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Investigations on Material Composition of Iron-containing Tails of Enrichment of Combined Mining and Processing in Kursk Magnetic Anomaly of Russia

K. R. Argimbaev*, D. N. Ligotsky, K. V. Mironova, E. V. Loginov

Faculty of Mining, Saint Petersburg Mining University, St. Petersburg, Russia Federation

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ABSTRACT

The inevitable depletion of mineral resources, the constant deterioration of the geological and mining conditions for the development of mineral deposits and the restoration of raw materials from mining waste by recycling are all urgent problems we faced today. The solution to this problem may ensure: a considerable extension of raw material source; decrease of investments in opening new deposits; cost savings for dumping and handling of tailing dumps, disturbed land remediation; obtaining social and economic effect due to a considerable reduction in pollution of the environment. This article deals with the study of iron-containing tailings dumped at the tailing dumps of ore-refinery and processing facilities located in Kursk Magnetic Anomaly (KMA GOKs), where samples were taken for this study. The article contains the results of the materials composition study, namely: chemical composition, the mineral-petrographic study of thin and polished sections, grain size distribution and physical-mechanical properties of tailing samples. Regularities were revealed for the change of the useful component content due to gravity differentiation. It was also noted that the sulphur content increased near the pulp discharge outlet due to pyrite accumulation. The ratio of ore minerals in tailings and the fineness ratio of the sand fraction were measured. The examination with a focused beam microscope with x90 to x600 magnification showed a variety of grain sizes and shapes that facilitate using tailing materials after additional processing in the construction industry as sand.

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1. INTRODUCTION

Processing of wastes from ore-refining facilities that accumulate at tailing dumps is among the major issues in complex treatment of mineral resources, environmental protection and remediation [1-3].

The idea of processing tailing was first conceived at the beginning of the 20th century in the 80s [4]. This idea is still being developed till date. Its main tasks comprise of the disposal of mining and metallurgical waste, development and implementation of measures toward considerable loss decrease and increase of the mineral recovery quality during ore mining and processing [5-10]. Despite the available vast technical potential and scientific-methodological background, efficient flowcharts for valuable component recovery from mineral processing waste have not been substantiated yet [11-15]. Big interest in elaboration technogenic formations started to manifest at the same time with new recycling technologies emergesing and partial depletion of large field.

Many investigators [9-15] have searched on process to systemize subsoil explorations and rationally resourse using potential techniques. The best scholars in this area were Trubetskoy et al. [11] and Trubetskoy [13] academician of russian science academy. They were the first who systemized and categorized the technological fields and process formations. The results of systems approaching to the questions about systemised subsoil explorations are:

- The intelligent method of subsoil explorations at the non-ferrous and ferrous metallurgy enterprises was generalized.

*Corresponding Author Institutional Email: *diamond-arg@mail.ru* (K. R. Argimbaev)

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- The features of the internally structure and spatial variabillity of useful components content were identifieded.
- The recommended intelligent methodogy for evaluation of technological fields were designed. Also it includes the forecasting method spatial variabillity of useful components content in tailings, which is based on information about aprobaration.
- The economical feasibility of using perspective metalic and nonmetalic minerals was studied.
- The economic and mathematical model and softwere were developed. It helped us to optimize the volume of using different metalic and nonmetalic technological raw materials, to determine minimal industrial content which are useful components in balance stocks. Besides, to make a choise more effective directions to use technological raw materials and technological circuits of the process development.

Complex aggregate circuit of complex development technological mineral recourses which covers all stages: from intelligent till finished product. That is used to devide to connected cybsystems [8-15]:

- Geo-technological scrutiny.
- Techno-economical assessment and grounding the conditions.
- Designing the technological fields.
- Recycling of the raw minerals.
- Targeted formation of technological field with adjusted parametrs and specifications.
- Ground recultivating which were destroyed by technological fields.

Two independent directions were made by virtue of analysis of this subsystems:

- Familiarization of two technological formations.
- Making technological fields with adjusted parametrs and in view of this issue we have the following exploration.

Research and calculations which are made by different laboratories in the world, shows us the principal possibility to work off and complex rework ferrous tailings. But we may ascertay that fundamental switching over principles of transiting to the low-waste technologies, which can promote developing minerals fields through technological fields formation, and also development of current technological formations [14-29].

In spite of extensive theoretical capacity, effective technological circuit of extraction useful components weren't unfounded.

