



Percolation leaching of clay mixed copper ores

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Abstract. The present work addresses the problem of improving the percolation properties of heap leaching piles of clay, slime-oxidised and mixed ores. These ores are prone to colmatation, which hinders percolation of the solution through the ore layer. Laboratory tests on percolation leaching were carried out using a 2 m column having an internal diameter of 190 mm, loaded with 89.42 kg of ore material having a grain size of -55+0 mm. In order to eliminate colmatation, the ore layer was divided into two equal parts by a drainage layer of polystyrene foam. The research object was ore material extracted from the northern Nurkazgan deposit (Karaganda region, Republic of Kazakhstan), in which copper is present in the form of sulphide (53.48%) and oxidised minerals (46.52%), including 23.5% of chrysocolla. The mineral composition of a test sample determined by optical and electron microscopy, X-ray diffraction, local X-ray spectral, X-ray fluorescence and inductively coupled plasma mass spectrometry was characterised by 93.78% of rock-forming minerals, 53.23% of which comprised layered silicates, namely, mica, chlorite and kaolinite. Ore mineralisation was characterised by both sulphide (copper sulphides, pyrite) and oxide (malachite, iron hydroxides and manganese oxides) phases. The content of easy-slimes minerals equalled 56.30%. Prior to leaching, moisture saturation during the period of one day was carried out. The ore was top irrigated with a solution of sulphuric acid having a concentration of 60 g/dm³. Pregnant solutions were processed following a sorption method (sorption/desorption–electrolysis). The copper extraction into the solution yielded 60.04% with a sulphuric acid consumption of 50.0 kg/t ore at an average irrigation rate of 10.58 dm³/(m²h) or 0.1058 dm/h per clear opening. Therefore, heap leaching of ores at a layer height of lower than 1 m can be performed following the "leaching–extraction/re-extraction or sorption/desorption–electrolysis" scheme.

Keywords: leaching, column, ore, copper minerals, solution, extraction

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МЕТАЛЛУРГИЯ И МАТЕРИАЛОВЕДЕНИЕ

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Научная статья

Исследования по перколяционному выщелачиванию меди из глинистых смешанных медных руд

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Резюме. Цель – повышение фильтрационных свойств штабеля кучного выщелачивания глинистых, шламистых окисленных и смешанных руд, которые склонны к кольматации и резко снижают просачивание раствора через слой руды. Для проведения лабораторных испытаний по перколяционному выщелачиванию использовалась колонна высотой 2 м и внутренним диаметром 190 мм, в которую была загружена руда массой 89,42 кг крупностью 55-0 мм. С целью устранения кольматации руду загружали слоем высотой 1 м, далее укладывали дренажный слой из пенополистирола и снова насыпали слой руды высотой 1 м. Объектом исследований является руда северного участка Нурказган (Карагандинская обл., Республика Казахстан), в которой медь практически поровну представлена сульфидными (53,48%) и окисленными (46,52%) минералами, из них хризокolla составляет 23,5%. В минеральном составе пробы, определенном с учетом данных оптических и электронномикроскопи-

ческих исследований, рентгеноструктурного, локального рентгеноспектрального, рентгенофлуоресцентного и масс-спектрометрии с индуктивно связанной плазмой, преобладают порообразующие минералы, составляющие 93,78%, из которых 53,23% приходится на слоистые силикаты – слюды, хлорит, каолинит. Рудная минерализация представлена как сульфидными фазами (сульфиды меди, пирит), так и оксидными – малахит, гидроксиды железа, оксиды марганца. Содержание легкошламуемых минералов составило 56,30%. Перед началом выщелачивания производили влагонасыщение руды в течение суток. Сверху руду орошали раствором серной кислоты с концентрацией 60 г/дм³. Переработку продуктивных растворов осуществляли по сорбционной схеме (сорбция/десорбция – электролиз). В результате проведения исследований извлечение меди в раствор составило 60,04% с расходом серной кислоты 50,0 кг/т руды при средней скорости орошения 10,58 дм³/(м²·ч) или 0,1058 дм/ч на свободное сечение трубы. Таким образом, использование послонного штабельного выщелачивания руды с высотой слоя не более 1 м может быть реализовано по схеме «выщелачивание – экстракция/реэкстракция или сорбция/десорбция – электролиз».

