

## INTERPHASE FORMATIONS IN COPPER EXTRACTION SYSTEMS

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**ABSTRACT.** The technology of Solvent extraction-electrowinning is widely used for the production of copper from poor oxidized ores. The main problem in solvent extraction is the formation of interfacial formations (crud) on the liquid/liquid interface. Many factors influence the formation of crud and their study of which is currently an actual problem. For research, we took the primary ore from the Oxide Ore Process plant in Kazakhstan with a copper content of 0.37%. As a result of ore leaching with sulfuric acid (30 g/l), we obtained a productive leach solution (PLS) of the composition, g/L: Cu 3.5-4.93; SiO<sub>2</sub> 0.6; Fe<sup>2+</sup> 3.0-3.1; S<sub>общ</sub> 54,3-62,1; Mn 0.5-0.55. To determine the phase separation time and the effect of the organic phase composition on the formation of crud, laboratory extraction tests were carried out with extractants ACORGA M5640 (with modifier) and LIX984N (without modifier) in diluent ShellSol D70. PLS contained Cu - 3.5 g/L and 370 mg/L of; pH - 1.2. It was established that the formation of crud in both extractants is the same. However, the phase separation time in experiments using the LIX984N extractant was 10 seconds shorter than in experiments using the ACORGA M5640 extractant and amounted to 110 and 120 sec, respectively.

**Keywords:** Solvent extraction, copper, liquid/liquid interface, crude, PLS, extractant

### МЕЖФАЗНЫЕ ОБРАЗОВАНИЯ В ЭКСТРАКЦИОННЫХ СИСТЕМАХ МЕДИ

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**РЕЗЮМЕ.** Для производства меди из труднообогатимых бедных окисленных руд широко применяют технологию «жидкостная экстракция, электролиз». Основной проблемой при экстракции меди является формирование на поверхности раздела жидкость/жидкость межфазных образований (крада), которая приводит к снижению производительности всего предприятия. На образование крада влияют многие факторы и изучение которых является в настоящее время актуальной проблемой. Для исследований нами была взята исходная руда с производственного комплекса Актогай с содержанием меди 0,37%. В результате выщелачивания руды серной кислотой концентрацией 30 г/л нами был получен продуктивный раствор состава, г/дм<sup>3</sup>: Cu 3,5-4,93; SiO<sub>2</sub> 0,6; Fe<sup>2+</sup> 3,0-3,1; S<sub>общ</sub> 54,3-62,1; Mn 0,5-0,55 и др. С целью определения времени расслоения фаз и влияния состава органической фазы на образования крада лабораторные тесты по экстракции были проведены с экстрагентами ACORGA M5640 (с модификатором) и LIX984N (без модификатора). Опыты проводились в условиях: концентрация экстрагента 16 %, разбавитель - ShellSol D70; соотношение водной и органической фаз - 1:1; продолжительность экстракции 180 сек, температура - 20°С. Состав РЛС: Cu - 3,5 г/л и 370 мг/л растворенных взвесей; pH - 1,2. Установлено, что образование межфазовой взвеси (крада) в обоих экстрагентах одинаково. Однако, время расслоения фаз в опытах с применением экстрагента LIX984N было на 10 секунд короче, чем в опытах с применением экстрагента ACORGA M5640 и составили 110 и 120 сек соответственно.

**Keywords:** Solvent extraction, copper, liquid/liquid interface, crude, PLS, extractant

### Introduction

Due to the depletion of reserves of copper-bearing ores in modern Kazakhstan, poor oxidized and mixed ores are increasingly involved in copper production. The copper content in the ore of the deposits that are currently being developed in Kazakhstan is on average 0.36-0.45% versus the average 0.95% worldwide. To extract copper from such poor raw materials, it is necessary to use new efficient technologies and processing facilities. These methods, in particular, include the technology Solvent Extraction - Electrowinning (SX-EW) with the use of modern extractants with high technological properties.

