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Study of the Adsorption Properties of Thermally Activated Karman Clay for the Recovery of Used Motor and Compressor Oils

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ABSTRACT: The article describes the experience of thermal activation of opoka-like clay from the Kerminensky deposit (Navoi region) used for the regeneration of motor and compressor oils. The influence of the main parameters of thermal activation of the structural and adsorption properties of the resulting adsorbents is considered. It has been studied that the resulting KG-400 brand adsorbent has a higher adsorption value of benzene vapor compared to other adsorbent samples and is characterized by the interaction of non-polar benzene molecules with cations between the layers of the adsorbent.

KEYWORDS: bentonite, adsorbent, Kermine clay, thermal activation, adsorption isotherm, benzene, modification, structural-sorption characteristics, specific surface area, adsorption, saturation, monolayer capacity, micropore, mesopore, macropore, pore radius.

I.INTRODUCTION

Currently, bentonites are widely used in various industries, including the adsorption of copper, iron, lead, arsenic ions and phenol molecules from industrial wastewater as adsorbents [1], waterproof materials for the production of waterproofing materials and ceramic tiles [2] , additives for increasing the heat resistance of silicones, rubber and rubber materials [3], obtaining bactericidal materials [4] and other areas. Also in the oil and gas industry, during the adsorption purification of various compounds [5, 6], organophilic bentonites (bentons) modified with organic cations obtained positive results as selective adsorbents for the adsorption of organic molecules-derivatives of aromatic amines (2-methylaniline) from wastewater [7].

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II. SIGNIFICANCE OF THE SYSTEM

The article describes the experience of thermal activation of opoka-like clay from the Kerminensky deposit (Navoi region) used for the regeneration of motor and compressor oils. 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.

III. METHODOLOGY

To date, the state balance of mineral reserves of the Republic of Uzbekistan includes 20 deposits of bentonite clays. One of them is the Kermine deposit of opoka-like clay in the Navoi region. The chemical composition of the mineral clays of this deposit is given in the table below.

Table 1.
Chemical composition of Kermine opoka clay

№	CuO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Others products	Σ	SiO_2 R_2O_6
1	50,79	16,58	6,49	0,50	3,65	0,25	2,44	19,60	100,30	3,81

Based on the above considerations, the production of mineral adsorbents from local raw materials, including the raw materials of the Kerminensky deposit of opoka-like clay in the Navoi region, is of particular importance. For this purpose, the raw material of the Kerminensky deposit, opoka-like clay, was chosen as the object of study and adsorbents were prepared using physical activation methods. First, the raw materials were crushed and then subjected to heat treatment (100-500°C). The resulting samples were conventionally named as follows. Natural clay Kermine -KG, thermally activated sample at 100°C - KG-100, sample at 200°C - KG-200, sample at 300°C - KG-300, sample at 400°C - KG-400, sample at 500 °C - KG-500.

IV. EXPERIMENTAL RESULTS

Adsorption isotherms of gas and liquid vapors of the resulting adsorbents were studied on high-vacuum McBen balances. The device is equipped with a highly sensitive quartz spiral. The degree of its sensitivity is 1.78-10-3 kg/m. The pressure difference in U-shaped monometers is measured using a cathetometer type B-630. The accuracy of the cathetometer is 0.05 mm. The samples prepared for the study were ground to a powder in an agate mortar and, after thorough mixing, weighed 1 g each and placed in a cup. The pressure in the system was stabilized by evacuation for 6-8 hours.

Benzene, taken in the form of an adsorbate, before using and studying its adsorption, was first purified and dried under vacuum conditions, for this it was frozen, and then heated to release dissolved gases from it until its vapor pressure was equal to the data indicated in tables for pure benzene and water.

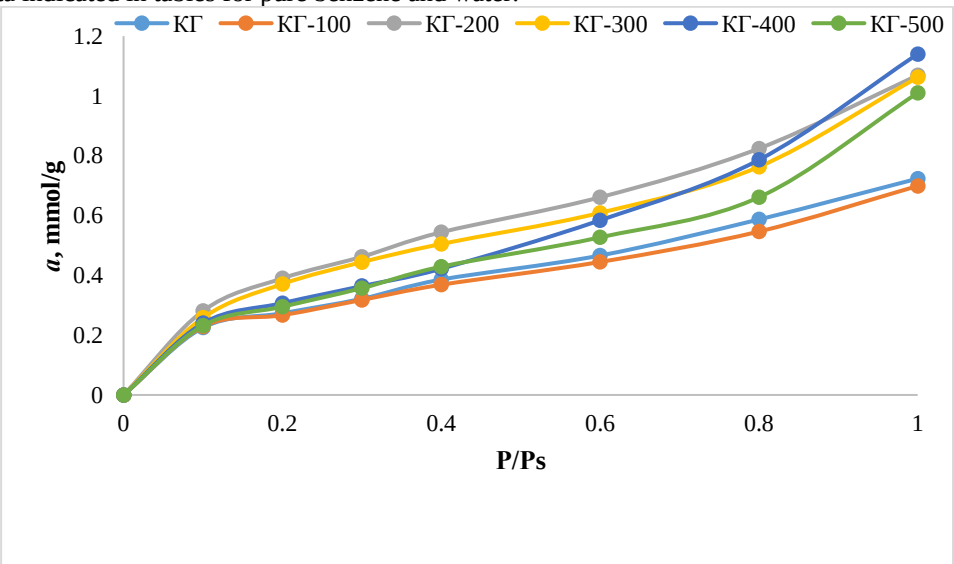

Figure 1. Adsorption isotherms of samples by benzene vapor.

