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Physical and chemical studies of finely-dispersed slurry tailings of the Donskoy Ore Mining and Processing Plant (DMPP) for chemical beneficiation to produce chromium concentrate

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Abstract. During the processing of chromium ores, chromite concentrate is obtained for the production of ferrochrome, and waste is also collected - tailings beneficiation. Fragment and sludge tailings depending on the beneficiation technology.

Finely dispersed sludge tailings of the Donskoy MPP of Kazchrome JSC are stored at the Dubersay and Akzhar tailings, which are man-made deposits (MMD) or man-made mineral formations (MMF). To develop a technology for processing sludge tailings, which contain up to 30% chromium oxide, their physical and chemical studies were carried out. According to the chemical analysis of sludge tailings, it follows that research should be directed to the removal of magnesium and silicon oxides, thereby increasing the content of chromium oxide to a standard chromium concentrate. A very thin dissemination of chromite with minerals of host rocks necessitates additional grinding of intermediate products, which are intergrowths of chromite with waste rock. According to the results of fractional analysis and IR spectroscopy, the content of a large number of flocculants in the studied sludge tailings and a large number of particles with a particle size of less than 20 μm, which, in heavy liquid solutions, due to its small size, is in suspension and does not stratify, was revealed. According to the granulometric composition, it was determined that the sludge minus 0.071 mm must also be classified into 0.04 and 0.02 mm and enriched each class separately.

It has been established that in order to obtain high technological performance, the traditional gravitational beneficiation scheme used at the DMPP is technologically cumbersome, because includes operations of flocculant disintegration, classification, grinding, beneficiation on concentration tables of each size class, regrinding of intermediate products. The results of the physicochemical study of chromium sludge tailings showed the need for a combined beneficiation scheme, including chemical enrichment with finishing of chromium concentrate by gravity beneficiation.

Keywords: *slurry tailings, mineralogical analysis, granulometric analysis, fractional analysis, chromium oxide*.

1. Introduction

At present, the technologies for gravity concentration of fine chromium raw materials used in the chrome industry are not sufficiently effective; therefore, it is required to improve process flows with the use of new advanced technological methods.

The long-term development of ore deposits associated with mining, concentration and smelting results in the accumulation of large amounts of waste in the form of stockpiled tailings and metallurgical slags, waste dumps of substandard ores and host rocks, industrial effluents, forming large-scale waste dumps and water settling ponds, i.e. technogenic mineral formations (TMF) [1-4].

Donskoy MPP (Kazchrome JSC, Aktobe region) has tailings mineral resources accumulated during its operation and subject to re-processing in the amount of about 0.4 million tonnes per year at the slurry tailings processing sites of Kazchrome JSC. Calculation of tailing mineral resources of the Donskoy MPP as of January 1, 2018, 2.2 million tons were considered with a content of 27.65% Cr_2O_3, which in terms of Cr_2O_3 is 0.6 million tons [5].

These reserves of technogenic mineral formations are comparable with natural deposits under the content of valuable components and represent an additional source of useful components, giving an increase in technical and economic parameters.

The main methods used to process chromite ores are gravity concentration processes. The Donskoy MPP uses settling and heavy medium ore minerals concentration processes to produce lumpy concentrate and beneficiation of fine grades in screw separators with the concentrate transferred to pelletizers to produce pellets [6-10].

Currently, poor chromite ores from different parts of the deposit and technogenic waste dumps are involved in processing; these ores can serve as additional sources of raw materials. The processing of slurry tailings from the Dubersay and Akzhar tailings storage facility is not sufficiently efficient, since the processing scheme includes a sequential classification scheme and beneficiation on screw separators, slurry concentration tables are used in the end of the scheme, and the flotation method of beneficiation is also experienced. The existing tailings concentration scheme is complex and does not consider the main principles of gravity concentration [11-19].

The main area of chromium and ferrochromium application is the smelting of alloyed steels, chromium bronzes and cast irons of special alloys. Corrosion-resistant steels and alloys can contain up to 30-40% Cr. The addition of up to 3% Cr to conventional carbon steels significantly improves their mechanical properties [20-22]. Steels containing 5-6% Cr are characterized by increased corrosion resistance. Steels undertake high corrosion resistance at 10% chromium content. According to a report from the U.S. Geological Survey, the world's chromium resources are concentrated in Kazakhstan, South Africa and India, which produce the bulk of the world's ferrochromium. The analysis of prices for ferrochrome suggests that all grades of ferrochromium are in demand and their prices are growing at a fairly high rate.

In this regard, it became necessary to perform study on the physical and chemical properties of fine sludge tailings for more efficient concentration and recovery of chromium oxide Cr_2O_3.