The advantage of extraction lies primarily in the organization of a continuous high-performance process, and, consequently, in reducing capital and operating costs and improving working conditions. It should also be noted that the extraction in most cases is carried out at normal pressure and

temperature. The extraction technology is characterized by high selectivity in relation to the recovered metal, which allows the process to be carried out with a short duration of the technological cycle, relatively low costs and expenses of chemical reagents. In accordance with this, it becomes possible to process poor raw materials, the extraction of metals from which was previously considered economically unprofitable. The extraction technology for producing copper is more complicated than the cementation of copper with iron scrap, but as a result of its application, cathode copper is immediately obtained, iron does not accumulate in the circulating solutions, and, in addition, sulfuric acid is regenerated. The latter allows saving up to one and a half kilograms of acid on each kilogram of copper. In this regard, experimental studies on the extraction method using new highly effective, readily available and relatively inexpensive extractants are relevant.

Since 2007, 4 projects have been implemented in Kazakhstan on the technology of solvent extraction and electrowinning. However, at the moment, two projects are suspended due to the problem of processing productive leach solutions (PLS) of complex composition.

The main problem during extraction is the formation of interfacial formations (crud) of a certain thickness at the liquid-liquid interface, which leads to a decrease in the productivity of extraction processes and the quality of the obtained cathode copper, and the consumption of expensive reagents.

Crud is the material formed at the interface, when the emulsion formed due to mixing with the organic phase is mixed with the solid phase or dissolved elements in the PLS production solution.

The emulsion is a stable third phase at the interface between the organic and aqueous phases in settling separators. It prevents normal phase separation and contributes to additional losses of the organic phase: "This data are published by David J. Readett (1997)".

The formation of crude is influenced by many factors, the study of which is an urgent problem. Therefore, the proposal of schemes for the extraction stage, measures to prevent the formation of crude at each of them is impossible without preliminary individual testing and solving problems.

The aim of our research was to study the formation of interfacial formations (crud) at the interface between the aqueous and organic phases during the extraction of copper with extractants ACORGA M5640 (with a modifier) and LIX984N (without a modifier).

## Experiment

### Materials

We took oxidized ore and a productive solution (PLS) from a cathode copper plant in Kazakhstan as the initial ore.

Physicochemical methods of analysis have established the material composition of the original ore (Table 1).

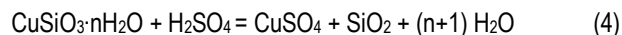
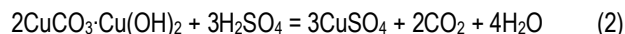
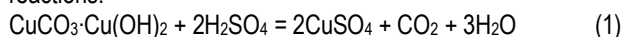
Table 1. Results of the analysis of oxidized ore

Component	Content, %
Cu – average	0.36-0.41
SiO <sub>2</sub>	51-67
Al <sub>2</sub> O <sub>3</sub>	13-22
FeO	0.3-5.5
Fe <sub>2</sub> O <sub>3</sub>	0.55-4.9
MnO	0.03-0.18
CaO	2-6
MgO	0.5-4
Chlorides	0-0.08

As the results of the analysis show, the copper content in the ore is low and averages 0.39 %, the ore is dominated by silicon. The main copper minerals in the ore are malachite, azurite, tenorite and chrysocolla.

Leaching of this type of raw material is efficiently carried out with mineral acids, and the most cost-effective is non-oxidative sulfuric acid leaching.

The process of leaching malachite, azurite, tenorite and chrysocolla with sulfuric acid can be described by the following reactions:



Under conditions of excess sulfuric acid in the leaching solution, the dissolution of chrysocolla can proceed with the formation of colloidal silicic acid, the increased content of which in solutions complicates the processing of these solutions by extraction.



At the process plants of Kazakhstan, leaching of the original ore is carried out by the heap method with a solution of sulfuric acid with a concentration of 20-35 g/l to obtain productive solutions. The main factor causing the formation of crud is the properties of the original PLS and the mode of operation of solvent extraction. For the study, samples of PLS and solid crud were taken from the cathode copper plant, the compositions are given in Tables 2 and 2.1.

Table 2. Chemical analysis of PLS and crud

№	Component	SiO <sub>2</sub>	Fe <sup>2+</sup>	S <sub>tot</sub>	Ca	Mg	Na
1	PLS, g/l	0,6	3,1	54,3	0,09	7,81	2,5
2	PLS, g/l	0,6	3,0	62,1	0,09	7,3	2,2
3	Crud, %	41,44	0,65	3,21	0,11	0,51	0,14
4	Crud, %	41,62	0,69	3,4	0,19	0,56	0,16

Table 2.1. Chemical analysis of PLS and crud

№	Component	K	Al	Fe	Mn	Cu
1	PLS, g/l	0,034	14,5	8,24	0,55	4,93
2	PLS, g/l	0,033	13,2	7,8	0,5	4,78
3	Crud, %	<0,05	1,15	0,55	0,03 5	0,3
4	Crud, %	<0,05	1,27	0,61	0,03 8	0,33

As the chemical analysis of PLS shows, a solution was obtained during leaching that is quite suitable for the extraction of copper by (4.78-4.93 g / l) solvent extraction.

