EFFICIENT METHODS FOR OBTAINING ADSORBENTS THROUGH CHEMICAL ACTIVATION OF CLAY POWDERS

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ЭФФЕКТИВНЫЕ МЕТОДЫ ПОЛУЧЕНИЯ АДСОРБЕНТА НА ОСНОВЕ ХИМИЧЕСКОЙ АКТИВАЦИИ ГЛИНОВОГО ПОРОШКА

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ABSTRACT

The methods for obtaining sorbents today depend significantly on the activation techniques used. Activation is primarily determined by the intended purpose of the product and its standard requirements. Most importantly, the type of sorbent must meet specific demands, and the molecular characteristics of the sorbates are identified. Experiments are conducted, taking into account the general size of the sorbates. This article focuses on experimental work to activate clay powders for use in cleaning, bleaching, and clarifying products. The obtained sorbents were analyzed during practical trials, and the results were compared to assess their effectiveness. These sorbents were employed to remove harmful substances from cottonseed oil and drinking water. Efficient activation methods for processing clay powders and obtaining high-performance sorbents were identified.

АННОТАЦИЯ

Сегодня способы получения сорбентов зависят от способов активации. Активация в основном основана на предполагаемом использовании продукта и его стандартных требованиях. Самое главное – определить, каким требованиям отвечают сорбенты и какие молекулы выполняют роль сорбатов. Эксперименты проводятся с учетом общего размера сорбетов. В статье проведены экспериментальные работы по активации глиняных порошков для чистки, отбеливания и осветления изделий. Полученные сорбенты были проанализированы в практических испытаниях. Результаты анализа сравнивались между собой и наблюдались сравнительные показатели. Сорбенты использовались для очистки хлопковых масел и технической воды от вредных веществ. Определены пути получения высокоэффективных сорбентов и активизации переработки глинистых порошков.

Keywords: cottonseed oil, clay powder, purification, decolorization, sorption properties, structural composition, sulfuric acid, grinding, size, sorbent, activation, sorbate

Ключевые слова: хлопковое масло, глинистый порошок, очистка, обесцвечивание, сорбционные свойства, структурная структура, серная кислота, помол, крупность, сорбент, активация, сорбат.

Introduction

The soil of Uzbekistan is rich in minerals due to its natural composition and structure. Among these minerals, bentonite clay powders stand out due to their specific properties and applications. Several scientific sources have highlighted the use of clay powders as adsorbents.

The characteristics of a sorbent depend on its selectivity, efficiency, and suitability for cyclic adsorption processes. Ideally, sorbents should meet the following requirements:

- High volumetric adsorption capacity
- Rapid adsorption kinetics
- Easy regeneration
- High mechanical strength

Operational performance requirements for sorbents include:

- Covering a large internal pore volume
- A large internal surface area
- Surface properties controlled by functional groups
- Adjustable pore size distribution
- Weak interactions between adsorbate and adsorbent within micropores (primarily in physical adsorption)
- Enhanced chemical and mechanical stability, utilizing inorganic or ceramic materials as cost-effective raw materials.

These requirements are primarily applied to sorbents used in cyclic adsorption processes based on physical adsorption [1, p.63; 2, p.54-56].

Due to its high sorption properties, clay is widely used in various processes, especially in the food industry, for purifying, bleaching, and ensuring the quality of plant-based and cottonseed oils. The chemical activation of clay powders is a complex process. Therefore, before chemically modifying clay powders, it is crucial to study the chemical composition of bentonite, analyze the properties of its elements, and examine the impact of factors such as modifier concentration, temperature, pressure, and solution environment during the modification process.

Materials and methods. To initiate this chemical process, clay samples obtained from deposits are analyzed and prepared for chemical activation. Initially, the clay is ground to a particle size of 0.1 mm, then sieved. A series of experiments were conducted to obtain high-quality sorbents, and their sorption properties were compared against each other.

