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The Analysis of Leach Solution Treatment By Liquid-Liquid Dispersion With Diluent

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Abstract

This article shows the treatment of the leaching solution by making a liquid-liquid dispersion with the diluent Massimo Sol with the aim of minimizing dissolved silica and suspended solids and studying the impact of this treatment on the solvent extraction of copper.

Materials and methods: The study on Shituru plants is a town in Likasi in the province of Haut-Katanga, Democratic Republic of Congo. The statistical methods of Taguchi and analysis of variance were used to process the experimental results, with a view to assessing, from a statistical and metallurgical point of view, the parameters influencing the yield of impurity removal from the leaching solution and the phase disengagement time on solvent extraction. Atomic absorption and optical emission spectroscopic methods coupled to an ICP - OES induced plasma were used to characterise the leaching solution sample in our study. The analyses revealed 4.00 g/L of copper and 0.70 g/L of cobalt for the metals in solution, and 845 ppm of dissolved silica and 1050 ppm of suspended solids for the impurities.

Results: For the solvent extraction tests, an orthogonal matrix 4 parameters with 4 levels was used to conduct these optimisation tests in order to evaluate the effect of the stirring speed (800 rpm, 1100 rpm, 1400 rpm and 1700 rpm), the ratio (0.8; 1.0; 1.2 and 1.4), contact time (120 seconds, 180 seconds, 240 seconds and 300 seconds) and percentage of extracting in the organic phase (15, 20, 25 and 30) on the extraction of copper from the leach solution by the organic phase. These tests to optimize the copper solvent extraction operation gave the results for the operating conditions of the controllable parameters: stirring speed of 1700 rpm, ratio of 1.4, and contact time of 180 seconds and percentage of extracting of 20% in the organic phase. The confirmation test under optimum conditions gave a copper recovery yield of 92.44% and a phase disengagement time of 95.17 seconds.

Conclusion: Confirmation tests were carried out under the optimum conditions obtained in order to confirm the results obtained. Removal efficiencies of 66.02% and 75.99% were obtained for dissolved silica and suspended solids content respectively, a phase disengagement time of 50.02 seconds and a copper recovery efficiency of 96.77% at solvent extraction.

Keywords: Solvent extraction; Contamination; Performance optimisation; Diluent treatment; Copper; Cobalt

Introduction

In recent years, liquid-liquid extraction has established itself as a technique in its own right in modern hydrometallurgy, for the enrichment, separation and purification of metal ions. From a technical point of view, managing a solvent extraction plant involves ensuring that it operates efficiently, taking into account the objectives set down [1]. any cause likely to lead to a reduction in the efficiency of the circuit requires special attention from informed industrialists. Currently, the technique of heap leaching followed by solvent extraction and extraction electrolysis is considered a better alternative for the treatment of poor ores as well as rejects. However, in the presence of sulphuric acid, oxidised copper ores composed of silicate ores also pass silica into solution. Quartz in these ores remains in solid form as a constituent of the residue [2]. When an industry is faced with a problem, a multi-critical approach is necessary in the sense that efforts are made to find treatment techniques adapted to each situation. In the present case, this problem can be summed up by the presence in the Pregnant Leach Solution of certain physical and chemical contaminants that can cause a number of harmful consequences, including stable emulsions, an increase in phase separation time, reagent degradation, a reduction in selectivity and poor extraction kinetics in some cases, an increase in turbulence, contamination of the rich electrolyte, and so on. These factors can lead to many problems in a solvent extraction plant, including entrainment of the organic phase in the aqueous phase, entrainment of the aqueous phase in the organic phase, low net copper transfer, impurity transfer, reduced efficiency of the solvent extraction circuit, etc. [3, 4]. According to Cognisa, it is preferable to run the solvent extraction plant in organic continuity to avoid problems with contaminants in the aqueous phase such as dissolved silica, colloidal silica, suspended solids, etc.. But the extraction plant at the Shituru plants, because of its somewhat limiting design, cannot continuously maintain the dispersion of phases in organic continuity [5]. With a view to limiting this damage, Générale des Carrières et des Mines has initiated a number of research projects aimed at improving the performance of the solvent extraction circuit by eliminating the contaminants using various techniques: clay treatment, coagulation and flocculation, etc. Therefore, still with the aim of minimising impurities and their effects on the solvent extraction process, a study of the purification of the Pregnant Leach Solution leaching solution

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in order to eliminate dissolved silica and the quantity of solids was initiated, through the metallurgical studies department [6], The is to get the solvent extraction plant at the Shituru plants running smoothly with good organic continuity and to improve the metallurgical performance of this circuit, while studying the impact of the Pregnant Leach Solution treatment operation by advancing our understanding of the phenomena linked to the efficiency of the process and selectivity for the element or elements to be eliminated.

Material and methods

Sample source

This study focused on the sample of leach solutions from the Shituru plants. Shituru has several sources of leaching solutions that feed its solvent extraction unit: solutions from agitated tank leaching, solutions from the large Panda heap and solutions from Kambove heap leaching. We focused on the solutions from the large Panda heap, where heap leaching is applied to Kamatanda ores. In order to demonstrate the origin of the silica in the Pregnant Leach Solution, a sample of Kamatanda ore was subjected to mineralogical characterization. Identification of the valuable minerals and gangue minerals of sample was carried out at the School of Resource and Safety Engineering central south university, using a Wild Heerbrugg binocular stereoscopic microscope.

Chemical characterization of our sample of Grand Heap Panda leaches solutions to determine the concentration of chemical elements and chemical properties. The instruments used for chemical analysis of the samples in the laboratory are:

- Perkins Elmer AA400 atomic absorption spectrometer;
- Pinacle 500 atomic absorption spectrometer;
- Perkins Elmer Optima 8300 inductively coupled plasma optical emission spectrometer.

The physical characterization of the Grand Heap Panda leach solution sample is aimed at determining the suspended solids content.

