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STUDY OF THE INFLUENCE OF ULTRASONIC WAVES ON THE SORPTION CAPACITY OF ENRICHED BENTONITE OF THE CHERKASY DEPOSIT IN RELATION TO COPPER IONS

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Abstract. The research subject was bentonite clay of layer II from the Dashukivka area of the Cherkasy deposit. The clay was enriched with montmorillonite using sedimentation, followed by the production of particles with a fraction size of ≤ 0.001 mm. Both natural montmorillonite and the nature of isomorphic substitutions in its structure were confirmed through X-ray diffraction and comprehensive thermal analyses. The activation of montmorillonite-rich bentonite clay was achieved through ultrasonic waves. The sorption capacity of natural bentonite and ultrasonically modified enriched bentonite against Cu^{2+} ions was assessed by modeling the sorption isotherm data, using the Langmuir equation. The Cu^{2+} ions sorption mechanism was studied using energy-dispersive and diffractometric X-ray analyses. The research provided an analysis of applications of natural bentonite and ultrasonically modified enriched bentonite clay.

Keywords: bentonite clays, montmorillonite, ultrasound, sorption, thermal analysis.

1. Introduction

Pollution of the natural environment by heavy metals is one of the most hazardous forms of human-induced environmental impact [1]. Ions of certain heavy metals precipitate as poorly soluble compounds, accumulate in bottom sediments, and serve as a source of secondary pollution [2]. Heavy metals such as copper, zinc, nickel, and iron are commonly present in the environment, particularly in their most toxic ionic forms.[3,4].

Currently, the sorption method, which utilizes either natural mineral sorbents or synthesized sorbents derived from carbon-containing raw materials, is widely used for the purification of wastewater contaminated with heavy metals.[5-10] It is characterized by its simplicity, efficiency, and capability to extract heavy metal ions at very low concentrations in the liquid medium.[11]

Promising natural sorbents include bentonite clays, with montmorillonite (MMT) being the primary pore-forming mineral. Ukraine has approximately 110 bentonite clay deposits, one of the largest being the Cherkasy deposit, known for its bentonite and palygorskite clay. The clay reserves in this deposit account for approximately 80% of the country's total bentonite reserves. The productive clay layers of the Cherkasy deposit are divided into five layers. Among these, Layer II of the Dashukivka area, which is rich in the montmorillonite component, holds the greatest economic significance.[12]

Montmorillonite is a finely dispersed, layered aluminosilicate. Its structure is based on a fundamental three-layer arrangement of the 1:2 type, consisting of two siloxane tetrahedral grids with an octahedral aluminum oxanohydroxyl grid in between. These grids are held together by shared oxygen atoms, forming a cohesive single layer. Non-stoichiometric isomorphic substitutions of Al^{3+} ions in the octahedral positions by Mg^{2+} or Fe^{2+} ions result in the development of a structural negative charge. The spaces between the layers contain water molecules and exchangeable cations of alkali and alkaline earth metals, which balance the negative charge of the crystal structure.[13] Hydrated interlayer cations can release interlayer water and exchange with other organic or inorganic cations, causing changes in layer thickness.[14] Montmorillonites are characterized by a structural lability, swelling capacity, a well-developed surface, thermal stability, and high ion exchange and sorption capacities.

The economic feasibility of using bentonite clays is determined by effective methods for regulating the geometric structure, surface area, and chemical nature of the primary mineral, montmorillonite. An increase in the

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sorption capacity of bentonite clays is achieved through chemical and physical activation. Chemical activation of clays occurs through solutions of salts, alkalis, and organic and inorganic acids, while physical activation involves the application of ultrasonic waves, electric fields, electromagnetic radiation, or a combination of these methods. The short-term effects of ultrasonic waves can lead to the dispersion of clay particles and enhance the specific surface area.[15] Microwave radiation in aqueous media leads to the partial destruction of siloxane tetrahedral grids and an increase in the content of hydroxyl (OH) groups, which can act as additional sorption centers on the basal surfaces of montmorillonite (MMT).[16]

The ability of modified clay to alter its physico-chemical properties and structural-sorption characteristics largely depends on its origin, the method of activation, the content of montmorillonite, the natural exchange complex of MMT, and the structural charge of the mineral.

The study aimed to investigate the sorption capacity of enriched bentonite clay and ultrasonically modified enriched bentonite clay of layer II from the Dashukivka area of the Cherkasy deposit regarding the copper ions.

