ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 6, June 2024

Study of Textural and Structural Characteristics of Bentonite to Increase the Efficiency of Adsorption and Purification

Ibadullaeva Saida Makhmudzhanovna Abdikamalova Aziza Bakhtiyarovna

Institute of General and Inorganic Chemistry of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan
Institute of General and Inorganic Chemistry of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan

ABSTRACT: The paper presents a comprehensive study of bentonite AB, including an analysis of its chemical composition, textural and structural characteristics. Using X-ray phase analysis, scanning electron microscopy and adsorption methods, the key properties of the material affecting its adsorption potential and the possibility of using it in various industrial processes were determined. The content of the main oxides, phase composition and morphology were determined, which made it possible to evaluate the suitability of bentonite for wastewater treatment, toxic emissions capture and as a catalytic carrier. The results of the study emphasize the prospects for using bentonite AB in environmental protection and adsorption technologies.

KEYWORDS: bentonite, adsorption, textural characteristics, chemical composition, X-ray phase analysis, microscopy, catalytic carrier, environmental safety.

I.INTRODUCTION

Bentonite clays are one of the most promising classes of natural materials for use in adsorption and catalytic processes, as well as in the field of environmental protection and industrial emissions purification. Their unique properties, including a developed porous structure, high specific surface area and chemical stability, make bentonites in demand for such processes as wastewater treatment, removal of toxic gases and separation of complex chemical mixtures. The ability of bentonite to effectively sorb various substances is due not only to its textural characteristics, but also to the chemical composition, phase structure and morphology of particles, which requires an integrated approach to the study of its properties [1-5]. The study of textural characteristics, such as specific surface area, volume and pore size, allows us to evaluate the adsorption potential of bentonite for various purposes. An important role is also played by the chemical composition of the clay, including oxides of silicon, aluminum, iron, calcium and other elements, which affect the interaction with adsorbates and reactivity in catalytic systems. X-ray phase analysis, used to determine the mineral composition, allows identifying the main crystalline phases, such as montmorillonite, kaolinite and illite, which are key components in the structure of bentonite and determine its sorption and mechanical properties. These data are supplemented by microscopic analysis, which allows visualizing the morphology and distribution of particles, as well as assessing the shape and size of pores, which is important for the practical use of the material [6-8]. This work is devoted to a comprehensive study of a sample of bentonite AB, including an analysis of its chemical composition, textural and structural characteristics using X-ray phase analysis, scanning electron microscopy and adsorption methods. A comprehensive study allows us to assess the possibilities of using this bentonite in industrial processes that require high sorption capacity, resistance to external influences and stability in aggressive conditions. This approach provides a complete understanding of the potential of bentonite AB for use in cleaning and catalytic technologies, as well as for the creation of new composite materials capable of effectively solving the problems of environmental protection and increasing the efficiency of industrial processes.

II. SIGNIFICANCE OF THE SYSTEM

The paper presents a comprehensive study of bentonite AB, including an analysis of its chemical composition, textural and structural characteristics. The study of methodology is explained in section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 6, June 2024

III. METHODOLOGY

The object for intercalation was bentonite from the Navbahor deposit, which was presented by BENTONITE LLC.

X-ray diffraction patterns were obtained on an X-ray diffractometer XRD Empyrean PANanalytical with a minimum scanning step of 0.0001 ° and an angle setting reproducibility of <0.0002°. Electron microscopic images of samples and elemental composition data were obtained using an EVO MA10 SEM scanning electron microscope. Thermogravimetric and differential thermal analysis were carried out on a Q-1500 D derivatograph in the range of 20-1000 ° C in an air atmosphere with a heating rate of 5 °/min.

In this study, the method of low-temperature nitrogen adsorption at 77 K on a Quantachrome Nova 1000e static adsorption unit was used to determine the characteristics of the porous structure of bentonite samples. Before measurements, the samples were pre-treated in vacuum at 100 °C for 12 hours. The partial pressure of nitrogen was varied in the range from 0.005 to 0.995 P/Po for the nitrogen adsorption and desorption curves. The BET, Langmuir, Dollimore and Heal (DH), Dubinin Radushkevich (DR), t-plot, As-plot methods were used to process the adsorption curves, determine the micropore volume and average pore diameter, and the Barrett-Joyner-Halenda (BJH) method was used to estimate the mesopore volume.

IV. EXPERIMENTAL RESULTS

The chemical composition of bentonite BS includes the main oxides: SiO2 (56.1%), Al2O3 (17.2%), Fe2O3 (2.4%), CaO (0.9%), MgO (2.1%), Na2O (2.8%), K2O (1.1%), P2O5 (0.5%), SO2 (0.5%) and CO2 (0.2%). Loss on ignition (LOI) is 16.2%.