Diluent Wash Tests

Various items of equipment were used to carry out washing tests on the Pregnant Leach Solution with Massimo Sol diluent, including: 250-mL, 500-mL, 800-mL and 1000-mL beakers; 500-mL test tubes; 500-mL separating funnels; a Hanna (HI 2221 pH meter). The reagents used in these tests were the diluent, Pregnant Leach Solution and NaOH to regulate the working pH. The NaOH was prepared at a concentration of 10N as follows: weigh 200 g of NaOH; take 500 mL and place in an 800 mL beaker; adjust the mechanical stirrer to its centre; start the stirrer and adjust its speed to 800 rpm; add the NaOH until it is completely dissolved in the water; keep the NaOH solution in a flat-bottomed flask. Washing the Pregnant Leach Solution with the diluent consists of a liquid-liquid dispersion in which the two liquids are nothing.

$$\eta_{SiO_2} = \frac{[SiO_2]_{\text{alimentéé}} - [SiO_2]_{\text{résiduelle}}}{[SiO_2]_{\text{alimentée}}} \times 100$$

With: η_(SiO_2): dissolved silica removal efficiency (en%); m[SiO_2] alimentééfeed: concentration (in ppm) of dissolved silica in the PLS before treatment with diluent; [SiO_2] résiduelle: concentration (in ppm) of dissolved silica in the PLS after treatment with diluent. The TSS removal yield is the ratio of the quantity of TSS removed from the liquor after treatment to the TSS in the PLS liquor before treatment. This ratio is expressed as a percentage (%).

$$\eta_{TSS} = \frac{TSS_{\text{alimenté}} - TSS_{\text{résiduel}}}{TSS_{\text{alimenté}}} \times 100$$

With:η_TSS: suspended solids removal efficiency (TSS) expressed in %:TSS_alimenté: the quantity of suspended solids in the PLS liquor before treatment with the diluent, expressed in ppm; TSS_résiduel: this is the quantity of suspended solids that could not be eliminated from the liquor after treatment with the diluent, also expressed in ppm. This is the phase separation time for solvent extraction of the leaching solutions after treatment with the diluent [7]. So we can assess the impact of this solvent extraction treatment.

Experimental designs

To investigate the influence of the various physicochemical parameters on the efficiency of the solvent extraction and diluent washing processes studied, we opted for a statistical approach using Taguchi's methodology coupled with analysis of variance. According to the literature, this approach offers many advantages due to the robustness of Taguchi's methodology, because it takes into account the effects of uncontrollable parameters grouped together in what is known as "noise". We therefore describe Taguchi's methodology and the concept of analysis of variance. Experimental designs are in fact a series of tests organised in advance in order to determine the influence of multiple parameters on one or more responses, and provide a solution that considerably reduces the number of experiments to be carried out compared with the methods traditionally used [8]. Generally, there are 3 characteristic categories of performance in S/N ratio analysis: minimum is best (minimise), maximum is best (maximise) and target is best (target value) [9]. In relation to the characteristic performance categories, the highest signal-to-noise ratio corresponds to the best performance. Consequently, the optimum level of a parameter is the one with the highest S/N ratio. Performance characteristics are evaluated by the following expressions [10, 11].

The maximum is the best:

$$SN_L = -10 \log\left(\frac{1}{n}\sum \frac{1}{Y_i^2}\right) \tag{3-1}$$

The minimum is the best:

$$SN_S = -10 \log\left(\frac{1}{n}\sum Y_i^2\right) \tag{3-2}$$

Where 〚SN〛_L and 〚SN〛_S_S are performance characteristics, the number of repetitions of the performance for the experimental combination and Y_i^2 the value of the With experiment performance. This functional metric or signal-to-noise ratio (S/N) is constructed so that the greater its value, the better the quality. The combination of controlled factor levels, or input factors that gives the largest ratio is the robust solution [12].In Taguchi's method, the experiment or trial corresponding to the optimal conditions found may or may not be done during the experimentation phase but the value of the experiment's performance can be predicted by using the prediction function represented by the relationship below [13]

$$\text{Yopt} = \frac{T}{n} + \left(\text{Ai} - \frac{T}{n}\right) + \left(\text{Bj} - \frac{T}{n}\right) + \cdots \tag{3-3}$$

Where n is the total number of trials, T is the sum of all trial responses and Ai, Bj, is the average of the responses for level i, j

Solvent extraction parameters and matrix

Four parameters were selected for the solvent extraction optimisation tests: agitation (A), ratio (B), contact time (C) and percentage extactant (D). Table 2 summarises all these parameters and their quantitative values (Table 1).

A series of 16 trials were carried out following the experimental design with the aim of determining the levels of controlled operating parameters that optimise copper extraction yield and phase separation time, and analyzing the influence and relative interactions of these parameters. The order of the experiments was obtained by inserting the parameters into the columns of the orthogonal matrix chosen as the experimental design. An orthogonal matrix is simply an integration table of integers whose columns represent the levels of the factors. Each row represents a trial, which is in fact a set of the specific levels of each factor. Table 2-3 describes the orthogonal matrix chosen for our experiments (Table 2).

To carry out the tests for the solvent extraction study with the diluent alone in order to eliminate silica and TSS, five parameters were selected, namely: Agitation (A), Ratio (B), Contact Time (C), pH (D) and Continuity (E) (Table 3).

The identification of valuable and gangue minerals in the Kamatanda ore sample that feeds the Grand Heap, the solutions of which were used in our microscopic study, revealed the presence of the elements listed in Table 6: Mineralogical characterisation of Kamatanda ore (Table 4).

A series of 16 runs were carried out following the L16 experimental design (54) in order to determine the levels of controlled operating parameters that optimise dissolved silica and TSS removal yields, and SX phase separation time, and to analyse the influence and relative interactions of these parameters. The order of the tests was obtained by inserting the parameters into the columns of the L16 orthogonal matrix chosen as the experimental design. An orthogonal matrix is simply an integration table of integers whose columns represent the levels of the factors. Each row represents a trial, which is in fact a set of specific levels for each factor. Table 2-5 describes the L16 (54) orthogonal matrix chosen for our experiments (Table 5).

Results

This article presentation and analysis of the experimental results obtained during the various tests carried out in the laboratory. These results include those of sample characterization, solvent extraction and diluent washing treated using the Taguchi statistical approach and analysis of variance, confirmation results and finally those of the determination of the number of stages.

Mineralogical Characterization

The identification of valuable minerals and gangue minerals for the Kamatanda ore sample that feeds the Grand Heap, the solutions of which were used in our microscopic study, revealed the presence of the elements listed in (Table 6).

The results presented in Table 6 show that this is an oxidised ore with a siliceous gangue and that a silicate mineral species, chrysocolla, is

Table 1: Experimental parameters and their quantitative values.

Parameter code	Name of parametres	Levels			
		1	2	3	4
A	Agitation (rpm)	800	1100	1400	1700
B	Ratio O/A	0,8	1,0	1,2	1,4
C	Contact time (seconds)	120	180	240	300
D	Percentage of extactant (%)	15	20	25	30

Table 2: Taguchi design for solvent extraction.

