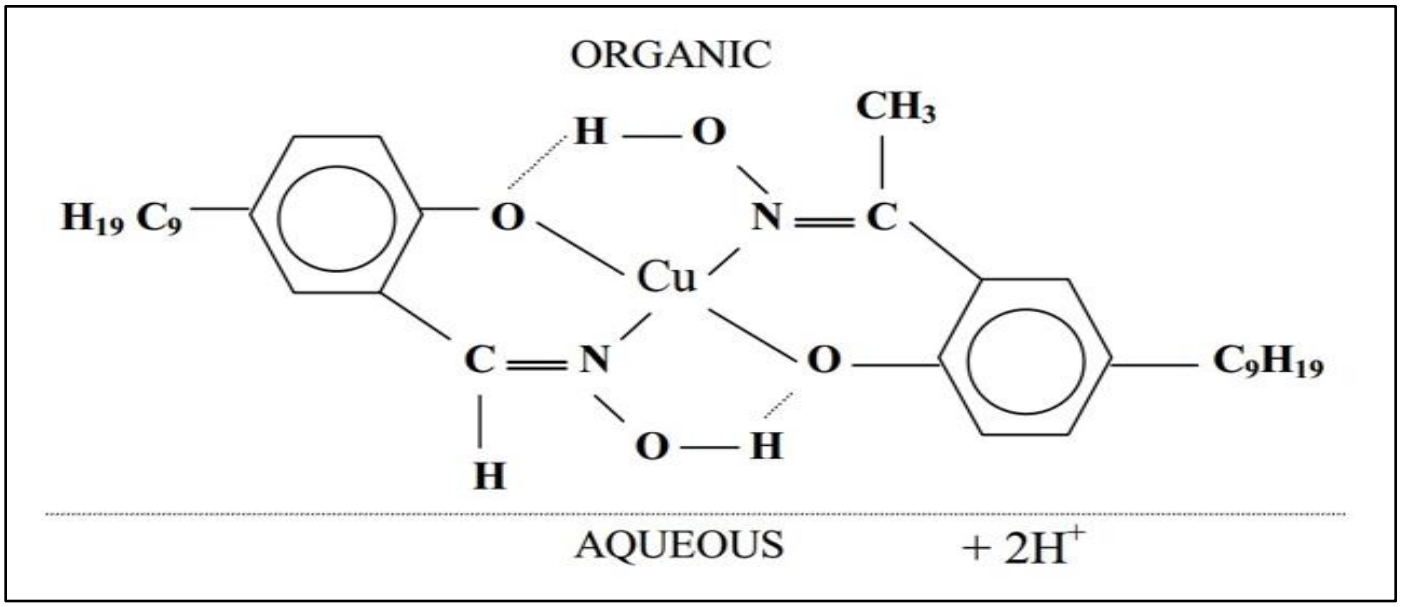

Fig 2 Copper (II) Complex with An Oxime or Salicyl Aldoxime Ligand

And so, the final reaction between copper and oxime-based extractants and chelating complexes forms; R= C9H19 or C12H25; for ketoximes: A= CH3 (SOLE et al, 2011)

