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Development of Reagents - Blowing Agents Based on Local Raw Materials and their Research

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***Abstract:** The development and search for effective reagents and optimal technological conditions is one of the main factors for improving the coal flotation process. Solving these problems increases the technological and economic efficiency of flotation enrichment. The article discusses methods for producing foaming regents based on waste from the distillation process of cottonseed oil - gossypol resin and methods of flotation of various classes of fine coal. The advantages of this foaming agent include the availability of raw materials, which are a product of domestic industry, produced at the enterprises of the Kattakurgan MJK and amino alcohols (mono- , di- and triethanolamine) , sufficient resources and relative low cost. Conducted research to assess the effectiveness, surface activity and foaming ability of the resulting reagents - in foaming agents, according to the proposed technology of the studied technical products, the resulting product belongs to the surface-active reagents and has high flotation activity. The physico-chemical and foam-forming properties, foam stability, destruction kinetics and other properties of flotation reagents - foaming agents SK-1 and SK-2 - have been studied. The results of studies of the influence of foaming reagents in the process of flotation and extraction of precious and non-ferrous metals are presented. The optimal option for the effective composition of composite chemical flotation reagents - foaming agents and their parameters was selected. The results of scientific research conducted at JSC NMMC on the use of analogues of the foaming agents SK-1 and SK-2 are given in comparison with the reagents (Oxal) currently used at the plant. The elemental composition of man-made waste samples using reagents SK-1 and SK-2 was determined.*

***Key words:** Coal, Flotation Reagents - Foaming Agents, Surfactants, Local Raw Materials, Waste, Composition, Ore Flotation, Chemical Reagents.*

I. INTRODUCTION

The use of recycled materials to extract useful materials for further use is becoming increasingly cost-effective.

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In particular, the use of flotation reagents obtained from secondary raw materials for the extraction of precious and non-ferrous metals in the coal and mining industries are profitable sources in many enterprises of the country [1]. There are a number of technologies and methods for processing such waste, but due to a number of problems they are not widely used. As modern production develops, with its scale and growth rate, the problems of development and implementation of low- and waste-free technologies become increasingly relevant [2][22]. For many decades, ores have been the main source of production of ferrous and non-ferrous metals. Mining and processing involve ores rich in valuable components (metals) [3]. It is necessary to enrich coal with high ash content mined in mines before sending it for coking. The flotation method is used for small classes of coals. Flotation is an effective method of enriching fine coal and is widely used in coal mining enterprises. The physicochemical properties of the reagents used affect the efficiency of the flotation process [4]. The flotation process uses collecting reagents and foaming reagents. Collector reagents are adsorbed on the surface of coals, thereby increasing the hydrophobicity of the grains, ensuring their high floatability. Foaming reagents, as a result of adsorption at the liquid-air interface, reduce surface tension. In this case, bubbles of a certain size are formed and suspended particles adhere to them, and foam stabilization increases [5]. Blowing agents have surface activity; at high molecular weights they can exhibit collecting properties. This property is important for flotation treatment of wastewater that contains synthetic surfactants such as alkyl sulfates, alkylaryl sulfonates, etc. They have foaming and collecting properties, which reduce reagent costs [6]. Ore flotation is the main technological process in the production of various non-ferrous metals. The content of non-ferrous metals in ore is steadily decreasing due to increased production and their mining and processing [7][21]. The amount of metals mined, which determines the efficiency and economics of production, depends on one ton of ore processed. Until today, various methods of improving and intensifying flotation processes are known:

-development of new enrichment schemes and equipment, automation of enrichment processes and reagent dosing;

- automated control of production processes;

- magnetic and electrochemical treatment of flotation pulp; -search for effective reagents [8].

One of the most convenient ways to improve and intensify enrichment is the synthesis of chemical reagents, the use of which can achieve high technical flotation performance on existing equipment [9]. To create new chemical reagents, it is necessary to carry out the process in several directions:

1) synthesis of xanthates with different natures of hydrocarbon radicals;

2) synthesis of new blowing agents [10].