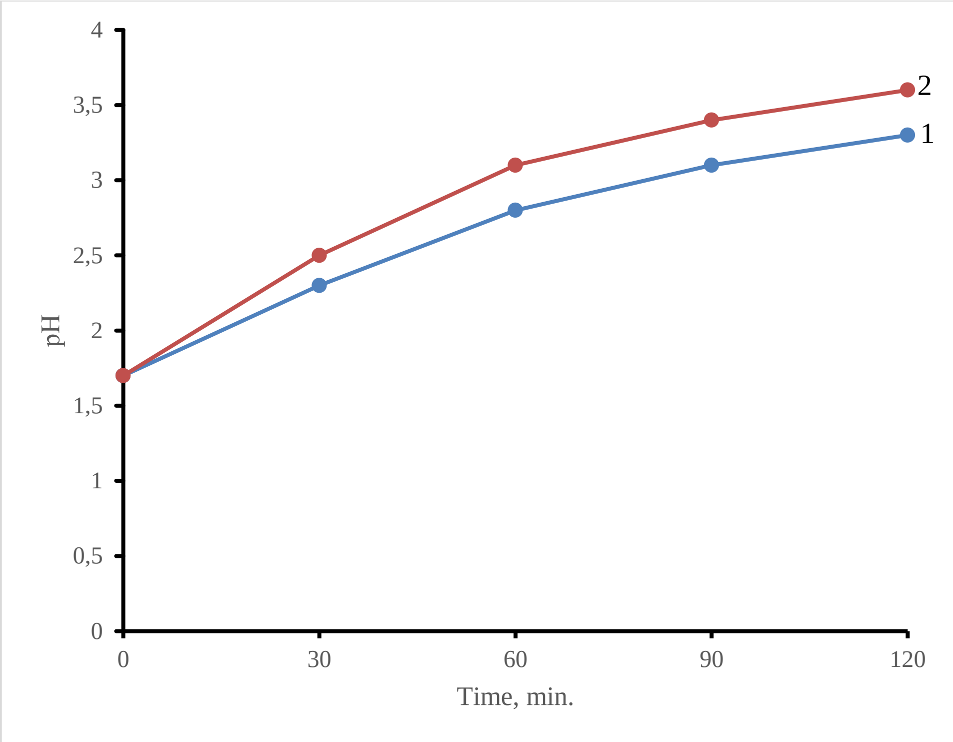
The modification process of clay powders involved two stages of activation to develop an efficient technology for producing sorbents. The optimal method for enhancing sorption properties was carried out as follows:

Stage 1: 20 grams of selected clay powder were weighed. Before grinding and weighing, the hardness and density of the clay were determined to establish the precise size of the particles. To activate the powdered clay, a solution was prepared by mixing 40 ml of water with 7 ml of concentrated sulfuric acid. The measured clay powder was added to the solution and mixed until a complete suspension was formed. The suspension underwent modification at various sulfuric acid concentrations, temperature-to-solid ratios (T:S), and temperatures ranging from 80-100°C for one hour.

The chemically activated suspension was dried in an air oven at 100-110°C for 2.5–3 hours. The semi-activated sorbent with sorption properties was washed until the pH reached 2 (using acid-resistant filter material with pore sizes not exceeding 0.01). The process was repeated under the same conditions [3, p.5; 4, p.123].

Stage 2: A solution was prepared by mixing 90 ml of water with 10 ml of concentrated sulfuric acid. The dried clay was added and mixed thoroughly. The mixture was heated in a hermetic container resistant to acid and heat at 200°C for two hours. The resulting sample was washed with distilled water until the pH reached 3-3.5, filtered, and dried. The dried clay was ground into a fine powder and sieved.

Results and discussion. The prepared sorbent was tested for its sorption properties by purifying drinking water and refining edible oils in industrial applications. The effects of raw material ratios (T:S) and temperature on sorption properties were analyzed, and the findings are illustrated in Figure 1.



1: Chemically modified; 2: Thermochemically modified.

Figure 1. Kinetics of pH change during the modification process

Observing the curves in the graph (Figure 1) derived from experimental results, it can be concluded that achieving sorbents with high sorption properties requires conducting the modification process in a highly acidic environment, i.e., with an initially low pH. It was established that sorbents modified in a strong acidic medium exhibited superior sorption characteristics compared to those modified in a weakly acidic environment. The results showed that a strong acidic environment facilitates the rapid formation of larger pores on the surface of the sorbent, thereby enhancing its sorption properties and expanding its potential applications [5, p.346-354; 6, p.18-20].

The next phase of the study focused on investigating the sorption kinetics of bentonite clay powder over time. The most effective and optimal activation method was as follows:

Preparation: 20 grams of clay powder was weighed and placed into a chemically resistant, heatproof container. A solution was prepared by adding 10 ml of concentrated sulfuric acid to 90 ml of water using graduated cylinders. The clay was added to the solution and mixed until a uniform suspension was formed.

Activation: The suspension was heated to 250°C in a sealed, heat-resistant container for one hour. The modified clay sample was filtered and washed with water until the pH reached 3.2. The sample was then dried, ground into powder, and sieved.

Analysis: The prepared sorbent's sorption properties were analyzed by applying it to various technological processes. Results were compared to assess its sorption efficiency.

This activation method's effectiveness depends on the type of contaminants present in the material to be purified, as well as the molecular or ionic composition of the impurities. The modified sorbent can be used in applications such as purifying wastewater from oil and fat industries or providing clean water for technological processes. Additionally, it is effective in purifying sunflower oil by removing unwanted substances and reducing color intensity.