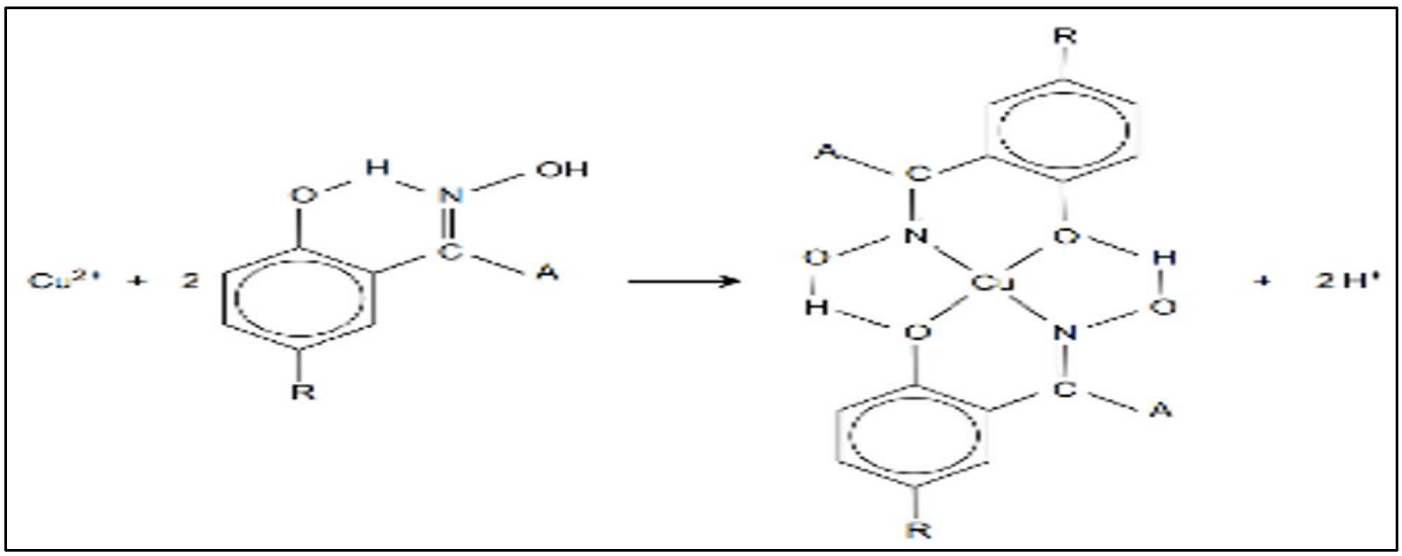

Fig 3 Complexation/Extraction Reaction of Copper (II) by An Aromatic Aldoxime

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The diluent is an organic liquid used to dilute and solubilise the extractant and modifiers. It is generally composed of various aromatic, paraffinic and naphthenic hydrocarbons. Economic and technical criteria often come into play when choosing a diluent, which is why kerosene is often used.

Modifiers are used to minimise the risk of a third phase forming, as the extractant is not completely soluble in the diluent. Modifiers usually act as depressants for the species to be extracted. Modifiers are rarely used nowadays, as new generations of diluent extractants prevent the production of a third phase (AMINIAN, 1999).

Table 1 Comparison of the Properties of Cetoximes and Aldoximes (COGNIS, Practical Guide to Solvent Extraction Plant Operation, 2005)

Propriétés	**Cétoximes**	**Aldoximes**
Pouvoir d'extraction	Modéré	Très fort
Strippage du cuivre	Très bon	Pas bon
Sélectivité Cu/Fe	Excellente	Excellente
Cinétique de réaction	Rapide	Très rapide
Séparation des phases	Très bonne	Très bonne
Stabilité	Excellente	Très bonne
Génération des crud	Faible	Variable

- *Industrial Parameters*

Solvent extraction is a delicate operation that requires the simultaneous control of several parameters. In addition to pH, temperature and concentration of the solute to be extracted, these include (COGNIS, Practical Guide to Solvent Extraction Plant Operation, 2005):

✓ The theoretical number of extraction and stripping stages;
✓ The concentration of the extractant in the organic phase;
✓ The phase volume ratio (organic volume/aqueous volume);
✓ The concentration of free acid in the aqueous phase during extraction and stripping;
✓ The continuity of the phases in the mixers;
✓ The efficiency of the mixers;
✓ The residence time in the mixers and the phase separation time;
✓ The depth of the organic phase in the decanters;
✓ Phase entrainment, etc.
✓ Only a few parameters will be useful to us in the.

II. EQUIPMENT AND METHODS

➢ *Equipment Used*

During the extraction tests, various materials were used. The main materials used are as follows:

- *Glassware* **:**

✓ 250 and 500 mL beakers;
✓ Erlenmeyer flasks;
✓ Measuring cylinder;
✓ Decanter

- *Equipment :*

✓ pH meter with brand HANNA INSTRUMENT;
✓ Agilent Technologies atomic absorption spectrometer;
✓ JSR mechanical stirrer;

- *Accessories*

✓ Pistols;
✓ Funnel;
✓ Filter paper;
✓ Stopwatch;

➢ *Reagents Used*

During this research, the following reagents were used:

- 23.12% LIX 984NC organic phase composed of as extractant for dissolved copper in Shellsol 2325 as diluent;
- An aqueous phase from the plant and previously characterised (PLS);
- 10 N caustic soda for pH regulation;
- sulphuric acid at 180 g/L for stripping tests;

➢ *Procedure*

Each extraction test was carried out according to the following steps:

- Place a volume X of the discharged organic phase in a beaker according to the pre-set O/A ratio for the test;
- Place the beaker under the stirrer;
- Start the stirrer at the speed required for the test;
- Add a volume of aqueous phase according to the set ratio and previously adjusted to the pH of the test;
- Start the stopwatch;
- Stop the agitator after a set time for the test performed;
- Allow the two phases to settle until they are completely separated;
- Take a sample of the aqueous phase to send to the laboratory for chemical analysis;
- Calculate the extraction yield.