Ключевые слова: выщелачивание, колонна, руда, медные минералы, раствор, извлечение

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INTRODUCTION

Improving the percolation properties of a leached mineral is essential for the efficient operation of heap leaching plants at deposits characterised by a high content of clay ores. The colmatation of clay and slime ores occurring during their leaching either impedes or reduces the solution percolation through the ore layer. In order to improve the percolation properties of a heap leaching pile, the pelletising of clay ores is widely used [1–18] in industrial mining of weathered gold-containing ores and alluvial and hard rock gold mining heaps having a high clay content.

In [2], various ores were pelletised at an average cement consumption of 5–6 kg per ton of ore and 3.5–4 kg of chlorinated lime. The strength of the as-pelletised ore amounts to 73.5–78.4 kPa. A further increase in the binder content reduces the percolation properties, prolongs the leaching process, as well as raises the cost of ore dressing. Moreover, when pelletising clay ore and tailings, an increase in cement consumption may lead to an opposite effect, namely, a decrease in the strength of pellets [10].

Ore material is pelletised using sulphuric acid as a binder [18]. Ore pellets and samples of various grades are loaded into percolation columns for leaching experiments. Due to the critical static pressure in the upper part of the pile (over 73.5 kPa with the strength of pelletised ore of 68.3 kPa), the leaching rate becomes low, followed by the formation of fine grains in the initial ore. As a result, the hydraulic conductivity of the pile is reduced.

The heap leaching of metals directly in the

ore pile can be intensified by mechanical loosening (in particular, blasting), which increases the porosity and ore jointing, thus facilitating the extraction of the target component to the pregnant solution [19–22]. However, during mechanical loosening by blasting, on the first day, the need for solution irrigation (leaching) increases by 5–8 times. The resulting ore repacking slows down the leaching process.

In [23], a cuvette-heap leaching of metals was carried out by leaching a mineral mass with a reagent solution, followed by metal extraction by sorption leaching in two steps: firstly, the mineral mass is placed in cuvettes having moisture-proof walls, initial reagent solution is introduced, further slime-clay and sand fractions are separated by hydrocyclone. The sand fraction is piled and subjected to heap leaching. Following the leaching of sand and clay-sand fractions, the remaining liquid phase is strengthened and fed to heap leaching.

MATERIALS AND METHODS

This research is aimed at improving the percolation properties of heap leaching piles of clay and slime oxidised and mixed ores, which are susceptible to colmatation. Colmatation is known to reduce the solution percolation through the ore layer. In order to solve this problem, leaching was carried out in layers having limited height. To this end, a porous material (polystyrene foam or inorganic-hydrophilic sorbent) was placed between the layers, or the ore was loaded into cuvettes by layers divided using a filtering material (polystyrene foam or inorganic-hydrophilic sorbent).

The residues of the leaching (cakes) can be utilised as a backfill material in underground mining [24].

Ore material extracted at the northern Nur-

kazgan deposit (Karaganda region, Republic of Kazakhstan) was used as a research object. The results of chemical and phase analysis are presented in tab. 1 and 2.

Table 1. Chemical composition of copper ore

Таблица 1. Химический состав руды

Component	Cu	Ag*	Au*	Fe	S	Zn	Pb	As
Weight percent, %, *g/t	0.417	1.79	0.33	10.37	0.94	0.052	0.001	0.0043
Component	P	SiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Mo
Weight percent, %, *g/t	0.114	53.36	19.64	0.52	2.25	4.11	0.16	0.004

Table 2. Copper phase analysis in ore

Таблица 2. Фазовый анализ меди в руде

Metal speciation	Cu content, % (abs.)	Cu distribution, % (rel.)
Cu in sulphide minerals	0.223	53.48
Cu in oxidised minerals, including chrysocolla	0.194	46.52
	0.098	23.50
Total	0.417	100.0

Note / Примечание: abs. – absolute; rel. – relative / abs. – абсолютный; rel. – относительный.

Tab. 2 shows that copper is almost uniformly distributed between sulphide (53.48%) and oxidised (46.52%) minerals, including 23.5% of chrysocolla.

Ore mineralisation is dominated by secondary supergene phases, including iron hydroxides, hematite, manganese oxides, jarosite, as well as the rarely occurring malachite. In rare cases, sulphide minerals, such as chalcocite, chalcopyrite, covellite and pyrite, are observed. The investigated ore belongs to the oxidised type, having predominantly ingrain and colloform textures.

