STUDY ON THE ENRICHMENT POTENTIAL OF VANADIUM-CONTAINING ORE FROM THE SIJJAK DEPOSIT

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Abstract: This study investigates the enrichment potential of vanadium-containing ore from the Sijjak deposit in Uzbekistan. The chemical, spectral, and scanning analyses of ore samples revealed a vanadium content ranging from 200 to 2500 g/t, with vanadium present mainly in oxidized form as V_2O_5. Gravity separation methods, including concentration table and jigging machine tests, were applied; however, the enrichment efficiency did not exceed 63%, and about 40% of vanadium remained in the tailings. Flotation was deemed impractical due to the low sulfide content of the ore. The findings suggest that direct leaching or pyrometallurgical processing may be more suitable for this type of ore, as further enrichment by traditional methods results in significant losses of the valuable metal.

Keywords: vanadium ore, Sijjak deposit, gravity separation, vanadium pentoxide, direct leaching, pyrometallurgy, rare metals, enrichment potential

Introduction. Vanadium is widely used in hydrogen energy and electronics. As a rare metal, vanadium very rarely occurs in nature as native deposits and is mainly obtained as a secondary metal during the extraction of iron-bearing ores. The primary technology for producing vanadium from blast furnace slag involves both pyrometallurgical and hydrometallurgical processes, which are developing

rapidly. This dissertation is dedicated to the science of combining pyro- and hydrometallurgical methods for vanadium extraction [3].

Vanadium is a relatively abundant element in the Earth's crust, with an average content of 0.005% of its total mass. Despite this abundance and the presence of more than fifty known vanadium-containing minerals, its use only slightly exceeds that of gold, which is due to the fact that primary vanadium deposits are quite rare.

Ores containing more than 1% V_2O_5 are considered extremely rich, which is why in the processing industry, it is deemed profitable to use ore containing more than 0.01% vanadium. In this context, the black shales (vanadium-containing ore) of Greater Karatau are of great interest, where the average vanadium content is around 8,000-100,000 g/t or about 1%. The main distribution of this black shale deposit is located in the Kyzylorda region, and there are few such deposits in the world. In the Republic of Uzbekistan, a vanadium-containing black shale deposit has been identified in the Kyzylkum Desert, named Rudnoye (Ma'dani), where, in addition to vanadium, other elements of industrial interest are also found [4].

A review of the literature shows that the metal is widely distributed as an accompanying element in titanomagnetite iron-bearing ores. Vanadium in the form of pentavalent oxide occurs at levels of about 0.1-0.2%, from which all useful components are extracted: initially, intermediate products - pig iron and titanium-rich slags - are obtained in blast furnace production, then steel and vanadium slag are produced from the pig iron. Slag containing vanadium pentoxide serves as the basis for the production of commercial pentoxide and ferrovanadium, which is used in ferrous metallurgy for alloying steel [5].

Methods and Results. Today, rare metals are considered "vitamins" for the metallurgical and electrical engineering industries, as the development of vanadium production technology provides a powerful boost to the country's steel industry. Furthermore, the future development of semiconductors and chemical

industry devices is closely linked to vanadium. The Republic of Uzbekistan possesses vast reserves of vanadium metals, both of secondary origin and primary mineral raw materials, which require thorough research to obtain high-quality metallic vanadium [6].

In our work, the studied samples were re-examined using chemical analysis methods and then subjected to roasting processes. The samples were analyzed at the Research Laboratory of Navoi State Mining and Technological University; 9 samples collected from various sections of the deposit were analyzed for vanadium content. The vanadium content in the samples ranged from 200 to 2500 g/t. The chemical analysis of sample No. 9 is presented in Table 1.

Table 1

Chemical analysis of ore sample 9 from the Sidzhak deposit

Component	$V(V_2O_5)$	Cu	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	$S_{общ}$	S_S	$C_{общ}$	$C_{орг}$
Content (%)	0,6(1,2)	0,26	76,5	4,5	4,6	1,9	1,1	0,9	0,3	1,2	1,5

The results of the chemical analysis were also corroborated by the SEM and spectral analysis results (see Tables 3.1 and 3.2), as the ore from the Sidjak deposit contains a high amount of vanadium pentoxide.

Table 2

Chemical analysis of ore sample 31 from the Sijak deposit

Component	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MnO	CaO	MgO	V_2O_5
Content (%)	74,56	5,72	3,45	0,84	0,43	0,95	0,75	0,48(0,24)

The study conducted showed promising results for vanadium ore with a vanadium content of 2400 g/t.

For a comprehensive rational analysis of the Sijjak deposit, spectral and chemical analyses were conducted, confirming the scanning analysis methods. The size of the main minerals for further processing was -50 μm, -30 μm, -20 μm, and -100 μm. The obtained results enabled the selection of an enrichment method. Applying the flotation method to vanadium ore is impractical, as the ore is low in sulfides, and the main mass of the valuable component is in oxidized form. For these reasons, experiments using the flotation method were not conducted. The gravity enrichment method was carried out using a concentration table and a jigging machine, as the particle size above the studied result confirmed very close values for vanadium and iron. This was reflected in the production of gravity concentrates, where the vanadium concentrate was contaminated with iron, and the product yield increased due to the large volume of iron. Moreover, the enrichment of vanadium in the concentrate during gravitational enrichment did not exceed 63%, with about 40% of vanadium remaining in the tailings, which would require additional extraction measures.

Conclusions. Thus, by analyzing literature sources, it was determined that such vanadium-containing ore with normal vanadium content is typically processed without enrichment, using direct leaching or pyrometallurgical methods.

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