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**B. K. Kenzhaliyev, S. V. Gladyshev, R. A. Abdulvaliyev, E. I. Kuldeev,
K. O. Beisembekova, S. A. Omarova, A. I. Manapova**

Institute of Metallurgy and Ore beneficiation, Almaty, Kazakhstan.
E-mail: rin-abd@mail.ru; a32745@gmail.com; k.o.beisembekova@mail.ru

**DEVELOPMENT OF TECHNOLOGY
FOR CHROMITE CONCENTRATE
FROM THE SLURRY TAILINGS OF ENRICHMENT**

Abstract. The exploration results of manmade residues retreatment – slurry tailings of chromite ore enrichment of Donskoi Ore Mining and Processing Plant of the Republic of Kazakhstan are performed in the article.

The technology of chromite concentrate extraction by chemical enrichment and centrifugal separator methods has been developed. The technology includes preliminary activation processes of chromite-containing tailings in sodium hydro-carbonate solution, leaching in ammonium bisulfate solution and gravity concentration in a centrifugal separator. The preliminary activation process is required to increase enrichment degree of chromite-containing tailings when leaching by means of accompanying elements removal – magnesium, silicium, ferrum. Quantitative composition of samples is changed insignificantly as a result of activation. At the same time, the phase composition of samples is changed, calcium oxides phases and ratio of magnesium-containing phases are disappearing.

Prime results through researches when choosing reagent to slurry tailings leaching have been achieved by using 30% NH_4HSO_4 solution. Out of data of X-ray phase and chemical analysis, follows that when leaching slime tailings, the rock-forming minerals mainly go to solution, while chromium and chromite-containing minerals, kaolinite and amorphous silica remain in the cake-the rough concentrate.

Chromite concentrate has been received at rough concentrate treatment using centrifugal separator KNELSON consisting of chromite mineral - $(\text{Fe}_{0.52}\text{Mg}_{0.48})(\text{Cr}_{0.76}\text{Al}_{0.24})_2\text{O}_4$ with Cr_2O_3 59,2% content when ejecting Cr_2O_3 into 86,8% concentrate. Technology engineering of chromite slurry retreatment contributes to solve an environmental problem and also to increase chromite concentrate production.

Key words: slurry tailings, activation, ammonium bisulfate, centrifugal separator, and chromite concentrate.

Introduction. Processing of accumulated and newly formed manmade waste, including chromite tailings, is an actual task of the present.

The importance of solving the problem of involving in the processing of wastes of enrichment products is associated not only with ecology but also with the need to increase the production of chromium. For the period from 2005 to 2012, the world production of chromium, according to the International Chromium Development Association (ICDA), increased from about 18 million tons to 24 million tons [1].

Donskoy Ore Mining and Processing Plant is the enterprise that extracts and enriches chromium raw materials in Kazakhstan. Gravitational technology for chromium ore enrichment makes it possible to obtain a chromium concentrate from large and medium fractions. At the same time, the fine-grained tailings are practically not enriched because of the difficulty of separating complex minerals into chromium concentrates and empty rock [2, 3].

Research in Physics and Chemistry. Slurry tailings of chromite ores enrichment of the Donskoy Plant were used in the work. Chemical analysis of slurry tailings is given in table 1.

The results of X-ray diffraction analysis of slurry tailings of the Donskoy Plant are presented in table 2.

Table 1 – Chemical composition of the chromite ores slurry tailings

Name	Content, %	Name	Content, %
Cr ₂ O ₃	25,47	Cu	0,008
Fe ₂ O ₃	9,1	Pb	0,05
SiO ₂	21,53	As	0,025
Al ₂ O ₃	1,51	Sb	0,23
H ₂ O(bound)	7,8	K	0,05
CaO	0,75	Na	0,05
MgO	29,4	P	0,008
MnO ₂	0,053	C	< 0,2
S _{com}	0,1	Ag g/t	< 2,0
S _{sulf.}	< 0,1	Au g/t	< 0,05
Zn	0,1	Ni	0,28
Co	0,02		