The mineral composition of the test sample determined based on optical and electron microscopy, X-ray diffraction, atomic emission spectrometry, local X-ray spectral, X-ray fluorescence and chemical analyses, is characterised by 93.78% of rock-forming minerals, including 53.23% of layered silicates, namely, mica, chlorite, kaolinite. Ore mineralisation comprises sulphide phases (copper sulphides, pyrite) and oxide phases (malachite, iron hydroxides, manganese oxides). The content of easy-sliming minerals equals 56.30%, which can reduce the efficiency of dressing processes.

Microscopic studies revealed that ferruginised clay-mica-quartz metasomatites are characterised by a relic porphyric structure, visible in cross-polarised light, and a solid, partly porous grain resulting from the destruction and leaching of primary sulphide and carbonate minerals. Iron hydroxides in the form of fine dust primarily impregnate mica-clay minerals. They occur as small clusters and films in interstices and over the grain interface of quartz in the binder mass and develop as sinter deposits on the walls of cavities and micropores (fig. 1 and 2).

Iron hydroxides and oxides are the principal ore minerals in the sample. They are represented by finely dispersed formations, evenly distributed over the host rock, resulting in a yellowish-brownish colour; linear aggregations of finely dispersed particles, developing along the cleavage of layered silicates; a non-uniformly distributed hematite impregnation (10–150 microns), pseudomorphically substituting pyrite; sinter, often zonal deposits (films, crusts) on the walls of pores and solution cavities; continuous solid isolations, infilling fragmenting cracks in deformation zones, associated with chlorite, kaolinite, and sericite (fig. 3).

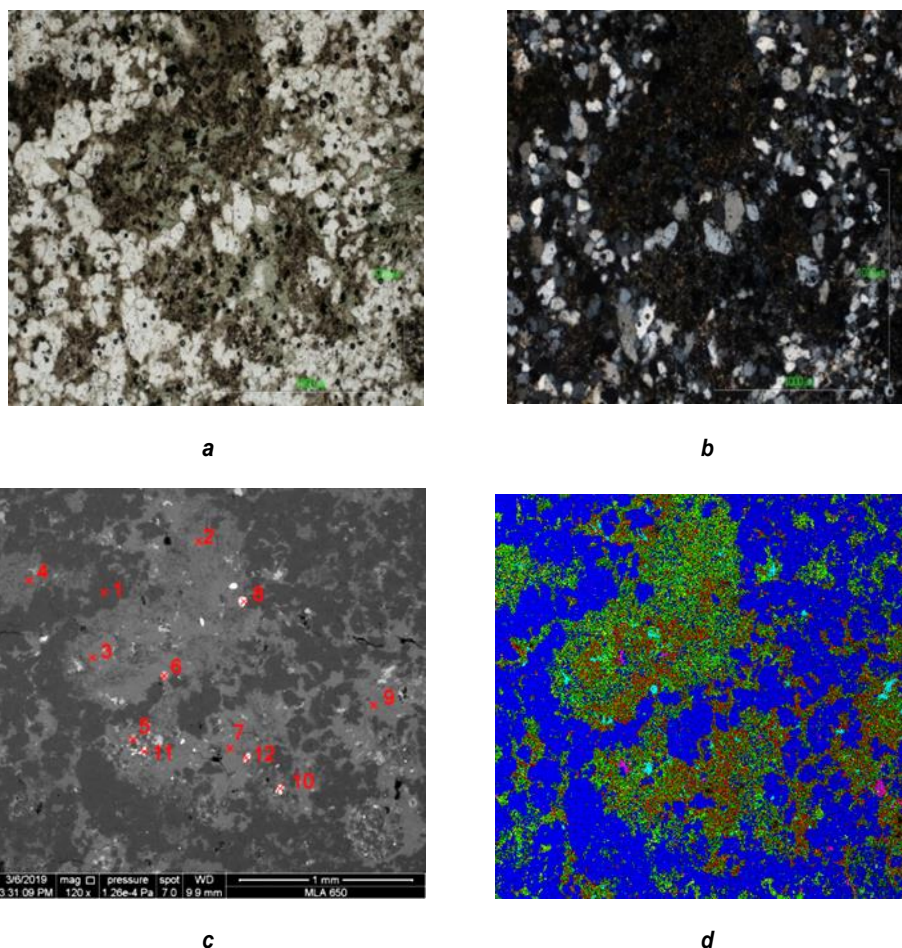


Fig. 1. Clay-mica-quartz metasomatite, characterised by a relic porphyritic structure: a – polarised-light transmission; b – cross-polarised light; c – in back-scattered electrons; d – combined in characteristic radiation of elements. Spectra in Fig. c:

1 – quartz; 2, 3, 7, 9 – chlorite; 4 – chlorite + sercite; 5 – apatite; 6 – rutile;
8 – covellite + chalcopyrite; 10, 12 – pyrite; 11 – barite

Рис. 1. Глинисто-слюдисто-кварцевый метасоматит, характеризующийся реликтовой порфировидной структурой: а – при одном николе; б – в скрещенных николях; с – в обратно рассеянных электронах; d – комбинированное в характеристическом излучении элементов. Спектры на рис. с: 1 – кварц; 2, 3, 7, 9 – хлорит; 4 – хлорит + серицит; 5 – апатит; 6 – рутил; 8 – ковеллин + халькопирит; 10, 12 – пирит; 11 – барит

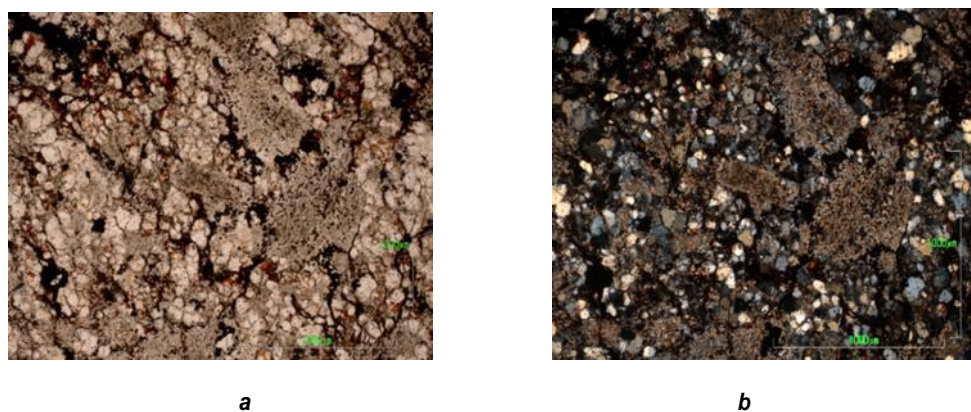


Fig. 2. Ferruginised clay-mica- quartz metasomatites

Рис. 2. Ожелезненные глинисто-слюдисто-кварцевые метасоматиты

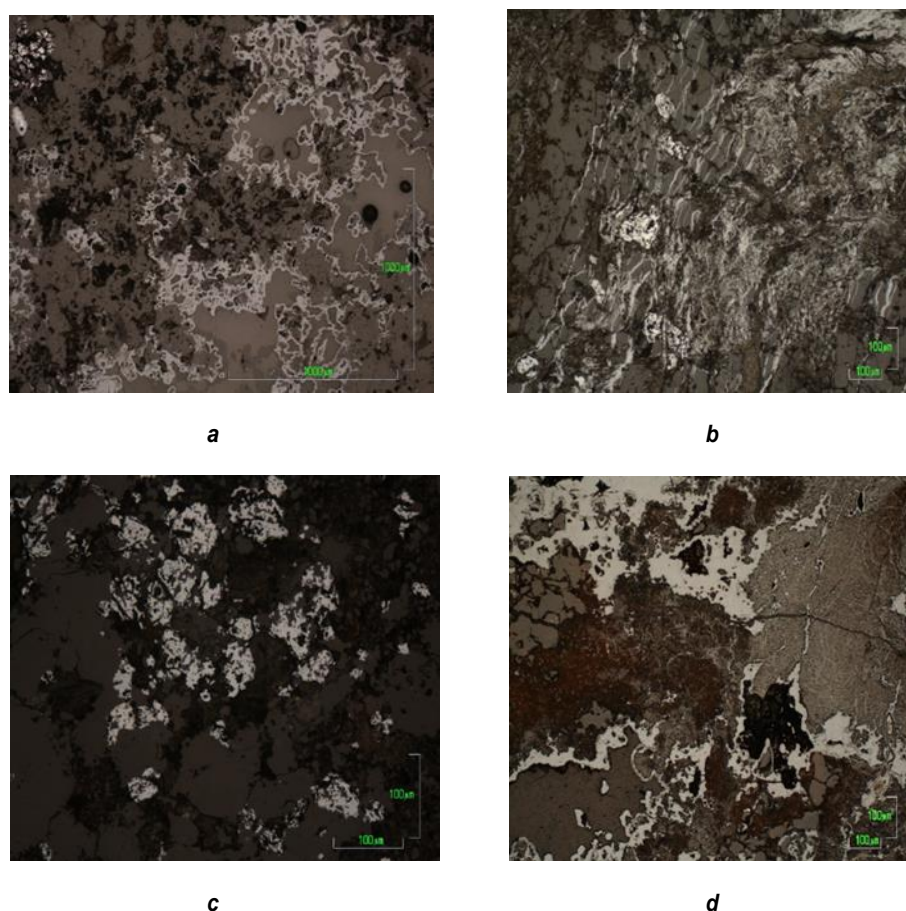


Fig. 3. Formation of iron oxides and hydroxides (reflection image): a – sinter deposits on the walls of solution cavities; b – impregnation of mica-clay minerals by finely dispersed formations; c – dissemination of hematite in pyrite; d – impregnation of rocks by finely dispersed formations and infilling of pores and voids by hematite

Рис. 3. Форма выделения оксидов и гидроксидов железа (изображение в отраженном свете): а – натежные образования по стенкам пустот выщелачивания; б – пропитка тонкодисперсными образованиями слюисто-глинистых минералов; с – вкрапленность гематита, образовавшегося по пириту; d – пропитка пород тонкодисперсными образованиями и выполнение пор и пустот гематитом

Copper constitutes an industrially valuable component, whose minerals-concentrators are represented by inherent phases, including sulphides (chalcopyrite, chalcocite, covellite) and carbonates (malachite), as well as iron hydroxides and mica-clay minerals, where copper is present as an isomorphic impurity.

For percolation leaching, a 2 m column was used, loaded with 89.42 kg of the ore having a grain size of -55+0 mm. The ore was irrigated from the top with a sulphuric acid solution at a rate of 300 ml/h. However, following one day, the process was halted due to the high content of clay and slime components. It is well known that such components can cause colmatation, thus reducing drastically the solution percolation through the ore layer up to its complete halt.

