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ИЗВЕСТИЯ

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INVESTIGATION OF SORPTION CHARACTERISTICS OF ANIONEX EXCHANGE RESINS RELATED TO GOLD AT ITS EXTRACTION FROM POLYCOMPONENT SOLUTIONS

Abstract. This article presents the results of studies of the sorption characteristics of various grades of resins used in the processing of gold-containing ores. The behavior of the main accompanying impurities in the process of ion exchange (Co and Cu) in the process of gold extraction by ion exchange resins of different basicity was studied: AM-2B (mixed basicity), AB-17-8 and Purolite A-500 (strongly basic resins).

Key words: anion exchange resin, sorption characteristics, capacity, resin selectivity for gold, accompanying impurities.

Currently, low-grade gold-containing raw materials are increasingly involved in processing, which, as a rule, undergoes heap leaching with alkaline cyanide solutions [1-3]. The method allows to provide low water consumption due to the use of circulating solutions, it is not energy-intensive, does not require the use of complex equipment.

As a result of the interaction of aqueous solutions of sodium cyanide with gold-containing ore, dilute solutions of gold (I) and silver (I) cyanocomplexes are formed. However, along with gold, the accompanying impurities - metals such as copper, zinc, nickel and cobalt - dissolve. For the sorption extraction of cyanide gold complexes from the obtained solutions, ion exchange resins and activated carbons are used [4-6]. In the process of sorption extraction of gold ions from the obtained solutions, the sorbents, to varying degrees, are exposed to metal impurities, while their capacitive characteristics are reduced. The main advantage of activated carbons is their high selectivity to gold. The main disadvantage of activated carbons is the relatively low absorption rate of noble metal compounds [7, 8]. Ion-exchange resins are inert with respect to the salt composition of simple salts, as well as to oil products that have fallen into the productive solution. Synthetic ion exchange resins in comparison with activated carbon have higher sorption capacity, mechanical strength, and can be reused [9]. The resin removes a part of the metals of the impurities, herewith the circulating solutions are conditioned by the impurity metals and the gold dissolves better. Studies aimed at investigation of the effect of accompanying metals-impurities on the sorption of gold by anion-exchange resins are important and timely. When developing an effective sorption method for processing productive gold-containing solutions, it is important not only to choose a selective anionite having high technological properties, but also to study the effect of the solution composition on sorption parameters.

When leaching gold from ore raw materials among soluble accompanying impurities (copper, zinc, nickel, cobalt, iron), copper has a significant effect on the sorption of gold [10, 11]. Copper, contained in leaching solutions (productive solutions), reduces the sorption of dissolved gold and the sorption activity of sorbents, and copper contained in circulating solutions reduces the solubility of gold due to the competing effect of copper on the leaching process. Copper in solutions is mainly presented in the form of cyanide complex compounds - $Cu(CN)_2^-$, $Cu(CN)_3^{2-}$ и $Cu(CN)_4^{3-}$ [12]. In this connection, one mass fraction of copper transits into an inactive state about 3-4 mass fractions of sodium cyanide added to the solutions. The single-charged $Cu(CN)_2^-$ anion in the composition of $KCu(CN)_2$ is a coordination polymer containing $Cu(CN)_3$ "units" that joining together form helicoidal anion chains, while in the composition $Na_2[Cu(CN)_3]\cdot 3H_2O$, a discrete flat triangular anion $Cu(CN)_3^{2-}$ is detected. Cu^+ ions can form mixed complexes based on cyanide ions and thiourea, thiocyanate, ammonia, chloride and iodide ions, for example $[Cu(CN)_3SCN]^{3-}$ and $[Cu(CN)_4SCN]^{4-}$ [13,14]. In the presence of free cyanide in solution, these mixed complex ions decompose rapidly. When the CN:Cu ratio is less than 3, copper cyanide is easily oxidized by air, which determines the lower stability of $Cu(CN)_2^-$.

In working solutions, the content of sodium cyanide is at the level of 0.7-1.0 g/l, from which up to 0.25 g/l is in inactive form as cyanide complexes with copper, which amounts to 25-36% of the total load sodium cyanide in the leaching process.