➢ *Varied Parameters*

During this research, four parameters were varied successively, namely: pH, O/A ratio, residence time and stirring speed. Table 2 shows the levels of variation for these different parameters.

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Table 2 Levels of Variation in the Parameters Studied

Parameters	1	2	3	4	5	6	7
pH	1,2	1,4	1,6	1,8	2	2,2	2,4
Ratio	1/3	1/2	1/1	2/1	3/1	4/1	5/1
Time (min)	1	2	3	5			
Agitation (rpm)	400	600	800	1000	1200	1500	

The levels of variation for each of the above parameters were chosen based on specific considerations. These are detailed below.

- *The pH*

The pH range for conducting the extraction tests was chosen based on the following considerations:

✓ The operating conditions of the plant, which dissolves copper at a pH of 1.7;
✓ Previous work on the evolution of extraction yield as a function of pH (al. T.e., 2009) (TSHIPESHI, 2019).

- *The O/A Ratio*

The range of variation of the O/A ratio during extraction tests was chosen based on the following factors:

✓ Previous work on the evolution of the extraction yield of an element as a function the O/A ratio (TSHIPESHI, 2019);
✓ The operating conditions of the plant shown in the table

- *Residence Time*

The levels of variation in residence time during the extraction tests were chosen based on the following factors:

✓ The literature, which indicates that residence time influences both the extraction yield of an element and the quantity of the element transferred (COGNIS, 2005);
✓ The plant's operating conditions ;
✓ Previous work on optimising residence time during solvent extraction (KABEYA, 2019) (TSHIPESHI, 2019).

- *The Stirring Speed*

Similarly, the different stirring speed values set during the extraction tests were chosen based on the following factors:

✓ The literature, which indicates that agitation speed influences the kinetics of material transfer of the element and on extraction yield (COGNIS, Practical Guide to Solvent Extraction Plant Operation, 2005);
✓ Previous work on the influence of agitation speed on extraction yield (KABEYA, 2019) (TSHIPESHI, 2019).

➢ *Calculation of Metallurgical Performance*

The metallurgical performances studied during this research are the copper extraction yield and the amount of copper transferred. It should be noted, however, that the evolution of iron co-extraction was also studied under the same conditions. The mathematical expressions for the extraction yield and the amount of copper transferred are given below.

- *Calculation of Extraction Yield*

The extraction yield was calculated from the chemical results obtained on the aqueous phases before and after extraction according to the following relationship:

$$\eta_{extraction} = \frac{([Cu]pls - [Cu]raffinat)}{[Cu]pls}$$

With:

✓ η Elément: : copper extraction yield (%)
✓ $[Cu]_{PLS}$: mass concentration of copper in the PLS (g/l);
✓ [Cu] raffinate: mass concentration of the element in the raffinate (g/l).

➢ *Calculation of the Quantity of Copper Transferred*

The quantity of copper transferred was calculated under the optimal operating conditions found for the copper extraction unit using the following mathematical expression X:

$$T_{Cu} = A \times \frac{([Cu]pls - [Cu]raffinat)}{1000}$$

Where:

✓ T Cu: the quantity of copper transferred (T/h)
✓ A: aqueous phase flow rate (m^3/h)
✓ [Cu]PLS: the concentration of copper in the solution resulting from leaching ($^{kg/m^3}$)
✓ [Cu]raffinate: the concentration of copper in the raffinate ($^{kg/m^3}$)

We note that these formulas were applied under the conditions of the train, with a feed rate of 600m^3 /h and an organic volumetric flow rate of 1444.50 m^3 /h in a series circuit.

III. RESULTS AND DISCUSSION

➢ *The Following Parameters Were Studied*

- The influence of pH on extraction yield: 1.2; 1.4; 1.6; 1.8; 2; 2.2 and 2.4
- The influence of the ratio on extraction yield: 1/3, 1/2, 1, 2/1, 3/1, 4/1, 5/1
- The influence of residence time on extraction yield: 1; 2; 3; 4 and 5 min
- The influence of stirring speed on extraction yield: 400; 600; 800; 1000; 1200; 1500 and 1700 rpm

In this study, extraction tests were carried out in the laboratory according to a single parameter plan each time, in order to study the evolution of copper extraction yield as a function of the following four main parameters: pH, O/A ratio, residence time and agitation speed. These tests were conducted

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on previously characterised industrial samples of PLS and discharged organic phase. We also performed a simulation with ISOCALC. To adapt the flow in order to achieve better yield and greater transfer.