2. Experimental

2.1. Materials

Bentonite clay sourced from the Dashukivka area (II layer) of the Cherkasy deposit was used for this research. The average thickness of layer II from the Dashukivka area was 7.5 m.

As the analysis of the chemical and mineral composition of bentonite clays from the Dashukivka area (layer II) was conducted at different laboratories and on various samples collected from different places of the layer, the data may vary. The following fluctuations in the chemical composition were observed: (wt.%): SiO_2 – 50.0-60.0; Al_2O_3 – 14.0-19.5; CaO – 1.3-3.0; MgO – 1.7-2.6; Fe_2O_3 + FeO – 2.4-7.0; H_2O – 10-14. K_2O i Na_2O, sulfur (SO_3^{2-}), carbon (CO_3^{2-}) were also present.

The bentonite clay of the Cherkasy deposit is primarily composed of montmorillonite, with impurities of finely dispersed quartz and its crystalline modifications.[17]

A model solution of copper ions with a concentration of 1 mg/mL was prepared using $CuSO_4 \cdot 5H_2O$ («pure per analysis») and distilled water. A series of working solutions was obtained from the initial solution by stepwise dilution with distilled water.

2.2. Methods

Bentonite clay, along with montmorillonite, is capable of incorporating admixtures of other minerals, including non-clay ones. The bentonite under investigation was enriched with montmorillonite through a coarse phase sedimentation. The sample was crushed in distilled water with a solid-to-liquid ratio of 1:10. To extract the sand fraction, the clay suspension was passed through a sieve d<0.1 mm, allowed to settle for 16 hours, and the top 10 cm layer was collected, which contained particles of the clay component measuring ≤ 0.001 mm.[18]

X-ray diffractometric studies were carried out on an ADP-2.0 diffractometer. The XRD system operated under the following conditions: 30kV, 15 mA, Mn-filtered Fe radiation. A step size of 0.025° 2Θ was used with an acquisition time of 3 s/step.

Montmorillonite was diagnosed by the intense reflex (001) in the area of small angles on the diffractogram of the oriented preparation.[19]

Oriented preparations were created through the gravitational sedimentation of montmorillonite-rich bentonite (enriched bentonite or shortly EB) suspension at 1:10 solid-to-liquid ratio. The presence of non-clay minerals in the natural bentonite was determined using unoriented preparations of mechanically ground rock. Mineral identification was conducted using the ICDD database and the Crystallographica Search-Match Version 3.1.0.0 program.[20]

Ultrasonic dispersion of montmorillonite-containing clay was performed in an aqueous medium for 4 min. Radiation frequency 40 kHz, power 60 kW, intensity 3 W/cm^2. Thus, ultrasonically modified enriched bentonite clay was obtained (ultrasonically modified EB)

Complex thermal analysis of EB samples was carried out on a derivatograph Q-1500 of the Paulik–Paulik–Erdey system connected with a PC. The sample was heated in an air atmosphere to a temperature of 800 °C. The rate of sample heating was 5°C/min. The mass of EV sample was 500 mg. Aluminum oxide served as a reference substance. To remove physically bound moisture before conducting thermal studies, the samples were dried for 3 days at a temperature of 50°C.

Sorption of Cu^{2+} ions with both EB and ultrasonically modified EB samples was carried out for two days. 50 cm^3 of copper ions solution of the known concentration was added to 250 mg of the samples. The suspension was stirred at a temperature of 25°C, and the equilibrium solution was separated from the dispersed phase by centrifugation. The acidity of bentonite suspensions was 4.0–4.1.

The elemental composition of the clay samples was analyzed using energy dispersive X-ray spectroscopy (EDX) with the INCA Energy 350 instrument, integrated into the Zeiss EVO-40XVP scanning electron microscope system.

The sorption value of the Cu^{2+} ions was determined by the difference in the initial c_i and the equilibrium c_e

solutions concentration of copper ions. The Cu^{2+} ions concentration in solutions was determined by atomic absorption spectrometry (SHIMADZU AA-7000 F/AAC spectrophotometer).

3. Results and Discussion

The diffractogram of an unoriented preparation of mechanically ground natural bentonite (Fig. 1) shows, in addition to the clay component, the presence of silicon oxides in the forms of quartz (0.424, 0.334, and 0.245 nm), cristobalite (0.402 nm), and tridymite (0.430 nm).

