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A STUDY ON THE BENEFICIATION ABILITY OF MANGANESE-CONTAINING TECHNOGENIC RAW MATERIALS

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Preliminary Note – Prethodno priopćenje

The work presents the results of studies on obtaining ferromanganese concentrate from technogenic manganese-containing raw materials with grain size less than 10 mm. It is found that the main valuable minerals of the feedstock are psilomelane, pyrolusite, bementite; among the rock-forming minerals, quartz and kaolinite, often saturated with finely dispersed iron compounds, prevail. Sieving and concentration of raw materials of - 10 + 5 mm and - 2 + 0,2 mm in two-chamber jigging machine with separation of two concentrates and tailingлs allowed to obtain a joint manganese concentrate with 35,1 % manganese content, 11,5 % iron content with 78,23 % manganese recovery. The obtained manganese concentrate is suitable for further metallurgical processing.

Keywords: ore beneficiation, ferromanganese concentrate, technogenic raw materials, manganese, X-ray research

INTRODUCTION

The growing industrial demand for manganese makes it urgent to develop processes intended to extract manganese from low-grade manganese ores and technogenic raw materials [1-4].

Recently, there has been a significant increase in interest in the recovery of valuable components from technogenic sources – tailings from beneficiation plants, mine dumps. This is due to the elimination of the extraction costs for raw materials and, the solution of environmental problems at the same time [5-9].

The work [1] presents the beneficiation results of ore raw materials from the Charagah deposit (Iran), containing 17 % pyrolusite, 78 % calcite and 4 % quartz. A pyrolusite concentrate with a manganese oxide content of 20 % was obtained by means of a jigging machine, with subsequent high-intensity magnetic separation it was possible to increase the MnO content to 44,3 % with an extraction of 61,3 %.

Studies were performed for beneficiation of Indian fine manganese ore with low manganese content [2]. Classification followed by a two-stage high intensity magnetic separation process (1,7 and 1,1 T) resulted in 35 - 40 % FeMn concentrate with 47 - 49 % Mn.

The main manganese ore beneficiation methods are: washing, gravitation, magnetic separation, flotation, radiometric separation. They are based on the use of differences in the physical and physical-chemical properties of the separated ore minerals [10, 11].

Ore beneficiation is predominantly performed by sedimentation that is not only an economic but also environmentally friendly process. A density difference of at least 400 kg/m^3 between manganese minerals and waste rock is required for settling. As most manganese minerals have a density of 3 200 – 3 800 kg/m^3 and waste rock does not exceed 2 800 kg/m^3, such an operation can be realized. Sedimentation is used to enrich large and small classes in one or two steps. The fine grades in ores with higher strength and greater contrast in the gravity properties of ore and rock minerals are separated well on screw sorters, concentration tables and other gravity apparatuses.

MATERIALS AND METHODS

The subject of the study was manganese-containing anthropogenic raw materials with a particle size of less than 10 mm.

The following equipment was used in the studies: Optima 2000 DV atomic emission spectrometer; D8 ADVANCE (Bruker) X-ray diffractometer, Cuα radiation; Thermo Nicolet Avatar 370 FTIR spectrometer; Venus 200 PANalyical B.V. X-ray fluorescence spectrometer, JEOL JXA-8230 electron scanning microscope, MIN-8 (transmitted light) microscope, laboratory 2-compartment diaphragm sedimentation machine.

Ore sieve sample - 10 + 0 mm and sieve products were examined under the microscope in immersion preparations and in reflected light. X-ray fluorescence and X-ray phase analyses were also performed for the sample. Manganese, iron and silicon contents were found in the sieve analysis products and artificial polished sections were produced.

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The initial ore screenings (- 10 + 0 mm) were sieved into classes – 10 + 5 mm; -5,0 + 2,0 mm; - 2,0 + 0,2 mm and - 0,2 + 0 mm. Manganese and iron content and distribution were determined in each size class.

Jigging machine beneficiation studies are performed for - 5,0 + 2,0 mm and - 2,0 + 0 mm material - 2,0 + 0 mm. Working parameters are oscillation frequency - 400 oscillations / min; artificial stone bed height - 40 mm; coarseness of artificial stone bed (metal shot) - 6 - 10 mm.

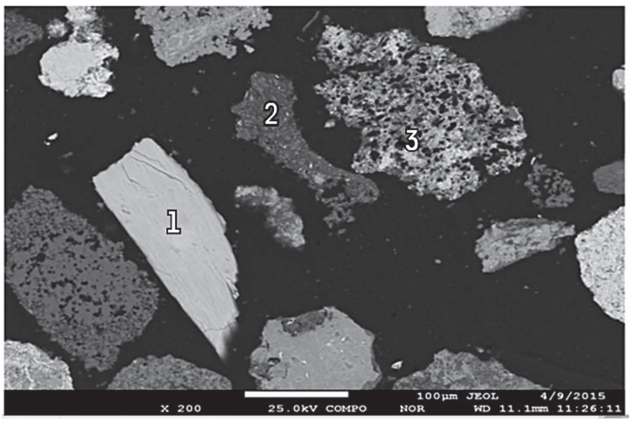
RESULTS AND DISCUSSION

X-ray fluorescence and chemical analysis determined that the manganese-containing ore screenings sample contains 18,66 % manganese and 13,28 % iron. The main valuable minerals are psilomelane, pyrolusite, bementite, possible presence of jianshuiite, orientite (a mineral with a similar composition to bementite). Due to the high iron content, the reflexes of the main manganese minerals do not appear strongly enough on an X-ray image. The accompanying minerals are iron oxides and hydroxides that interfere with the release of manganese minerals during beneficiation. The rock-forming minerals quartz and kaolinite are often saturated with fine iron compounds (Table 1).