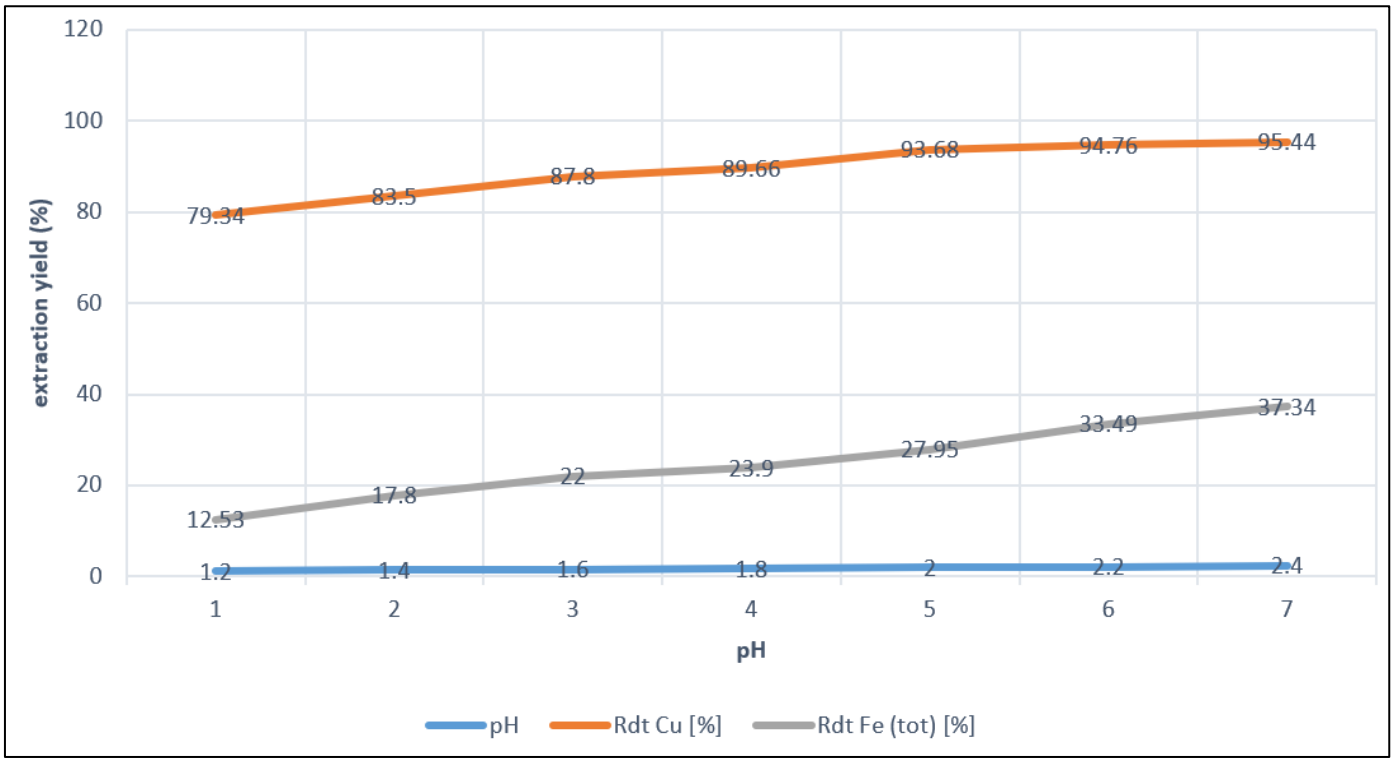

Fig 4 Influence of pH on Copper Extraction and Iron Co-Extraction Yields

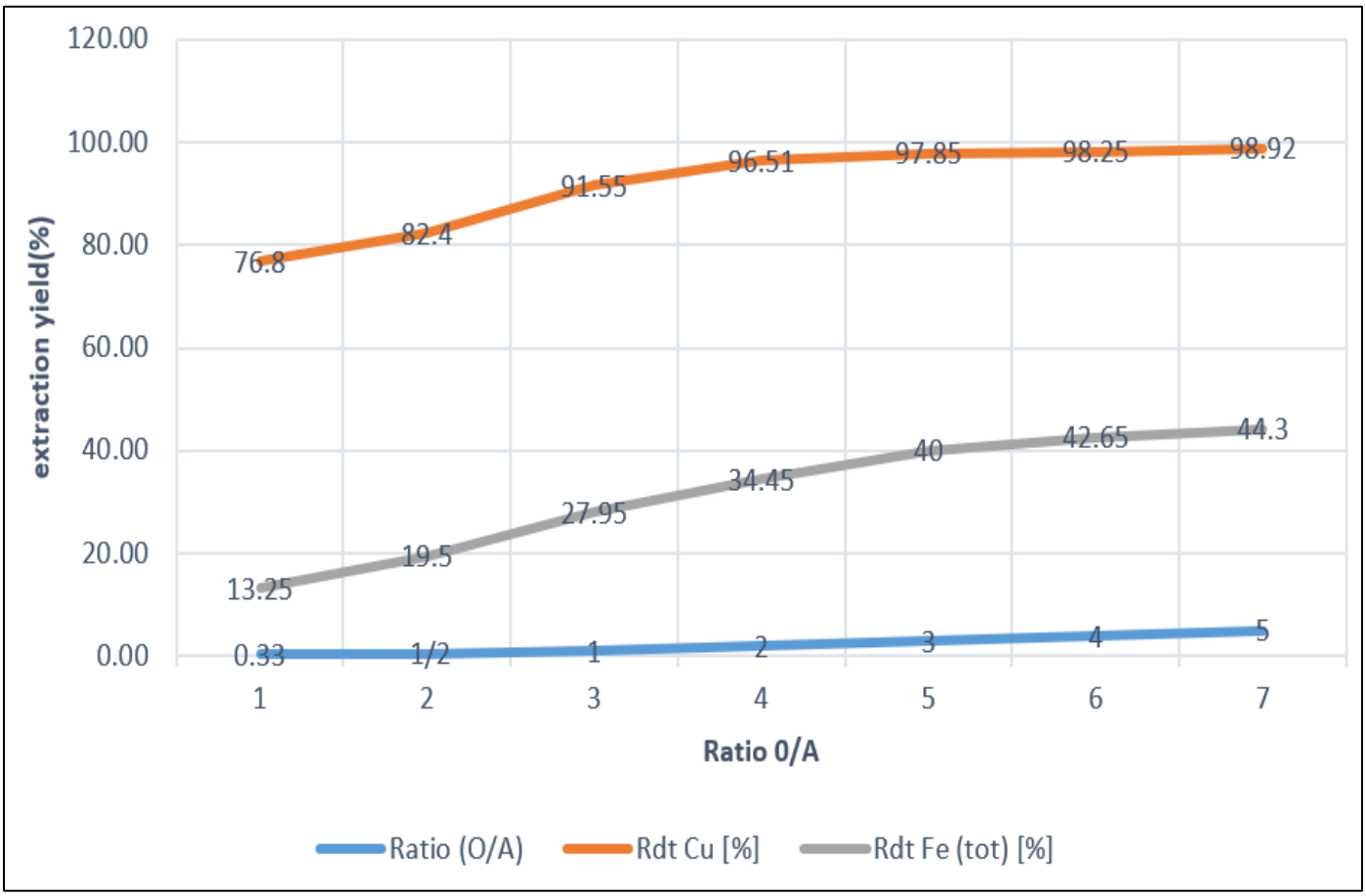