According to studies, the main factors causing the occurrence of interphase formations are the composition of the initial solution (PLS), the organic phase, suspended solids in the PLS and the operating mode of the solvent extraction stage.

The chemical composition of the productive solution obtained by leaching the original ore shows that, in addition to dissolving copper as the base metal, undesirable impurity metals such as silicon, aluminum, magnesium, iron and manganese are present in the solution.

It is known that the dissolved silicon oxide, entering the liquid extraction cycle, forms crud due to the polymerization reaction, and dissolved aluminum and magnesium, interacting with sulfuric acid, increase the viscosity of the solution "This result is published by P. Cole and T. Bednarski \* (2016)".

The presence of manganese impurities in the productive solution negatively affects both the extraction rates and the copper electrolysis process. This is due to the fact that manganese ions are prone to oxidation and the formed MnO<sub>4</sub>-

and other high-valence manganese ions increase the electrolyte oxidation potential, and upon contact with the organic phase lead to its oxidation, thereby forming interfacial suspensions.

$\text{Fe}^{3+}$ ,  $\text{Mg}^{2+}$ , fine air bubbles and suspended particles in the leach solution contribute to the formation of crud.

The authors noted that at  $\text{pH} > 2.5$   $\text{Fe}^{3+}$  enters into hydrolysis and polymerization reactions with the formation of complex ions  $\text{FeOH}^{2+}$ ,  $\text{Fe}_2(\text{OH})_2^{4+}$ . Reference needed is needed

The volume of crud formation also increases with an increase in the pH of the solution and decreases with an increase in the phase ratio: This data are published by R.F.Dalton, C.Maes (1983).

*Reagents:* organic phase containing ACORGA M5640 extractant (16 %) and ShellSol D70 diluent (400 ml); organic phase containing LIX984N extractant (16 %) and ShellSol D70 diluent (400 ml); PLS solution, Table 3.

Table 3. Properties of extractants

Extractants for copper	LIX984N	ACORGA M5640
Chemical components	Aldoxime + Ketoxim	Aldoxime + modifier
Selectivity (Cu/Fe)	Medium	High
pH	Medium acidity	Acidic
Cu	Average content	High content
Manufacturer	BASF	SOLVAY

As a productive solution, a solution from a copper cathode plant was used, with a copper content of 3.5 g/l and PPH -1.2 and 370 mg/l of dissolved suspensions. The test was carried out at room temperature.

### Crud formation studying

To study the effect of the organic phase on the formation of interfacial formations (crud) at the boundary between the aqueous and organic phases, we used the extractants ACORGA M5640 (with a modifier) and LIX984N (without a modifier). Some experts on solvent extraction of copper, argue that modified extractants lead to the formation of interfacial suspension (crud) in the process of liquid extraction, which aroused interest in this work.

Extractant ACORGA M5640, consists of an active molecule aldoxime mixed with an ether modifier, while extractant LIX984N, consists of active molecules aldoxime and ketoxime without the addition of a modifier.

As a diluent, a dearomatized hydrocarbon solvent ShellSol D70, consisting mainly of naphthenes and paraffins C 11 - C 14, and with a high boiling point ( $> 190^\circ\text{C}$ ) was used.

The experiments were carried out under the following conditions: the concentration of the extractant in the diluent was 16 %, the volume of the organic phase was 400 ml, the ratio of the organic and aqueous phases was 1: 1, the temperature was  $20^\circ\text{C}$ , the stirring rate of the phases was 600 rpm, the duration of stirring was 180 sec.

## Results and discussion

The experimental results are shown in table 4. The copper content in PLS was 3.5 g/l, pH was 1.2.