Table 2 – Phase composition of the slime tailings

Name	Formula	%
Antigorite	Mg ₃ Si ₂ O ₅ (OH) ₄	41,8
Aluminum-ferruginous magnesite	MgFeAlO ₄	29,7
Magnesium Chromite	MgCr ₂ O ₄	12,5
Clinochlore	Mg ₆ Si ₄ O ₁₀ (OH) ₈	5,1
Calcium Iron Oxide	CaFe ₂ O ₄	4,8
Aluminous Iron Oxide Of Calcium	Ca ₂ Fe _{1.28} Al _{0.72} O ₅	3,9
Brown millerite	Fe _{1.33} Al _{1.67} Ca ₂ O ₅	1,7
Aluminum Calcium Silicate	Ca ₄₆ (Al ₉₂ Si ₁₀₀ O ₃₈₄)	0,3
Aluminum Magnesium Calcium Silicate	Ca _{23.20} Mg _{22.4} (Al ₉₂ Si ₁₀₀ O ₃₈₄)	0,3

Mineralogical analysis of the samples was carried out using the microscope MIN-8 at 320x magnification, and using the OLYMPUS microscope at 200x, 400x magnification in transmitted light in an immersion medium and in polished sections in reflected light under an inverted Leica microscope. The photomicrographs of the samples in reflected light were made at 300x magnification using an inverted Leica microscope, in transmitted light with the help of the OLYMPUS microscope at 200x, 400x magnification using the StreamBasicR software (figure 1).

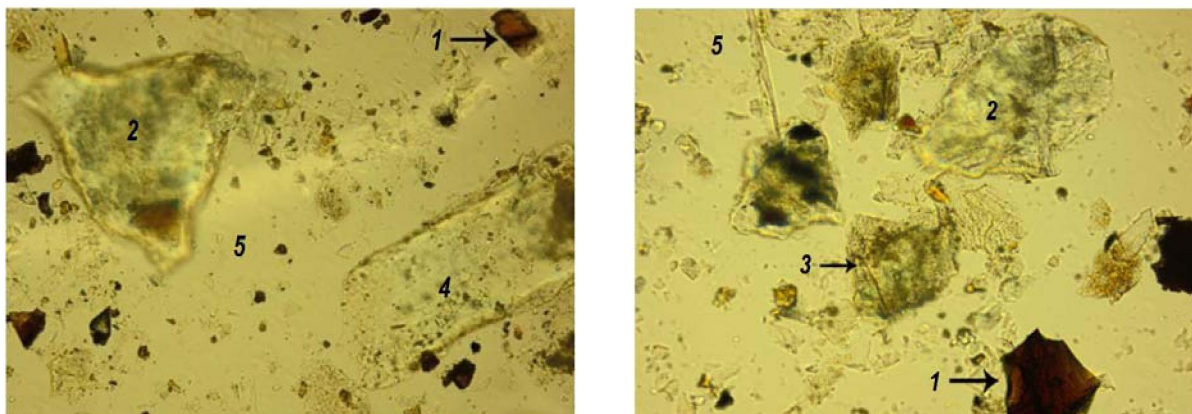


Figure 1 – Mineralogical composition of the slime tailings:

1 – shungit; 2 – spinel minerals chlorite group; 3 – aluminum-magnesium spinel; 4 – antigorite; 5 – immersion environment

formed. The process is displayed on the thermogram with an exothermic effect. Based on these data, it can be assumed that exothermic effects, in addition to the processes described above, also show the formation of solid solutions of chromspinelides from the dehydration products of the phase constituents of the sample.

The results and its discussion. A technology for processing slurry tailings has been developed to produce chromite concentrate, which includes preliminary activation in sodium hydrogen carbonate solution, leaching in a solution of ammonium hydrogen sulfate and gravitational enrichment with the use of a centrifugal separator.

The preliminary activation is necessary to increase the degree of enrichment of chromite-containing tailings during leaching by the removal of the accompanying elements - magnesium, silicon, iron.

The possibility of activation of slurry tailings by treatment with sodium hydrogen carbonate solution of 120 g/dm³ concentration at temperatures of 100-240°C, T:F = 1.0:10.0 and a duration of 90 minutes were studied.

Chemical analysis of the activated tailings showed (table 3) that, as a result of the activation, the quantitative composition of the samples changes insignificantly, except for a decrease in the calcium content. At the same time, as follows from the data of X-ray phase analysis, the phase composition of the samples changes (Table 4), the phases containing calcium oxide are disappearing; the quantitative ratios of the magnesium-containing phases are also changing.