From literary and patent sources, several methods for extracting copper from cyanide solutions are known [15, 16]:

- treatment of solutions with oxidants in an alkaline medium, as a result of which dissolved copper passes into a precipitate in the form of a hydroxide;
- cementing of copper with metallic zinc to produce metallic copper powder;
- by electrolysis to obtain a powder of metallic copper;
- treatment of the solution with mineral acids (preferably sulfuric acid) to obtain a precipitate of copper cyanide;
- sorption by anion-exchange resins and extractants.

When cyanide solutions are treated with oxidizing agents (chloragents, hydrogen peroxide, ozone), all the cyanide compounds contained in the solution are completely destroyed (degraded) and, therefore, a large consumption of oxidants is required to precipitate copper. The resulting solutions practically do not contain sodium cyanide and they are not able to leach gold without additives of the latter when using solutions in circulation. In this regard, for heap leaching conditions, this method of precipitating dissolved copper is ineffective and cannot be recommended for industrial use.

Methods of carbonization of copper with metallic zinc, copper separation by electrolysis and treatment with mineral acids also do not attract attention for the following reasons: when zinc copper is carbonized, copper precipitates with simultaneous dissolution of zinc, which also as copper suppresses gold dissolution when solutions are used in circulation and reduce sorption extraction ions of gold. It should be noted that the electrolysis of copper from cyanide solutions of this composition passes with a low current yield, which causes high energy costs and loss-making process.

The process of treatment of alkaline cyanide solutions with mineral acids requires a large expenditure on reagents (mineral acids for acidification of alkaline cyanide solutions to pH 1.8-2.0 and sodium hydroxide for subsequent alkalinization of solutions after separation of precipitated copper from them). In addition, as a result of the processing of cyanide solutions with mineral acids, hydrogen cyanide (hydrocyanic acid) is formed which is a highly toxic and volatile gas and, in this connection, expensive equipment is required to avoid the release of prussic acid into the atmosphere. The cyanide precipitate of copper is also a toxic substance and has limited demand, and to extract copper from it in the form of commodity products having increased demand, additional expensive operations and equipment are required, the costs for which are often not paid off by the product being sold.

Scientific and practical interest is the sorption methods of extraction of dissolved copper by anion-exchange resins and extractants based on quaternary ammonium salts (QAS) [16].

Extractants diluted in organic solvents (kerosene, toluene, diesel fuel, etc.) are insoluble in water liquid synthetic sorbents. When the extractants are mixed with cyanide solutions, they together with diluents are emulsified and their entrainment is carried out with the treated solutions. In this connection, conditions for heap leaching of gold require deep purification of circulating solutions from emulsified extractants that otherwise are adsorbed by the surface of the ore and reduce the leaching of gold from the ore material (gold dissolved from the ore is sorbed by the extractant and remains with it on the surface of the ore particles).

The attraction of anion-exchange sorbents is that they are able to concentrate a large number of cyanide complex metal compounds from very dilute solutions with a low degree of sorption of the simple cyanide ions that make up sodium cyanide, which almost completely remain in solutions and can be reused in circulation for dissolution of gold from ore.

For industrial processing conditions for polycomponent gold-containing solutions obtained by heap leaching, the most acceptable are anion exchange resins - water-insoluble solid synthetic sorbents.

We studied the behavior of the main accompanying impurities (Co and Cu) in the process of gold extraction by ion-exchange resins of different basicity: AM-2B (mixed basicity), AB-17-8 and Purolite A-500 (strongly basic resins).

The studies were carried out using industrial cyanide solutions obtained from heap leaching of gold from ore raw materials, in composition of, mg/l: gold 1.13-1.20; copper 60.8-63.2; cobalt 1.73-1.78.

Sorption was carried out dynamically by passing solutions through the resin bed in the column from bottom to top (Figure 1). The ratio of the height of the resin bed in the columns to the diameter of the column was (4-6): 1. The rate of transmission of the solutions through the resin bed was maintained at 4-5 specific volumes per hour.

The frequency of sampling was carried out 2 times a day: after 8 and 24 hours of sorption. The solutions were analyzed for the content of gold, copper and cobalt. After reaching the content of copper in the solution after sorption at the level of the initial content, the sorption was stopped.