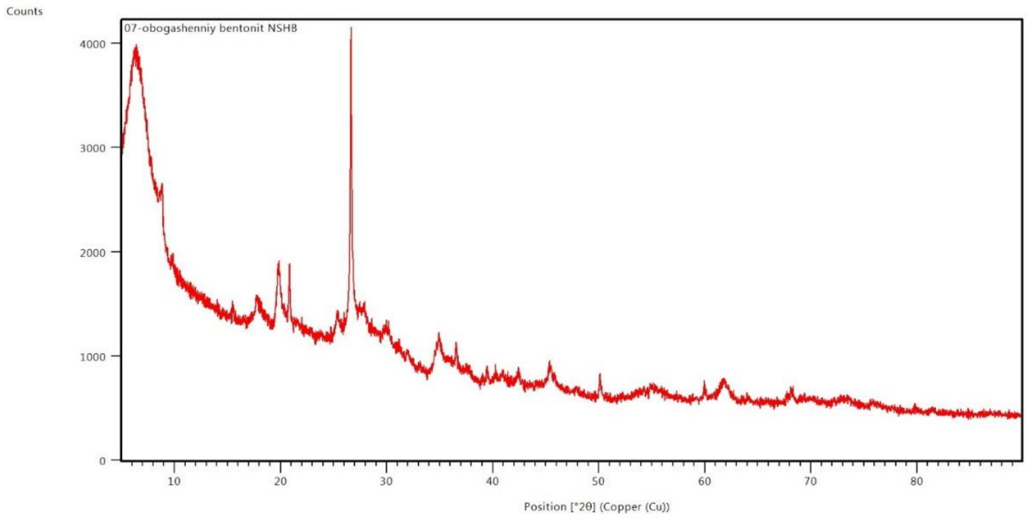

Fig. 1. X-ray diffraction pattern of AB.

The results of X-ray phase analysis of Navbahor clay revealed the presence of sodium montmorillonite, illite, kaolinite, hydromicas and feldspar. Characteristic diffraction lines were found for each mineral, which confirms the complex mineralogical composition of the clay and its similarity to other montmorillonite-containing clays.

During the study, three samples of bentonite clay were analyzed: one was treated with glycerin, the other was subjected to heat treatment at 500°C. The sample with glycerin demonstrates the typical behavior of montmorillonite-containing clays, maintaining a basal reflection at 17 Å. After heat treatment, this value decreases to 10 Å.

Table 1.
Chemical composition of BS, %

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	CO_2	ППП
56,1	17,2	2,4	0,9	2,1	2,8	1,1	0,5	0,5	0,2	16,2

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 6, June 2024

Table 2.
Comparison of the d_{001} effect of minerals treated with glycerol and calcined at 500°C

Clay mineral	Natural form	Treated with glycerin	Calcined at 500°C
	Values d_{001} of effect, nm		
alkaline bentonite	1,2-1,5	1,7	1,0

Analysis of the energy dispersive spectrum of montmorillonite crystals allows us to determine the content of the following chemical elements (in descending order): oxygen (O), silicon (Si), aluminum (Al), sodium (Na), calcium (Ca), and others. According to the analysis results, the content of the main sorption-active mineral montmorillonite in AB is about 54-57% of the mass. Electron micrographs of AB samples showed a different distribution of montmorillonite crystals and associated minerals, and the sizes of the aggregates ranged from 20 to 80 micrometers. The structure of montmorillonite was determined by the shape and structural features in electron micrographs, which supplemented the data of X-ray phase and thermal analysis.

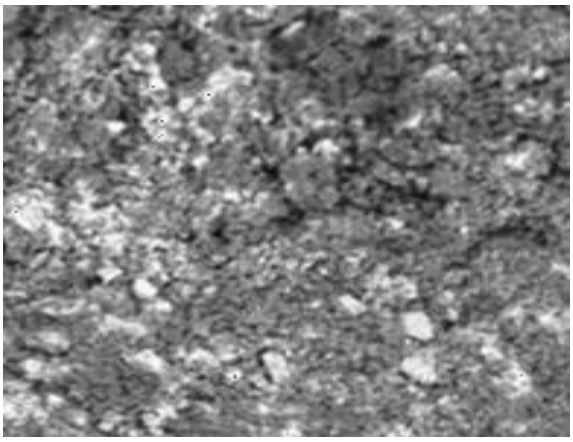

Fig. 2. Micrograph of the AB. The isotherm obtained during the measurements is shown in Fig. 3.

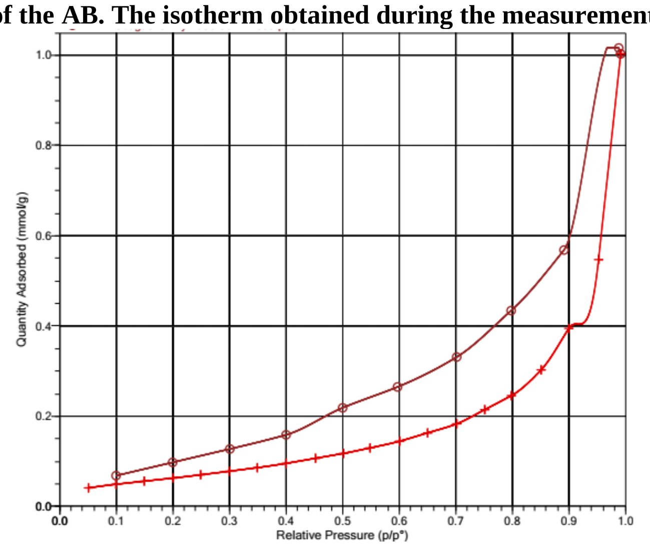

Fig. 3. Nitrogen adsorption and desorption isotherms on bentonite.

