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WASTEWATER TREATMENT WITH SORBENTS MADE OF MODIFIED VERMICULITE AND ORGAN VERMICULITE

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Abstract. The article investigates the modified Vermiculite with chitosan and adsorption capacity of organ sorbent based on.
This paper investigates the efficiency of wastewater treatment using sorbents based on modified vermiculite and organ vermiculite. Vermiculite, a layered aluminosilicate with high cation exchange capacity and thermal stability, was chemically and thermally modified to enhance its adsorption properties. Additionally, surface modification with organic compounds was applied to obtain organ vermiculite with increased affinity for organic pollutants. The sorption capacity of both materials was evaluated for removing heavy metals (such as Pb^{2+}, Cu^{2+}, and Zn^{2+}) and organic contaminants (such as phenols and dyes) from industrial and domestic wastewater. Experimental results demonstrated that organ vermiculite exhibited higher sorption efficiency toward organic pollutants, while thermally modified vermiculite was more effective in capturing heavy metal ions. The study confirms the potential of using natural and modified vermiculite-based sorbents as cost-effective and environmentally friendly materials for advanced wastewater treatment applications.
Key words: technology modification, vermiculite, chitosan, organ sorbent, adsorption, organ vermiculite, wastewater treatment, heavy metals, organic pollutants.

Introduction. Despite the many physical and chemical processes currently used in wastewater treatment, the most effective and promising for removing the bulk of pollutants are sorption processes using natural adsorbents. Along with traditional sorption materials, activated carbons, natural aluminosilicates such as clays with an expanding (montmorillonite, vermiculite) or rigid structural cell (kaolinite, hydromica, palygorskite) are widely used for these purposes. Considering the fact that the composition and properties of clays are individual for each deposit, it is important to obtain new cheap and universal sorbents based on local mineral raw materials, study the mechanisms of interaction of pollutants with the obtained sorbents and develop wastewater treatment technologies that allow creating closed water circulation systems and reducing the burden on the environment.

Among the variety of adsorbent materials studied, natural layered silicates, such as vermiculite, have attracted increasing attention due to their abundance, low cost, thermal stability, and relatively high cation exchange capacity. Vermiculite is a hydrated magnesium–aluminum–iron silicate with a layered structure, which can be thermally expanded or chemically modified to enhance its adsorptive properties. Thermal treatment leads to exfoliation of layers and an increase in surface area, making the material more accessible to pollutants. Meanwhile, chemical surface modification, particularly with organic cationic surfactants, leads to the formation of organ vermiculites—materials that combine the structural stability of silicates with the hydrophobicity and affinity for organic molecules typical of carbon-based adsorbents. Despite numerous studies on individual types of modified clays, comparative research on the performance of thermally modified vermiculite versus organ vermiculite in wastewater treatment remains limited. Moreover, the selectivity of these materials toward different classes of pollutants (inorganic vs. organic) is not yet fully understood, especially under realistic multi-contaminant conditions. The aim of this study is to evaluate and compare the adsorption

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efficiency of thermally modified vermiculite and organ vermiculite in removing both heavy metals and organic pollutants from synthetic wastewater. The materials are characterized using modern physicochemical methods, and their performance is assessed through batch adsorption experiments under varying operational parameters. The results are analyzed in terms of adsorption isotherms, kinetics, and reusability, providing insight into the potential application of vermiculite-based sorbents in sustainable and low-cost wastewater treatment technologies.

One of the aims of this scientific work is to develop a technology for wastewater treatment with sorbents based on vermiculite modified with chitosan. The relevance of the development is determined by the growing interest in the creation of new environmentally friendly sorbents from natural hydromicas and aluminosilicates. However, it should be noted that the limiting factor for the mass use of organovermiculites for the treatment of textile wastewater (TSW) is the lack of effective granulation technologies, since sorbents are prone to dispersion in aqueous media.