Industrial wastes have been studied and their shortcomings have been identified, which determine the insufficiently high efficiency during enrichment. The development and chemical synthesis of new reagent substances is considered as a way to eliminate these shortcomings [11]. With the constant increase in the intensity of extraction of metals from pulp, the demand for blowing reagents is increasing. Foam stability is a major factor in the flotation process. The effectiveness of foamers is assessed by their consumption per ton of ore during flotation. The lower the reagent consumption, the more effective the reagent [12][23][24]. When enriching coals from the Chertinskaya-Koksovaya mine at the Belovskaya Central Processing Plant, the following foaming reagents were selected: bottom residues from the production of butyl alcohols (KOBS), high molecular weight alcohols (HMA), ECOFOL 440 (EK-440). Thermal gas oil was chosen as a collecting reagent [13]. Characteristics of foaming reagents are presented in table. 1.

Table 1 Group Chemical Composition Of Foaming Reagents

Reagent	Group Chemical Composition in - % wt.
COBS	Alcohols (C8) - 5.40-5.52 Acetals (C12) - 33.50-35.10 Acetals (C16) - 15.00-15.80 Esters (C12) - 4.90-5.30 Ethers (C12-C16) - 37.50-39.50 Resins - 1.06-1.16 Water - 0.10-0.16
Navy	A mixture of high molecular alcohols from C 9 -C 13
EK-440	A mixture of aliphatic alcohols, esters, ethers, hydrocarbons and C10-C15 olefins

When using the foaming reagent EK440, the total concentrate yield was 65.4% with an ash content of 14.5%. The extraction of combustible mass into concentrate is 88.3% [14].

II. METHODOLOGY

The following methods of physical and chemical analysis were used to determine the quality of new foaming reagents: IR spectroscopy, mass spectroscopy, flotation enrichment method. To determine the surface tension of foaming reagents, the Rebinder method was used. Foaming ability was determined by dynamic and static (pseudo static) and other standard research methods. Currently, in the Navoi (NMMC) and Almalyk Mining and Metallurgical Combine (AMMC) of the Republic of Uzbekistan, gold and copper ores are floated using expensive flotation reagents-foaming agents T-66, T-80, T-92 (1,3-dioxane derivatives) and MIBK, as well as organophosphorus and sulfhydryl collectors imported from abroad. The development of import-substituting reagents - foaming agents, the study of their possibility of use in the practice of flotation concentration of ores is an urgent task [15]. Experimental studies on the creation of new foaming reagents were carried out at the Institute of Inorganic Chemistry and Chemistry of the Republic of Uzbekistan in the laboratory of chemical technology and surfactants. The objects of research are solutions of the following surfactants: SK-1 and SK-2, in various combinations and concentrations, waste from gas processing and fat-and-oil enterprises.

III. RESULTS AND DISCUSSIONS

To extract precious and non-ferrous metals and lighten drilling fluids, foaming agents SK-1 and SK-2 were synthesized. The foaming agents are based on cotton soap stock Kattakurgan MFA and amino alcohols (mono- di- and triethanolamine). Float reagents-blowing agents are easily available and have positive technological characteristics [16].

the liquid-air interface blowing agents reduce surface tension. Interfacial tension was measured at room temperature and atmospheric pressure [17]. To do this, a sample of the blowing reagent was drawn into a syringe in the device. For a few seconds, the syringe was positioned in the correct position relative to the chamber. A drop of solution was squeezed out of the syringe until it came off the needle. After this, the camera captures the digital image [18]. The results obtained are presented in Table 1.