2. Materials and methods

2.1 Materials

Three process samples of slurry tailings from the Donskoy MPP were tested to study the chemical composition:

- Dubersai slurry tailings (big bag 1);
- Dubersai slurry tailings (big bag 2)
- Akzhar slurry tailings (big bag 3)

Samples No. 1 and No. 2 were represented by fine material in the form of slurry sands with a maximum particle size of 2 mm; Sample No. 3 included several pieces of 10 mm in the slurry material scooped up with the soil during sampling from the tailing's storage facility. Therefore, large grades of +1 mm were discarded prior to study as their presence reduced the Cr_2O_3 content in the original sample. The weight of each sample was 500 kg.

2.2 Methods of analysis

Methods of analysis: X-ray experimental data were obtained on a BRUKER D8 ADVANCE of BRUKER AXS GmbH (Germany) with the use of Cu-K radiation PDF2 International Center for Diffraction Data ICDD (USA) at an accelerating voltage of 36 kV, current of 25 mA.X-ray fluorescence analysis was performed on an AxiosPANalytycal wave dispersion spectrometer (Holland).

Chemical analysis of the samples was performed on an Optima 8300 DV inductively coupled plasma optical emission spectrometer (USA, Perkin Elmer Inc.). Mineralogical analysis was performed with a Leica DM-2500M polarization microscope in reflected light and a binocular magnifying glass with photography.Infrared spectroscopy was performed on an Avatar 370 CsI FTIR spectrometer.

3. Results and discussion

3.1 Chemical composition of sludge tailings from the Donskoy MPP

Three process samples of slurry tailings from the Donskoy MPP were studied. The samples were represented by fine material in the form of sludge with a maximum particle size of several pieces of 10 mm. The chemical composition of the sludge tailings was studied in the course of research.

The results of passport data of chemical analysis of samples of sludge tailings of the tailings of Dubersay and Akzhar of the Donskoy MPP are presented in Table 1.

Table 1. Chemical composition of original tailings according to Data Sheet for Samples

Sample	Mass fraction of elements, %						
	Cr_2O_3	SiO_2	AL_2O_3	CaO	MgO	FeO	S_{total}
Data Sheet for Sample No. 413 Dubersai	32.34	18.20	5.07	0.52	27.17	9.11	0.042
Data Sheet for Sample No. 414 Akzhar	29.26	18.98	5.69	0.47	28.17	9.69	0.031

The results of X-ray fluorescence analysis (elemental composition, semi-quantitative) are given for three samples in Table 2.

Table 2. Results of X-ray fluorescence analysis

Element	Content, %		
	Sample No. 1	Sample No. 2	Sample No. 3
O	41.576	45.872	46.996
Na	0.105	0.078	0.094
Mg	17.898	17.182	18.222
Al	1.450	1.379	1.112
Si	11.576	10.879	12.317
P	0.008	0.012	0.005
S	0.054	0.045	0.060
Cl	0.113	0.059	0.071
Ca	0.448	0.380	0.227
Ti	0.096	0.066	0.070
V	0.020	0.018	0.010
Cr	18.544	17.145	12.613
Fe	6.101	5.425	4.789
Co	0.020	0.014	0.012
Ni	0.241	0.218	0.194
Zn	0.014	0.016	0.009
Cr_2O_3	27.859	27.108	20.189

The chemical analysis showed chromium oxide content in original tailings from Dubersai tailings storage facility (samples No.1 and No.2) at the rate of 29-35%, and chromium oxide content in original tailings from Akzhar tailings storage facility - 20-23% that is connected with Kempirsai deposit development year and beneficiation technology of the Donskoy GOK and as consequence the stockpiling location in Dubersai or Akzhar tailings storage facilities.

The average chromium oxide content based on chemical analysis of accumulated sludge tailings at tailings storage facilities ranges from 20% to 35%.

According to the chemical composition in the sludge tailings of the Donskoy GOK, waste rock is represented mainly by silicon oxide 18.20-18.98% and magnesium oxides 27.17-28.17%. In a smaller amount, iron oxides 9.11-9.69% and aluminum oxides 5.09-5.69%. The total sulfur content is negligible.

According to the chemical analysis, it follows that it is necessary to direct research on the removal of magnesium and silicon oxides, thereby increasing the content of chromium oxide to a standard chromium concentrate.

3.2 X-ray phase analysis of slurry tailings

The results of the X-ray phase analysis are shown in Table 3, the diffractogram is shown in Figure 1.