Since the issue of processing man-induced deposits formed by tailing dumps of ore-dressing facilities is the nearest future problem. The study of the material composition of iron-containing tailings formed at ore-refining and processing facilities of Russian Kursk Magnetic Anomaly is required a very long duration of time research. It will provide the ground for further scientific study dedicated to highly efficient processing ensuring minimal loss of useful components with waste.

2. NOVELITY RESEARCH AND PRACTICAL VALUE

The novelity of this research work is to establish the scientific approach to regulate and handling the enrichment of magnetite-containing tails. It depends on the content rating -0.044 mm in them, which makes it thus to tedermine optimal number 15 25% in which enrichment indicators are maximal.

The practical value of the work reflects that the main results have been used to design the processing enrichment tails.

3. METHODS

The objective of this work was to enrich substances of iron content and to justify the opportunity of using technological fields which are based on wasting results from enrichment Kursk Magnetic Anomaly (KMA GOKs). Such issues were adressesed during the process:

- Due to statistical analysis for the information in processing about quality and quantity of taillings.
- Recearch conducted on substances enrichment tails.
- Identification of the kind relationship of composition and enrichment.

To solve the tasks, research was carried out in three stages: field, laboratory and analytical parts. In the field period, gross samples were taken weighing 40-50 kg of waste from the taillings of GOKs: at Lebedinskiy Ore-Refinery and Processing Facility (LGOK) - 6 samples, at Stoilensky Ore-Refining and Processing Facility (SGOK) - 4 samples, at Mikhailovsky Ore-Refinery and Processing Facility (MGOK) - 6 samples. Samples were taken at different distances from the pulp outlet. That is due to the formation of spatially isolated sections of large fractions, as well as fractions with a high iron content in large taillings especially with unilateral discharge of pulp and to a lesser extent with contour. Taillings of Kursk Magnetic Anomaly (KMA GOKs) have all the prerequisites for the formation of such sites. As a result of the gravitational differentiation of the solid part of the pulp, the stored material is redistributed into the taillings dump and areas near the pulp outlets are formed with an increased iron content (compared to other taillings storages dump sections).

Significant influence at the iron lossing and enrichment tails render: imperfection of the existing technology for the enrichment of quartzite, which leads to incomplete extraction of iron in concentrate; such as emergency equipment shutdowns, especially during commissioning, accompanied by as a rule, by emergency discharges of enrichment products with an abnormally high iron content; imperfection or lack of schemes for the disposal and capture of spills and industrial wash products; insufficient organization production and low qualification staff.

During the analytical phase, quantitative and qualitative statistics were collected about enrichment tails, their use and recommendations were made for further use in tails, in various industries. The researching were carried out on certified equipment manufactured in the USA, Australia, Japan and Russia according to international standard methods. Chemical analyzes are performed in accordance with current GOSTs. Technological tests were carried out according to standard enrichment schemes, taking into account characteristics of the material composition of the enrichment tails.

4. RESULTS

4. 1. General Information about Deposit and Tailings of KMA

The Kursk Magnetic Anomaly (KMA) is the most powerful iron ore basin on earth, where KMA mining and processing plants (GOKs) are located. In mineralogical terms, the ores in the deposit are two-component or three-component formations consisting the hematite (and its morphological variety - martite), magnetite (and its morphological variety - musketovite), goethite, less often hydrohematite and carbonates. Minor minerals are: berthierin, chamosite, apatite, quartz, mica. Hematite is often hydrated in red cystral formation, sometimes brown, iron hydroxides, often staining ores in red and brown; the content in such interlayers of various hydroxides is very different.

The prevalence of mushy ores (hematite varieties) increases in those places where gentle paleoscopes along quartzites are noted. By genetic characteristic, all the minerals of weathering zone (oxidation) quartzites are divided into three groups: 1) relict, metamorphogenic - hematite, magnetite, quartz; 2) weathering minerals - martite, goethite, hydrohematite, hematite, berthierin (chamosite), marshall; 3) infiltration - siderite, calcite, glandular chlorite, pyrite, marcasite and iron hydroxides.

Among them, ore-forming ones are hematite, martite, goethite, hydrohematite and magnetite; minor - carbonates, chamosite (ferrous chlorite and berthierin) and quartz. A complex structures and equipment for hydraulic transport and hydraulic tailing of enrichment tails plants exists for the storage of enrichment waste at GOKs.

To store the wasting production of the ore processing plant, GOKs use large capacities of natural formations - ravine beams with the construction of dams and enclosing dams - tailings. Tailings ponds are filled in the initial period of GOKs operation by gravity hydraulic transport with subsequent application as production capacities increase and volumes of taillings pressuring hydraulic conveyors are increased by gradually increasing the length of slurry pipelines and dumping tails around the taillings perimeter.