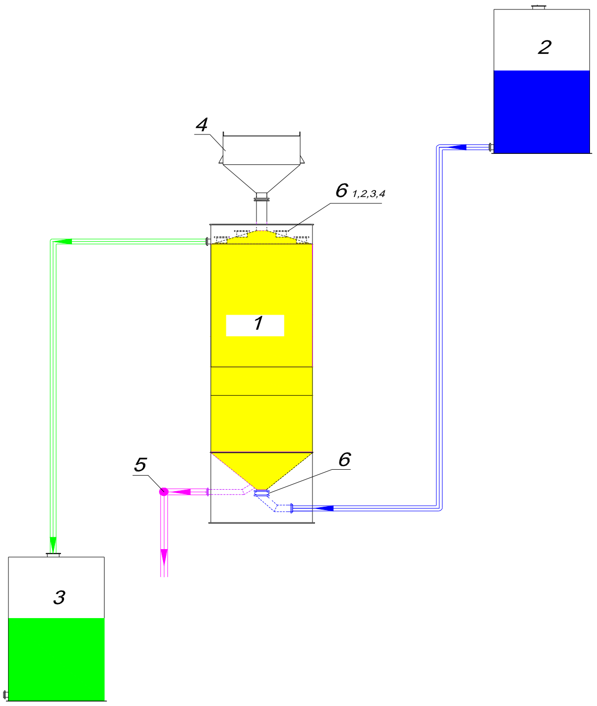

Figure 1 – Scheme of the sorption installation: *1* – sorption column; *2* – consumption tank of a productive solution; *3* – mother solution tank; *4* – loading of fresh ion exchanger; *5* – unloading of saturated ion exchanger; *6* – drainage mesh

The results of the studies are given in Table.

From the obtained data, it can be seen that the AB-17-8 resin has the largest capacity for the studied metals, mg/g: 3.14 of gold; 89.31 of copper; 4.69 of cobalt.

Saturation with gold of AM-2B resin is 2.98 mg/g, of Purolite A-500 resin is 2.86 mg/g. Purolite A-500 resin has quite high rates for sorption of cobalt (4.64 mg/g) and satisfactory indicators for copper sorption (68.48 mg/g). The lowest capacity for copper and cobalt is AM-2B resin. The resin capacity for copper was 24.77 mg/g, for cobalt - 3.03 mg/g.

Gold is most efficiently sorbed by AB-17-8 ion exchange resin. The content of gold in solutions after sorption does not exceed 0.05 mg/l up to 500 specific volumes of polycomponent productive solutions passed through the resin. AM-2B resin for sorption of gold is 15-20% inferior to AB-17-8 resin. Decrease (less than 0.05 mg/l) of gold content is observed before passing through the column of 150 specific

Results of gold, copper and cobalt sorption experiments
with ion-exchange resins AM-2B, AB-17-8 and Purolite A-500