Based on the data obtained and on the basis of complex experimental studies, scientific and methodological principles for the creation of modified vermiculites with organic reagents were developed:

At the beginning of the process, careful selection and sorting of quarry clay is necessary. An important part of the preparation of the raw material for the technological process of adsorbent production is their separation from impurities of non-clay minerals after preliminary grinding.

The technological scheme for the production of organobentonite sorbents consists of the following stages:

- extraction of raw materials;
- preparation of raw materials, consisting of the processes of separation of non-clay substances (feldspar, quartz, micas, etc.) from impurities and preliminary grinding;
- enrichment of clays with the preparation of paste-like suspensions and sedimentation of coarse fractions;
- preparation and dosing of chemical reagents – modifiers;
- modification of clay paste with polymer compounds;
-drying and grinding, packaging and storage of the resulting adsorbents.

Research results and discussion. As a result of the conducted laboratory studies, the technological scheme of using organ vermiculite for cleaning textile wastewater was compared. The scheme includes a preparation stage, for adjusting the pH from the tank (1) hydrochloric acid is fed then into the reactor with a stirrer for precipitation coagulant aluminum sulfate (2) and mixed with water (2) at a mass ratio of 1:3 and stirred for 2 hours. After 24 hours of swelling in water, the clay is broken into a suspension using a mechanical stirrer, then water is added in a ratio of 1:2 and the suspension is thoroughly mixed . Next . After sedimentation, the water was drained through the upper side siphon (6), the raw material from the middle part of the tank was extracted (6) into a flat tank for air drying. Through the lower part of the sedimentation tank (7) coarse sand and other sedimentary substances settled on the bottom of the tank were separated and did not participate in the further technological process. The dispersed raw material was laid out in a thin layer (7) and air-dried for 24-48 hours. Then the semi-dried raw material was pre-crushed using a hand crusher, which could be a disk mill. This was followed by drying in a drying cabinet at a temperature of 110°C for 4 hours to a residual moisture content of 20% . Then the dried clay samples were fed into a planetary mill, where certain portions of modifiers (12) were fed using a dispenser (3) and subjected to modification and dispersion for 30 minutes. The mass of each sample was 1 kg (0.8-0.9 kg is the mass of the original bentonite clay and 0.1-0.2 kg is the mass of the modifier).

The results of the conducted experiments confirm the high efficiency of using modified vermiculite and organ vermiculite as sorbents for wastewater treatment. The observed

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differences in adsorption capacities between the two materials can be attributed to their structural and surface modifications. In contrast, organ vermiculite, prepared by surface modification with organic cationic surfactants, exhibited significantly higher adsorption efficiency for organic pollutants, such as phenols and synthetic dyes. The hydrophobic organic groups on the vermiculite surface created an environment favorable for the sorption of non-polar and semi-polar organic molecules. The presence of π-π interactions, hydrogen bonding, and van der Waals forces likely contributed to the improved retention of these contaminants. Similar behavior was reported in studies on organoclays used for removal of aromatic compounds from wastewater. The selectivity observed in the two sorbent types indicates their potential for targeted applications. Thermally modified vermiculite is more suitable for treating wastewater contaminated with heavy metals, particularly from mining, electroplating, or battery industries. Organovermiculite, on the other hand, is effective for treating effluents containing organic pollutants from textile, pharmaceutical, and petrochemical industries.

It is also important to note that both sorbents exhibited high stability and low leaching under experimental conditions, which is critical for environmental safety. Additionally, their regeneration potential, assessed through desorption tests, showed promising results, indicating the possibility of multiple reuse cycles with minimal efficiency loss. However, certain limitations were observed. For example, in multi-component systems containing both metals and organics, competitive sorption reduced the efficiency of both materials. This suggests that further surface functionalization or combined sorbent systems may be required for complex wastewater streams.

Overall, the study confirms that vermiculite-based sorbents—when properly modified—can be cost-effective, environmentally sustainable alternatives to conventional adsorbents like activated carbon or synthetic resins, particularly in regions with abundant natural vermiculite resources.