Table 3 – Chemical composition of the slurry tailings after the activation

Name	Cr ₂ O ₃	MgO	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO
Initial tailings	25,47	29,4	21,53	10,4	2,97	1,95
Tailings after activation at 100°C	25,4	29,49	21,73	10,28	2,96	0,864
Tailings after activation at 120°C	25,52	29,53	21,69	10,56	2,99	0,812
Tailings after activation at 150°C	25,42	29,5	21,4	10,5	2,91	0,8
Tailings after activation at 200°C	25,48	29,39	21,35	10,46	2,8	0,794
Tailings after activation at 240°C	25,5	29,38	21,38	10,5	2,75	0,641

Table 4 – Phase composition of the tailings after activation

Name	Composition, %							
	Antigorite-8M Mg _{3-x} (Si ₂ O ₅) (OH) _{4-2x}	Clinochrysoile - Mg ₃ Si ₂ O ₅ (OH) ₄	Lizardite - 1M (Mg,Fe) ₃ Si ₂ O ₅ (OH) ₄	Aluminum-ferruginous magnesite - MgAl ₁₋₆ Fe ₁₋₄ O ₄	Chromite- (Fe _{0,52} Mg _{0,48}) Cr _{10,76} Al _{0,24} O ₄	Clinochlore - Mg ₆ Si ₄ O ₁₀ (OH) ₈	Aluminum magnesium silicate - Ca _{23,20} Mg _{22,4} (Al ₉₂ Si ₁₀₀ O ₃₈₄)	Quartz SiO ₂
Initial tailings	41,8	5,1	12,5	8,7	15,3	5,6	11,0	–
Tailings after activation at 100°C	21,8	20,9	20,4	7,6	15,8	5,6	0,8	1,2
Tailings after activation at 120°C	21,8	21,6	20,6	15,3	15,7	5,2	0,8	1,4
Tailings after activation at 150°C	22,0	21,3	20,6	15,9	15,4	4,2	0,6	1,0
Tailings after activation at 200°C	22,4	21,4	19,7	15,7	15,8	5,0	–	–
Tailings after activation at 240°C	23,7	21,0	21,5	18,2	15,6	5,2	–	–

The analysis of the given data for the preliminary activation of tailings shows that practically all main changes in the phase composition are terminating at the temperature of 120°C.

After activation, the slurry tailings were processed by leaching at a temperature of 95-100°C in the regenerated solution of ammonium hydrogen sulfate NH_4HSO_4 .

The carried out study in the process of leaching of slurry tailings, a solution of ammonium hydrogensulfate with a concentration of 30.0% was used. Leaching was carried out at a temperature of 95°C for 60 minutes.

For comparison, in addition to the ammonium hydrogen sulfate solution, a solution of 5% H_2SO_4 and a solution consisting of 30% $\text{NH}_4\text{HSO}_4 + 1\% \text{H}_2\text{O}_2$ were used for leaching.

The obtained results of leaching are shown in table 5.

The best results were obtained using a leaching solution consisting of 30% NH_4HSO_4 , in this case, the content of chromium in the cake (rough chromite concentrate) was 38.4% Cr_2O_3 at cake output of 65.5% of the weight of the initial slurry tailings.

Table 5 – Cake (rough concentrate) from the leaching of slurry tailings

Name	Cr_2O_3		Fe_2O_3		MgO		SiO_2		Al_2O_3		Cake output, %
	%	$\epsilon, \% *$	%	$\epsilon, \%$	%	$\epsilon, \%$	%	$\epsilon, \%$	%	$\epsilon, \%$	
Initial tailings	25,47	100	10,5	100	30,0	100	22,7	100	2,74	100	
Cake form leaching with 5% H_2SO_4	32,1	95,4	9,94	69,9	18,8	46,3	30,7	100	3,04	82,1	75,0
Cake form leaching with 30% NH_4HSO_4	38,4	96,8	9,25	39,9	7,08	10,7	34,0	70,0	4,56	75,0	65,5
Cake form leaching with 30% $\text{NH}_4\text{HSO}_4 + 1\% \text{H}_2\text{O}_2$	36,9	95,5	7,47	33,5	8,07	12,06	40,8	84,6	3,2	55,7	67,1

$\epsilon, \% *$ – extraction of the component in the cake (rough concentrate).

For the regeneration of a solution of ammonium hydrogen sulfate, a method [6] of thermal decomposition of ammonium sulfate into hydrosulfate and ammonia according to reaction (1) is known:



Cakes from leaching were dispatched to enrichment using gravity separator KNELSON.