Table 4. Results of studying the effect of the organic phase on the formation of interphase formations (crud)

No	Organic phase	Aqueous phase	Mixing time	Separation time, s	Visually observation
1	ShellSol D70 + 16% LIX984N	PLS (Cu – 3.5 g/L, pH - 1.2)	180 se	110-115	A gray film was observed at the boundary between the aqueous and organic phases
2	ShellSol D70 + 16% ACORGA M5640	PLS (Cu – 3.5 g/L, pH - 1.2)	180 s	120 s	A gray film was observed at the boundary between the aqueous and organic phases

On the basis of the experiments carried out, it can be concluded that the appearance of interfacial formations (crud) occurs in the two experiments in the same way, and the phase separation in the first experiment with the use of the extractant LIX984N is 10 seconds shorter.

The formation of interfacial suspensions is clearly seen in Figure 1.

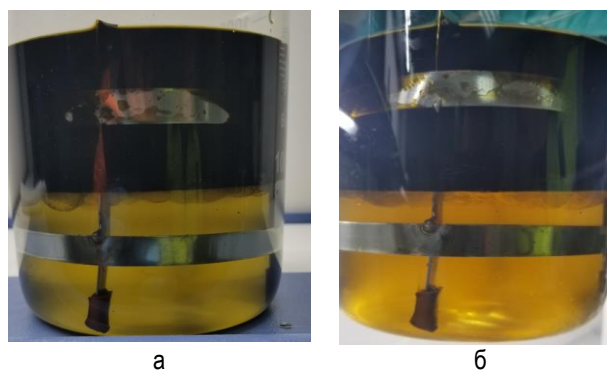


Fig. 1. Formation of interfacial suspensions (crud) during copper extraction with extractants LIX984N (a) and ACORGA M5640 (b)

During research, it was found that the formation of crud is promoted by:

- the presence of organic phase oxidation products.
- unfavorable composition of product solutions (increased content of solid slime particles, increased content of dissolved silicon in the solution, etc.);
- excessive intensity of mixing during extraction.

Thus, on the basis of our studies, we can conclude that the ratio of interfacial suspension (crud) in both extractants is the same, and the phase separation in the experiments using the LIX984N extractant (without the modifier) was 10 seconds shorter than in the experiments using extractant ACORGA M5640 (with modifier). The presence of the modifier in the organic phase did not affect the formation of interfacial suspension.

### Study of the effect of silicon on PLS solutions

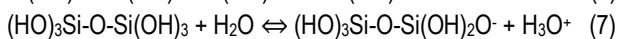
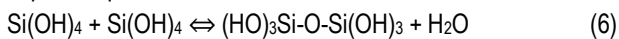
We have studied the effect of various impurities on the formation of interfacial suspension. Silicon in solution appears during leaching of silicon ores as a result of the interaction of silicon ores with sulfuric acid, especially at low pH values, or during the dissolution of copper silicon minerals such as chrysocolla. Dissolved silicon can affect the properties of the organic / water interface by interacting with the active components of the organic phase, resulting in the appearance of suspended solids.

Natural silicon dioxide, found in minerals, has a low aqueous solubility. However, when these minerals are dissolved in strong acids, large amounts of silicic acid are released. This can then polymerize in solution to form colloidal silicon dioxide. This colloidal silicon dioxide can be stable in solution at high levels and over time.

The colloidal silicon can pass through the leaching process without affecting any performance in weak solution irrigation and copper recovery in extraction. However, this can cause several problems when mixing with organic matter, settling, and the dynamics of solutions in extraction. When mixed with an organic solution, they can form a waste mass and significantly interfere with the flow of the aqueous phase of the solvent extraction.

In the water continuity mode of the SX mixer and in the presence of dissolved silicon, long periods of disruption of phase interaction often occur, which leads to a significant increase in the entrainment of organic and aqueous phases (up to 200 mg / L and above).

The stability of dissolved silicon depends on chemical and physical factors. Certain cations such as aluminum, manganese and molybdenum are very effective in stabilizing colloidal silicon and pH is very important, with stability maximizing around pH 2. Silicic acid undergoes a complex series of interrelated condensations (equation 6) and ionizations (equation 7) depending on temperature, pH and impurities present:



In the solvent extraction process, silicon can have the most dramatic effect. With the transition of the mixer operation to water continuity, the phase separation time increases several times, respectively, the dispersed belt in the settler shifts to the organic and aqueous phase gutters. These changes upset the stability of the compacted crud and then this crud is poured through the chute into the next stages. This phenomenon is considered undesirable, since when crud goes to the next stage, the mode of operation of the mixer of the next stage switches to water continuity, which can effect dramatically to organic loses or process cost.