Table 3. Results of semi-quantitative X-ray diffraction analysis

Name of the mineral	The formula	Concentration, %
Lisardite	$Mg_3(Si_2O_5(OH)_4$	57.4
Magnesiochromite	$(Mg,Fe)(Cr,Al)_2O_4$	33.2
Apophyllite	$KFCa_4Si_8O_20(H_2O)_8$	7.1
Chlorite	$(Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$	2.3

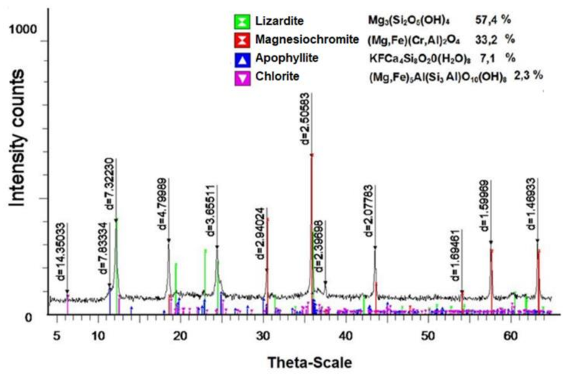

Figure 1. Diffractogram of slurry tailings

3.3 Mineralogical studies

The material composition of the tailings was studied with a Leica DM-2500M polarisation microscope in indirect light and with a binocular magnifier and photography. Polished sections were made by sealing the slurries in epoxy resin and then by their polishing in order to study the mineral composition of the ore under the microscope.

The mineralogical composition was studied at two size classes +0.071 mm and - 0.071+0.0 mm.

Mineralogical description of slurry tailings from Dubersai tailings storage facilities. Sample 1 (polished section 1/17, press.) of -0.071+0.0 mm fraction. When it was studied with a binocular magnifier, it can be seen that the ore is represented with a fine-grained aggregate consisting of a dusty grayish-brown mass and resin- black grains (probably chromospinelides) with the size of 0.025-0.071 mm (Figure 2).

Chromospinelide shots of about 10-20% were observed in the reflected light under a microscope (in the profile of the polished section, Sample 1). The shape of the grains was irregular, sharp, sometimes elongated, needle-shaped, with 0.035 to 0.07 mm grain size, in rare cases up to 0.21 mm. The colour in reflected light was greyish-white, isotropic (Figure 3).

Figure 2. Micrograph of -0.071 mm chromite ore: -0.071+0.0 fraction; bin. magnifier, 1 div. = 0.025 mm; polished section 1/17 (press.)

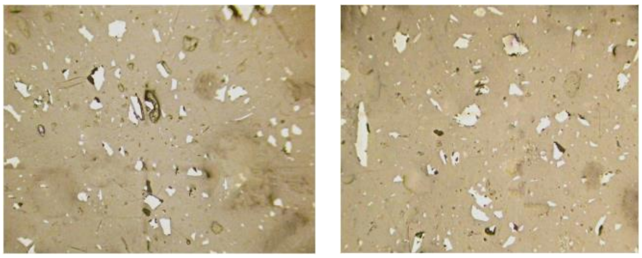

Figure 3. Micrograph of -0.071 mm chromite ore (Sample No. 1). Chromespinelide grain shots (white) in amorphous non-metallic mass (polished section 1/17 (press.), magn. 72)

A few grains up to 0.007 mm in size, light yellow, highly reflective, oval in shape with jagged edges (possibly sulphides) were found.

When Sample 2 with +0.071 mm fraction (polished section 2/17, press.) was studied under a binocular magnifier, a non-uniform composition of the sample, along with the main grain mass of relatively the same size, lumpy formations of larger size could be observed after sifting from dust particles. The main ore mass consists of lisardite grains, a layered silicate of serpentine group, greenish-gray in color, in the form of hidden crystalline mass or fine-grained aggregates.

The main ore mineral was chrompicotite, a magnesian variety of chromospinelides, observed as irregular, sharp-angled grains in the form of spherical segregations - modules (Figure 4b).

Octahedral crystals were rare. The colour was black to brownish black. The luster was metallic to greasy. Grains of apophyllite, a mineral from the group of hydromicas, pale green to yellowish-brown, were not uncommon. There were single flake-shrouded grains of yellowish-green chlorite, calcite, and fluorite (Figure 4a).