Total amount of solutions, S.V.	Content in solutions, mg/l						Content in resin, mg/g		
	productive solution			mother solution					
	Au	Cu	Co	Au	Cu	Co	Au	Cu	Co
AM- 2B									
45	1,14	61,0	1,75	0,06	0,05	0,10	0,15	8,23	0,22
146	1,14	61,0	1,75	0,04	3,65	0,25	0,48	25,98	0,69
252	1,14	61,0	1,75	0,07	53,50	0,70	0,82	31,33	1,04
322	1,19	63,2	1,78	0,17	64,50	0,42	1,04	31,19	1,31
425	1,19	63,2	1,78	0,11	66,00	0,74	1,37	29,83	1,61
495	1,19	63,2	1,78	0,06	66,50	0,78	1,60	29,02	1,85
605	1,13	60,8	1,73	0,17	64,25	0,89	1,91	27,59	2,15
725	1,13	60,8	1,73	0,18	63,75	0,71	2,25	26,34	2,44
820	1,20	61,0	1,75	0,18	62,00	0,99	2,52	25,79	2,68
987	1,20	61,0	1,75	0,28	63,50	1,02	2,98	24,77	3,03
AB-17-8									
55	1,14	61,0	1,75	0,01	0,01	0,01	0,19	10,06	0,27
150	1,14	61,0	1,75	0,01	0,01	0,13	0,51	27,44	0,73
254	1,14	61,0	1,75	0,02	0,07	0,10	0,86	44,75	1,25
318	1,19	63,2	1,78	0,04	0,19	0,11	1,08	56,86	1,57
410	1,19	63,2	1,78	0,05	3,41	0,11	1,40	73,77	2,03
498	1,19	63,2	1,78	0,05	15,75	0,24	1,70	87,51	2,46
591	1,13	60,8	1,73	0,15	58,00	0,25	1,98	91,50	2,88
694	1,13	60,8	1,73	0,15	60,00	0,21	2,28	91,20	3,34
791	1,20	61,0	1,75	0,15	63,25	0,15	2,57	90,70	3,79
973	1,20	61,0	1,75	0,22	63,00	0,15	3,14	89,31	4,69
Purolite A-500									
57	1,14	61,0	1,75	0,03	0,09	0,09	0,19	10,42	0,28
147	1,14	61,0	1,75	0,01	0,05	0,11	0,49	26,87	0,73
263	1,14	61,0	1,75	0,01	0,18	0,10	0,89	48,05	1,31
334	1,19	63,2	1,78	0,02	2,86	0,11	1,14	61,13	1,67
433	1,19	63,2	1,78	0,12	48,75	0,19	1,47	70,42	2,15
528	1,19	63,2	1,78	0,19	64,25	0,25	1,76	73,33	2,60
617	1,13	60,8	1,73	0,21	65,50	0,19	2,01	72,29	3,00
729	1,13	60,8	1,73	0,24	64,00	0,20	2,30	71,21	3,51
835	1,20	61,0	1,75	0,33	63,00	0,22	2,56	70,16	3,99
979	1,20	61,0	1,75	0,57	63,25	0,24	2,86	68,48	4,64

volumes of the solution, and at 987 specific volumes - increases to 0.28 mg/l. Purolite A-500 resin sorbs gold quite efficiently (with a transmission of ~ 400 S.V. of solution), the content of gold in solutions after sorption does not exceed 0.03 mg/l. At large volumes of productive solutions passed through the resin, the gold concentration in the mother solution increases rapidly and at 979 specific volumes of the passed gold-containing solution is 0.57 mg/l.

With regard to copper extraction, the highest metal capacity is observed when using the AB-17-8 resin - 89.3 mg/g. The sorption of copper ions by AM-2B resin is less effective: the metal capacity does not exceed 24.8 mg/g. Purolite A-500 resin has intermediate results between the AM-2B and AB-17-8 resins. After the breakthrough (the concentration of copper in the solution after sorption reaches 3-4 mg/l), all resins sharply reduce the sorption properties with respect to copper. The concentration of copper in the mother solution increases noticeably and at the end of the sorption exceeds the initial value.

There is a displacement (desorption) of copper from the resin phase, but it occurs with different specific volumes of productive solutions passed through the resin. Thus, copper desorption from AM-2B resin is observed after passing 288 specific volumes, with Purolite A-500 resin - after 528 specific volumes, and with AB-17-8 resin - after 658 specific volumes. Thus, according to the sorption characteristics with respect to copper, the most effective resin is AB-17-8.

With respect to cobalt, the AB-17-8 and Purolite A-500 resins have approximately the same sorption characteristics. They significantly exceed the sorption characteristics of the AM-2B resin. After sorption with AB-17-8 and Purolite A-500, the maximum cobalt content in mother solution is 0.26 mg/l, and when using AM-2B resin in the filtrate, a cobalt concentration of 1.08 mg/l is achieved.

It should be noted that the capacity of the studied resins for gold is fairly close and amounts to 2.86-3.14 mg/g. For copper, AB-17-8 resin has the largest capacity (91.5 mg/g), and AM-2B has the smallest (31.33 mg/g) (Figure 2). The intermediate value for the capacity of copper is Purolite A-500 resin (73.45 mg/g). In all types of resins, after full saturation with copper, a certain decrease in the metal capacity occurs, i.e. desorption of copper from the resin is observed.