Fig 5 Influence of the O/A Ratio on Extraction Yield

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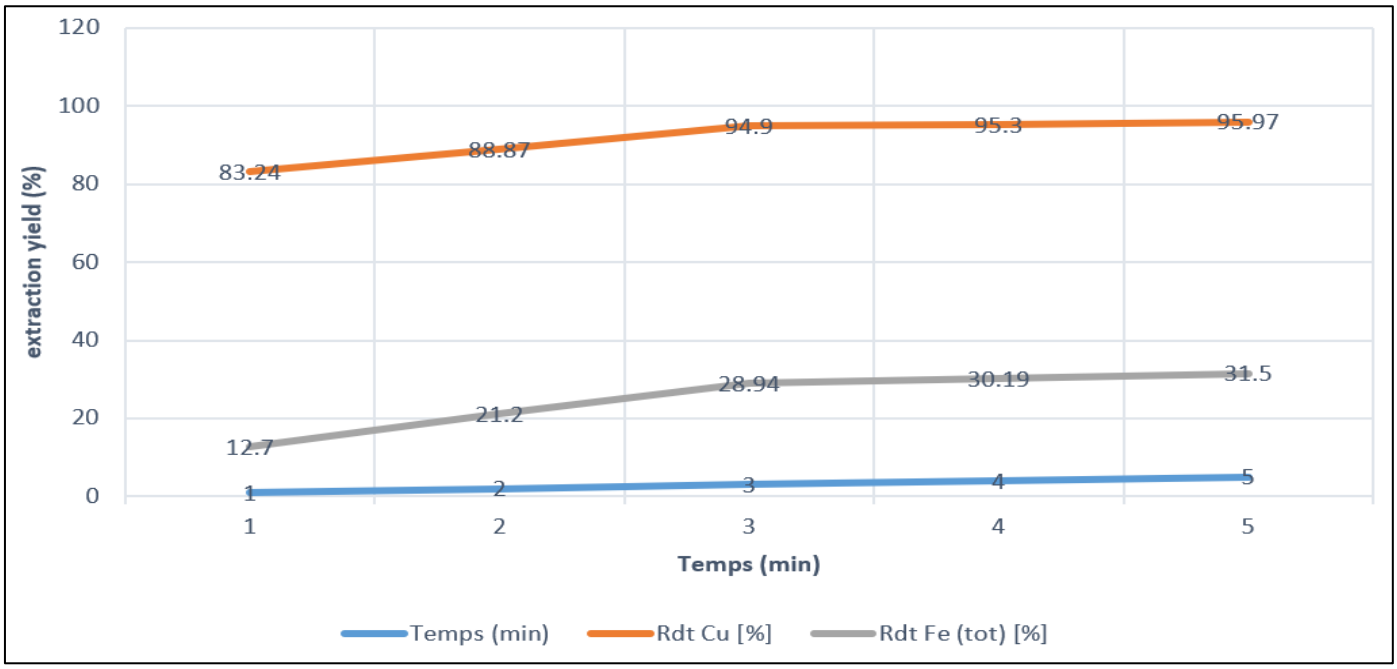