As a result of the centrifugal separation of cakes, chromite concentrates with the following content, mass% were obtained:

- from the cake after leaching in (30% $\text{NH}_4\text{HSO}_4 + 1\% \text{H}_2\text{O}_2$) solution – 53,4 Cr_2O_3 ; 9,8 MgO ; 19,1 SiO_2 ; 13,1 Fe_2O_3 ; 4,1 Al_2O_3 ; 0,14 CaO . The output of the concentrate accounted 32.4% of the weight of the initial tailings. The extraction of Cr_2O_3 into the concentrate accounted for 76.2%;

- from the cake after leaching in 5% H_2SO_4 solution – 42,6 Cr_2O_3 ; 18,7 MgO ; 23,0 SiO_2 ; 11,0 Fe_2O_3 ; 3,67 Al_2O_3 ; 0,2 CaO . The output of the concentrate accounted 36.9% of the weight of the initial tailings. The extraction of Cr_2O_3 into the concentrate accounted for 72.7%;

- from the cake after leaching in 30% NH_4HSO_4 solution – 59,2 Cr_2O_3 ; 9,1 MgO ; 12,4 SiO_2 ; 13,05 Fe_2O_3 ; 4,63 Al_2O_3 ; 0,21 CaO . The output of the concentrate accounted 32.9% of the weight of the initial tailings. The extraction of Cr_2O_3 into the concentrate accounted for 86.8%. The material balance of cake enrichment under these conditions is given in table 6.

Table 6 – Material balance of cake enrichment after leaching in a 30% NH_4HSO_4 solution using KNELSON centrifugal separator

Product name	Output		Content, %	Production	Extraction, %
	g	%	Cr_2O_3	Cr_2O_3	Cr_2O_3
Concentrate KNELSON	49,35	32,9	59,2	1947,68	86,8
Tailings KNELSON	100,65	67,1	4,35	291,7	13,2
Total	150	100,0		2239,38	100,0

X-ray phase analysis of cake enrichment products after leaching in 30% NH_4HSO_4 solution is presented in tables 7, 8.

Table 7 – X-ray phase analysis of tailings enrichment of cake after leaching in a 30% NH_4HSO_4 solution

Name	Formula	%
Kaolinite	$Al_2Si_2O_5(OH)_4$	44,9
Clinochlore	$(Mg,Fe,Al)_6(Si,Cr)_4O_{10}(OH)_8$	44,5
Chromite	$(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$	10,6

Table 8 – X-ray phase analysis of chromite concentrate

Name	Formula	%
Chromite	$(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$	100

The data of X-ray phase and chemical analysis shows that leaching of slurry tailings with a 30% NH_4HSO_4 solution of ammonium hydrogensulfate, the rock-forming minerals commonly convert into solution, and chromite and chromite-containing minerals, coalitol and amorphous silica remain in the cake-the rough concentrate. The amorphous silica resists the X-ray phase analysis.

When enriching the rough concentrate using the centrifugal separator KNELSON, a chromite concentrate consisting of a chromite mineral - $(Fe_{0.52}Mg_{0.48})(Cr_{0.76}Al_{0.24})_2O_4$ was obtained.

Thus, in the process of slurry tailings enrichment, using the technology including the operations on the preliminary activation of the chromite-containing tailings in a solution of sodium hydrogen carbonate; leaching in a solution of ammonium hydrogen sulfate, and gravitational enrichment using centrifugal separator, a chromite concentrate with a 59.2% content of Cr_2O_3 was obtained with the extraction of Cr_2O_3 into a concentrate of 86.8%.

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**Б. К. Кенжалиев, С. В. Гладышев, Р. А. Абдулвалиев, Е. И. Кульдеев,
К. О. Бейсембекова, С. А. Омарова, А. И. Манапова**

Металлургия және кен байыту институты, Алматы, Қазақстан

БАЙЫТУ ҮРДІСІНІҢ ШЛАМ ҚАЛДЫҚТАРЫНАН ХРОМ КОНЦЕНТРАТЫН АЛУ ТЕХНОЛОГИЯСЫН ЖАСАУ

Аннотация. Техногенді қалдықтарды – Қазақстан Республикасының Дондық тау-кен байыту комбинатының (Дондық ТКБК) хромитті кенін байытқандағы шлам қалдықтарын қайта өндеудің зерттеу нәтижелері келтірілген.