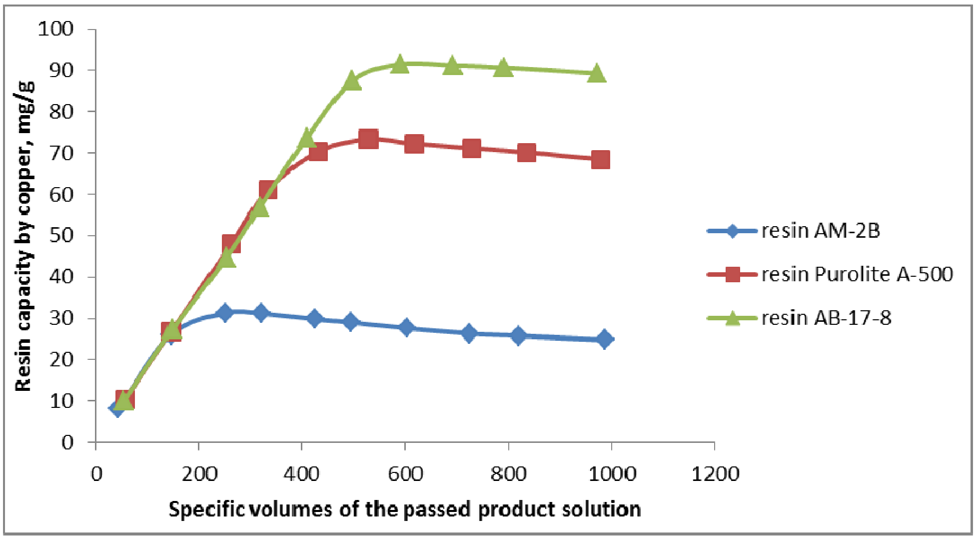

Figure 2 – Capacity of ion-exchange resins in copper, depending
on the specific volumes of passed gold-containing productive solutions

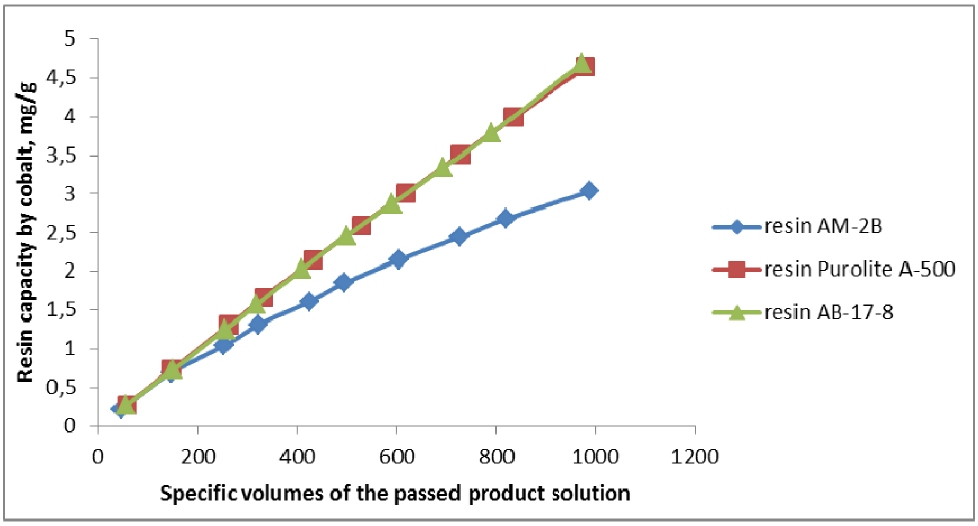

Figure 3 – Capacity of cobalt-based anion exchangers, depending
on specific volumes of omitted gold-containing productive solutions

The capacity of the anion exchangers AB-17-8 and Purolite A-500 in cobalt (Figure 3) is approximately the same and is 4.64-4.69 mg/g. The capacity of the AM-2B resin for cobalt is lower than other resins and is 3.03 mg/g.

The obtained data on the sorption of gold, copper and cobalt from polycomponent cyanide solutions confirm the increased selectivity to gold of the mixed basic AM-2B resin. Strongly basic resins AB-17-8 and Purolite A-500 are collective sorbents, they sufficiently well sorb all the anionic complexes of metals.

Figures 4-6 show the results of the extraction of metal ions from productive solutions by AM-2B, Purolite A-500 and AB-17-8 ion-exchange resins, depending on the specific volumes of the passed productive solution.