According to the IUPAC classification, this isotherm belongs to type III, typical of adsorption on non-porous materials or porous materials with a pore diameter exceeding the micropore size. In the initial section of the isotherm, adsorption is insignificant, but increases as the surface is filled with adsorbate molecules, which interact with each other more strongly than with the adsorbent surface. This indicates the hydrophilic nature of the bentonite surface.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 6, June 2024

A sharp decrease in the volume of adsorbed nitrogen on the desorption branch at low pressures indicates the presence of narrow micropores. At high P/P_0 values, the absence of closure of the adsorption and desorption isotherm branches indicates weak filling of the mesopores. The increase in adsorption at pressures close to saturation is due to condensation on the outer surfaces, and the presence of a type H-III hysteresis loop associated with capillary condensation in mesopores indicates the presence of plate-like particles forming slit-like pores.

Surface area and porosity are key characteristics of porous solids, determining surface activity and adsorption properties. Parameters such as pore volume and size distribution play an important role in the selectivity and transport of substances. The data of nitrogen (N_2) adsorption isotherms allow us to quantitatively characterize the porosity of the material, as presented in Table 3.

Table 3.
Textural characteristics of AB

S^1, м²/г	S^2, м²/г	S^3, м²/г	*t-Plot**, м²/г	V_a, см³/г	V_b, см³/г	*R*, Å	D^{**}, Å	D^{***}, Å
28,62	142,13	82,86	51,16	0,01	0,089	43,3	14,36	7,80

*1 – BET specific surface area; 2 – Langmuir specific surface area; 3 – mesopore specific surface area, m2/g; * – external surface area; ** – average pore width; *** – average micropore size; R – average pore size.*

The textural characteristics of BSch bentonite indicate a mesoporous structure with a moderately developed surface area, which is important for its application in adsorption processes. The specific surface area determined by the BET method is 28.62 m²/g, indicating limited development of microporosity. However, the specific surface area according to the Langmuir method is 142.13 m²/g, which reflects the maximum surface potential when completely filled, especially in the case of larger pores. The mesopore surface area (82.86 m²/g) also emphasizes the dominance of mesopores in the sample structure, confirming its adsorption capacity. Pore volume is also an important parameter characterizing the adsorption properties of bentonite. The micropore volume is 0.01 cm³/g, indicating a limited number of small pores, while the mesopore volume is more significant and equals 0.089 cm³/g. These data confirm that the main structure of the material is represented by mesopores, which play a key role in its adsorption properties.

Pore size analysis shows that the average pore size (R) is 43.3 Å, which is typical for mesopores. The average pore width is 14.36 Å, confirming the predominantly mesoporous nature of the material, while the average micropore size is 7.80 Å, confirming the presence of a small number of micropores. Thus, the structure of bentonite AB with developed mesoporosity makes it an effective adsorbent for molecules that can fill larger pores, which is especially important for industrial applications in processes requiring high adsorption capacity.

V. CONCLUSION AND FUTURE WORK

In conclusion, the results of the study of the textural characteristics of bentonite BS showed that this material has a mesoporous structure with a developed specific surface, especially at the mesopore level. Analysis of the surface area, volume and average pore size confirmed its high adsorption capacity, which makes bentonite BS a promising material for use in adsorption processes that require effective capture of molecules of different sizes. Such properties are especially important for use in industry, where reliable and effective adsorbents are required.

REFERENCES

1. Robert A. Smectite-type clay minerals as nanomaterials // Clays and Clay Minerals. 2007. V.50. № 4. P. 411.
2. Abdikamalova A.B. Development of polyfunctional drilling fluids based on clay minerals and soda production waste in Karakalpakstan Abstract of PhD thesis (02.00.11). – Tashkent. 2018. – 47 p.
3. Clearfield A. Preparation of pillared clays and their catalytic properties in Advanced Catalysts and Nanostructured Materials // Academic Press. 1996. P. -394.
4. Beletskaya, V.A. Adsorption and catalytic properties of aluminosilicates / V.A. Beletskaya // Sorbents as a factor in the quality of life and health: Proc. II All-Russian scientific conference with international participation, Belgorod, September 13-18, 2006 - Belgorod: Belgorod State University Publishing House, 2006. - Pp. 23-27.
5. Kormosh E.V. Modification of montmorillonite-containing clays for complex sorption treatment of wastewater: diss. ... Cand. of Engineering Sciences. Belgorod. 2009. 177 p.
6. Structural characteristics of bentonite from the Krantau deposit // Universum: technical sciences: electronic scientific journal. Seitnazarova O.M. [et al.]. 2020. 12 (81). Pp. 49-54.
7. Utashev E.I., Abdikamalova A.B., Eshmetov I.D. Intercalated systems as adsorbents // Universum: chemistry and biology: electronic. scientific journal. 2020. No. 6 (72). URL: https://7universum.com/ru/nature/archive/item/9524 (date of access: 02/24/2021).