Number of tests	Agitation (rpm)	Parameters and their lèves Ratio	Times of contact	% extactant
1	800	0,8	120	15
2	800	1,0	180	20
3	800	1,2	240	25
4	800	1,4	300	30
5	1100	0,8	180	25
6	1100	1,0	120	30
7	1100	1,2	300	15
8	1100	1,4	240	20
9	1400	0,8	240	30
i 10	1400	1,0	300	25
11	1400	1,2	120	20
12	1400	1,4	180	15
13	1700	0,8	300	20
14	1700	1,0	240	15
15	1700	1,2	180	30
16	1700	1,4	120	25

2.5. Taguchi clarification plan

Table 3: lists the parameters monitored with their respective quantitative values.

Code of parameter	Name of parameter	Levels			
		1	2	3	4
A	Agitation (rpm)	700	1100	1500	1900
B	Ratio O/A	1,0	1,4	1,8	2,2
C	contact of time (seconds)	120	180	240	300
D	pH	1,1	1,4	1,7	2,0
E	Continuity	OC	OC	AC	AC

Table 4: Experimental parameters and their levels for clarification.

Parameter code	Name of paramètres	Levels			
		1	2	3	4
A	Agitation (rpm)	700	1100	1500	1900
B	Ratio O/A	1,0	1,4	1,8	2,2
C	Contact of time (seconds)	120	180	240	300
D	pH	1,1	1,4	1,7	2,0
E	Continuity	OC	OC	AC	AC

2.6. Mineralogical characterisation

Table 5: Taguchi experimental design for L16 (54) clarification.

Nimber tests	Parameters and their lèves				
	Agitation (rpm)	Ratio O/A v/v	contact of times	pH	Continuity
1	700	1,0	120	1,1	OC
2	700	1,4	180	1,4	OC
3	700	1,8	240	1,7	AC
4	700	2,2	300	2,0	AC
5	1100	1,0	180	1,7	AC
6	1100	1,4	120	2,0	AC
7	1100	1,8	300	1,1	OC
8	1100	2,2	240	1,4	OC
9	1500	1,0	240	2,0	OC
10	1500	1,4	300	1,7	OC
11	1500	1,8	120	1,4	AC
12	1500	2,2	180	1,1	AC
13	1900	1,0	300	1,4	AC
14	1900	1,4	240	1,1	AC
15	1900	1,8	180	2,0	OC
16	1900	2,2	120	1,7	OC

Table 6: Mineralogical characterisation of Kamatanda ore.

Minerals	Formules chimiques	Quantity
Malachite	$CuCO_3.Cu(OH)_2$	Many
Heterogenitis	$CoO.2Co_2O_3.6H_2O$	Little
Chrysocole	$CuSiO_3.2H_2O$	-
Quartz	SiO_2	Many
Iron oxyde	-	Little

Table 7: Chemical characterisation of Grand Heap solutions.

Reagents	Types	Density (kg/m³)	Ignition point (°C)	Viscosity
Diluent	Masimo Sol GTL G80	750 - 800	≥ 80	≤2 mm2/s
Extactant	Mextral 5640H	-	≥90	≤200 cP

Table 8: Experimental design and test responses for the Solvent extraction (solvent extraction).

Number of tests	Parameters and their levels				Responses	
	Agitation (rpm)	Ratio O/A-	Contact of times (Sec)	% extactant (%)	Extraction (%)	TDT (Sec)
1	800	0,8	120	15	88	126
2	800	1,0	180	20	89	106
3	800	1,2	240	25	85	116
4	800	1,4	300	30	92	112
5	1100	0,8	180	25	87	119
6	1100	1,0	120	30	85	114
7	1100	1,2	300	15	88	124
8	1100	1,4	240	20	92	107
9	1400	0,8	240	30	90	103
10	1400	1,0	300	25	85	102
11	1400	1,2	120	20	92	100
12	1400	1,4	180	15	90	115
13	1700	0,8	300	20	89	107
14	1700	1,0	240	15	85	103
15	1700	1,2	180	30	92	104
16	1700	1,4	120	25	93	110

Table 9: Responses for marginal averages on extraction efficiency.

Levels	Parameters for extraction efficiency			
	A	B	C	D
1	89,75	89,00	90,75	89,25
2	90,25	89,75	90,00	90,50
3	90,76	91,00	90,25	90,75
4	90,75	91,75	90,50	91,00
Expected S/N Ratio under optimal conditions	A3 = 1400 rpm	B4 = 1,4	C1 = 120 minute	D4 = 30 %
Delta	1,00	2,75	0,75	1,75
Rank	3	1	4	2

present, which justifies the origin of the silica dissolved in the leaching solution on which our study is based.

Chemical characterization

The results obtained from the chemical analyses of the solution samples from the panda heap are shown in Table 7. Chemical analysis was carried out by atomic adsorption and spectrometry (Table 7).

Table 7 shows the difference in density between the diluent, the extactant and the Pregnant Leach Solution liquor (which has a slightly higher density than water), thus facilitating phase separation during liquid-liquid dispersion tests (solvent extraction and washing of the Pregnant Leach Solution.

Solvent extraction

Tests were carried out on the sample of the leaching solution from the large heap at the Shituru plants using Mextral 5640H diluted in Masimo Sol, with the aim of optimizing this operation. To achieve this, we used the Taguchi experimental design methodology to study the robustness of the Solvent extraction (solvent extraction). We selected two responses for this study, which are shown in Table 3-3: during the tests (Table 8).

The signal-to-noise ratio was calculated to optimise the copper extraction field and phase disengagement time during the operation.

Copper extraction yield

Looking at the results in (Table 9) we can see the most important and least important parameters, where the factor with the highest mean value, the highest delta value and the lowest rank is the most influential or important factor. Otherwise it is the least influential or important factor. In view of the results in table 3-4, the ratio is the most influential or most important parameter and the contact time is the least influential or least important parameter.

We will analyse the graph in (Figure 1), which shows the main effects of the signal-to-noise ratio of the copper extraction yield on solvent extraction. The most important parameter is the one with the greatest difference between the lowest and highest points. We will use the highest points for each factor in the graph as the optimum conditions. Looking at in Figure 3-1, we can see, while confirming the results in Table 3-4, that the ratio is the most influential parameter and time is the least influential. The optimum conditions are A3B4C1D4, i.e. stirring at 1400 rpm, a ratio of 1.4, a contact time of 120 seconds and a percentage of extactant of 30%. Under these optimum operating conditions for solvent extraction copper extraction yield, the predictive model gives a copper extraction yield and phase separation time of 93.65% and 105.25 seconds respectively.