Table 1. Physico-Chemical Properties of Surfactants at the “Solution - Air” Interface

No.	Surfactants and their Concentration in Solution (%)	Contact Angle θ, Deg	Surface Tension σ, mN/m	Drop Volume, μl	Drop Area, mm^2	Drop Length, mm
1	Sulfonol (0.2%)	119.2	27.25	3.57	11.02	0.755
2	Sulfonol -K (0.2%)	121.2	29.92	3.90	11.70	0.753
3	SK-1 (0.1%)	119.6	28.5	4.46	12.93	0.675
4	SK-2 (0.2%)	119.7	30.05	3.67	11.30	0.702
5	OP-10 (0.2%)	118.9	30.69	4.07	12.13	0.628

To ensure the least penetration of the solution into the rock, the contact angle should not exceed 90 ºC. The surface and foaming properties of the solution when using a 0.2% aqueous solution of the SK-1 reagent are effectively reduced to σ = 28.5 MN/m and show a stable foaming ability of ν = 265 ml. Surface tension of the SK-2 reagent σ= 30.5 MN/m; foaming capacity = 260 ml. The T-80 foaming agent forms a fast-breaking foam [19]. At a concentration of the SK reagent of 1000 mg/l, approximately 1.7 times more foam is formed compared to T-80. In the pH range from 8.0 to 10.0, changes in alkalinity do not affect the foaming ability of the reagent. And the foaming reagents we are studying meet this requirement in the form of droplets [20]. The technological properties of foaming reagents such as destruction kinetics, multiplicity, stability, etc. were studied. Mixtures were studied, which included the following components: solutions of anionic surfactants (C K-1, Sulfanol-K), structure-forming polymers (PAA, KMK, viscosity regulator). Table 2 presents the indicators of the mixtures obtained after the experiments.

Table 3. Parameters of Reagents - Blowing Agents

No. Rastvo - ra	Density of Foaming Solution, kg/m3	Foaming Agent Density, kg/m3	Foam Destruction Coefficient	Gas Content	Stability, s/cm3
1	1007	298	0.82	0.70	4.36
2	1005	218	0.85	0.78	5.00
3	1012	250	0.83	0.75	5.72
4	1013	283	0.84	0.72	9.28
5	1004	266	0.87	0.74	21.34

As can be seen from the table, the presented solutions have the ability to re-foam. Joint scientific research was also carried out with Navoi Mining and Metallurgical Combine JSC to determine the possibility of using analogues of the SK-1 foaming agent , presented by the Institute of the Academy of Sciences of General and Inorganic Chemistry in comparison with the reagents currently used at NMMC JSC. Flotation enrichment experiments were carried out on a sulfide sample of ore from the Auminzo-Amantaytau deposit. Results of comparative experiments when replacing Oxal T-92 (NMMC) for the tested frother analogs are given in Table 3. Flotation tests in an open cycle were carried out in the following reagent mode :

- and grinding – 55% class -0.074mm, Cq-100g/t Na_2CO_3-2500g/t, I-20 -60g/t;
- m /c flotation – 25 min, Kst-200 g/t, Air.-407-20 g/t, foaming agent - 100 g/t , regrinding - 80% class -0.074mm; soda-1500g/t, Cq-80g/t ;
- main flotation–25 min, $CuSO_4$-100g/t, Kst-140g/t, air-407–20g/t, foaming agent – 60g/t ,
- cleaning – 3 min ;
- control flotation – 25 min, kst-100g/t, air-407-10g/t, foaming agent - 30g/t.