The layer height was reduced to avoid colmatation during the leaching of oxidised ore from the Northern section of the Nurkazgan deposit. Leaching was carried out in a 1 m high column having a diameter of 140 mm. About 21.5 kg of the ore having a grain size of -55+0 mm were loaded into the column; leaching was carried out at the initial sulphuric acid concentration of 60 g/dm³. The pregnant leaching solutions were processed according to the “sorption/desorption–electrolysis” scheme. The daily volume of pregnant solution from the column was forwarded to the sorption columns filled with Lewatit MonoPlus cation-exchange resin (LANXESS Deutschland GmbH (Germany)) [25–28]. Solutions obtained upon sorption extraction of copper, following strengthening to the

required concentration of sulphuric acid, were directed to feed the leaching process. The sorption scheme was selected based on a rather low copper content in pregnant leaching solutions (0.3–0.8 g/dm³).

The following parameters were controlled: copper mass, solution volume and process duration. According to the obtained data, the first four cycles ensure 84% of copper extraction with a maximum in the third cycle (fig. 4).

On completing the percolation leaching, the cake yield equalled 96.42%. The total leaching time amounted to 14 days. The chemical and phase compositions of the cake are presented in tab. 3 and 4.

Thus, upon percolation leaching in a 1 m high column, the copper recovery into solution amounted to 56.06%. Further studies were carried out in a 2 m column.

The research was carried out on a setup comprising 2 m high plastic percolation columns ("Evonik Operations GmbH", Germany), having

an inner diameter of 190 mm. The ore was ground to the grain size of -55+0 mm; 89.42 kg of the ore were loaded into the column. It had been established earlier that, for an ore layer height of 2 m, the leaching process halted, while for a 1 m layer, no colmatation was observed. In order to address this limitation, 1 m layer of ore was first loaded, followed by a Styrofoam drainage layer, and one more 1 m layer of ore was added. Prior to leaching, the ore was moistened for a day. The ore was irrigated with sulphuric acid solution from the top at a rate of 300 ml/h or per specific flow rate in the column:

$$\frac{0.3 \cdot 4}{F \cdot 0.19^2} = 10.58 \text{ dm}^3 / (\text{m}^2 \cdot \text{h}).$$

This corresponds to a flow rate of 0.1058 dm/h in the column per clear opening (or 1.058 cm/h). Such a feed rate is used in conventional copper production with low permeability ores and is selected given the strong colmatation of