Analysis of phase disengagement time

Unlike the extraction yield, which has been maximized, the phase separation time should be minimized; hence it is preferred to be smaller. The analysis will be carried out in the same way as for the copper extraction yield

The most important parameter is % extactant (D), followed by agitation (A), then the ratio (B) and finally contact time (C), which is the least important. Figure 3-1 below is a graph representing the effects of the controllable factors with their levels on the statistical performance (S/N) for the Phase disengagement time during Solvent extraction (Figure 2).

It appears from Figure 2 that the optimum for phase disengagement time corresponds to levels A3B2C3D2. The values of 1400 rpm for agitation, 1.0 for the ratio, 180 seconds for contact time and 20% for the extactant percentage. Under the operating conditions which optimize the phase separation time, the predictive model gives us extraction efficiency and a phase disengagement time of 87.14% and 92.50 seconds respectively.

Optimization of solvent extraction

Having separately obtained optimal conditions for the extraction yield and the phase separation time, we do not know how to choose among them the conditions for the continuation of the study. Hence the need to find optimal conditions which simultaneously maximize the extraction yield and minimize the phase disengagement time. The Figure 3 is a solvent extraction optimization diagram which provides us in red with the values of the factors retained as well as their values and in blue with the optimization responses: For stirring at 1700 rpm; an ratio of 1.4; a contact time of 180 seconds; and an extracting percentage of 20% (Figure 3).

It is under these conditions that the solvent extraction tests will be carried out after treatment of the PLS liquor with the diluent.

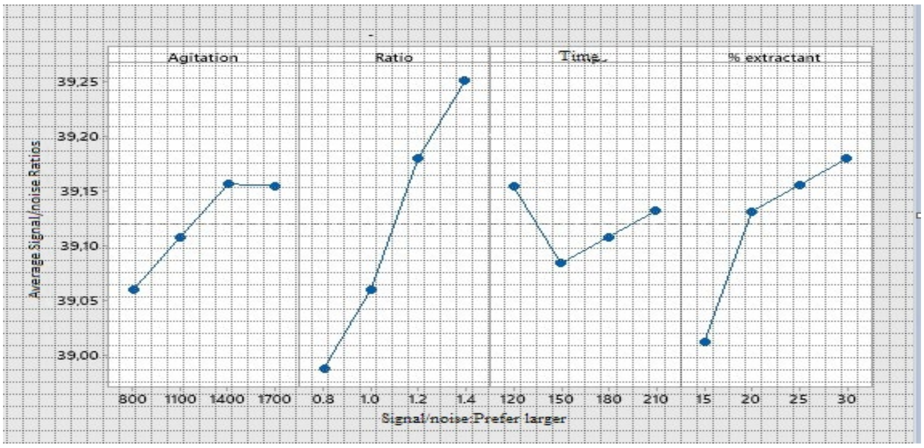

Figure 1: Main effects of the signal-to-noise ratio on extraction.

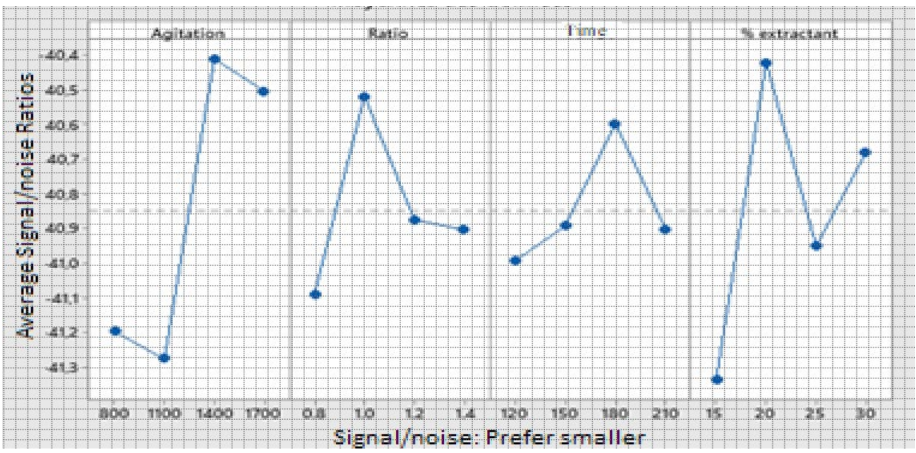

Figure 2: Main effects plot for Signal-to-Noise Ratios on Phase disengagement time.

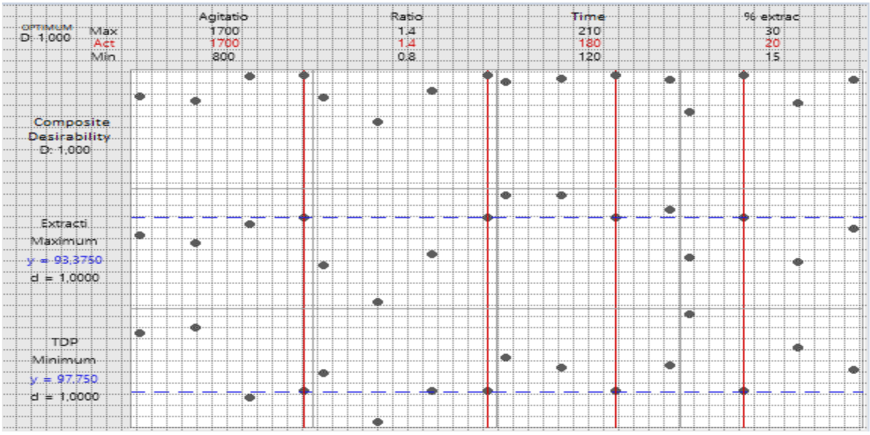

Figure 3: Solvent extraction optimisation diagram.

Table 10: The results of the confirmation tests are.

Designation	Answer	
	Extraction efficiency (%)	Phase disengagement time (seconds)
Optimal conditions for extraction field	92,99	103,25
Optimal conditions for the time of the phases	87,89	91,73
Optimal overall condition	92,34	95,17

Table 11: Results of clarification tests according to the experimental plan.