From the results of the studies shown in Figures 4-6, it follows that the highest sorption index with respect to gold, copper and cobalt is AB-17-8 resin. The AM-2B resin is quite effective with respect to gold ion, and has low sorption characteristics when copper and cobalt are extracted, i.e. This resin shows selectivity with respect to gold. Pulrolite A-500 resin has slightly reduced gold extracting performance, satisfactory copper extracting performance and fairly high cobalt extracting rates comparable to those of metal ions on the AB-17-8 resin.

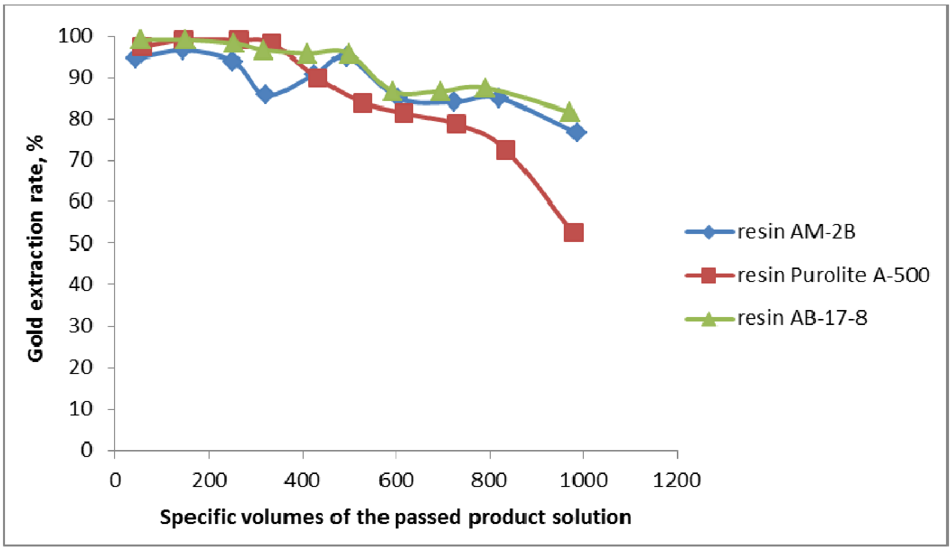

Figure 4 – Dependence of the degree of gold extraction from productive solutions by ion-exchange resins depending on the specific volumes of the passed solutions

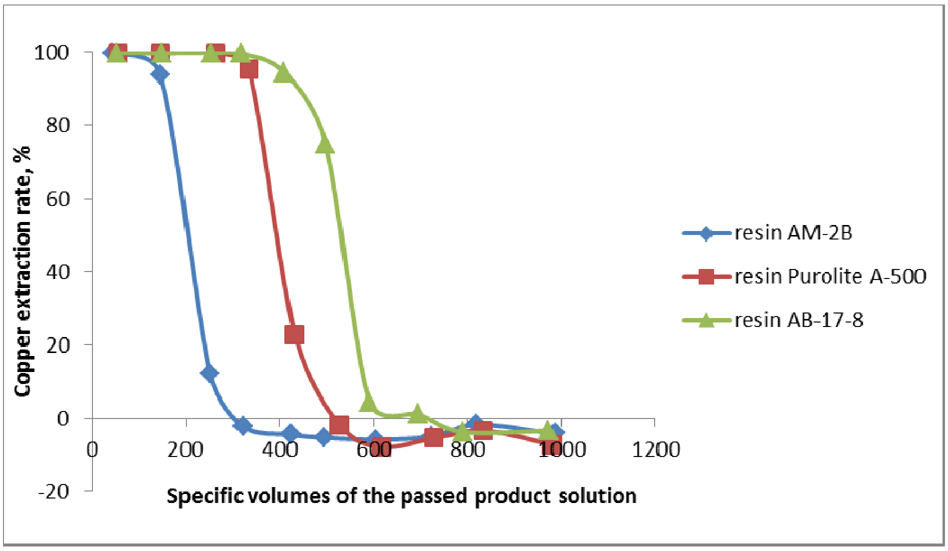

Figure 5 – Dependence of the degree of copper extraction from the productive solutions by ion exchange resins, depending on the specific volumes of the passed solutions