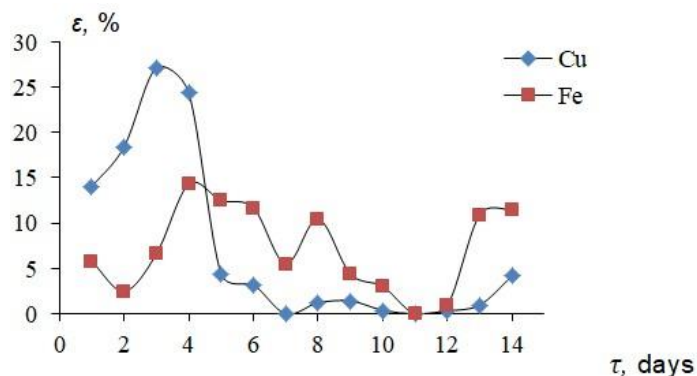


Fig. 4. Dependencies of copper and iron extraction into solution on duration of leaching

Рис. 4. Зависимости извлечения меди и железа в раствор от продолжительности выщелачивания

Table 3. Chemical composition of the ore residue (cake) following percolation leaching in a 1m high column

Таблица 3. Химический состав остатка руды (кека) после перколяционного выщелачивания в колонне высотой 1 м

Cu	Fe	Zn	Pb	Al	S	Mo, g/t
0.190	9.67	0.039	0.003	8.55	0.84	30.3
P	Au, g/t	Ag, g/t	As, g/t	Si	Mg	Ca
0.080	0.32	1.63	24.9	18.0	1.636	0.394

Table 4. Copper phase analysis in cake following percolation leaching of ore

Таблица 4. Фазовый анализ меди в кеке после перколяционного выщелачивания руды

Copper components	Abs. %	Rel. %
Oxides, including chrysocolla	0.091	47.89
	0.062	—
Sulphides	0.099	52.11
Total	0.190	100.0

Note / Примечание: abs. – absolute; rel. – relative / abs. – абсолютный; rel. – относительный.

the column material. The initial solution was fed from a reservoir by a Qudos 60 Watson Marlow peristaltic pump to a distribution device installed at the top of the column, which distributed the solution evenly over the column section. The solution passing through the ore mass was collected in a storage tank. Upon reaching a specific copper concentration in the solution, the latter was fed for copper sorption. Solutions, fully or partially strengthened with acid and refilled with water to the required volume, were recycled for irrigation. Acidity was adjusted using a pH meter and chemical analysis for the residual acidity of the solution. Leaching was carried out up to the trace level of oxidised copper in ore.

The grain size distribution of the initial ore intended for percolation leaching was studied. The grain size distribution and chemical composition of the initial ore are shown in tab. 5.

Fig. 5 shows the scheme used for ore heap leaching. This method can be carried out as a cuvette ore loading with a layer height of less than 1 m. Drainage material is deposited on top of this layer, followed by the next ore layer of up to 1 m high. Thereby, the weight pressure of the ore layer is applied to the drainage material instead of the underlying layer. Therefore, the permissible accumulation of finer ore fractions occurs in individual layers, rather than in the bottom layer [29].

Table 5. Granulometric and chemical composition of the initial ore for percolation leaching

Таблица 5. Гранулометрический и химический состав исходной руды для перколяционного выщелачивания

Class, mm	Yield, %	Components, %						Distribution, %		
		Cu	Fe	Al	Ag, g/t	Si	Ca	Cu	Fe	Ag, g/t
-55 + 45	6.68	0.459	10.46	10.13	1.86	25.04	0.378	7.36	6.73	7.01
-45 + 40	4.28	0.649	8.5	11.02	1.28	25.84	0.370	6.66	3.51	3.10
-40 + 31.5	8.88	0.738	10.91	10.05	3.91	24.54	0.258	15.73	9.32	18.42
-31.5 + 25	8.69	0.196	10.72	11.14	0.58	23.04	0.347	4.09	8.97	2.90
-25 + 20	6.45	0.502	10.18	10.14	1.36	25.54	0.319	7.76	6.33	4.96
-20 + 14	9.61	0.363	9.65	9.66	1.72	26.24	0.329	8.38	8.95	9.33
-14 + 10	8.16	0.325	9.72	10.11	1.42	26.04	0.369	6.36	7.65	6.56
-10 + 7	5.58	0.307	9.66	10.52	1.45	24.84	0.591	4.11	5.21	4.58
-7 + 5	7.42	0.334	9.95	10.18	1.54	24.94	0.385	5.95	7.13	6.46
-5 + 3.4	7.46	0.322	10.09	10.49	1.39	26.04	0.383	5.76	7.26	5.87
-3.4 + 2	5.58	0.359	10.22	10.68	1.54	24.64	0.371	4.80	5.50	4.86
-2 + 0	21.21	0.453	11.48	10.66	2.17	24.24	0.468	23.04	23.44	25.95
Ore/sum	100.0	0.417	10.37	10.40	1.79	24.95	0.390	100.0	100.0	100.0