Number tests	Wash Parameters					Answer		
	Agitation	Ratio	Time	pH	Continuity	Silica	TSS	TDP
1	700	1,0	120	1,1	OC	4,75,728	62,500	88
2	700	1,4	180	1,4	OC	4,95,146	66,375	71
3	700	1,8	240	1,7	AC	5,04,854	75,000	64
4	700	2,2	300	2,0	AC	5,72,816	75,375	80
5	1100	1,0	180	1,7	AC	4,56,311	71,250	67
6	1100	1,4	120	2,0	AC	5,24,272	53,750	65
7	1100	1,8	300	1,1	OC	5,82,524	81,250	52
8	1100	2,2	240	1,4	OC	6,11,650	78,750	52
9	1500	1,0	240	2,0	OC	5,33,981	75,250	67
10	1500	1,4	300	1,7	OC	6,31,068	64,000	58
11	1500	1,8	120	1,4	AC	6,13,592	61,375	73
12	1500	2,2	180	1,1	AC	5,78,641	81,250	67
13	1900	1,0	300	1,4	AC	6,69,903	56,250	57
14	1900	1,4	240	1,1	AC	6,89,320	59,750	59
15	1900	1,8	180	2,0	OC	6,50,485	76,375	62
16	1900	2,2	120	1,7	OC	6,21,359	77,625	49

Confirmation tests

We conducted three confirmation tests regarding the experimental results for the solvent extraction: the operating conditions that optimise the copper extraction yield, then those that optimise the Phase disengagement time and finish with the operating conditions that optimise both the copper extraction yield and the Phase disengagement time (Table 10).

We will retain as operating conditions for the Solvent extraction the conditions that optimise both the copper extraction efficiency and the phase engagement time and therefore the overall optimal conditions.

Clarification test

Tests to clarify the liquor by washing with diluent were carried out on the sample of the leaching solution from the large heap of the Shituru factories with MasimoSol diluent, these tests aimed to eliminate silica dissolved and Performance of removal of suspended solids removal to improve metallurgical performance in solvent extraction. To achieve this, we used the Taguchi experimental design methodology to be able to study the robustness of the Pregnant Leach Solution clarification and an analysis of variance was carried out for each factor. As shown in Table 3-7, for this study we selected as responses the silica removal efficiency, the removal efficiency of the rate of suspended solids in the Pregnant Leach Solution and phase separation time (TDT) at solvent extraction after Pregnant Leach Solution treatment (Table 11).

Analysis of silica reduction

The S/N ratio calculation was performed to maximize the reduction of silica from the leaching solution, in the liquid-liquid liquor-diluent system. We can rank the parameters in increasing order of influence

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where stirring speed is the most important factor followed by contact time, O/A ratio, and pH ending with continuity the least important factor (Figure 4).

Analyzing Figure 3-4, we clearly notice that the optimal conditions are A4B4C4D2E1 corresponding to a stirring speed of 1900 rpm, an ratio of 2.2, a contact time of 300 seconds, a potential of hydrogen pH of 1.4 and according to organic continuity. In these diluent washing conditions, with the help of the predictive model, we say the removal efficiencies of 73.88% for silica and 65.38% for Suspended solids removal efficiency (TSS) and a disengagement time of 53.50 seconds.

Discussion

The elimination of dissolved silica is due to the polymerization of the silica which first forms the colloidal then the silica salt. In this way the silica is removed from the leaching solution because we will have three distinct phases, two of which are liquid diluent and Pregnant Leach Solution and the third phase is a solid: silica gel. It also emerges from the above that the polymerization of silica occurs well both in organic continuity and in aqueous continuity. This is explained by the fact that the polymerization is dictated by the frank and intense contact between the aqueous phases Pregnant Leach Solution and the organic phase (diluent) whatever the continuity. The speed of agitation of the dispersion is the most influential parameter because it is the latter which allows contact without which there is no dispersion and without dispersion there is no there is no emulsion therefore no polymerization [14]. This is why for the gelation of silica it is recommended to have a very high speed or even greater than 1900 rpm. The Pareto chart of normalized effects also tells us about the statistical importance of factors on silica removal. By observing Figure 4, we clearly realize that we have three factors which are statistically significant because they exceed the red reference line: the most significant stirring speed, the contact time and the ratio. The latter have an effect greater than [15], (Figure 5).

Below is Table 4-1 containing the analysis of variance results for dissolved silica removal (Table 12).

In view of what is presented in the analysis of variance in Table 4-1 the control factors can be classified according to their importance and/or the influence on the elimination of dissolved silica according to the contribution. We see that the stirring speed is the most influential parameter with a contribution of 63.533%, followed by the contact time with 14.735%, the ratio with 12.674%, the pH with 5.504%, to finish with the continuity whose contribution of almost 0.005% means that regardless of the continuity of work, OC or AC, the elimination of dissolved silica would happen in the same way. The error is estimated at 3.550% contribution to the process of removing dissolved silica, which means errors due to the operator, equipment, climate, etc. can 3.550%

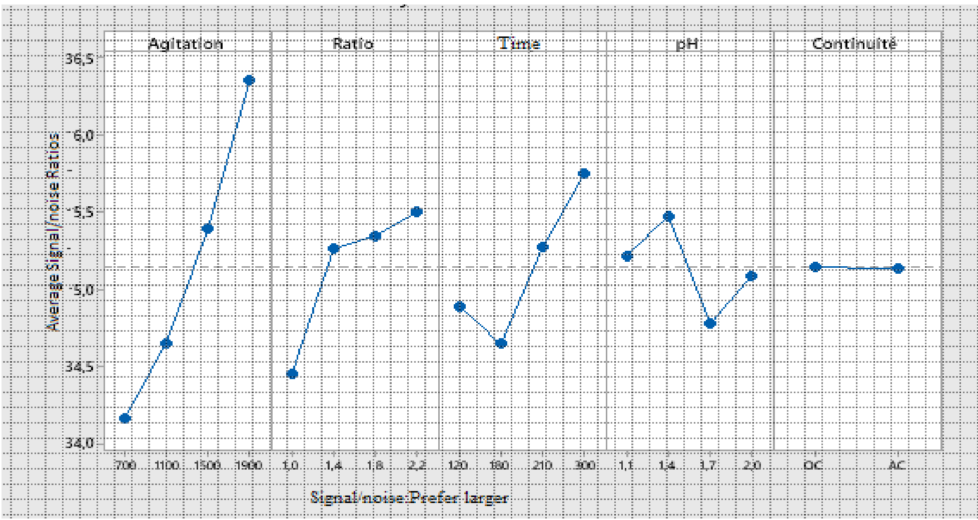

Figure 4: Silica Removal Signal-to-Noise Ratio Chart.