4. 2. Tailings Chemical Composition Study

The process of the material composition tail's scrutiny for the gerruginous quartzites enrichment whick were taken from taillings KMA GOKs which was consisted of two sequentially carried out operations: taking an average sample from a certain amount of the mass of the product being tested; laboratory analysis of the sample substance. To obtain an average laboratory sample, the initial ore was crushed, mixed and reduced to the minimum allowable mass. The prepared chemical samples were subjected to spectral, chemical analyzes (according to the content of the main rock-forming oxides (SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O and Fe_{total}, $Fe_{mag.}$).

The results of the chemical composition of the initial samples are summarized in Tables 1-3.

Tables 1-3 show that the tailings chemical composition is caused by the initial rock properties. All tailings contain silicon dioxide SiO_2, iron oxide Fe_2O_3, and ferrous iron FeO as basic components.

Silicon dioxide content in Stoilensky and Lebedinsky tailings varied from 47.50 to 75.08%; mill tailings of Mikhailovsky GOK featured lower SiO_2 content. Mostly, silicon dioxide was bonded with quartz, and only a small part of constituted silicates. The highest content silicon dioxide was in SGOK tailings (up to 75.08%), the lowest – in MGOK tailings (up to 36.13%).

Iron oxides formed ore minerals – magnetite and hematite. Silicates contained small amounts of iron oxides. Their ratio in mill tailings was different. The highest Fe_2O_3 content was typical for MGOK tailings (39.91 to 38.12%) where hematite prevailed. LGOK tailings featured high FeO content (6.26 to 10.71%), it

TABLE 1. Chemical composition of mill tailing initial samples taken at LGOK, %

Components	ChVL-1	ChVL-2	ChVL-3	ChVL-4	ChVL-5	ChVL-6
SiO_2	67.58	68.02	66.37	54.07	65.77	65.47
Al_2O_3	1.98	2.04	1.77	2.36	3.37	3.60
Fe_2O_3	10.18	9.91	10.75	18.24	8.56	8.26
FeO	7.18	6.26	7.35	10.71	7.14	7.30
MgO	3.50	3.96	3.70	2.93	4.61	4.24
CaO	2.58	3.08	3.37	2.50	2.65	2.86
Na_2O	0.67	0.65	0.67	1.21	1.11	1.08
K_2O	0.44	0.45	0.49	0.70	0.72	0.75
Other	5.30	4.70	4.89	6.05	5.23	5.50
Total	99.41	99.07	99.07	98.77	99.16	99.06
Fe_{total}	12.70	11.76	13.09	21.07	11.53	11.45
$Fe_{mag.}$	3.02	2.18	3.17	8.06	2.10	2.0

TABLE 2. Chemical composition of tailing initial samples taken at SGOK, %

Components	ChVS -1	ChVS -2	ChVS -3	ChVS -4
SiO_2	63.89	71.63	47.50	75.08
Al_2O_3	3.13	1.84	1.92	2.69
Fe_2O_3	16.62	9.85	32.44	6.93
FeO	5.90	4.79	7.03	5.04
MgO	2.11	2.95	2.10	2.18
CaO	2.07	2.55	2.05	2.18
Na_2O	0.58	0.39	0.41	0.54
K_2O	0.77	0.53	0.49	0.73
Other	5.05	4.94	5.59	4.46
Total	100.36	99.92	100.05	100.19
Fe_{total}	16.20	10.61	28.15	8.76
$Fe_{mag.}$	1.65	1.14	4.02	1.13

TABLE 3. Chemical composition of mill tailing initial samples taken at MGOK, %

Components	ChVM -1	ChVM -2	ChVM -3	ChVM -4	ChVM -5	ChVM -6
SiO_2	47.48	51.75	36.13	42.28	33.84	47.46
Al_2O_3	0.04	0.07	0.07	0.04	0.14	0.04
Fe_2O_3	44.69	39.91	56.76	50.21	58.12	44.36
FeO	2.90	3.38	2.91	3.10	3.57	3.20
MgO	0.82	0.82	0.91	0.97	0.97	1.12
CaO	0.98	0.98	0.68	0.68	0.68	0.68
Na_2O	0.50	0.55	0.49	0.55	0.56	0.60
K_2O	0.44	0.40	0.33	0.37	0.32	0.38
Other	2.01	2.40	1.85	1.96	2.0	2.25
Total	99.86	100.6	100.3	100.6	100.2	100.9
Fe_{total}	33.5	30.5	41.9	37.5	43.4	33.5
$Fe_{mag.}$	1.78	1.58	1.94	2.19	2.5	1.74