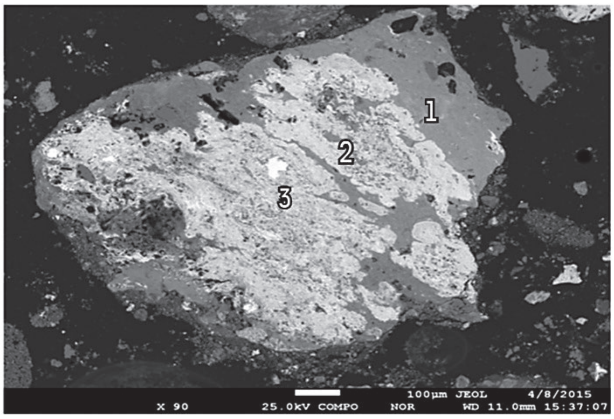
Identification of manganese minerals under the microscope and especially their quantification is very difficult. As the composition of the oxide manganese minerals is very similar, even electron-probe analysis does not make it possible to diagnose them unambiguously.

Table 1 **Results of X-ray phase analysis of the ore sieve sample**

Compound name	Formula	S-Q
Quartz	SiO_2	43
Hematite	Fe_2O_3	27
Kaolinite 1A	$Al_2Si_2O_5(OH)_4$	13
Bementite	$Mn_5Si_4O_{10}(OH)_6$	16
Braunite-1Q, Vernadite	$Mn^{2+}Mn^{3+}{}_6SiO_{12}$, $Mn(OH)_4$	3-5
Pyrolusite, Jianshuiite	MnO_2, $(Mg,Mn^{2+})Mn^{3+}{}_4O_7{\cdot}3H_2O$	5-10



Pyrolusite (1) and hematite (2) in association with non-manganese and manganese minerals (3)
Figure 1 Size class - 0,2 + 0,1 mm in polished artificial polished section



Natural mixture of pyrolusite (1), vernadite (2) with iron hydroxides (3)
Figure 2 Size class - 0,2 + 0,1 mm in artificial polished section

Pyrolusite makes up about 5 % in the average sample, forming intergrowths in association with psilomelane and rock-forming minerals but also present as individual lamellar grains with well-defined cleavage (Figures 1, 2).

Hematite makes up 15 - 16 % in the average sample. Hematite forms together with finely dispersed rock-forming minerals iron-silicon-caolinite aggregates (Figure 2) sometimes with inclusions of manganese minerals. In siliceous rocks, hematite is present as a finely dispersed mass, pigmenting the rock in red-orange tones.

Quartz is one of the main minerals in the host rock, with a content of 36 to 43 % in the sample. It is found as a cryptogranular mass in association with hematite, kaolinite and manganese minerals but is also found in loose grains, forming with them characteristic collomorphic, spotty, nodular structures.

Kaolinite is the second most important rock-forming mineral, comprising 13 - 15 % of the sample. In the ore, it is noted as a dispersed substance with an admixture of ore minerals manganese and hematite. Ore matter in clay formations is observed in the form of thin and fine (0,01 - 0,1 mm) disseminated dissemination.

Sludge samples were analyzed on a JXA-8230 electron probe microanalyser from JEOL. Figure 3 shows the results of energy dispersive spectrometry (EDS analysis) “from the surface” of the studied samples that allow us to estimate the concentration of elements on their surface. As can be seen from the data obtained, the sludge sample contains fine particles with irregularly shaped grains that are oxidized manganese, silicon, aluminium and calcium compounds.

The results of microanalysis “from the surface” of the sludge sample at a magnification of x100, show the distribution of impurities. The sludge sample contains a small amount of impurities of Al, Si, K The manganese content is 54,13 %.

Based on the material composition, the sample can be characterised as an oxidised iron-manganese sample.

The feed product was classified into – 10 + 5 mm, - 5 + 2 and – 2 + 0,2 mm grades that were further enriched in the jigging machine (Figure 4).