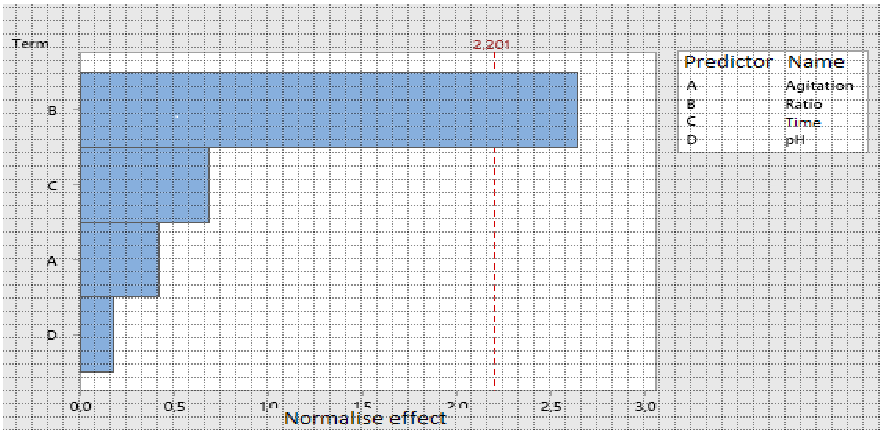

Figure 5: Pareto chart of dissolved silica removal Rend (Sio-2): α=0.05.

Table 12: Analysis of variance table on silica minimization.

Source	DL	Som Car ajust	CM ajust	Value F	Value de P	Contribution (%)
Agitation	3	4,79,423	1,59,808	11,93	0,078	63,533
Ratio	3	95,636	31,879	2,38	0,310	12,674
Time	3	1,11,189	37,063	2,77	0,277	14,735
pH	3	41,531	13,844	1,03	0,526	5,504
Continuity	1	0,038	0,038	0,00	0,963	0,005
Mistake	2	26,789	13,394			3,550
Total	15	7,54,605				1,00,000

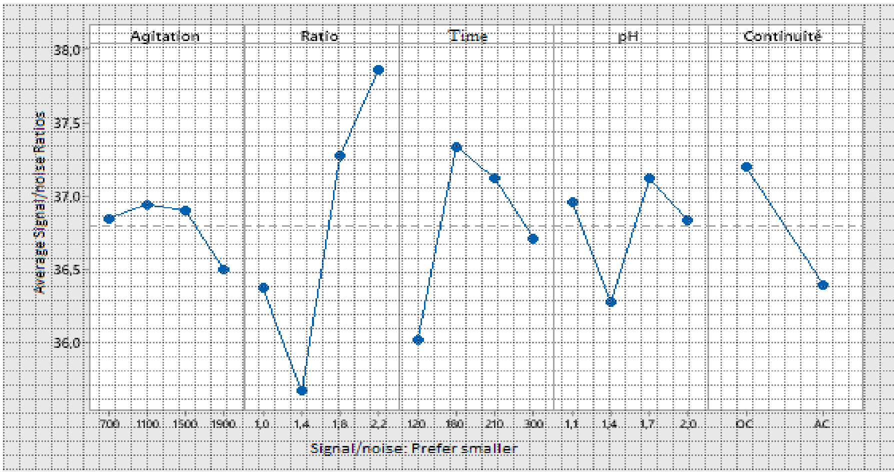

Figure 6: Main effects for signal/noise ratios on the elimination of Performance of removal of suspended solids.

influence the efficiency of the removal of dissolved silica.

The decrease in Suspended solids removal efficiency (TSS)

The analysis of the elimination rate of suspended solids is based on the removal performance of TSS. We will do a Taguchi analysis and variance analysis. We will identify the classification of the factors according to their influence of which the rank depends then the most influential parameter in this case is the O/A ratio which has the highest delta value, followed by contact time, pH, and continuity to finish with the agitation speed which has the smallest delta value (Figure 6).

The analysis in Figure 6 above, being a graph of the effects of signal-to-noise ratios, will shed light on the conditions that optimise the elimination of Performance of removal of suspended solids. It is A2B4C2D3C1 corresponding to an agitation speed of 1100 rpm, an ratio of 2.2, a contact time of 180 seconds, a pH of 1.7 in organic continuity . Thank to the predictive model, under these operating conditions of diluent clarification, the elimination yields are 51.17% for silica and 83.00% for Performance of removal of suspended solids and a phase disengagement time of 57.15 seconds. The decrease in suspended solids is very evident after washing with the diluent of the aqueous phase. This would be explained by a physical phenomenon similar to the reason for the drive of solids during solvent extraction [16] because the diluent retained the solids in the form of a stable emulsion. The diluent is an agent promoting the formation of stabilised emulsions; then when it is mixed with PLS by dispersion, a certain amount of the suspended solids will be found in this stabilised emulsion that remains at the diluent-Pregnant Leach Solution interface: the aqueous phase collected after diluent treatment then sees the Performance of removal of suspended solids decreased. Here the continuity of dispersion has a considerable influence on the elimination of suspended solids contrary to the observation made during the analysis of the reduction of silica. In organic continuity we obtain better results than in aqueous continuity. This would be explained by Cognis' famous rule of working in reverse continuity to the phase to be valued. In aqueous continuity, there is the possibility of having the training of the organic phase [17]. Diluent in the Pregnant Leach Solution. Since Figure 4-9 is a of Pareto's standardised effects, it tells us about the statistical significance of the parameters. Looking at the figure we see that only one factor is statistically because it exceeds the reference line it is ratio. The statistical significance is more than 2.201 (Figure 7).

the ranking of the suspended solids removal process control factors in the Pregnant Leach Solution based on the contribution value is as follows: the ratio with a contribution value of 56.144% far superior to the others, followed by contact time with 18.576%, continuity with 11.594%, pH with 7.588%, to finish with the stirring speed of which the contribution is 2.509%.The contribution of the error of the treatment process of the solution resulting from leaching is approximately 3.589% on the reduction in the quantity of suspended solids.

The effect of the treatment on the disengagement time of the Phase decommitment time phases

We will study the effect of the treatment of Pregnant Leach Solution liquor with the liquid-liquid dispersion diluent on par extraction by analysing the signal-to-noise ratio on the Phase decommitment time followed by a variance analysis. Tables 5-13 show the response values for signal-to-noise ratios on the Phase decommitment time at solvent extraction after Pregnant Leach Solution clarification (Table 13).

We obviously realize the order (rank) of the parameters according to their influence (delta) on the clarification; it appears that the stirring speed is the most important parameter, followed by pH, ratio, contact time and finally continuity.