was somewhat less in SGOK tailings (5.04 to 7.03%). Aluminium oxide Al_2O_3 as a component of mica, feldspar, amphiboles was in LGOK and SGOK mill tailings in approximately equal amounts (1.84 to 3.6%). Its content is minor in MGOK tailings – hundredths of a percent. The rest of the components – CaO, MgO – prevailed in LGOK tailings (1.77 to 3.60%). Na_2O and K_2O content was approximately the same for all tailing sites.

The regularities in the component content change were caused by gravity separation; they were similar for Lebedinsky and Stoilensky tailing dumps – iron-containing minerals (magnetite, hematite) accumulate near the pulp discharge outlet while the content of SiO_2 (pure quartz without joints), CaO, MgO, K_2O, Na_2O (silicates, amphiboles, carbonates) increases in remote areas.

Increased sulphur content due to pyrite accumulation was also noted near the discharge outlet.

4. 3. Tailings Mineralogical-Petrographic Study

Thin and polished sections of tailings were studied in transmitted and reflected light using EM3900M microscope.

Visually, LGOK and SGOK mill tailings were dark grey mineral of varied grain sizes, MGOK tailings were dark-brown. Grain size varied 5 mm to -0.05mm.

Tailing material composition was caused by mineral composition of the initial ore, specific features of the refining process and the nature of the material separation during the tailing dump filling.

Coarse fractions +5 mm, +2.5 mm were represented by ferrous quartzite fragments with amphibole-quartz composition with magnetite impregnations. Fine fractions were represented by separate minerals. Basic ore minerals comprised of magnetite, hematite; barren minerals – quartz, amphiboles, mica, carbonates, feldspar. Auxiliary minerals were represented by ilmenite, rutile and apatite.

Quartz was the main mineral that formed tailings; its content in samples varied from 35.0% (ChVM-3) to 58.4% (ChVL-2). Sample ChVS-3 was the exception, its quartz content was low – 27.3%. Quartz presented as sharply-angular irregular fragments with magnetite impregnations (Figure 1a). In finer fractions, quartz had round shape and virtually did not contain ore impregnations. Magnetite was the main ore mineral, which was presented as impregnations in quartz grains, in silicates, less often – as separate thin interlayers in ferrous quartzite fragments. The free magnetite amount increased with the fraction size decrease. Crystals had regular isometric shapes (Figure 1b).

Hematite was presented in two varieties: as fine impregnations in quartz and as small tabular flakes.

The second hematite variety was typical for Mykhailovsky tailings. Here, hematite contained in all fractions: as aggregates with irregular shape with translucent ruby-red edges (Figure 1c) in coarse fractions and as separate flakes of regular shape in fine ones. Most often, hematite was found as shots in green mica. Hematite content in MGOK tailings was 39 to 53.5%.

Mica existed of two minerals. Biotite-phlogopite type mica was typical for Lebedinsky and Stoilensky deposits. It formed black aggregates in coarse fractions and separate round or long tabular brown flakes in fine ones. Magnetite impregnations were rarely observed in biotite. Green mica was typical for the tailings of Mikhailovsky deposit. Fine fractions contained mica as dissipated lath-like emerald-green flakes; it often contained hematite impregnations.

Amphiboles existed as cummingtonite, alkaline amphibole, riebeckite, actinolite. Crystals had elongated prismatic or tabular shape with uneven edges at end faces (Figure 1d). Polysynthetic twins were typical for cummingtonite.

Carbonates presented as two minerals: yellow-brown ferrous siderite with ore impregnations and white dolomite with pearly lustre. Crystal shape was irregular, most often round. Pyrite had golden-yellow colour with tarnish, with irregular grains; its content was 0.5 %. Apatite, ilmenite, rutile were met as single auxillary minerals.

There was the following specific ratio of ore minerals: LGOK tailings featured the highest magnetite and low hematite content; SGOK tailings contained somewhat less magnetite (2.9 to 5.2%). However, discharged materials contained significant magnetite amount (2.1 to 3.3%) and maximum hematite amount (35 to 53.5 %).

Since samples were taken in the tailing dumps at different distance from discharge outlets, grain size distribution within one site considerably differed.