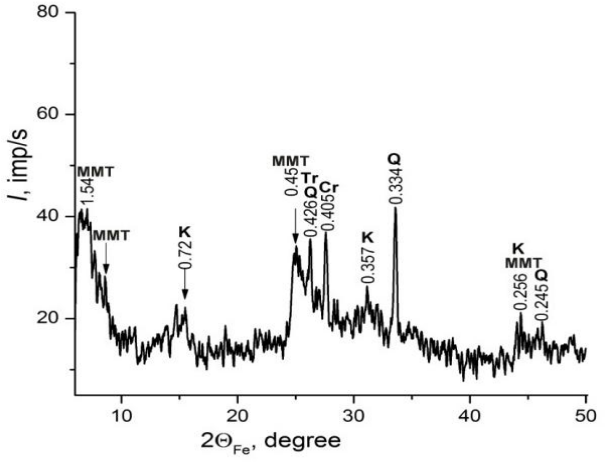

Fig. 1. Diffractogram of an unoriented preparation of bentonite clay Designation: MMT– montmorillonite, K – kaolinite, Q – quartz, Cr – cristobalite, Tr - tridymite

According to X-ray diffractometric analysis (Fig. 2), the primary mineral in EB is montmorillonite. The identification of MMT was based on its main basal reflection, which appeared on the diffractogram of the oriented sample in the low 2θ angle range of 6.8–7.2.[19]

A sharp and intense peak indicates the homogenization of the interlayer spaces within the mineral structure, suggesting it is nearly monophasic. Silicon oxide present in the original rock appears in the diffractograms of the enriched sample only as a background increase in the 22–37° 2θ region, with minor reflections indicating trace amounts of pelitomorphic silica (opal, cristobalite). Minor reflections with interplanar distances of 0.72 nm and 0.357 nm suggest the presence of a kaolinite admixture.

The primary reflection of montmorillonite shows a split peak with an average interplanar distance of 1.54 nm, suggesting the presence of exchangeable cations Ca^{2+} and Mg^{2+} within the interlayer space of MMT, which can retain two layers of water molecules. Adjacent to the main MMT basal line, minor reflections appear at 2θ angles of 5° and 10.6°, corresponding to interlayer distances of 2.15 nm and 1.06 nm, respectively. This addition to the primary reflections indicates the presence of a small number of montmorillonite (MMT) packets in the EB, with cations in the exchange complex K^+ i Na^+.[21]

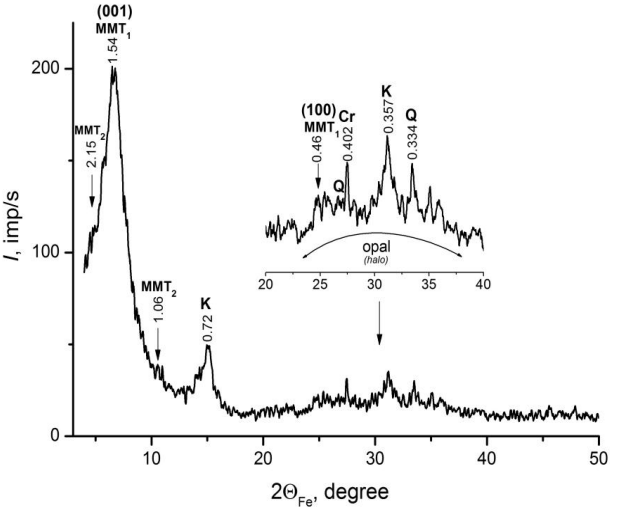

Fig. 2. Diffractogram of the oriented preparation of enriched bentonite: Designation: MMT_1 – packages of Ca, Mg -montmorillonite; MMT_2 – packages of Na, K montmorillonite; K – kaolinite; Q – quartz; Cr – cristobalite

The results of the X-ray analysis of the EB sample are supported by data from the complex thermal analysis, presented in the form of a thermogram (Fig. 3).

The significant mass loss (8.58%) of the EB sample in the range of 20–313°C corresponds to the release of interlayer water from montmorillonite, which is coordinatively bound to the exchangeable cations.[22] In the same temperature range, there is also a loss of physically bound water. A distinct inflection on the differential curves at a temperature of 140°C indicates a significant presence of alkaline earth montmorillonite in the EB, which gradually loses interlayer water upon heating. The loss of the first layer of coordination-bound Ca^{2+} and Mg^{2+} cations occurred in the temperature range of 20–140°C, while the next layer of water was lost between 140–313°C. The loss of interlayer water was accompanied by structural compression and a reduction in the interlayer space of MMT.