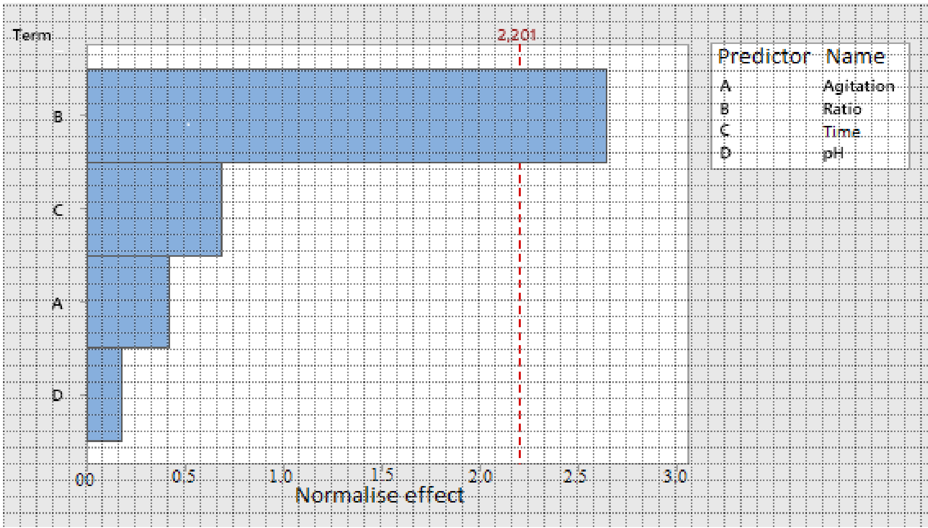

Figure 7: Pareto chart on TSS elimination.

Table 13: Average responses for phase disengagement time.

Levels	Parameters for extraction yield				
	A	B	C	D	E
1	75,75	69,75	68,75	66,50	62,38
2	59,00	63,25	66,75	63,25	66,50
3	66,25	62,75	60,50	59,50	
4	56,75	62,00	61,75	68,50	
Ratio S/N attendu sous conditions optimales	A4=1900 rpm	B4 =2,2	C3=240	D3= 1,7	E1= OC
			secondes		
Delta	19,00	7,75	8,25	9,00	4,13
Rank	1	4	3	2	5

Observing Figure 4-16 of the signal-to-noise ratios informs us about the robustness of the clarification by giving the optimal conditions which A4B4C3D3E1 are corresponding respectively to the agitation of 1900 rpm, to the ratio 2.2, to the time of contact of 240 seconds, at pH of 1.7 and continuity.

It is clear that the phase separation time in solvent extraction tests decreased after treatment of the aqueous phase by diluent washing. Two possible explanations:

On the one hand, the washing with diluent carried out on the liquor had a clarification objective, that is to say the reduction of suspended solids. Having less Performance of removal of suspended solids we have less stable emulsion formation facilitator agent. The latter increases the Phase decommitment time when extracted with raw materials. Hence the decrease in Performance of removal of suspended solids Inevitably leads to a decrease in Phase decommitment time.

On the other hand, the treatment with diluent aims to clean PLS, that is to say the elimination of dissolved silica, which, also being a forming agent of stable emulsions. As before, stable emulsions via cruds are the basis of the long duration of Phase decommitment time. Hence the removal of silica directly has a positive effect on Phase decommitment time .Under these conditions, the general model generated for our study predicts removal efficiencies of 66.55% for dissolved silica and 77.63% for Performance of removal of suspended solids and at solvent extraction a phase disengagement time of 48.50 seconds (Figure 9).

Looking at the Pareto normalized effects in Figure 4-23, we also classify the clarification parameters according to the normalized effect and say which one is statistically significant. Agitation is the most influential parameter and the only one that is statistically significant for phase disengagement time during solvent extraction of treated PLS (Table 14).

Based on the results of the analysis of variance in Table 14, we can also rank according to the contribution of the process control factors to the phase disengagement time during solvent extraction: the stirring speed is largely the most influential with a contribution of 54.506%, followed by the contact time with a contribution of 11.567%, then the pH, which is slightly less influential than the previous factor with a contribution of, then the ratio with 9.523% contribution, to finish with continuity with a contribution of 4.217%.It should be noted that the error of this operation on the phase separation time contributes to 8.651% of the results.

Optimization of solution clarification

The study of the clarification of the leaching solution was done by analysing while optimizing the responses one after the other separately which gave us three optimal conditions for the removal efficiency of dissolved silica., the others for the TSS removal yield and the others for the phase disengagement time in solvent extraction. So it is imperative to find operating conditions that optimize all three responses at the same time. To achieve this, we will use the optimization diagram generated by the Minitab 19 software. Figure 5-10 below represents said optimization diagram (Figure 10).

By observing Figure 4-29, we clearly draw the optimal operating

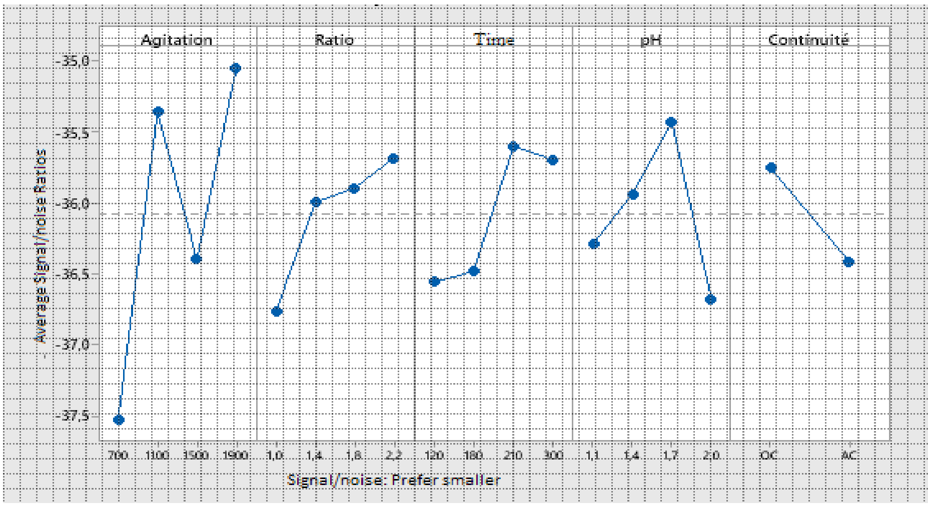

Figure 8: Main effects plot for signal-to-noise ratios on Phase decommitment time.