Scientific studies revealed that the efficiency of the sorbent in removing ions from drinking water is illustrated in Figure 2. The data indicate that sorbents activated at 250°C for 70 minutes demonstrate superior sorption properties.

Process for Larger Sorbate Molecules:

To prepare sorbents for larger sorbate molecules, the following process was used:

1. Weigh 20 grams of clay powder.

2. Prepare a solution by adding 7 ml of sulfuric acid to 93 ml of water.

3. Mix the clay into the solution until a uniform suspension is achieved.

4. Heat the mixture in a sealed, heat-resistant container at 250°C for 3.5 hours while stirring.

5. Filter and dry the suspension, then wash it with distilled water until the pH reaches 3–3.4.

6. Dry the sorbent, grind it into a powder, and sieve it.

The prepared sorbent can be tested and applied for cleaning various products, demonstrating its effectiveness in practical applications.

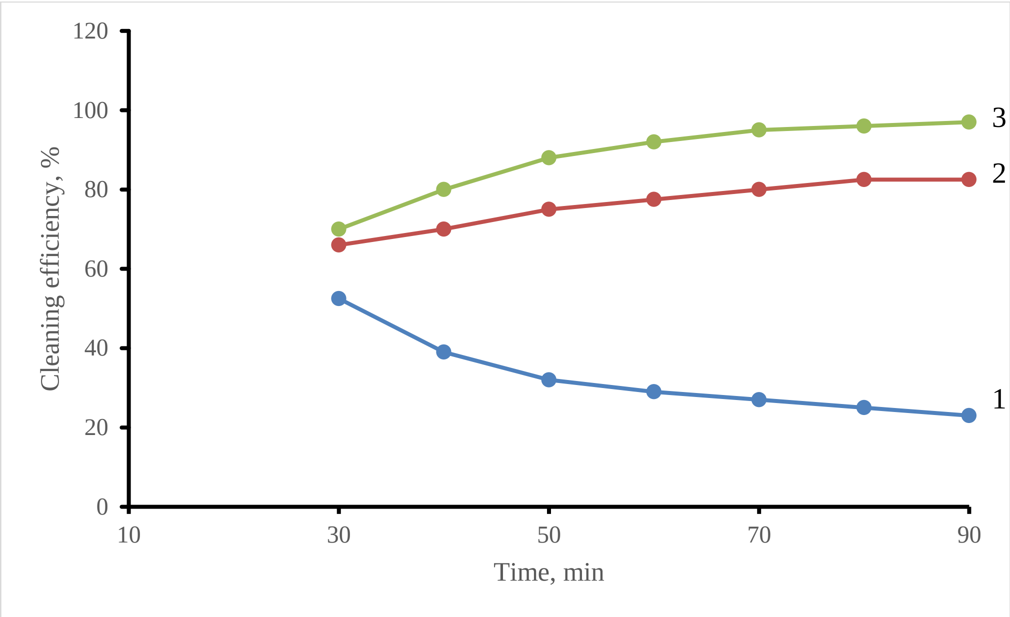


Figure 2. The efficiency of thermochemically modified bentonite sorbents in purifying drinking water at different temperatures

Sorbents (produced by thermal, chemical, or thermochemical modification methods) must have their hydrogen index (pH) checked before use. To do this, 1 g of modified bentonite powder is mixed with 15 ml of water, and the pH value is determined. For each prepared sorbent, the pH should be ≥ 4.

The research results indicate that time and temperature are critical parameters in the modification process of bentonite powders. When the bentonite is heated with acid under high pressure for a short period, its pore size increases, enhancing its sorption properties.

Table 1.

Effect of pressure on the activation process (Table results)

No.	Temperature (°C)	1 atm	2 atm	3 atm	4atm
1	150	70	75	78	80
2	200	80	85	88	88
3	250	85	96	84	10
4	300	88	95	50	3

The following table presents the results of activating 20 g of bentonite with 7 ml of acid in 100 ml of solution under different pressure and temperature conditions.

The data show that performing the modification process under different pressure levels improves the sorption capacity of the obtained sorbents. However, applying pressures of 3 atm or higher leads to a decrease in sorption efficiency.

For example:

- At 250 °C and 2 atm, the sorption capacity of the sorbent reached 96%.
- At the same temperature, the capacity dropped to 84% at 3 atm and only 10% at 4 atm.

Therefore, conducting the activation process within a 1-2 atm pressure range is recommended.

Bentonite powder activated with acid can be used for:

- Purification of oil and fat products,
- Refining petroleum products,
- Treating wastewater from various industrial facilities.

Conclusion. This technology is cost-effective, time-efficient, and economically advantageous for industrial use. According to the results, the high-performance sorbent achieved through this method is 23-27% more effective than conventional sorbents in purifying drinking water for the oil and fat industry.

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