Fig 6 Influence of Residence Time on Extraction Yield

These conditions would also minimise iron co-extraction to approximately 31.32%. Working under these conditions would guarantee copper extraction yields of at least 91.92%. For an average phase flow rate of 600 m³/h, the amount of copper transferred for one circuit train through extraction would be at least 4.92 dm³/h. This is for train 1 only, as train 2 operates at a flow rate of between 900 and 910m³/h. In order to meet the plant's raffinate requirements or demand, we have been forced to increase the train's flow rate from 600 to 900 m³/h.

We ran simulations with ISOCALC to find the best configuration to solve our problem. As mentioned above, the pump that feeds the series circuit of train 1 has a maximum capacity of 600m³/h, which meant we had to run simulations with series-parallel and parallel circuits using the plant's integrated bypass system to achieve a flow rate of 900m³/h.

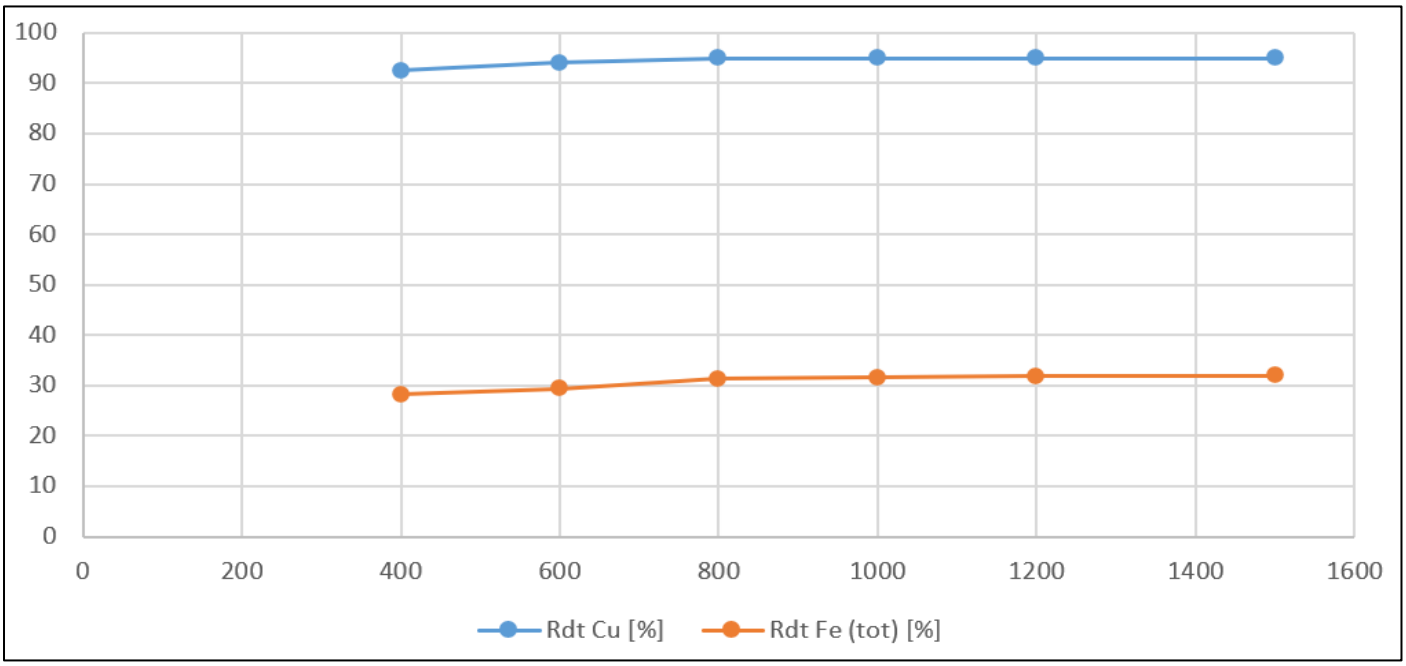

Fig 7 Influence of Agitation on Extraction Yield

We note that we can adapt the flow using the MC CABE-THIELE diagram, but ISOCALC provides us with reliable results and allows us to vary several parameters at once.

The results obtained above enabled us to determine the margins within which we carried out our simulations and thus achieve the best yields. We performed several simulations but chose the optimum.

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Table 3 Simulation with a 500-400 Power Supply

Isocalc™ Report

BASF We create chemistry

Client	KCC			**Isocalc™ Version**	2020.01	
Project Name	HGSX train 1 optimisation			**Date**	18 October 2024	
Project Description	2Ex1Ex2S (500-400)					
Series PLS Stream				**Raffinate Series**		
Volumetric Flow	500	m3/h		Copper Concentration	2.58	g/L
Copper Concentration	15.00	g/L		pH	0.61	-
pH	1.28	-		Acid Concentration	24.31	g/L
Acid Concentration	5.15	g/L				
Sulphate Concentration	200.00	g/L				
Sulphate Activity	20	%				
Parallel (I) PLS Stream				**Parallel (I) Raffinate**		