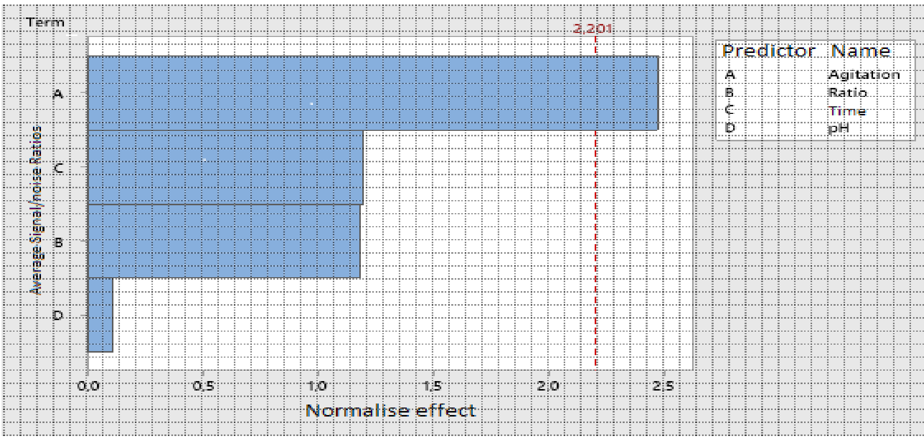

Figure 9: Pareto chart of standardized effects on Phase decommitment time: α=0.05.

Table 14: Analysis of variance for phase separation time.

Source	DL	SomCar ajust	CM ajust	Value F	Value P	Contribution (%)
Agitation	3	879,69	293,23	4,20	0,198	54,506
Ratio	3	153,69	51,23	0,73	0,621	9,523
Time	3	186,69	62,23	0,89	0,567	11,567
pH	3	186,19	62,06	0,89	0,568	9,523
Continuity	1	68,06	68,06	0,97	0,428	4,217
Mistic	2	139,62	69,81			8,651
Total	15	1613,94				100

Table 15: The test results are Table 15 Confirmation tests for clarification.

Designation	Residual concentration		For clarification For SX		Pour le SX	
	Silica (ppm)	TSS (ppm)	Silica removal (%)	Solids removal (%)	Copper extraction (%)	PDT (seconde)
Optimal conditions for silica removal	263	311	69,07	70,35	95,89	52,34
Optimal conditions for solids removal	405	177	52,11	83,11	95,44	55,65
Optimal conditions for phase disengagement time	30	263	63,37	74,98	96,33	46,56
Optimal overall conditions	270	252	66,02	75,99	96,77	50,02

conditions for the entire system studied. The conditions that optimize the removal of dissolved silica and Performance of removal of suspended solids and Phase decommitment time are: agitation of 1900 rpm, an ratio of 2.2, a contact time of 300 seconds, a pH of 1.7 and organic continuity. Under optimal conditions, the predictive model estimates the phase disengagement time at 45 seconds with removal of suspensions and dissolved silica of 80.67% and 69.38% respectively. We will discuss the results of multiple optimization; we will focus on the most important factor, agitation. The stirring speed chosen is 1900 rpm. For a stirring speed higher than this value, but difficult to bring

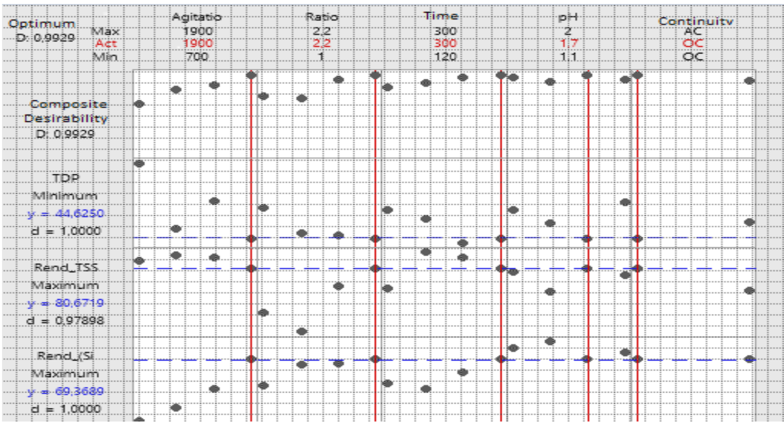

Figure 10: Clarification optimization diagram.

into play, we would have higher silica and Performance of removal of suspended solids removal yields because the stirring speeds favor the emulsions which are desired in this case for elimination of impurity. For low stirring speeds (less than 1900 rpm), silica and TSS removal yields are also low following the slow kinetics due to the non-stability of the emulsions which are favourable for the removal of impurities [18].

Confirmation tests for clarification

After the optimization tests carried out according to the Taguchi experimental plan for the clarification with the diluent of the solution, it is imperative to carry out verification tests to confirm the results, hence the tests in the optimal conditions for the removal of dissolved silica and Performance of removal of suspended solids, Phase decommitment time and overall optimal conditions.

Conclusion

The objective of this Article was to study the treatment with diluent of the liquid-liquid dispersion leaching solution in order to eliminate dissolved silica and the level of suspended solids as well as to highlight the benefits of this solvent extraction process, which has previously been the subject of optimization. The experimental results of the solvent extraction tests, carried out in accordance with the orthogonal matrix, using the predictive model, showed that the optimal operating conditions for the extraction of copper and the phase disengagement time, would be: Stirring speed: 1700 rpm; at ratio: 2.2; contact time: 300 seconds; pH: 1.7; Continuity: organic. Under these conditions, we obtained clarification 66.02% and 75.99% as removal yields of dissolved silica and suspended solids and at solvent extraction of the treated Pregnant Leach Solution the copper extraction yield of 96.77% and 50.02 seconds as phase separation time. The analysis of the results of the treatment of Pregnant Leach Solution with diluent following statistical approaches revealed on the one hand, that the influential parameters are, agitation and contact time, for the elimination of silica, the ratio and the contact time for the elimination of Suspended solids removal efficiency and agitation and the ratio for the phase disengagement time, according to the Taguchi methodology and on the other hand the significance of these parameters with contributions of 78.06 % and 11.52%, on the elimination of silica, % and % on the elimination of Suspended solids removal efficiency, and 86.61% and 3.68%, on the phase disengagement time at solvent extraction, within the meaning of the analysis of variance. This analysis allowed us to state that the process of elimination of impurities, silica and suspensions, by liquid-liquid dispersion of the Pregnant Leach Solution with the diluent, is controlled and is dependent on the stirring speed and the ratio which are the most influential and significant parameters. We also obviously noticed the effects of the treatment of PLS with diluent on solvent extraction, among other things, a 4.33% increase in the recovery efficiency from 92.44% to 96.77% and a gain of 45.15 seconds in the phase separation time because it started from 95.17 seconds to 50.02 seconds.

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