The mass loss (5.67%) of the EB sample in the temperature range of 313–572°C corresponds to the structural breakdown of MMT, accompanied by the release of constitutional water.[23]

In this temperature range, the MMT packets were destroyed, with some Al^{3+} cations in the octahedral positions isomorphically replaced by Fe^{3+} cations. It is known that this type of isomorphic substitution Al^{3+}® Fe^{3+} (Fe^{2+}), can reduce the thermal stability of montmorillonite

and alter the dehydroxylation process of the mineral at lower temperatures[14]. The destruction of the MMT structure is accompanied by a sharp peak on the DTG curve, with a maximum at 500°C, and a distinct endothermic effect on the DTA curve.

The mass loss (0.82%) of the EB sample at temperatures above 572°C corresponds to a further degradation of MMT, involving the release of hydroxyl water bound to Mg^{2+} cations located in the octahedral positions of the MMT structure. It is known that isomorphic substitution of Al^{3+} by Mg^{2+} can increase the structural charge and thermal stability of MMT[24]. The completion of the mineral's dehydroxylation process was accompanied by a minor endothermic effect observed on the DTA curve.

The thermal analysis results of ultrasonically modified EB samples indicate that ultrasound treatment did not affect the nature of their dehydration or the content of constitutional water. It is likely that, under the influence of ultrasound, the MMT crystals were separated along the basal surfaces without undergoing transverse destruction, which may have led to an increase in the number of hydroxyl (OH) groups.

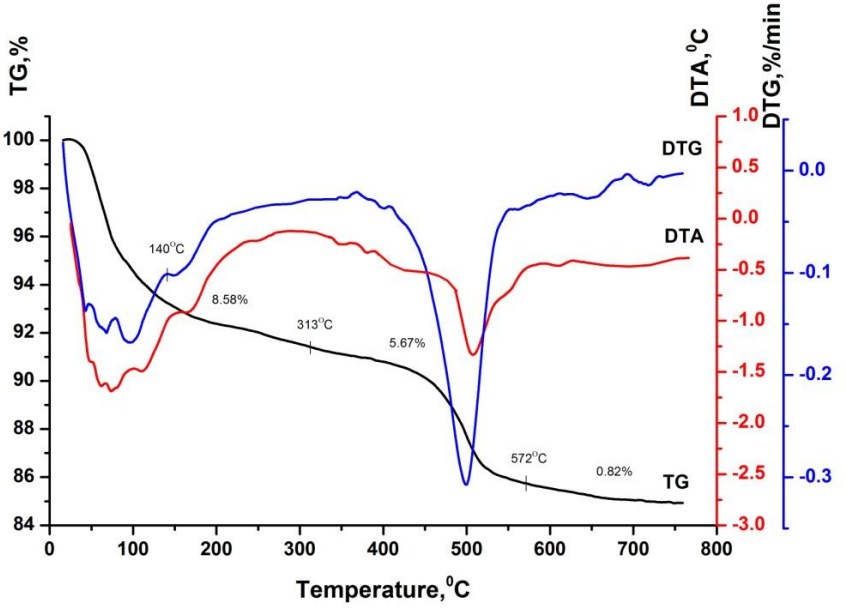

Fig. 3. Thermogram of a sample

Based on data from complex thermal and X-ray diffraction analyses, it can be stated that the bentonite clay, enriched by sedimentation of layer II from the Dashukivka area of the Cherkasy deposit, is monophase and primarily consists of Ca, Mg-montmorillonite. The interlayer spaces of some montmorillonite packets are filled with hydrated Na^+ or K^+ cations. In the octahedral positions of the montmorillonite structure, isomorphic substitution occurs, where some Al^{3+} cations are replaced by Fe^{3+} (or Fe^{2+}) and Mg^{2+} cations.

The ferruginous type of montmorillonite, which is the primary rock-forming mineral of the Cherkasy bentonite, has been confirmed by other researchers. Rakitskaia *et al.*[25]analyzed infrared (IR) spectroscopic data on the bentonite clay from the Dashukivka area of the Cherkasy deposit. Infrared spectroscopy is highly sensitive to the presence of octahedral atoms in the MMT structure. The band observed at 3622 cm^{-1} in the spectrum of the bentonite clay corresponds to the vibrational stretching of OH groups in the Al-Al-OH structural unit. At the same time, a band at 875 cm^{-1} was distinctly observed in the spectrum, corresponding to the deformation vibrations of hydroxyl groups in the Al-Fe-OH structural fragment of the MMT octahedral lattice.