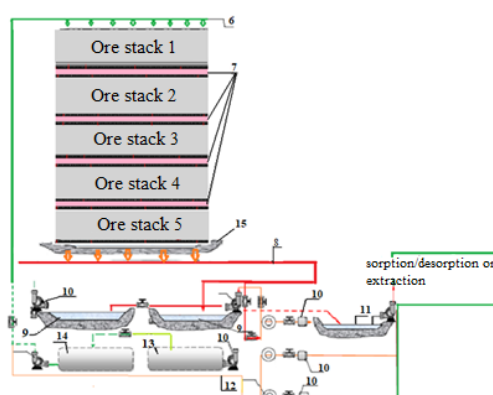


Fig. 5. Chain of apparatuses of ore heap leaching: 1–5 – leach (ore pile), particle size – 55+0 mm; 6 – heap irrigation system; 7 – drainage layer of polystyrene foam or inorganic-hydrophilic sorbent; 8 – process solution collection header; 9 – solution ponds; 10 – pumps; 11 – settling tank; 12 – pipelines; 13 – sulphuric acid solution; 14 – freshwater tank; 15 – ore container

Рис. 5. Схема цепи аппаратов послойного штабельного кучного выщелачивания руды: 1–5 – выщелачиваемый материал (рудный штабель), крупностью -55+0 мм; 6 – система орошения кучи; 7 – дренажный слой из пенополистирола или минеральногидрофильного сорбента; 8 – коллектор сбора технологического раствора; 9 – прудки для сбора растворов; 10 – насосы; 11 – отстойник; 12 – трубопроводы; 13 – раствор серной кислоты; 14 – бак свежей воды; 15 – рудная кювета

The sorption process of ore leaching solutions was carried out in the following stages: sorption/desorption and sorbent scrubbing. The solution following the sorption process was recycled for leaching. The sorbent was subjected to a desorption process (with cycling), yielding an electrolyte containing $\geq 40 \text{ g/dm}^3$ of copper. The wash water following scrubbing of the sorbent was fed (strengthened) to the leaching process. Chemical and phase analysis of residue (cake), following percolation leaching of ore, as well as particle size distribution, are presented in tab. 6–8.

An analysis of cake grain size distribution following percolation leaching showed a minor redistribution of grain size grades. The copper

content in grades decreases from 0.649–0.196% to 0.295–0.114%, indicating successful leaching. This is also confirmed by the residual distribution of components by grades in cake (see tab. 9). Here, the copper content decreases from 0.417% in the ore to 0.164% in a cake; its yield of 90.65% corresponds to the 60.04% extraction of copper into the solution.

Given that the ore contains a higher concentration of fine grades (see tab. 5), it can be assumed that sulphide minerals in them are released more fully, which indicates their higher activity in the leaching process.

Copper and iron extraction into solution (relative) depending on leaching duration is shown in fig. 6.

Table 6. Chemical composition of the residue after percolation leaching of ore

Таблица 6. Химический состав остатка (кека) после перколяционного выщелачивания руды

Cu	Fe	Zn	Pb	Al	S	Mo, g/t
0.164	9.52	0.0385	0.0006	9.46	0.848	48.02
P	Au, g/t	Ag, g/t	As, g/t	Si	Mg	Ca
0.0901	0.17	1.753	24.4	18.0	1.353	0.269

Table 7. Copper phase analysis in residue (cake) following percolation leaching of ore

Таблица 7. Фазовый анализ меди в остатке (кеке) после перколяционного выщелачивания руды

Copper components	Abs. %	Rel. %
Oxides	0.079	48.17
Sulphides	0.085	51.83
Total:	0.164	100.0

Note/Примечание: abs. – absolute; – relative / abs. – абсолютный; rel. – относительный.