Volumetric Flow	400	m3/h		Copper Concentration	1.92	g/L
Copper concentration	15.00	g/L		pH	0.59	-
pH	1.28	-		Acid Concentration	25.34	g/L
Acid Concentration	5.15	g/L				
Sulphate Concentration	200.00	g/L				
Sulphate Activity	20	%				
Organic				**Spent/Advance Electrolyte**		
BASF Extractant	LIX984N			Volumetric Flow	950.00	m3/h
Edit	None			Spent Acid Concentration	190.00	g/L
Volumetric Flow	1445.00	m^3/h		Spent Copper Concentration	40.0	g/L
Extractant Concentration	23.12	vol		Adv Copper Concentration	52.04	g/L
Maximum Copper Loading	12.48	g/L				
Extraction Circuit				**Stripping Circuit**		
Circuit Type	Parallel			Number of Stripping Stages	2	
Number of Extraction Stages	2E-1E			O/A Ratio	1.52	
Advance O/A Ratio	2.89			Stripped Organic Copper	3.93	g/L
Loaded Organic Copper	11.85	g/L		Strip Temperature	40.00	°C
Percentage of Maximum Loading	89.49	%				
Net Transfer	0.3046	g/L per 1% extract		**Stage Efficiencies**		
Series Circuit Recovery	82.79	%		Series Extraction	91, 93	
Parallel (I) Circuit Recovery	87.22	%		Parallel (I) Extraction	95	
Overall Circuit Recovery	84.76	%		Strip	98	
Daily copper transfer	274.61	t/day				
Annual copper transfer	100.23	kt/year				

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The results obtained above enabled us to determine the margins within which we carried out our simulations and thus achieve the best yields. We performed several simulations but chose the optimum one.

➢ *Simulation with a 500-400 Supply*

We opted for a simulation with a feed of 500m3/h at the series stages and 400m^3 /h at the parallel stage with a feed of 15g/l of copper, this the latter gives a yield of 84.20, which is a good transfer, and it answers the question of feeding the large flow, but we have noticed a degradation of the organic phase used in the plant of more than 10%, which is also a factor that causes the yield to be low due to the double feeding of PLS. This is the result of the plant in order to achieve our objectives while maintaining the train's operating parameters.