Орталықтан тепкіш бөлгіші және химиялық байыту арқылы хром концентратын алудың технологиясы жасалынды. Бұл технология құрамында хром бар қалдықтарды гидрокарбонат натрий ерітіндісінде алдын ала белсендіруді, аммонийдің бисульфат ерітіндісінде шаймалау және орталық тепкіш бөлгішінде гравитациялық байытуды қамтиды. Алдын ала белсендіру үрдісін жүргізу – шаймалау кезінде қосымша элементтердің (магний, кремний, темір) жойылу есебінен, құрамында хром бар қалдықтарды байыту дәрежесін жоғарлату үшін керек. Алдын ала белсендіру нәтижесінде үлгілердің құрамы сәл өзгереді. Сонымен қатар,

үлгілердің фазалық құрамы өзгереді, құрамында магний бар фазалардың қатынасы, құрамында кальций оксиді бар фазалар жойылады.

Жүргізілген зерттеу жұмыстарында шлам қалдықтарын шаймалау үшін реагентті таңдағанда – 30% NH_4HSO_4 ерітіндісін қолданғанда өте жақсы нәтижелер алынды. Рентгенфазалы және химиялық талдаулар нәтижесінен шлам қалдықтарын шаймалағанда жыныстарүзегіш минералдар негізінен ерітіндіге өтеді, ал кекте – алғашқы концентратта хромит және хромитті минералдар, коалин, аморфты кремний диоксиді қалатынын көруге болады.

KNELSON ортадан тепкіш бөлгішінде алғашқы концентратты байытқанда хромит минералынан тұратын - $(\text{Fe}_{0.52}\text{Mg}_{0.48})(\text{Cr}_{0.76}\text{Al}_{0.24})_2\text{O}_4$ құрамындағы Cr_2O_3 – 59,2% - хромитті концентрат алынды. Cr_2O_3 концентратқа алынуы 86,8%.

Хром қалдықтарын өңдеу технологиясын жасау экологиялық мәселелерді шешіп қана қоймай, сонымен қатар хром концентратының шығысын арттырады.

Түйін сөздер: шлам қалдықтары, белсендіру, аммоний бисульфаты, орталық тепкіш бөлгіші, хром концентраты.

**Б. К. Кенжалиев, С. В. Гладышев, Р. А. Абдулвалиев, Е. И. Кульдеев,
К. О. Бейсембекова, С. А. Омарова, А. И. Манапова**

Институт металлургии и обогащения, Алматы, Казахстан

РАЗРАБОТКА ТЕХНОЛОГИИ ПОЛУЧЕНИЯ ХРОМИТОВОГО КОНЦЕНТРАТА ИЗ ШЛАМОВЫХ ХВОСТОВ ОБОГАЩЕНИЯ

Аннотация. В статье приведены результаты исследований переработки техногенных отходов - шламовых хвостов обогащения хромитовой руды Донского горно-обогатительного комбината Республики Казахстан.

Разработана технология получения хромитового концентрата методом химического обогащения и центробежной сепарации. Технология включает операции предварительной активации хромитсодержащих шламов в растворе гидрокарбоната натрия, выщелачивание в растворе гидросульфата аммония и гравитационное обогащение на центробежном сепараторе. Проведение операции предварительной активации необходимо для повышения степени обогащения хромитсодержащих шламов при выщелачивании за счет удаления сопутствующих элементов – магния, кремния, железа. В результате активации количественный состав проб изменяется незначительно. В то же время меняется фазовый состав проб, исчезают фазы, содержащие оксид кальция, соотношения магнийсодержащих фаз.

В проведенных исследованиях при выборе реагента для выщелачивания шламовых хвостов наилучшие результаты получены при использовании раствора с 30% NH_4HSO_4 . Из данных рентгенофазового и химического анализов следует, что при выщелачивании шламовых хвостов, породообразующие минералы в основном переходят в раствор, а в кекке - черновом концентрате остаются хромит и хромитсодержащие минералы, коалинит и аморфный кремнезем.

При обогащении черного концентрата на центробежном сепараторе KNELSON получен хромитовый концентрат, состоящий из минерала хромита - $(\text{Fe}_{0.52}\text{Mg}_{0.48})(\text{Cr}_{0.76}\text{Al}_{0.24})_2\text{O}_4$ с содержанием Cr_2O_3 59,2% при извлечении Cr_2O_3 в концентрат 86,8%

Разработка технологии переработки хромитовых шламов позволит не только решать экологическую проблему, но и увеличить выпуск хромитового концентрата.

Ключевые слова: шламовые хвосты, активация, гидросульфат аммония, центробежный сепаратор, хромитовый концентрат.