Study of the physical properties of the crud. Increasing the viscosity of the solution. When designing SX-EW plants, it is important not only to control the content of iron, chlorides, silicon and so on, but also the presence of aluminum and magnesium in the productive solution, which can increase the PLS viscosity, leading to a deterioration in the physical parameters of the solution, as well as to a decrease in copper recovery. due to low extraction efficiency. The efficiency of the extraction process depends on many factors, some of them are listed below: temperature, separation time, stirring speed / mixer rotation speed, quality of the organic phase, impurities in

PLS solutions, PLS solution viscosity, phase ratio, extractant formula etc.

Table 5. Datas on the values of the viscosity of solutions with the corresponding extraction efficiency

Dilution with water, %	Solution viscosity, Poise	Extraction efficiency, %
0	7,8	91,6
25	4,2	94,1
50	2,8	95,6
75	1,7	98,3

It was found that with an increase in the viscosity of the solution, the time of phase separation increases, which in turn leads to significant carryover of the organic phase together with the aqueous phase, and most of it is irretrievably lost in the process of heap leaching.: The data are published by Alexis Soto L. and Hector Yáñez F. (2017).

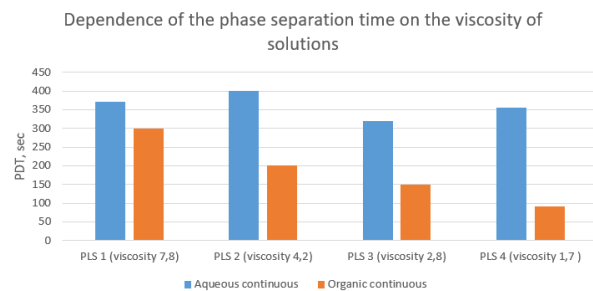


Fig. 2. Dependence of the phase separation time on the viscosity of the solutions

Thus, the conducted technological studies show that control of the viscosity of the aqueous phase can provide a low cost of the extraction processing in the SX-EW process.

To clarify the composition, we carried out X-ray diffraction studies of samples of interfacial suspensions (crud) formed during extraction. The survey was carried out on a D8 Advance (Bruker) apparatus, Cu K $\alpha$  radiation, voltage across the tube 40 kV, current 40 mA. The processing of the obtained data of diffraction patterns and the calculation of interplanar distances were carried out using the EVA software.

Phase analysis (diffractometer DRON-3) shows that the waste mass is partially in an amorphous state, the compositions of interfacial suspensions (crud) in both extractants differ in composition by decimal fractions. The main components of crud are aluminum and magnesium hydrogen sulfates. The silica content in the crud formed when using the ACORGA M5640 extractant is 0.9% higher compared to the LIX984N extractant.

In order to study the microstructure of the samples, the waste mass samples were examined using a JEOL ISM - 25S 3 scanning electron microscope. The Figure 3 shows images in backscattered electrons at a magnification of x100.

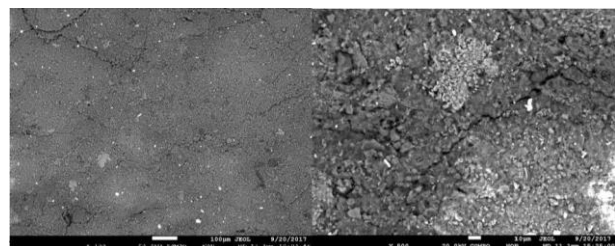


Fig.3. Microscopic structure of crud mass

A high silicon content and amorphous structure are recorded. This silicon content causes swelling, difficulty in separation. It is possible that the silicon itself in the samples is amorphous, which affects the viscosity of the structure.

Electron microscopic studies in backscattered electrons have established that the tetrahedral coordination of silicon with respect to oxygen is due to the value of the ratio of the ionic radii of silicon and oxygen, equal to 0.29. As is known, the quadruple coordination of the cation is most stable in the range of  $k = 0.225-0.414$ . The Si-O distance is 0,162 nm, and the distance is 0-0-0.265 nm. The angle inside the O-Si-O tetrahedron is approximately 109-110°. The Si-O bond is predominantly covalent, and in the transition from crystalline substances to glassy, the degree of covalence can increase from 50 to 80 %. Which explains the alignment of the oxygen scaffolds during crate formation.