Grain size distribution in the initial material had the following specific features: most fine tailings material formed fraction -0.14 mm; the rest small portion was distributed between fractions -0.315+0.14 mm and -0.630+0.315 mm. The majority was distributed between fractions -0.315+0.14 mm and -0.63+0.315 mm with the material prevailing in the first one. As a rule, the main part of coarse tailings was formed by -0.315+0.14 mm and -0.63+0.315 mm fractions. LGOK and SGOK tailings were less uniform in terms of grain size, while MGOK tailings feature more uniform material distribution by grain structure.

Fineness ratio of the tailing sand fraction (i.e., fraction -5+0.14 mm) varied: 1.06 to 2.45 (average value 1.75) for LGOK, 1.12 to 2.57 (average value 1.85) for SGOK, and 1.69 to 2.79 (average value 2.24) for MGOK.

Sand fraction yield varied within 4.6 to 77.5 % for LGOK tailing dump, 10.2 to 80.8 % at SGOK dump and 48.5 to 77.1% at MGOK dump.

Thus, sand fraction of tailings was attributed to fine (fineness modulus < 2), middle (fineness modulus =2.0 to 2.5) and coarse sand (fineness modulus > 2.5) in terms of fineness ratio, which are suitable for construction works according to GOST 8736-2014 Sand for Construction Works. Specifications (Russia).

Tailing examination under the focused beam microscope has shown the presence of mineral particles ranging from less than a micron to several hundred microns (Figure 1e) in size. Quartz grains shape varied, but isometric sharply-angular particles prevailed. Elongated prismatic particle shape was less common (Figure 1f).

Elongated, prismatic, flaky particles were found more often in MGOK tailings. A detailed study of the mineral grain surface topography for the mill tailings at KMA GOKs showed that it had changed significantly due to shock loads during ferrous quartzite crashes. Grain surface is rough, irregular, with numerous defects (Figure 1g). Natural sand has even and smooth surfaces, with rare pits and cavities (Figure 1h).

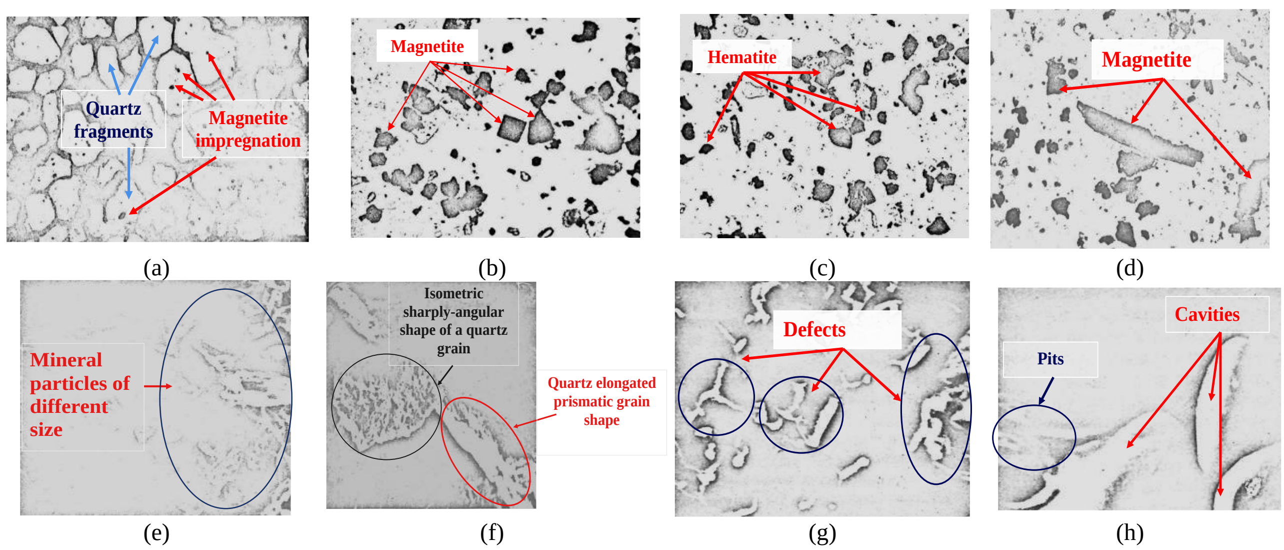

Figure 1. Scanning electron microscopy results: a - quartz grains with magnetite impregnations (Sample ChVM-2, Quartz is grey, magnetite is black. Transmitted light, x125 magnification); b - magnetite automorphic shape (Sample ChVL-2. Transmitted light, x125 magnification); c - fine hematite impregnations in green mica (Sample ChVM-6. Transmitted light, x 200 magnification); d - alkaline amphibole with magnetite impregnations (Sample ChVS-3. Transmitted light, x150 magnification); e - Lebedinsky GOK tailings (Sample ChVL-5. Transmitted light, x190 magnification); f - topography of quartz grain surface at Mikhailovsky GOK (Sample ChVM-5. Transmitted light, x190 magnification); g - the surface of the tailing quartz grain (Sample ChVS-1. Transmitted light, x600 magnification); h - Volsk sand deposit (Sample 1. Transmitted light, x450 magnification)