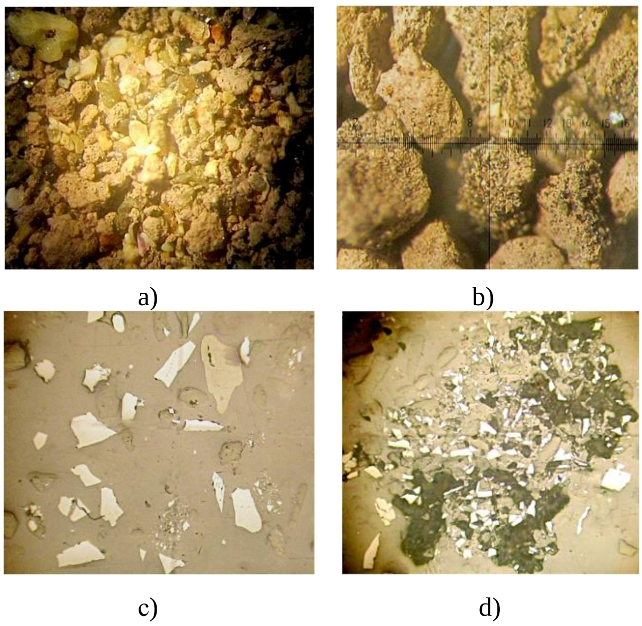

Figure 4. Micrograph of +0.071mm chromite ore (Sample No. 2): a - chromite ore of +0.071 fraction; b - hedgehog-like lumps with inclusions of chrompicotite grains (b) (bin. magnifier, 1 div. = 0.025mm) c - grains of chrompicotite (white) and chlorite (brownish-grey); d - hedgehog-like formations of lisardite with chrompicotite inclusions (white), polished section 2/17 (press.), magn.72

Besides the grains of relatively equal size, the ore contains hedgehog-like, semi-oval, greenish-grey formations, probably composed of a dense, fine-grained lisardite aggregate with brownish-grey chrompicotite inclusions. The size of these formations ranges from 0.25 to 1.0 mm, sometimes up to 2.0 mm. Chrompicotite inclusions range from 0.025 to 0.12 mm.

Irregularly shaped chrompicotite grains ranging in size from 0.07 to 0.24 mm, and chlorite grains, leaf-shaped, brownish-gray in colour with whitish-green internal reflexes were observed under the microscope in reflected light. Hedgehog-like, elongated lysardite formations with 0.2 mm chromospinelide inclusions were in the lower part of the polished section. Figure 5b shows a dense lysardite aggregate, 1.6 mm in size, with inclusions of chromopicotite grains, elongated, rectangular in shape, 0.05 mm in size.

The following conclusions were made based on the analysis of the original chromite tailings. The mineral composition of the slurry tailings, according to X-ray diffraction analysis and mineralogical studies, was represented by the following minerals: lisardite - 57.4%, magnesiochromite or chrompicotite - 33.2%, apophyllite - 7.1%, chlorite - 2.3%, olivine, fluorite.

A very thin dissemination of chrompicotite with minerals of host rocks necessitates additional grinding of intermediate products, which are intergrowths of chromite with waste rock. The regrinding process in the enrichment scheme is the most energy-consuming and leads to an increase in the cost of chromium concentrate.

3.4 Fractional analysis of slurry tailings

Fractional analysis by specific gravity was performed according to the method specified in paper [23]. Theoretically possible parameters of gravitational concentration of different size classes were determined by their stratification in «M-45» heavy liquid solutions into fractions with the density of more than 3.000 kg/m^3, less than 3.000 kg/m^3 and more than 2.850 kg/m^3, less than 2.850 kg/m^3. The resulting density fractions were washed from heavy liquid solutions, dried, weighed, and abraded for chemical analysis sampling. Fractional analysis was performed for particle size classes above 0.071 mm and below 0.071 mm. The coarseness class greater than 0.071 mm was stratified by a density of 3.000 kg/m^3. The results of the fractional analysis are shown in Table 4.

Table 4. Fractional composition and distribution of chromium oxide content

Density fractions, kg/m^3	Output, % of		Cr_2O_3 content, %	Extract from ore, %	Extract from class, %	Size class
	classes	ores				
+3.000	14.38	3.49	46.26	5.84	34.72	+0.071 mm class
-3.000	85.62	20.76	14.61	11.00	65.28	
Total	100.0	24.25	19.16	16.84	100.0	
+2.850	10.55	7.99	47.18	13.66	16.43	-0.071 mm class
-2.850	89.45	67.76	28.31	69.50	83.57	
Total	100.0	75.75	30.30	83.16	100.0	
Slurry tailings	-	100.0	27.60	100.0	-	+0.071-0.0 mm class

It follows from results of fractional analysis (Table 4) that it is possible to obtain heavy concentrate fraction in 3.49% of original raw material with chrome oxide content of 46.26% at 5.84% of original raw material recovery from +0.071 mm size class.

The heavy concentrate fraction with a chrome oxide content of 47.18% and recovery of 13.66% of the original raw material can be obtained from the -0.071 mm coarseness grade.