**Tests of waste mass removal using coagulants**

In this experiment, a Polysil coagulant was used to precipitate dissolved silicon in PLS production solutions. Polysil coagulants are intended for use in the mining industry for treating fine particles in aqueous suspension. Polyester coagulants are one of the few that are effective against colloidal silicon dioxide formed during acid leaching of ores or slags containing silicates.

Coagulants of the POLYSIL® RM1250 and POLYSIL® RM2050 brands were used to carry out the dissolved silicon precipitation tests.

An experimental extraction unit was launched for testing. Extraction with the addition of POLYSIL® RM1250 was started on one line and extraction on the other without the addition of coagulant. Dosing of POLYSIL® RM1250 was carried out at a continuous dosage of 250 g/m<sup>3</sup>. This dosage has been calculated and determined from laboratory tests.

Crud in the test circuit formed after 5 hours of operation and the circuit was stopped due to the resulting waste mass. The crud began to break through to overflows and disrupt the extraction process. Table 6 shows the operating mode of the experimental extraction plant. As can be seen from the data, both lines were tested in organic continuity.

Table 6. Operating conditions of the extraction plant

Parameters	Control line	Test line
PLS flow (l/min)	6	6
Organic phase flow (l/min)	8,5	8,5

The extraction plant was rebooted and operated with POLYSIL® RM2050 at 300 g / m<sup>3</sup>, in this chain, too, after 6-7 hours of operation, levels of waste mass were created to such an extent that they led to overflows of the organic phase and disrupted the extraction process.

The fast waste mass formation rate in the test circuits was since the coagulated silicon solids were not efficiently separated from the PLS before it was fed to the SX. The settling time of the solutions after adding coagulants was chosen 4-5 hours. The current conditions for the addition of coagulants did not allow the sedimentation of coagulated particles, so an alternative sedimentation method was investigated in the laboratory to speed up this process and propose an alternative strategy for the addition of coagulants.

The extraction unit was cleaned and replaced with fresh organic phase for a second test with a POLYSIL® RM2050

coalescer. The control line, as in the previous test, remained without adding any new organic substances (coagulants). POLYSIL® RM2050 was added to PLS at a dosage of about 330 g / m<sup>3</sup>. The coagulant treated PLS solution was left overnight to calm the coagulated particles.

After starting the pilot plant, a crud was again formed in the E1 test line after 4-5 hours of continuous operation, the raffinate solution with the addition of coagulants (lean solution after the extraction plant) was contaminated than the control line indicating that there was poor sedimentation of coagulated solids silicon.

An alternative technique for the precipitation of coagulated silicon dioxide was developed - the addition of a surfactant (bentonite) in combination with a flocculant. Surfactants help as reaction points for coagulation and as a medium to promote flocculation as the silicon coagulates, chlorinates on its own. Samples of the PLS solution from coagulant testing were sent for the analysis of silicon and other elements.

The laboratory program consisted of the following items: 1 L PLS; adding a coagulant (330 g / m<sup>3</sup>); addition of bentonite at a dosage of 10 kg/m<sup>3</sup>; addition of flocculant at 200 g/t; settling for 2 hours before taking a sample for analysis.

The addition of POLYSIL® RM1250 and POLYSIL® RM2050 shows that both coagulants decrease silicon levels with increasing dosage, Table 7. POLYSIL® RM1250 reduced silicon from 0.72 g/dm<sup>3</sup> to 0.37 g/t at a dosage of 200 g/m<sup>3</sup>. Dependence of the concentration of dissolved silicon dioxide on the amount of addition of coagulants introduce in Figure 3.