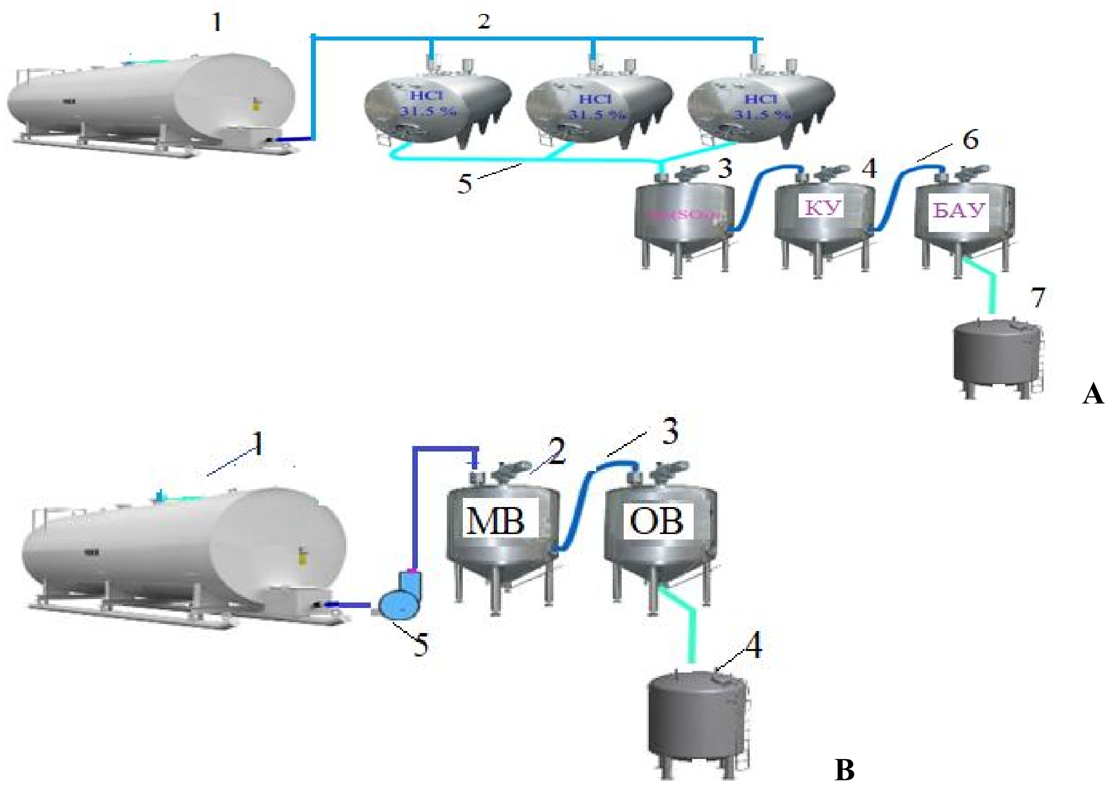

Fig. A) Traditional technological scheme of wastewater treatment for textile production at JSC Bukhara cotton »

B) simplified developed technology

2) bunkers for hydrochloric acid clay; 3) reactor with a stirrer for coagulant; 4) sedimentation tank; 5) lower siphon for draining water; 6) upper siphon; 7) tank for technical water

As a result of extrusion molding, cylindrical granules with a diameter of 0.5–2 mm and a height of 1–2.5 mm were formed, which were subjected to heat treatment. The resulting granules were then sent to a packer.

It is necessary to emphasize the simplicity, low cost , environmental and chemical safety of the proposed technological scheme for the production of a pilot batch of adsorbent based on natural vermiculites and organic modifiers. Mini-industrial form of this laboratory technology has been mastered at the Department of General Chemistry at TSTU, and on its basis in the production conditions of this enterprise, various adsorbents (X-VVK, MVV) were produced in the amount of 2 kg each, which were transferred for pilot production testing to " Bukhara" cotton textile ».

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