The poor technological results of the fractional analysis can be explained as follows:

- The large amount of flocculation agents in the sludge studied, i.e. the presence of cohesive chromium minerals and waste rock particles;

- The large number of particles below 20 μm suspended in heavy liquid solutions due to their small size and not stratified.

In practice, slurry parts of tailings in gravity concentration create a turbid environment and prevent the separation of coarse particles, so such feedstock must be divided into narrow size classes and further concentrated separately in each class.

3.5 Granulometric composition of slurry tailings

The granulometric analysis of DMPP slurry tailings based on sample data is shown in Table 5. The granulometric composition of slurry tailings was studied according to the methods [24-26] before the studies intended to determine their beneficiation. Due to the fact that the tailings were represented by fine slurry particles, the particle size distribution of tailings must be determined by sedimentation analysis (weeding method based on particles falling velocity in aqueous medium into the following size classes 0.071-0.041 mm, 0.041-0.020 mm, 0.020-0.010 mm and less than 0.010 mm).

The chrome slurries received for testing were subject to wet sieving (washing) on a 0.071 mm (71 micron) sieve. Table 6 shows the results of washing on a 0.071 mm sieve.

Table 5. Granulometric composition of slurry tailings according to Data Sheet for Sample

Size class, mm	Sample No. 413 Dubersai		Sample No. 414 Akzhar	
	Yield, %	Cr_2O_3 content, %	Yield, %	Cr_2O_3 content, %
+20	0.1	1.2	-	-
-20+16	0.1	1.2	-	-
-16+13	0.3	2.1	-	-
-13+10	0.3	4.9	-	-
-10+5	2.0	2.0	1.0	3.8
-5+3	1.1	6.3	0.6	3.8
-3+2	0.9	10.1	14.2	10.4
-2+1	0.9	10.1	5.4	16.7
-1+0.5	0.6	5.3	10.5	13.7
-0.5+0.2	1.8	17.4		
-0.2+0.071	9.0	35.7	24.3	29.6
-0.071+0.040	14.3	43.4	22.2	41.0
-0.40+0.026	10,8	45,5	9,8	43,0
-0.26	57.5	30.1	21.9	27.0
Total	100.0	32.34	100.0	29.26

Table 6. Results of wet sieving of slurry tailings

Name	Yield, %	Cr_2O_3 content, %	Cr_2O_3 distribution, %
Class + 0.071 mm	24.25	19.10	16.77
Class - 0.071 mm	75.75	30.55	83.23
Total	100.0	27.77	100.0

The results of the slurry tailings classification showed that the main amount of chromium oxide was concentrated in the particle size class less than 0.071 mm. The yield of this particle size class -0.071 mm was 75.75%, with a chromium oxide content of 30.55% with a distribution of Cr_2O_3 83.23%.

According to the granulometric composition, it is clear that the sludge minus 0.071 mm must also be classified into 0.04 and 0.02 mm and enriched each class separately. In production, it is very difficult to carry out such a fine classification of sludge. This means that the enrichment of sludge by standard gravity processes is difficult.

3.6 Flocculation agent disintegration study

When sedimentation analysis was performed for the tailing's samples, it was determined that the Donskoy MPP tailings received for research are treated with large amounts of organic flocculation agents which are very strongly adsorbed on the surface of mineral particles.

Flopam FW 926 flocculation agent which has high settling properties for thickening, is used at the DMPP. This agent is characterized in Table 7.

A flocculation agent is used for rapid thickening of the fine chromium slurry fractions in the tailings feeding process to tailing storage facility [27]. The approved flocculation agent consumption rate at Donskoy MPP is 0.07 kg per ton of slurry tailings. But a turbid discharge is formed due to poor operation of thickeners at slurry tailings and discrepancy between the volume of tailings and the thickening area. Such discharge is clarified by increased flocculation agent consumption at the plant. It was adversely affected by the tests, as the flocculus formed from the chromite grains and the waste rock prevented their separation.

Three samples were analyzed with IRS for polymers and organics.

Table 7. Flopam FW 926 flocculation agent characteristic

Name	Parameters
Chemical compound	Acrylamide and sodium acrylate copolymer
Appearance	White powder
Ionicity	Anionic
Molecular weight	Medium
Brookfield viscosity, cP 5.0 g/dm^2 2.5 g/dm^2 1.0 g/dm^2	 1,600 600 200
Granulometry % of particles > 10mesh (2mm) % of particles > 100mesh (0.15mm)	 No more than 2 No more than 6
Recommended working concentration, g/dm^2, %	0.05
Maximum concentration, g/dm^2, %	0.5
Dissolution time in distilled water at a concentration of 5g/dm^2 and t=25°C, min	90
Solution stability in distilled water, days	1

The results of the IRS analysis of the samples:

IR method: Spectra were obtained on an Avatar 370 CsI FT-IR spectrometer in the spectral range 4.000-400 cm^{-1} from tablet preparations obtained by pressing 2 mg of sample with 200 mg of KBr. Experiment attachment: Transmission E.S.P

Sample 1, (Figure 5).