Table 7. Chemical analysis of PLS saturated solutions with the addition of coagulants POLYSIL® RM1250 and POLYSIL® RM2050

Coagulant	Cu	Al	Mg	Na	Ca	Si
PLS solution without coagulant	4,63	18,17	8,91	3,77	0,93	0,72
POLYSIL® RM1250, 50 g/m <sup>3</sup>	4,41	17,16	8,56	3,59	0,97	0,62
POLYSIL® RM1250, 100 g/m <sup>3</sup>	4,47	17,33	8,79	3,68	0,97	0,44
POLYSIL® RM1250, 200 g/m <sup>3</sup>	3,58	17,60	8,89	3,58	0,98	0,37
POLYSIL® RM1250, 500 g/m <sup>3</sup>	4,10	16,21	8,24	3,35	0,94	0,26
POLYSIL® RM2050, 50 g/m <sup>3</sup>	4,43	17,39	8,64	3,67	1,18	0,81
POLYSIL® RM2050, 100 g/m <sup>3</sup>	4,36	17,14	8,76	3,63	1,02	0,73
POLYSIL® RM2050, 200 g/m <sup>3</sup>	4,28	16,58	8,55	3,61	0,99	0,46
POLYSIL® RM2050, 500 g/m <sup>3</sup>	4,11	16,09	8,19	3,42	0,96	0,3

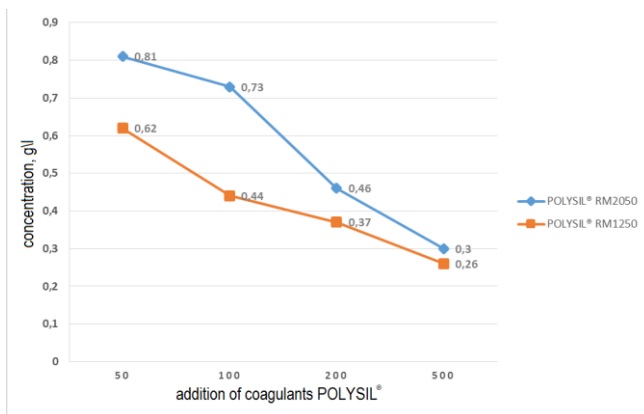


Fig. 4. Dependence of the concentration of dissolved silicon dioxide on the amount of addition of coagulants

The poor raffinate solution was also tested with the addition of POLYSIL® coagulants. The dosage of coagulants was 200 and 500 g/m<sup>3</sup>. Adding POLYSIL® coagulant to the lean raffinate solution will require a solid-solution separation step to remove coagulated particles before the raffinate is fed back to the heap leach. Coagulated particles not removed by the solid / solution separation step are likely to lead to plugging in the heap leach irrigation system.

Samples of the saturated PLS and the lean raffinate solution were taken for chemical analysis. Table 8 shows analyzes that show that during sampling, no significant change in silicon levels was observed during solvent extraction.

Table 8. Chemical analysis of solutions

Samples	Content of elements, g/l					
	Cu	Al	Mg	Na	Ca	Si
PLS	4,63	18,17	8,91	3,77	0,93	0,72
Raffinate solution from E2	2,58	17,8	8,96	3,76	0,9	0,71
Raffinate solution from E3	1,85	17,99	9,03	3,85	0,94	0,74
Raffinate solution from E1	3,4	17,86	8,86	3,73	0,9	0,73

In conclusion, we can say that both POLYSIL® coagulants tested in an experimental setup showed an effect on the solvent extraction process with the formation of a rapidly dissolving fraction in E1 and an unstable processing operation.

It was found that the formation of waste mass was caused by poor deposition of coagulated silicon. It was found that an increase in suspended solids in the PLS before the test line results in the formation of a cloudy raffinate.

To quickly remove finely dispersed coagulated silicon dioxide, a solid liquid separation stage is required; an additional filter is required to purify the solution prior to extraction.

When 1 g per 500 ml of flocculant is added, flocs are precipitated, but during extraction the crud in flocs floats to the surface and makes it difficult to separate the organic and aqueous phases.

Studies have shown that an increase in pH to 2 leads to a decrease of crud by up to 15 %, while colloidal silicon becomes more passive.

The following technological recommendations have been developed: monitoring the phase separation zone, controlling the phase disengagement time in extraction and stripping, continuously treatment of crud from the separation zone in the settlers of SX, study and tests for crud reduction with chemical reagents.

## Conclusion

The work solved the problems of the Cathode Copper Plant, determined the optimal technological parameters for the formation of waste mass (crud), proposed solutions to reduce the formation of waste mass (crud), proposed universal methods and conditions for processing similar copper raw materials for all countries of copper producers.

Economic calculations have established that when removing the waste mass from extraction, it is possible to increase the flow of the saturated solution to the design parameters and additionally produce cathode copper ~ 500 tons per year.

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