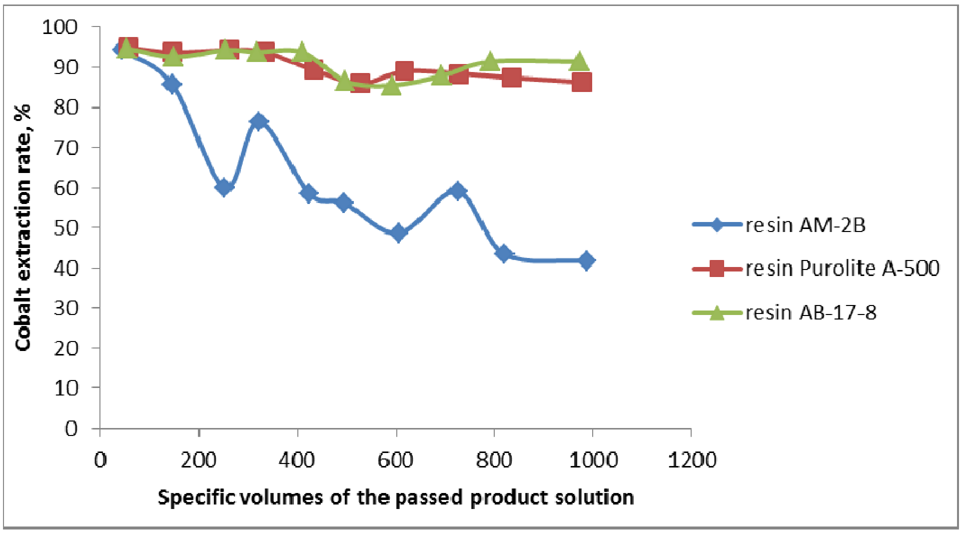

Figure 6 – Dependence of the degree of cobalt extraction from the productive solutions by ion-exchange resins, depending on the passed solutions

According to the results of the studies, it was not possible to select metals from the polycomponent product solution (copper and cobalt) by tested ion-exchange resins.

Thus, for the implementation of the method of sorption conditioning of solutions for metals-impurities, it is possible, as one of the options, the two-stage sorption method, the preliminary sorption of gold by the AM-2B ion-exchange resin, which has a lower capacity for copper and cobalt, followed by the sorption of impurity metals by the AB-17-8 anion exchange resin, which has a high sorption ability with respect to copper and cobalt. Along with the AM-2B resin, two-stage sorption of gold from the productive solution can use activated carbons, usually having the highest selectivity for gold during sorption from solutions with a high content of metal impurities.

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АЛТЫНДЫ ПОЛИКОМПОНЕНТТІ ЕРІТІНДІЛЕРДЕН ӨНДІРУ БАРЫСЫНДА АНИОНАЛМАСТЫРҒЫШ ШАЙЫРЛАРДЫҢ АЛТЫНҒА ҚАТЫСТЫ СОРБЦИЯЛЫҚ СИПАТТАМАЛАРЫН ЗЕРТТЕУ

Аннотация. Мақалада алтын құрамды кеннен алтынды өндіру барысында қолданылатын әр түрлі маркалы анионалмастырғыш шайырлардың алтынға қатысты сорбциялық сипаттамаларын зерттеу жұмыстарының нәтижелері көрсетілген. Иондық алмасу кезінде негізгі қоспа металлдардың әсері зерттелген.

Түйін сөздер: ионалмастырғыш шайыр, сорбциялық сипаттамалар, сіңіру көлемі, шайырлардың алтын бойынша таңдаушылық қасиеттері, қоспа металлдар.

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ИССЛЕДОВАНИЕ СОРБЦИОННЫХ ХАРАКТЕРИСТИК АНИОНООБМЕННЫХ СМОЛ, ОТНОСЯЩИХСЯ К ЗОЛОТУ, И ЕГО ИЗВЛЕЧЕНИЯ ИЗ ПОЛИКОМПОНЕНТНЫХ РАСТВОРОВ

Аннотация. В статье приведены результаты исследований сорбционных характеристик разных марок смол используемые при переработки золотосодержащих руд. Изучено поведение основных сопутствующих примесей в процессе ионного обмена (Co и Cu) в процессе извлечения золота ионообменными смолами различной основности: АМ-2Б (смешанной основности), АВ-17-8 и Purolite А-500 (сильноосновные смолы).

Ключевые слова: анионообменная смола, сорбционные характеристики, емкость, селективность смол по золоту, сопутствующие примеси.

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