The sample contained a Brugnatellite type compound - $Mg_6Fe(CO_3)(OH)_{13} \cdot 4H_2O$ – 3.687, 3.650, 1.429, 1.077, 1.015, 956, 551, 439 cm^{-1}.

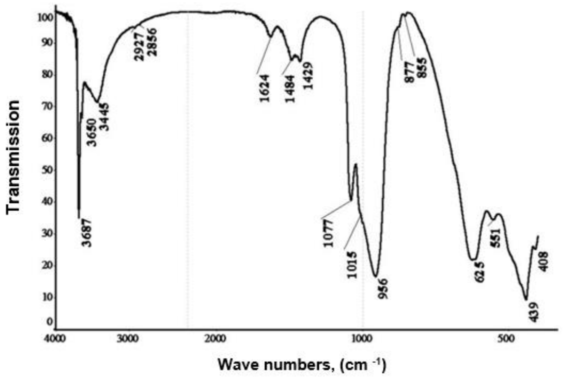

Figure 5. Infrared spectrum of sample 1

Group $[CO_3]_2$- -1.484, 1.429, 877, 855 cm^{-1}.

The band with a maximum at wave number 625 cm^{-1} fell into the region of Fe^{3+} - O bonding in silicates and carbonates.

Valence vibrations ν(OH) – 3.445 cm^{-1} and strain vibrations δHOH-1.624 cm^{-1} of water molecules.

The absorption bands of the valence vibrations of the methylene groups ν CH2 – 2.927, 2.856 cm^{-1}.

Sample 2, (Figure 6).

The sample contained Brugnatellite type compound - $Mg_6Fe(CO_3)(OH)_{13} \cdot 4H_2O$ – 3.684, 3.646, 1.431, 1.078, 1.015, 957, 551, 440 cm^{-1}.

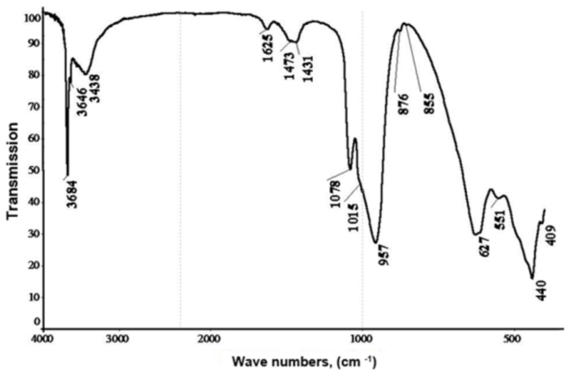

Figure 6. Infrared spectrum of sample 2

Group $[CO_3]_2$- - 1.473, 1.431, 876, 855 cm^{-1}.

The band with a maximum at wave number 627 cm^{-1} fell into the region of Fe3+ - O bonding in silicates and carbonates.

Valence vibrations ν(OH) – 3.438 cm^{-1} and strain vibrations δHOH-1.625 cm^{-1} of water molecules.

Sample 3, (Figure 7).

The sample contains BRUGNATELLITE type compound - Mg6Fe(CO3)(OH)13 · 4H2O – 3.687, 3.650, 1.430, 1076, 1016, 955, 557, 440 cm^{-1}.

Group $[CO_3]_2$- - 1.489, 1.430, 876, 855 cm^{-1}.

The band with a maximum at wave number 614 cm^{-1} fell into the region of Fe^{3+} - O bonding in silicates and carbonates.

Valence vibrations ν(OH) – 3.437 cm^{-1} and strain vibrations δHOH-1.624 cm^{-1} of water molecules [27, 28].

Figure 8 compares the spectra which show the varying content of carbonate, oxide and possibly silicate phases in Samples 2, 3 and 4.