The sorption of heavy metal ions by montmorillonite can occur through various external mechanisms, including ion exchange, precipitation as poorly soluble compounds, complex formation, and others. The sorption mechanism is influenced by the pH value of the medium, the presence of specific anions in the solution, the nature of the montmorillonite cation exchange complex, and the activation conditions of the sorbent.[26]

One of the primary mechanisms for the sorption of heavy metal ions by montmorillonite is ion exchange. During this process, the ions of the natural exchange complex are replaced by ions of the same charge in equivalent amounts. Various types of sorption centers in montmorillonite can participate in cation exchange: oxygen

atoms on the basal surfaces and hydroxyl groups on the side faces of montmorillonite, which arise due to the breaking of chemical bonds within the tetrahedral and octahedral grids of montmorillonite.[27]

Figure 4 shows the diffractometric curves of ultrasonically modified EB samples that absorbed copper ions from solutions with different initial concentrations. The diffractometric curves of the samples show the appearance of reflections at 1.26 nm and 1.23 nm (8.8–9.0° angles 2θ). It is known that Ca^{2+} and Mg^{2+} ions in the interlayer space of air-dried MMT samples can retain approximately two layers of coordination-bound water molecules21. In contrast, Cu^{2+} ions are capable of holding only one layer of water molecules[28,29]. When Ca^{2+} and Mg^{2+} ions are exchanged for Cu^{2+} ions, the interlayer gap can shrink, resulting in a decrease in interlayer distance from 1.54 nm to 1.23 nm. The appearance of reflections at 1.23 nm and 1.26 nm corresponds to the gaps in the MMT structure where the complete exchange of Ca^{2+} and Mg^{2+} ions for Cu^{2+} ions has occurred.

As shown in Fig. 4a, since the concentration of Cu^{2+} ions in the solution increases, the intensity of the basal reflection (001), corresponding to an interplanar distance of 1.26 nm, also increases, while the intensity of other reflections decreases, which may indicate a more intense counterflow of ion exchange.

In the MMT structure of samples that adsorbed Cu^{2+} ions, some gaps indicate incomplete cation exchange, along with a few relic packets where ion exchange did not occur. This observation is supported by reflections on the diffractometric curves corresponding to interplanar distances of 1.54 nm and 1.46 nm.

The diffractograms of samples that sorbed Cu^{2+} ions show no reflections across a wide range of diffraction angles, confirming the formation of new crystalline phases (Fig. 4c). The region of 10–50° in 2θ contains only broad lines of low intensity, which correspond to higher-order MMT basal reflections.

The compression of the MMT structure and the absence of new crystalline phase lines in the sample diffractogram indicate that no insoluble copper compounds precipitated on the surface of the MMT crystals. This suggests that the sorption of Cu^{2+} cations occurs through an ion-exchange mechanism.