Table 4. Results of Flotation Experiments

Name Products	Exit %	Content			Extraction,%		
		Au g/t	Ss%	Sorg.%	Au	Ss	Sorg .
Experiment No. 1 Oksal T-92 (NMMC) – total Consumption 190g/t							
Concentrate m /c	3.23	20.00	13.50	6.8	30.93	25.88	31.03
Pepper concentrate	2.73	23.30	26.70	2.8	30.41	43.19	10.78
tail pepper	3.13	5.20	2.60	1.0	7.79	4.83	4.42
total number of basics	***5.86***	***13.63***	***13.82***	***1.8***	***38.20***	***48.02***	***15.20***
control kit	1.72	6.40	6.40	1.4	5.26	6.52	3.39
combined concentrate	***10.81***	***14.38***	***12.54***	***3.25***	***74.39***	***80.42***	***49.63***
Tails	89.19	0.60	0.37	0.40	25.61	19.58	50.37
Ore	***100.0***	***2.09***	***1.7***	***0.71***	***100.0***	***100.0***	***100.0***
Experiment No. 2 "SK-1" -240g/t *							
Concentrate m /c	2.77	15.40	11.00	6.0	21.89	19.34	24.25
Pepper concentrate	2.38	30.00	31.40	2.8	36.56	47.32	9.70
tail pepper	2.87	3.10	2.50	1.6	4.56	4.55	6.70
total number of basics	***5.25***	***15.28***	***15.59***	***2.1***	***41.12***	***51.87***	***16.40***
control kit	2.18	5.90	9.30	2.2	6.59	12.85	6.99
combined concentrate	***10.20***	***13.31***	***13.00***	***3.20***	***69.61***	***84.05***	***47.63***
Tails	89.80	0.66	0.28	0.40	30.39	15.95	52.37
Ore	***100.0***	***2.0***	***1.6***	***0.69***	***100.0***	***100.0***	***100.0***
Experiment No. 3 "SK-1" - 330g/t **							
Concentrate m /c	5.30	16.50	20.60	3.3	42.87	60.16	28.19
Pepper concentrate	2.70	17.80	13.00	2.4	23.56	19.34	10.44
tail pepper	6.30	1.80	0.63	1.1	5.56	2.19	11.17
total number of basics	***9.00***	***6.60***	***4.34***	***1.5***	***29.12***	***21.53***	***21.61***
control kit	3.80	3.40	0.77	1.3	6.33	1.61	7.96
combined concentrate	***18.10***	***8.83***	***8.35***	***1.98***	***78.32***	***83.30***	***57.76***
Tails	81.90	0.54	0.37	0.32	21.68	16.70	42.24
Ore	***100.0***	***2.04***	***1.8***	***0.62***	***100.0***	***100.0***	***100.0***

- in experiment No. 2, when using the foaming agent substitute SK-1 at a flow rate of 100 g/t , there was no foam in the inter-cycle flotation, so the flow rate was increased by another 50 g/t. Then the total blowing agent consumption was 240 g/t. - in experiment No. 3, the foaming agent consumption was increased in inter-cycle flotation to 200 g/t, in the main flotation to 100 g/t. The total blowing agent consumption was 330 g/t, instead of 190 g/t in the basic experiment with T-92. Gold recovery in flotation concentrate in basic experiment No. 1 with Oksal T-92 (NMMC) was 74.39%, with a concentrate yield of 10.81%, quality 14.38 g/t and a content in flotation tailings of 0.60 g/t. In experiment No. 3, when replacing T-92, the consumption of the reagent analogue of the SK-1 blowing agent was increased in the m/c operation to 200 g/t, and in the main operation to 100 g/t. With such a total reagent consumption of 330 g/t, the recovery of gold into the concentrate was higher by 3.93% (78.32%), due to an increase in the concentrate yield to 18.1%. At the same time, the quality of the flotation concentrate, the content of which was 8.83 g /t gold and the content in the flotation tailings was 0.54 g/t. When replacing the foaming agent Oxal T-92 to the analogue "SK-1" with an increase in reagent consumption from 190 g/t (basic experiment) to 330 g/t, due to an increase in the yield of concentrate, the extraction of gold into the concentrate was higher by 3.93% (78.32 %). Based on the results of experimental work on the enrichment and extraction of metals, it was revealed that the foaming reagents SK-1 and SK-2 in the process of ore flotation increase the yield of the main concentrate by 3-4%, the extraction of precious metals Au, Ag is 80-85%.

IV. CONCLUSIONS

Based on the experimental work carried out, the following conclusions can be drawn: the raw materials for the production of foaming reagents are industrial waste and are easily accessible and have positive technological characteristics. When using a foaming reagent at JSC NMMC, the concentrate yield increased by 3-4%, the extraction of precious metals (Au, Ag) amounted to 80-85%. Foaming agents are stable, they lower the surface tension of solutions and have the ability to re-foam.

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DECLARATION STATEMENT

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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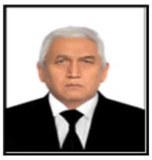

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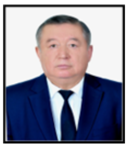

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