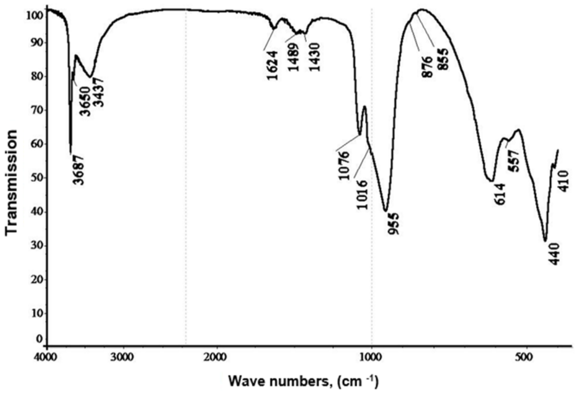

Figure 7. Infrared spectrum of Sample 3

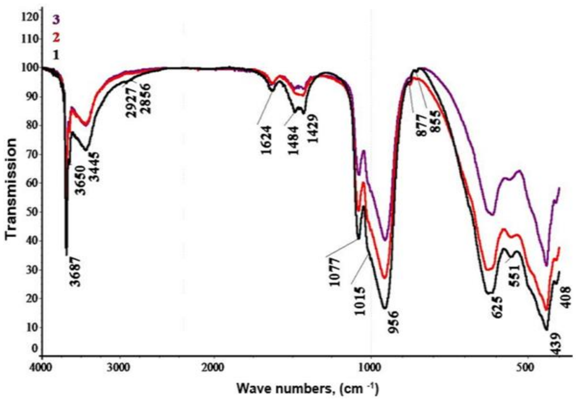

Figure 8. Infrared spectra in Samples 1, 2 and 3

According to IR spectroscopy, the organic part of the flocculants is identified by absorption bands of stretching vibrations of methylene groups ν CH_2 - 2927, 2856 cm^{-1}, which indicates the adsorption of flocculants on the surface of fine particles of tailings. In this regard, tests were performed on various options to repulp slurry tailings in order to remove flocculation agents from the surface of the test material or to destroy existing floccules. The following tests, shown in Figure 9, were performed.

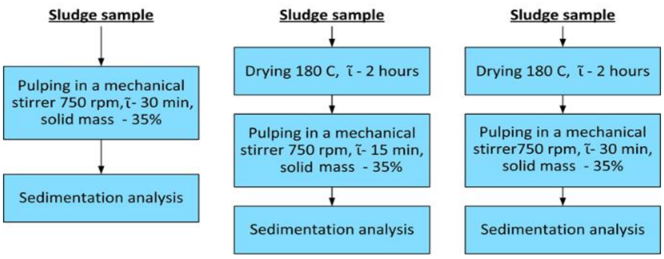

Figure 9. Preparation of slurry tailings for sedimentation analysis

Sedimentation analysis was performed after the above-mentioned repulping types. The results of all tests showed rapid and simultaneous settling of all solids. Sedimentation took place within 5-6 seconds with the formation of a clear drain.

All tests effectively remove the flocculation agent from the surface of the slurry particles. It is economical to use the mechanical method in agitator vats or scrubber drums in production.

4. Conclusions

Physical and chemical studies of the finely-dispersed slurry tailings of the Dubersai and Akzhar tailings storage facility of the Donskoy MPP showed:

1. The mineral composition of the slurry tailings, according to X-ray diffraction analysis and mineralogical studies, is represented by the following minerals: lizardite-57.4%, magnesiochromite or chrompicotite - 33.2%, apophyllite - 7.1%, chlorite - 2.3%, olivine, fluorite. Waste rock minerals have many minerals containing magnesium which can be isolated by chemical concentration methods.
2. A very thin dissemination of chrompicotite with minerals of host rocks necessitates additional grinding of intermediate products, which are intergrowths of chromite with waste rock. The regrinding process in the enrichment scheme is the most energy-consuming and leads to an increase in the cost of chromium concentrate.
3. According to the fractional analysis the gravity extraction of chromium oxide from the fine particle size classes is difficult.
4. Based on the particle size distribution it was found that chromium oxides are concentrated mainly in the fine particle size classes. Of the very fine particle classes of slurry tailings, gravity concentration is not effective on screw separators and concentration tables without prior classification of the tailings.
5. Waste rock minerals (magnesium, aluminium, silicon, etc.) are effectively leached from the finely-dispersed slurry tailings to produce a rich chrome product.
6. Chemical concentration eliminates the operations of flocculation agent disintegration, the classification of original tailings into size classes and the grinding of intermediate products. These operations increase the complexity of the apparatus chain and lead to an increase in operating and capital costs.
7. Based on the above studies of chrome slurry tailings from the Donskoy MPP, the conclusion is that it is necessary to conduct concentration studies with the use of combined concentration methods: chemical concentration that leaches out the waste rock minerals and gravity concentration to bring the chrome product to conditioned chrome concentrate.

Conflict of interest

The corresponding author declares that there is no conflict of interest on the part of all authors.

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Дөң КБК-ның ұсақ дисперсті шлам қалдықтарының байыту шарттарын анықтау үшін физикалық-химиялық зерттеулері

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Аңдатпа. Хром кендері нөңдеу кезінде феррохромды өндіру үшін хромит концентраты алынады, сонымен қатар байыту қалдықтары пайда болады. Байыту технологиясына байланысты кесек және шламды қалдықтар пайда болады.