Specific features of grain micro-pattern for tailings caused their increased adhesive ability as compared with traditional sand. In this connection, using tailings as fine filler for concrete should ensure an additional increase in concrete strength due to better adhesive bonds with a binding agent.

The examination of polished samples of tailings with Epiquant structural analyser has shown that magnetite particle linear sizes were 20.0 µm to 42.9 µm (average value 30.1 µm) for LGOK tailings, 21.3 µm to 44.3 µm (average value 39.4 µm) for SGOK and 14.4 µm to 34.1 µm (average value 22.2 µm) for MGOK. It followed that the most coarse magnetite was contained in SGOK tailings while the fine one – in MGOK tailings.

Analysis of the samples taken from well No. 2 at LGOK has revealed that magnetite particles of 44.5 µm to 45.0 µm in size was contained in tailing coarse fractions (+5 mm, +2.5 mm). Fine fractions (+0.63 mm - 0.14 mm) featured magnetite grains with prevailing size 22.3 µm to 22.8 µm.

4. 4. The Influence of Material Composition of Tailings on Enrichment The researchings of tailability tails samples for enrichment were carried out on samples in which the content ranges from 3.07 to 10.88%, from 13.25 to 20.06%, which makes it possible to compare the results of the enrichment of samples with different iron contents in the initial product.

It was established that tails enrichment are significantly affected by their material composition, in particular, the iron content in tails (especially magnetite) and the content of fine particle size fractions. The maximum indicators of tails enrichment are achieved with a grade of -0.044 mm in the initial product at the range of 15–25% (Figures 2 and 3).

This is due to the fact that this class contains the largest number of discovered magnetite grains, while the larger fractions contain quartz and aggregates of non-metallic minerals with magnetite, while the finely dispersed fractions contain barren sludge and over-crushed magnetite particles, which are weakly captured

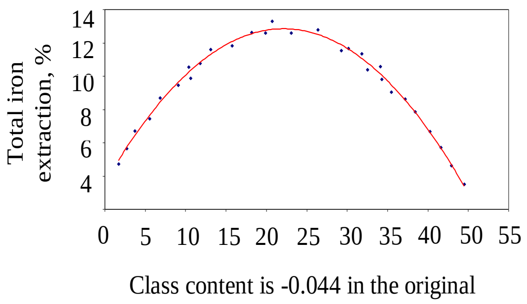

Figure 2. Dependence of the extraction of total iron on the grade content of -0.044 mm in the initial samples

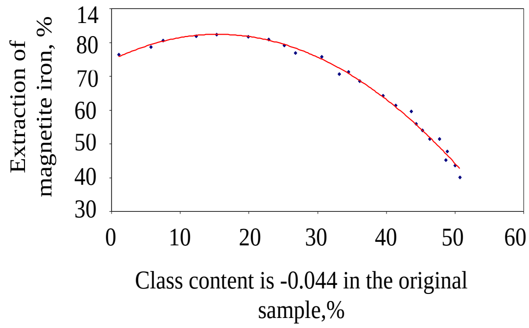

Figure 3. Dependence of the extraction of magnetite iron on the grade content of -0.044 mm in the initial samples

during enrichment. Based on the results of studying the enrichment of enrichment in laboratory conditions, the possibility of obtaining iron ore concentrate with iron content for the tailings of KMA GOK was established (initial tailings content of 5.95%) - 61.47%.

The proposed scheme to have a production of concentrate from tails according to the summary indicators of laboratory tests includes the following operations: screening, desliming, preliminary magnetic separation, the intermediate product of which has a yield of 34.8%. The total iron content is 30.6% and the recovery is 68.7%. After regrinding up to 98% of the class -0.044 mm and magnetic separation, the final product has qualitative characteristics: yield - 15%, total iron content 65.2%, recovery - 62.7%, with the initial parameters of the tailings: total iron content - 15.5 %, magnetite iron - 5.2%.