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From the adsorption isotherms in these systems it is clear that the adsorption value increases sharply from zero relative specific pressure to P/Ps≈0.4, then adsorption slowly increases and approaches the saturation state.

The sharp increase in adsorption isotherms at such a low relative pressure (R/Rs≈0.4) gives us grounds to assert that benzene vapor, upon initial filling, is adsorbed on surfaces with a high adsorption potential.

In some samples (KG-200 and KG-300) one can see the steepness of the isotherm due to the high degree of adsorption up to R/Rs=0.2 at low relative pressures. It can be noted that the adsorption isotherms of all adsorbents belong to type IV of the classification of adsorption isotherms proposed by Brunauer.

The shape of adsorption isotherms depends on the properties of the adsorbent, the absorbed substance and the interaction forces between them. Firstly, this is due to the size, nature and charge of the exchange cations in the samples, and secondly, to the specifics of the interaction of non-polar benzene molecules with modified adsorbents, that is, a change in the hydrophilic and lyophilic nature of the adsorbents. KG-400 has a higher adsorption value of benzene vapor compared to other adsorbent samples, characterized by the interaction of non-polar benzene molecules with cations between the layers of the adsorbent.

It can be seen that the adsorption isotherm increases again in the relative pressure range R/Rs=0.6-1.0. The absorption of adsorbate molecules in this case indicates that in these samples adsorption occurred as a result of capillary condensation of benzene vapor in secondary pores.

The study of the porosity structure of mesoporous solids is often associated with the interpretation of type IV adsorption isotherms. This type of isotherm is mainly characterized by absorption in mesoporous regions. At low pressure, the initial parts of isotherms IV and II are similar to each other. But a type IV isotherm shifts upward from a certain point and then its slope decreases at higher pressures. When approaching the saturated vapor pressure (R/Rs=1), the adsorption value can increase significantly.

The structure of the adsorbents was determined from adsorption indices using the specific surface area (S) equation of the Brunauer, Emmett, Teller (BET) theory.

Based on the adsorption isotherms of benzene vapors of mineral clay adsorbents, such important parameters of adsorbents as monolayer capacity αm, saturation volume Vs (or adsorption αs) and specific surface area S were calculated. The results obtained are presented in Table 2.

Table 2
Structural and sorption indicators for the adsorption of benzene vapor in samples

Samples	Monolayer capacity, $a_м$, mol/kg	Specific surface area, $S \cdot 10^{-3}$, m^2/kg	Saturation adsorption, a_s, mol/kg
KG	0,226	54,52	0,72
KG -100	0,220	52,91	0,70
KG-200	0,320	76,95	1,07
KG-300	0,320	76,95	1,06
KG-400	0,301	72,43	1,14
KG-500	0,251	60,36	1,01

The main part of the absorption of benzene molecules by adsorbents is: in CG - 31.4%, in CG-100 - 31.4%, in CG-200 - 30.0%, in CG-300 -30.2%, in CG-400 -26.4%, in KG-500 -24.9% corresponds to the sum of the monolayer capacity of the adsorbents.

Based on the adsorption isotherms of benzene vapor in the samples and the equation of the theory of volumetric saturation of micropores (VSM), the micropores of adsorbents (W_0), adsorption volumes for saturated states (V_s) and the volume of mesopores were determined using the formula $W_{me} = V_s - W_0$. The average pore radius was calculated using the formula. The results obtained are presented in Table 3.

Table 3.
Indicators of pore volumes for the adsorption of benzene vapors

Samples	$W_0 \cdot 10^3$	$V_s \cdot 10^3$	$W_{me} \cdot 10^3$	Average pore radius R_{ar}, nm
KG	0,047	0,064	0,017	2,35
KG-100	0,044	0,062	0,018	2,34
KG-200	0,044	0,062	0,018	1,61
KG-300	0,068	0,095	0,027	2,46
KG-400	0,064	0,094	0,030	2,6
KG-500	0,061	0,101	0,04	3,35

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From the results obtained it is clear that the sizes of micropores in samples KG-300, KG-400, KG-500 are close to each other, but the number of mesopores in KG-500 is relatively large and the saturation volume of adsorption is also relatively high. It has been established that for adsorbents KG, KG-100 and KG-200, the volume of micropores and the saturation volume of adsorption are almost equal to each other. But the fact that the average pore radius of the KG-200 sample is r<2 indicates its microporous structure. All other adsorbents are equal to M.M. in terms of their average porosity radius. According to the classification of pores proposed by Dubinin, it was established that they belong to a number of mesoporous (2< r <50 nm) adsorbents

V. CONCLUSION AND FUTURE WORK

Due to the fact that the composition, structure and nature of the resulting adsorbents are practically similar to each other, the amount of benzene vapor adsorption does not differ significantly. KG-400, compared to other adsorbents, is characterized by a higher degree of adsorption of benzene vapor, higher active centers between the adsorbent layers and greater porosity.

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