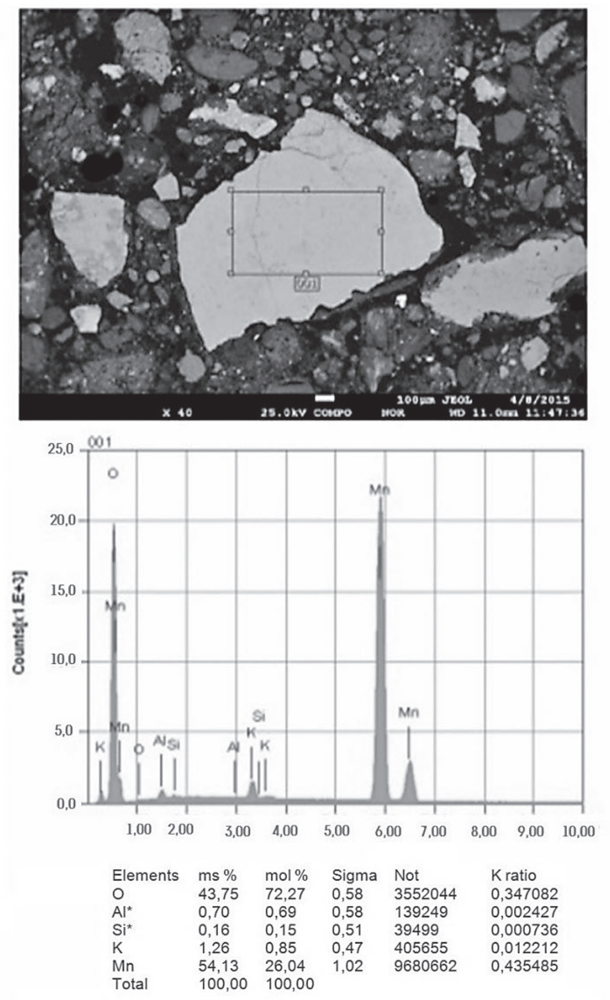


Figure 3 Results from energy dispersive spectrometry "from the surface"

The sieving of the initial manganese-containing raw material has resulted in a size class of - 10 + 5 mm with 37,5 % manganese and 9,05 % iron that can be certified as a finished manganese concentrate. The particle size class - 0,2 + 0 mm with a manganese content of 5,9 % and iron content of 15,3 is a dumping grade.

The extracted particle size products - 5 + 2 mm and - 2 + 0,2 mm were enriched in the jigging machine. Processing of - 5,0 + 2,0 mm product in a jigging machine resulted in a manganese concentrate yield of 6,84 %, manganese content 32,74 % with a recovery rate of 12,0 %.

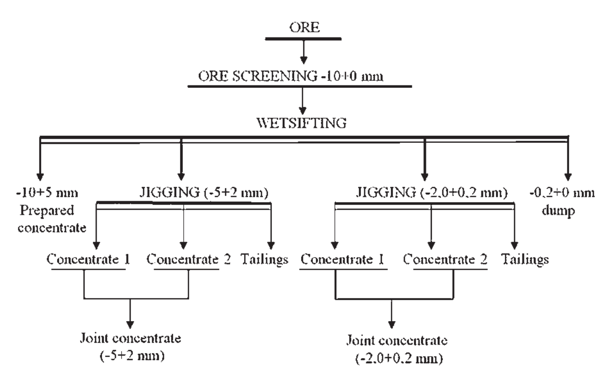


Figure 4 Enrichment scheme for ferromanganese ore screenings

Table 2 **Summary technological indicators of gravity concentration of technogenic raw materials**

Name of products	Output / %	Content / %		Extract / %	
		Mn	Fe	Mn	Fe
Size class - 10 + 5 mm	16,73	37,50	9,05	33,60	11,40
Concentrate of size class - 5 + 2 mm	6,84	32,74	13,73	12,0	7,0
Concentrate of size class - 2 + 0,2 mm	18,36	33,15	12,31	32,63	17,06
Joint manganese-containing concentrate	41,93	35,10	11,50	78,23	35,46
Tailings of the grain size category - 5 + 2 mm	2,16	10,30	11,10	1,20	1,86
Tailings of grain size category - 2 + 0,2 mm	6,94	13,70	12,10	5,10	6,34
Size class - 0,2 + 0	48,97	5,90	15,30	15,47	56,34
TOTAL (initial technogenic raw materials)	100,0	18,66	13,28	100,0	100,0

Concentrate with a manganese content of 33,15 % at a recovery rate of 32,63 % was obtained by beneficiation at - 2,0 + 0,2 mm. Summary technological indicators of gravity concentration of technogenic raw materials are presented in Table 2.

Thus, the beneficiation of technogenic ferromanganese ore screening makes it possible to obtain a joint manganese-containing concentrate with a manganese content of 35,1 %, iron – 11,5 %, with the extraction of manganese 78,23 %.

CONCLUSION

Based on the study of the material composition of manganese-bearing technogenic raw materials using mineralogical, chemical, X-ray fluorescence and X-ray phase analysis and electron microscopy, it has been found that the examined sample is characterised as an oxidised iron-manganese. The main manganese minerals are psilomelane, pyrolusite, bementite.

The beneficiation of the narrow-graded technogenic iron-manganese raw material in a jigging machine makes it possible to obtain a manganese concentrate with 35,1 % manganese content and 11,5 % iron content, at 78,23 % and 35,46 % extraction respectively. The obtained manganese concentrate is suitable for further metallurgical processing.

Acknowledgments

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Note: The person responsible for English language is Kurash A. A., Almaty, Kazakhstan