The output of building sands by fractionation the preliminary magnetic separation is 30.0%, the total iron content is 8.4%, the recovery is 16.2%. The general tailings according to this scheme have a yield of 55.1%, the total iron content in them is 5.9%, and the recovery is 21.1%.

4. 5. Physical and Mechanical Properties of Tailings The physicomechanical properties of taillings are based on the results of testing tailings. The basic laboratory results are shown in Table 4 and in Figures 4 to 5, which illustrated that the weighted average diameter d_{wa} of the studied tailing materials changed from 0.02 mm to 0.21 mm. Within the specified rangedd_{wa}, the internal friction angle ϕ varied within the wide range 26° to 38° while adhesion value C changed from 0.002 to 0.011 MPa. In particular, shearing angle ψ (at $P = 1$ MPa) was 32 in the sample with the minimal angle ϕ and C.

Natural gravimetric humidity W of the studied tailing samples varied from 15 to 35% with average value 25 %. Porosity factor E was sufficiently low and changed from 0.67 to 0.81 depending the distance from the pulp discharge outlet L.

TABLE 4. Shearing test results for Lebedinsky GOK tailings

$d_{св}$, mm	ϕ, rad.	C, MPa	ψ, grad.	W, %	E	L, m
0.02	26	0.0021	32	35	0.777	300
0.03	27.21	0.003	33	28	0.726	250
0.051	28.42	0.0042	33	25	0.691	200
0.091	30.48	0.005	34	21	0.666	150
0.13	32.51	0.007	35	17	0.814	100
0.15	35.05	0.009	36	15	0.717	40
0.21	37.94	0.011	40	–	–	–

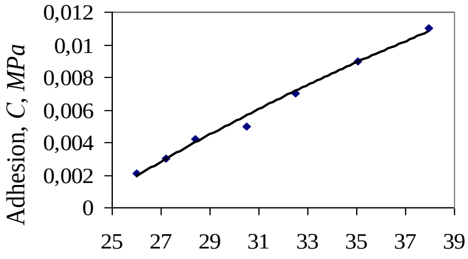

Figure 4. Adhesion vs. the internal friction angle plot

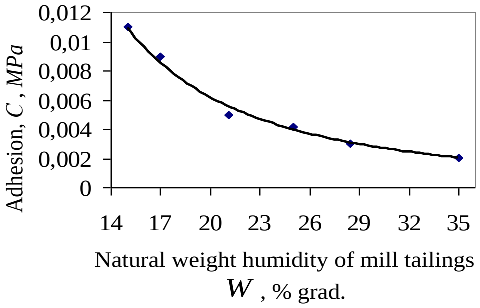

Figure 5. Adhesion vs. natural gravimetric humidity plot

The research results showed that the increase of the distance from the tailing discharge outlet resulted in the growth of humidity percentage for iron-containing mill tailings and, hence, to the decrease of physical and mechanical properties and the bearing capacity of the surface tails when mining equipment is located on it.

5. DISCUSSION

The recearching of the material composition to assess the possibility of using enrichment tailings for KMA GOKs to obtain iron ore concentrate showed that the selected samples differ in chemical, mineralogical and granulometric composition both within the same taillingd dump and between taillings of different GOKs.

When the tail pulp is stratified, larger and heavier particles are placed in the pulp duct in the lower part, and the pulp concentration is higher here than in the upper part of the stream. As a result, through the first alluvial outlets from the distribution slurry conduit, larger and heavier particles enter the beach tail zone dump than through the subsequent ones (for example, to tailings in the MGOK).

Further segregation of particles occurs on the alluvial beach and in the taillings pond under the influence of changes in the hydrodynamic characteristics of the carrier flow. On the surface taillings dump during the alluvial formation, taillings zones with a similar composition are formed, and the configuration of the zones depends on the pattern of tails storages dump. The general regularity of the formation of tachy zones is the accumulation of heavy iron minerals and large tiles articles near the outlets, while the light quartz, micaceous, silicate minerals and the finely dispersed part of tiles cover a considerable distance, forming another technogenic mineral association.

Based on these features of tail accumulation, the process of fractionation by size and density might be considered as the process of enrichment of certain areas with any mineral or fraction of particles. The differences in taillings of ore dressing plants are determined by the type of quartzite mined and by the specific features of the dressing technology. The characteristic differences between the GOK taillings can be attributed to the following: in taillings of the MGOK enrichment, the main iron-containing mineral is hematite (39-53.5%), while for the storages of the GOKK and SGOK it is magnetite (2.9-10.7%); in terms of particle size distribution, the wastes of MGOK enrichment are more finely dispersed (fraction content is -0.044 mm 53%) than LGOK, SGOK (23.5%).