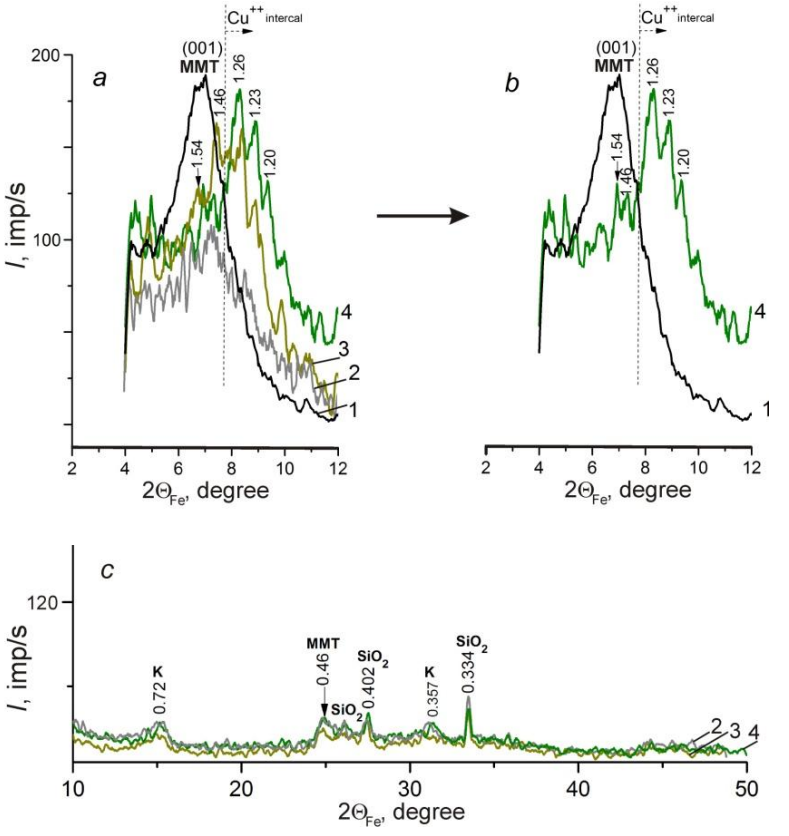

Fig. 4. Diffractograms of bentonite samples: EB (1); ultrasonically modified EB that absorbed Cu^{2+} ions from a solution with a con

The results of the X-ray analysis were corroborated by the EDX elemental analysis data. Fig. 5 presents the EDX spectra of EB sample and the ultrasonically modified EB sample that absorbed Cu^{2+} ions from a solution with a concentration of 1.5 mg/mL.

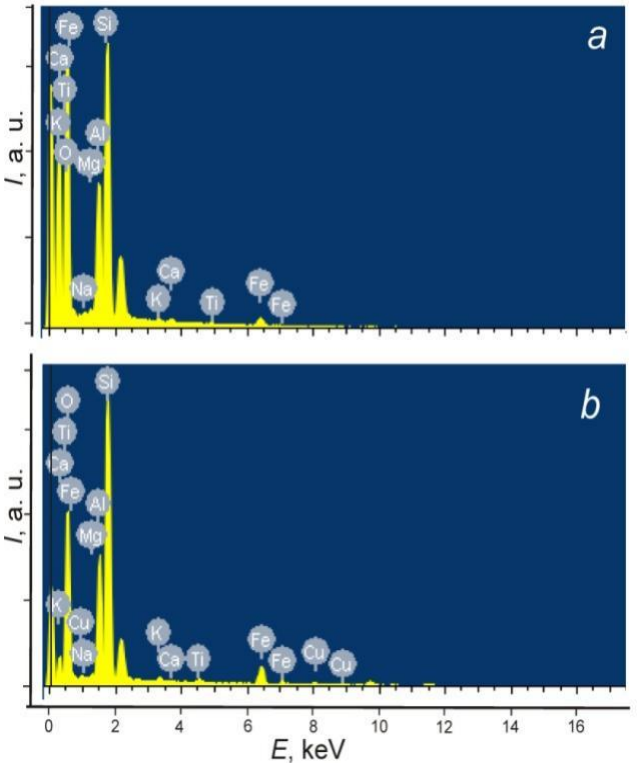

Fig. 5 EDX spectrum of EB sample (a) and EB sample that absorbed Cu^{2+} ions from a solution with a concentration of 1.5 mg/mL (b).

The spectrum of the EB sample corresponds to a layered aluminosilicate with a notable content of calcium (0.86 wt%) and magnesium (0.53 wt%). Smaller amounts of potassium (0.46 wt%) and sodium (0.32 wt%) are also present in the EB sample (Fig. 5a). In the EDX spectrum of the ultrasonically modified EB sample that absorbed Cu^{2+} ions from a solution with a concentration of 1.5 mg/mL., the calcium and magnesium content is less prominent compared to that of EB sample (Fig. 5b). However, a copper band appears in this spectrum.

According to energy-dispersive X-ray analysis, the copper ion content in the sample modified by ultrasonic waves is 1.93 wt%, while the content of calcium and magnesium ions decreases to 0.13 wt% and 0.33 wt%, respectively. A slight reduction in the content of K^+ ions to 0.36 wt% and Na^+ ions to 0.21 wt% is also observed. The change in the MMT exchange complex of Ca^{2+} and Mg^{2+} ions (0.529 mEq/g) and K^+ and Na^+ ions (0.0733 mEq/g) within a margin of error (0.8%) corresponds to the increase in Cu^{2+} ions (0.607 mEq/g). These results indicate that the sorption of Cu^{2+} ions by MMT occurs through an ion exchange mechanism.

The substantial residual content of magnesium in the ultrasonically modified EB saturated with copper ions can be attributed to the presence of Mg^{2+} ions in the octahedral positions of the MMT crystal lattice. The slight decrease in K^+ and Na^+ ion content during the saturation of MMT with Cu^{2+} ions is likely due to the lower ability of these ions to participate in ion exchange processes.