АҚ "Қазхром" Дөң КБК-нің жұқа дисперсті шламды қалдықтары техногендік кен орындары (ТКО) немесе техногендік минералды түзілімдер (ТМТ) болып табылатын Дуберсай және Ақжарқалдық қоймаларында жиналады. Құрамында 30%-ға дейін хром оксиді бар шламды қалдықтарды өңдеу технологиясын әзірлеу үшін олардың физика-химиялық зерттеулері жүргізілді. Суспензия қалдықтарын химиялық талдауға сәйкес, зерттеулерді магний мен кремний оксидтерін жоюға бағыттау керек, осылайша хром оксидінің құрамын кондициялық хром концентратына дейін арттыру керек. Хромпикотиттің тау жыныстарының минералдары өте ұсақ бос тау жыныстары өсінділерімен байланысқандықтан, аралық өнімдерді қосымша ұнтақтауды қажет етеді. Фракциялықталдау және Х-спектроскопия нәтижелері бойынша зерттелетін шламды құйрықтардағы флокулянттардың көпмөлшері және көлемі 20 мкм-ден аз бөлшектердің көпмөлшері анықталды, ол ауырсұйықтықтың ерітінділерінде өзінің шамалы мөлшеріне байланысты суспензияда болады және қабыршақтанбайды. Гранулометриялық құрамы бойынша минус 0.071 мм шламдарды 0.04 және 0.02 мм-ге жіктеп, әр сыныпты бөлек байыту керек екендігі анықталды.

Жоғары технологиялық көрсеткіштерді алуүшін DӨҢ КБК -та қолданылатын дәстүрлі гравитациялық байыту схемасы технологиялық тұрғыда науырекендігі анықталды, өйткені ол флокулянтты ыдырату, жіктеу, ұнтақтау, әр класс концентрациялық үстелдерінде байыту, аралық өнімдерді ұнтақтау операцияларын қамтиды. Шламды хром қалдықтарын физика-химиялық зерттеу нәтижелері хром концентратын гравитациялық байыту мен жақсарта отырып, химиялық байытуды қамтитын аралас байыту схемасын қолдану қажеттілігін көрсетті.

Негізгі сөздер: *мембрана, ниобий, сутегі өткізгіштігі, Сивертс заңы, дилатация, термиялық кеңею коэффициенті, фазалық ауысулар.*

Физико-химические исследования тонкодисперсных шламовых хвостов Донского ГОКа для определения условий их обогатимости

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Аннотация. При переработке хромовых руд получают хромитовый концентрат для производства феррохрома, а также образуются отходы – хвосты обогащения. В зависимости от технологии обогащения образуются кусковые и шламовые хвосты.

Тонкодисперсные шламовые хвосты Донского ГОКа АО «Казхрома» складируются на хвостохранилищахДуберсай и Акжар, которые являются техногенными месторождениями (ТМ) или техногенными минеральными образованиям (ТМО). Для разработки технологии переработки шламовых хвостов, в которых содержится до 30% оксида хрома, проведены их физико-химические исследования. По данным химического анализа шламовых хвостов следует, что исследования необходимо направить по удалению оксидов магния и кремния, тем самым повышая содержание оксида хрома до кондиционного хромового концентрата. Весьма тонкая вкрапленность хромпикотита с минералами вмещающих пород обуславливает необходимость доизмельчения промежуточных продуктов, которые являются сростками хромита с пустой породой. По результатам фракционного анализа и ИКС-спектроскопии было выявлено содержание большого количества флокулянтов в исследуемых шламовых хвостах и большое количество частиц крупностью менее 20 мкм, который в растворах тяжелой жидкости в виду своего незначительного размера находится во взвешенном состоянии и не расслаивается. По гранулометрическому составу определено, что шламы минус 0.071 мм необходимо еще классифицировать на 0.04 и 0.02 мм и обогащать каждый класс отдельно.

Установлено, что для получения высоких технологических показателей используемая на ДГОКе традиционная гравитационная схема обогащения является технологически громоздкой, т.к. включает операции дезинтеграции флокулянта, классификации, измельчения, обогащения на концентрационных столах каждого класса крупности, доизмельчения промежуточных продуктов. Полученные результаты физико-химического исследования шламовых хромовых хвостов показали о необходимости применения комбинированной схемы обогащения, включающей химическое обогащение с доводкой хромового концентрата гравитационным обогащением.

Ключевые слова: *шламовые хвосты, минералогический анализ, гранулометрический анализ, фракционный анализ, оксид хрома.*

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