The moisture content of taillings in the explored sections of taillings varies widely. Humidity of taillings increases along the height of the washout with the depth of sampling. In the near-surface stratum at a depth of 1.0 m, humidity varies from 15 to 20% with an average value of 17.5%. At great depths, humidity ranges from 21 – 35%. The porosity coefficient of the stocked tails in the considered area has an average value of 0.74.

During the process of studying the material composition, the following was established: taillings might be used in the construction industry as sand or gravel, to obtain additional products as a main or associated useful component in mining enterprises of KMA, and also used in agriculture and forestry (crop production).

6. CONCLUSIONS

An assessment of the utilization of enrichment waste in agriculture and forestry requires a preliminary study of the mineralogical, chemical, and particle size distribution, agrophysical, physical, and agrochemical properties. The main condition for using waste is the presence of necessary components for the soil. Recommended doses of waste are established on the basis of data from agrochemical analyzes, field experiments, economic and environmental indicators. The use of waste as fertilizers and substances that improve the physical and chemical properties of soils should ensure an increase in the productivity of plants, the quality of their yield, as well as an economic or environmental-social effect.

Waste which was introduced into peat bog soils contributes to the improvement of their hydrothermal regime. Taillings of processing plants can also have an increased absorption capacity due to the presence of residual amounts of clay minerals in them. The factors limiting waste utilization in crop production are reduced to three categories: 1) the presence of concomitant impurities and elements that cause soil pollution and damage; 2) the possibility of re-processing enrichment waste in order to extract the main or related substances; 3) the possibility of disposal in other industries with great economic effect.

Thus, the researching showed that the iron-containing taillings of the KMA GOKs are promising the involvement in development with the allocation of the main and associated useful components, as well as their using as sand, especially since during the reprocessing of iron-containin taillings, energy-intensive operations such as crushing are not necessary and partial grinding [14]. These research results will become a good reserve for conducting experimental studies of the possibility of processing iron-containing taillings of enrichment of KMA GOKs.

The research results will become a good basis for experimental study of the possibility to process iron-containing tailings accumulated from ore-refining and processing facilities in Kursk Magnetic Anomaly (Russia).

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Persian Abstract

چکیده

هدر رفتن اجتناب‌ناپذیر از منابع معدنی، وخامت مداوم شرایط زمین‌شناسی و معدن برای توسعه ذخایر معدنی و احیای مواد اولیه از زباله‌های معدن با بازیافت، همه مشکلات متعددی هستند که امروزه با آن روبرو هستیم. راه‌حل این مشکل می‌تواند گسترش قابل ملاحظه مواد اولیه خام، کاهش سرمایه‌گذاری در بازیابی از منابع‌های جدید، صرفه‌جویی هزینه برای دورریزهای معدن و رسیدگی به زباله‌های باطله، به دست آوردن اثرات اجتماعی و اقتصادی به دلیل کاهش قابل توجه آلودگی محیط زیست را تضمین کند.. در این مقاله به بررسی مواد دوریز که حاوی آهن در حوضچه‌های نهایی پالایش سنگ معدن و تاسیسات فرآوری‌شده واقع در ناهنجاری مغناطیسی کورسک (KMA GOKs) است، پرداخته شده و نمونه هایی از این مطالعه گرفته شده است. مقاله حاوی نتایج حاصل از مطالعه ترکیب شیمیایی مواد، اجزاء مواد، مطالعه مواد معدنی-پتروگرافی مقاطع انتهایی و صیقل، توزیع اندازه دانه و خصوصیات فیزیکی و مکانیکی نمونه‌ها است. به دلیل تمایز گرانش، مقررات مربوط به تغییر محتوای مؤلفه مفید است. همچنین خاطر نشان شد که به دلیل تجمع پیریت میزان گوگرد در نزدیکی محل تخلیه تفاله‌ها افزایش یافته است. نسبت مواد معدنی سنگ در بافندگی و نسبت ظرافت کسری ماسه اندازه‌گیری شد. بررسی با میکروسکوپ پرتو متمرکز با بزرگنمایی x90 تا x600، و تعیین انواع اندازه و اشکال دانه نشان داد که مواد انتهایی معادن بعد از پردازش اضافی در صنعت ساخت و ساز به عنوان ماسه قابل استفاده می‌باشند.