It is known that oxygen atoms located on the basal surfaces of the mineral can act as cation exchange centers in MMT, referred to as Regular Exchange Sites (RES).[30] These RES centers arise due to an uncompensated negative charge in the octahedral aluminoxane lattice of the MMT structure, resulting from isomorphic substitutions. The RES centers in montmorillonite EB from the Cherkasy deposit are capable of holding hydrated divalent cations such as Ca^{2+} and Mg^{2+} in the interlayer space. These centers can actively participate in ion exchange processes with Cu^{2+} ions.

One type of ion exchange center is the hexagonal surface of siloxane tetrahedra. These centers can selectively exchange monovalent cations, while the access of large hydrated divalent cations is sterically hindered. Such centers can participate in ion exchange processes if located at the edge regions of the MMT base surfaces. In this case, they are referred to as Frayed Edge Sites (FES).[31] Therefore, only a small amount of K^+ and Na^+ cations, sorbed by the FES centers of MMT, could participate in ion exchange processes with Cu^{2+}. This may explain the relatively low cation exchange capacity of ultrasonically modified EB compared to potassium and sodium cations.

Fig. 6 shows the sorption isotherms of Cu^{2+} ions by EB and ultrasonically modified EB. The sorption capacity of both EB and ultrasonically modified EB was evaluated by modeling the experimental sorption isotherms using the Langmuir equation.

$$q_e = \frac{q_m K c_e}{1 + K c_e} \quad (1)$$

where q_e – sorption value, q_m – the monolayer sorption capacity or the maximum value of monomolecular sorption, K – sorption-desorption equilibrium constant.[32]

The sorption results indicate that monomolecular sorption occurs on both the surface and in the interlayer space of montmorillonite, suggesting that the MMT sorption centers are energetically homogeneous. The RES centers on the basal surfaces of MMT can act as these sorption centers. The participation of group faces and basal surfaces of MMT in cation exchange hydroprocesses is limited. Hydroxyl groups associated with cations such as Al^{3+}, Mg^{2+}, and Fe^{3+} (Fe^{2+}) in the octahedral layer of MMT can only be engaged in anion exchange in acidic, neutral, and mildly alkaline environments. Additionally, hydroxyl groups linked to Si^{4+} ions in the tetrahedral layer of MMT

actively participate in cation exchange only at pH > 5.[33] In this study, the sorption of Cu^{2+} ions was conducted at pH of 4.1. Under these conditions, the hydroxyl groups on the MMT surfaces participated minimally in cation exchange.

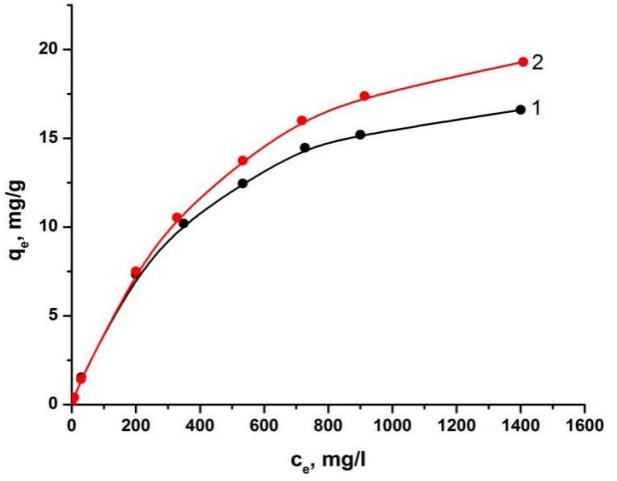

Fig. 6. Sorption isotherms of Cu^{2+} ions: 1 – EB; 2 – ultrasonically modified EB

Table 1. Parameters of the sorption isotherm for Cu^{2+} ions by EB and ultrasonically modified EB

Sample	Sorption capacity q_m, mg/g	Equilibrium constant K, L/mg	R^2
Natural EB	21.696	0.0026	0,993
Activated EB	27.203	0.0019	0,999

It is noteworthy that ultrasonically modified EB exhibited a higher sorption capacity for Cu^{2+} ions (see Table 1). This result can be attributed to the short-term application of ultrasound (from 5 to 6 minutes), which facilitates the active dispersion of clay suspension particles, opens the basal surfaces of MMT, and increases the number of active centers on the MMT surface available for ion exchange. Ultrasonic activation presents additional opportunities for utilizing Cherkasy bentonite to purify wastewater from heavy metal ions.