Table 4-Feed 500-400 at 28% Extractant

	Isocalc™ Report			BASF We create chemistry	
Client	KCC		**Isocalc™ Version**	2020,01	
Project Name	HGSX train 1 optimisation		**Date**	18 October 2024	
Project Description	2Ex1Ex2S (500-400)				
Series PLS Stream			**Series Raffinate**		
Volumetric Flow	500	m3/h	Copper Concentration	2.58	g/L
Copper Concentration	15.00	g/L	pH	0,61	-
pH	1,28	-	Acid Concentration	24.31	g/L
Acid Concentration	5,15	g/L			
Sulfate Concentration	200.00	g/L			
Sulfate Activity	20.00	%			
Parallel (I) PLS Stream			**Parallel (I) Raffinate**		
Volumetric Flow	400	m3/h	Copper Concentration	1.92	g/L
Copper Concentration	15.00	g/L	pH	0,59	-
pH	1,28	-	Acid Concentration	25.34	g/L
Acid Concentration	5,15	g/L			
Sulfate Concentration	200.00	g/L			
Sulfate Activity	20.00	%			
Organic			**Spent/Advance Electrolyte**		
BASF Extractant	LIX984N		Volumetric Flow	950.00	m3/h
Modifier	None		Spent Acid Concentration	190.00	g/L
Volumetric Flow	1445.00	m3/h	Spent Copper Concentration	40.00	g/L
Extractant Concentration	28.00	vol %	Adv Copper Concentration	52.04	g/L
Maximum Copper Loading	15.038	g/L			
Extraction Circuit			**Stripping Circuit**		
Circuit Type	Parallel		Number of Strip Stages	2	
Number of Extraction Stages	2E-1^E		O/A Ratio	1.52	
Advance O/A Ratio	2.89		Stripped Organic Copper	3.93	g/L
Loaded Organic Copper	11.85	g/L	Strip Temperature	40.00	°C
Percentage of Max Loading	89.99	%			
Net Transfer	0,3046	g/L per 1% extract	**Stage Efficiencies**		
Series Circuit Recovery	87,90	%	Series Extraction	91, 93	
Parallel (I) Circuit Recovery	96.79	%	Parallel (I) Extraction	95	
Overall Circuit Recovery	92.32	%	Strip	98, 98	
Daily copper transfer	277.15	t/day			
Annual copper transfer	101.16	kt/annum			

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Having the possibility of increasing the loading capacity of the organic material without modifying its properties, we improved it by adding organic matter up to 28%, giving it a loading capacity of 15.0383g/l, which is much higher than that of the plant. Phase separation time (PDT) tests were used to check the properties of the organic matter

By studying these parameters, we found that a copper extraction yield of 92.32% could be achieved by working at a pH of 2 to 2.5, an O/A ratio of 1.5, a residence time of 3 minutes, an agitation speed of 800 revolutions per minute and a flow rate of 900m3 /h with a series-parallel configuration of (500m3 /h on the series stages and 400m3 /h on the parallel stage) with a 28% extractant. In addition, these conditions would limit iron co-extraction to 31.32%. Discussions on the present results indicated that they would ensure both satisfactory extraction yields and a high amount of transferred copper, thereby enabling the plant to meet its production targets.

IV. CONCLUSION

It should be noted that this article addressed practical considerations relating to solvent extraction of copper as applied to the Luilu hydrometallurgical plants. The main objective was to determine the optimal operating conditions that would achieve copper extraction yields greater than 80% by maximising copper transfer while limiting iron co-extraction at a flow rate of 900 m³/h.

In this study, extraction tests were carried out in the laboratory according to a single-factor design in order to study the evolution of copper extraction yield as a function of the following four main parameters: pH, O/A ratio, residence time and agitation speed. These tests were conducted on previously characterised industrial samples of PLS and discharged organic phase. We also performed a simulation with ISOCALC to adjust the flow for better yield and greater transfer.

At the end of this work, the results obtained showed that a copper extraction yield of 92.32% could be achieved by working at a pH of 2 to 2.5; an O/A ratio of 1.5; a residence time of 3 minutes; an agitation speed of 800 revolutions per minute and a flow rate of 900m^3 /h with a series-parallel configuration of (500m^3 /h on the series stages and 400m^3 /h on the parallel stage) with a 28% extractant. Furthermore, these conditions would limit iron co-extraction to 31.32%. Discussions on the present results indicated that they would guarantee both satisfactory extraction yields and a high amount of transferred copper, thus enabling the plant's production targets to be met.

Due to time constraints, it was not possible to conduct a more in-depth study to evaluate the economic aspect.

The latter could highlight the relentless pursuit of improved efficiency, which affects other processes in the plant due to the addition of 300m³/h of HG raffinate to the scrubber decanters that feed the LG circuit, thereby impacting the Cobalt circuit.

We suggest that our successors focus on the impact of adding HG raffinate to the cobalt circuit and also conduct an economic impact study to assess the cost of the added extractant compared to the cost of acid and lime used in the WOL (whole area leaching) and cobalt sections.

This addition of extractant has made it possible to achieve an extraction yield of 92.32% with good transfer and low iron co-extraction.

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