Table 8. Granulometric and chemical composition of the residue by size classes after percolation leaching of ore (italics – weighted average content in the residue after leaching, cake)

Таблица 8. Гранулометрический и химический составы кека по классам крупности после перколяционного выщелачивания (курсив – средневзвешенное содержание в остатке после выщелачивания (кеке))

Class, mm	Exit, %	Components, %						Distribution, %		
		Cu	Fe	Al	Ag, g/t	Si	Ca	Cu	Fe	Ag, g/t
-55+45	5.79	0.295	10.78	9.80	1.971	18.7	0.358	10.36	6.41	6.51
-45+40	4.35	0.257	10.62	10.22	1.351	17.1	0.259	6.79	4.82	3.35
-40+31.5	8.98	0.212	10.84	10.05	1.441	18.4	0.233	11.56	9.48	7.38
-31.5+25	8.81	0.221	8.97	8.45	1.574	17.6	0.235	11.82	9.05	7.91
-25+20	6.53	0.179	8.54	11.20	1.662	19.0	0.214	7.10	5.69	6.19
-20+14	9.41	0.141	8.37	10.21	7.729	18.9	0.235	8.05	9.19	9.28
-14+10	9.13	0.131	8.42	10.09	1.571	18.7	0.289	7.26	8.85	8.18
-10+7	5.88	0.120	8.52	12.20	1.342	20.1	0.243	4.28	5.86	4.50
-7+5	7.33	0.118	8.77	8.73	1.435	19.1	0.211	5.25	6.39	6.00
-5+3.4	8.79	0.117	9.54	9.97	1.663	18.8	0.200	6.24	8.04	8.34
-3.4+2	4.98	0.114	9.86	8.641	1.944	18.2	0.231	3.44	4.33	5.52
-2+0	20.02	0.147	10.98	9.45	2.351	18.8	0.324	17.85	21.89	26.84
<i>Cake/Sum</i>	<i>100.00</i>	<i>0.164</i>	<i>9.52</i>	<i>9.46</i>	<i>1.753</i>	<i>18.0</i>	<i>0.269</i>	<i>100</i>	<i>100</i>	<i>100</i>

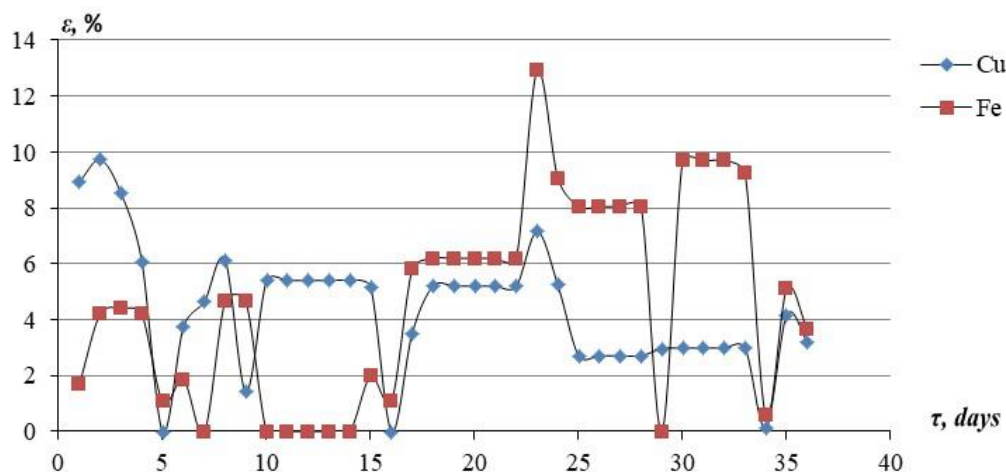


Fig. 6. Dependencies of copper and iron extraction into solution on duration of leaching

Рис. 6. Зависимости извлечения меди и железа в раствор от продолжительности выщелачивания

Acid consumption increases sharply at a copper recovery of approximately 40%. At the initial stage, along with the dissolution of copper, the readily soluble waste rock compounds (oxides, iron hydroxides, calcium and magnesium carbonates, etc.) are intensively leached. By reducing their content in the ore, the efficiency of the process improves. In the latter case, however, the dissolution rate of copper and its concentration in the solution decreases.

CONCLUSION

In the conducted study, copper extraction into the solution amounted to 60.04% with a sulphuric

acid consumption of 50.0 kg/t ore or 21 kg per kilogram of extracted copper at an average irrigation rate of $10.58 \text{ dm}^3/(\text{m}^2 \cdot \text{h}) = 0.1058 \text{ dm}^3/\text{h}$.

The obtained results show that:

- between 1 and 10 days of leaching, most of the copper (30%) is extracted into the solution;
- low copper concentration solutions obtained in the final stages of leaching should be recycled.

Heap leaching of ore piles having a height of lower than 1 m can be performed via the following stages: "leaching–extraction/re-extraction or sorption/desorption–electrolysis".

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