In addition to their high sorption capacity for heavy metal ions, Cherkasy bentonites also exhibit a strong affinity for water.[34] Water, being a polar compound, easily penetrates the structure of natural sorbents and interacts with cation centers. The activity of water depends on a combination of the sorbents' structural, physical, and chemical properties, as well as their origin. Compared to the bentonites from the Gorbsky, Kirovohradsky, and other deposits in Ukraine, the bentonite from the Dashukivka area of the Cherkasy deposit exhibits a lower thermodynamic activity of sorbed water but a higher water absorption capacity. The montmorillonite-rich bentonite clay from the Cherkasy deposit is suitable for engineering solutions in landfill leachate protection, particularly for creating anti-filtration barriers.[35]

4. Conclusions

The results of physical and chemical studies indicate that the montmorillonite-enriched bentonite clay of layer II from the Dashukivka area of the Cherkasy deposit is nearly monomineralic, consisting primarily of Ca, Mg-montmorillonite. Within the octahedral positions of montmorillonite (MMT), some Al^{3+} cations are isomorphically substituted by Fe^{3+} (or Fe^{2+}) and Mg^{2+} cations. Additionally, K^+ and Na^+ cations are partially present in the exchange complex of MMT.

In the examined range of concentrations and pH levels, the sorption of Cu^{2+} ions by both EB and ultrasonically modified EB occurs through an ion exchange mechanism. EDX analysis reveals that the reduction in the interlayer space of naturally exchangeable cations corresponds to an increase in Cu^{2+} ions. Additionally, X-ray analysis indicates that this ion exchange is accompanied by a contraction of the montmorillonite structure, resulting in a decrease in interplanar distance from 1.54 nm to 1.23–1.26 nm.

The experimental results of the sorption isotherms for Cu^{2+} ions by both EB and ultrasonically modified EB conform to the Langmuir equation, indicating the energy homogeneity of the montmorillonite sorption centers. The active centers can be identified as negatively charged regions on the base surfaces of MMT (Regular Exchange Sites), where hydrated divalent exchange cations can be retained.

The linearization of the Langmuir model revealed estimated sorption capacities of 21.696 mg/g for EB and 27.203 mg/g for ultrasonically modified EB regarding the Cu^{2+} ions. The increased sorption capacity of the ultrasonically activated EB is attributed to the dispersion of clay particles, which enhances the number of active montmorillonite (MMT) centers available for ion exchange.

Ultrasonically modified montmorillonite-rich bentonite clay of layer II from the Dashukivka area of the Cherkasy deposit exhibits a higher sorption capacity for Cu^{2+} ions. This activated bentonite clay has potential as an effective sorbent for the purification of wastewater contaminated with heavy metal ions.

Increased water-holding capacity enhances the potential of EB from the Cherkasy deposit for developing engineering methods to protect against landfill leachate by establishing anti-filtration screens and engineering barrier systems for radioactive substances. This capability is

supported by the geological compatibility of bentonite clay with the ecological burial site, the presence of significant deposits of layer II bentonite from the Dashukivka area of the Cherkasy deposit, and the straightforward method of its extraction.

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ДОСЛІДЖЕННЯ ВПЛИВУ УЛЬТРАЗВУКОВИХ ХВИЛЬ НА СОРБЦІЙНУ ЗДАТНІСТЬ ЗБАГАЧЕНОГО БЕНТОНІТУ ЧЕРКАСЬКОГО РОДОВИЩА СТОСОВНО ЙОНІВ КУПРУМУ

Анотація. *Об'єктом дослідження була бентонітова глина шару II Дашуківської ділянки Черкаського родовища. Збагачення глини монтморилонітом проводили методом седиментації з отриманням фракції £ 0.001 мм. Природний тип монтморилоніту та характер ізоморфних заміщень у його структурі підтверджували Х-променевим дифрактометричним і комплексним термічним аналізами. Активацію збагаченої монтморилонітом бентонітової глини проводили дією ультразвукових хвиль. Сорбційну ємність природної та модифікованої дією ультразвукових хвиль збагаченої глини стосовно іонів Cu^{2+} оцінювали за допомогою моделювання даних ізотерм сорбції рівнянням Ленгмюра. Механізм сорбції іонів Cu^{2+} досліджували енергодисперсійним і дифрактометричним Х-променевими аналізами. Окреслено перспективи використання природної й активованої дію ультразвукових хвиль збагаченої бентонітової глини.*

Ключові слова: *бентонітові глини, монтморилоніт, ультразвук, сорбція, термічний аналіз.*