

Study of Benzene Vapor Adsorption in Adsorbents Based on Oil Waste

Hudayberganova Nagima Turdibayevna^{1,*}, Rizaev Abdumalik Nabievich¹,
Musaev Olimjon Mavlandjanovich²

¹Engineering Communications and Systems Department, Construction Faculty, Tashkent State Transport University, Tashkent, Uzbekistan
²Heading Specialist, The Administration of the President of the Republic of Uzbekistan, Tashkent, Uzbekistan

Abstract The article studied the optimal conditions for obtaining effective adsorbents on the basis of coke, the adsorption of benzene vapor on activated adsorbents. It was found that benzene vapor in the obtained adsorbents is strongly bound by the formation of ~ 10% adsorbate p complex in K-4 (coke-asphalt) during adsorption.

Keywords Coke, Benzene, Adsorbent, Absorbent, Adsorption, Desorption, Isotherm, Monolayer capacity, Specific surface

1. Introduction

Today, due to the rapid development of industries in the world and the expansion of the application of adsorption processes, the production of cheap adsorbents based on local raw materials and industrial waste is one of the most pressing issues [1]. It is known that activated carbon adsorbents are derived from various carbon raw materials: lignite and coal [2], wood and cellulose [3], peat [4], liquid and gaseous hydrocarbons [5], synthetic polymers [6], plant waste [7], and other raw materials (waste from construction, bitumen, car tires, polyvinyl chloride and other synthetic polymers).

Pyrolysis of wood waste in an oxygen-free environment for the production of activated carbon and its activation using water vapor [8] and orthophosphate acid [9] have also been studied in detail. Currently, the technology of production of carbon adsorbents, which activates natural or synthetic raw materials by steam-gas method, involves two different processes: carbonization of the raw material (pyrolysis) and activation with oxidizing agents at high temperatures, often using water vapor [10]. Carbon dioxide, oxygen and inert gases are also used as oxidizing agents.

The cracking process in oil refineries produces large amounts of coke, tar and asphalt. It is possible to obtain effective adsorbents based on coke, tar and asphalt and to treat industrial wastewater using these adsorbents.

2. Materials and Methods

* Corresponding author:

khmt90@mail.ru (Hudayberganova Nagima Turdibayevna)

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The coke is pulverized at 10 nm and heated at 800°C for 4 hours in an airless medium. Coke adsorbent (K-1), K-1 is activated by water vapor at 800°C in airless conditions. K-2, tar in a 1: 1 mass ratio to the crushed coke and asphalt (coke-tar, coke-asphalt) were added and quenched for 6 h, then each was activated with water vapor at 400°C for 2 h and at 800°C for 4 h in airless conditions, respectively (K-3, K-4) adsorbents were obtained and conditionally named. The adsorption properties of the obtained adsorbents were studied according to the adsorption of benzene vapor.

Benzene obtained as an adsorbent was purified under vacuum before use in adsorption, its vapor pressure was frozen until it was the same as the vapor pressure data given in the table for pure benzene, and then dissolved gases were released [11].

In activated adsorbents, benzene vapor adsorption isotherms were measured in a McBen-sensitive quartz coil device [12]. Before measuring the adsorption of benzene vapor on adsorbents, each adsorption system was vacuumed to a residual pressure of $1.33 \cdot 10^{-3}$ Pa and heated at 473 K for 8 h after which adsorption isotherms were obtained.

3. Results and Discussion

From the adsorption isotherms in the studied systems, it was found to be 2.5 times higher in K-2, 3.3 times higher in K-3, and 4.2 times higher in K-4 than in K-1. From the adsorption isotherms in the studied systems, benzene adsorption at K-4 was found to be higher than other adsorbents. In adsorbents, the amount of adsorption was observed to rise sharply from the relative pressure zero to $P/P_s \approx 0.2$ and approach the saturation state in the range $P/P_s \approx 0.8-1$. The hysteresis in the isotherms formed adsorption rings in the range of specific relative pressure

($P/P_s \approx 0.1-0.2$) where the adsorption lines merged with the desorption lines. This suggests that adsorption at higher specific pressures is accompanied by capillary condensation (Figure 1).

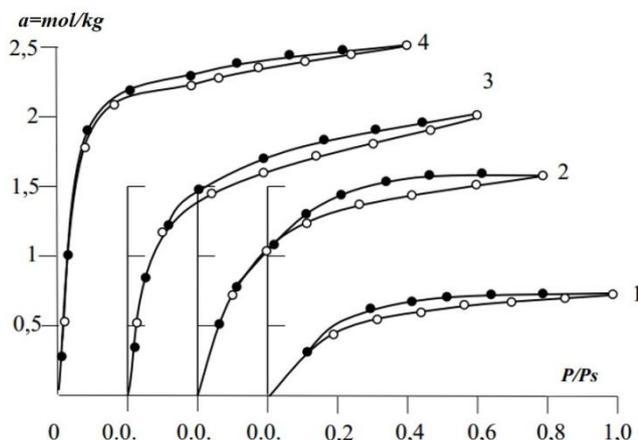


Figure 1. Benzene vapor adsorption isotherms in K-1 (1), K-2 (2), K-3 (3), K-4 (4)

Based on the obtained isotherms, the monolayer capacity (a_m), specific surfaces (S) and saturation adsorption (a_s) of the adsorbents were calculated using the BET equation. It was observed that the specific surface area and saturation volume of K-4 were higher than the remaining adsorbents. The main part of benzene vapor adsorption in adsorbents: 55% in K-1, 51% in K-2, 50% in K-3, 57% in K-4 correspond to the monolayer capacity of adsorbents and K in relation to K-1. At -4, the specific surface area (S) was found to be the highest, i.e., 4.3 times larger (Table 1).

Table 1. Structural-sorption characteristics of benzene vapor adsorption on adsorbents activated under different conditions on the basis of coke

№	Adsorbents	Single-layer capacity, a_m , mol/kg	Specific surface, S m ² /g	Saturation adsorption, a_s , mol/kg
1	K-1	0.33	80	0.6
2	K-2	0.76	183	1.5
3	K-3	1.0	240.8	2
4	K-4	1.43	344.1	2.5

The high adsorption on K-4 is explained by the fact that the asphalt enters the coke structure as a result of mixing of asphalt with coke, the formation of additional pores as a result of heating and the release of amorphous carbon atoms in the coke when activated by water vapor. However, in the initial state of adsorption in K-4 is higher than in other adsorbents due to changes in the structure of the adsorbent, the amount of pores between the layers and the electronic nature and interaction of benzene molecules.

In the obtained adsorbents, the adsorption volumes determined at different relative pressures (P/P_s) on the basis of benzene adsorption isotherms are 0.4, the pores volume W_0 , mesocellular $W_{me} = V_s - W_0$ and saturation adsorption volumes V_s are given in the following table (Table 2).

Table 2. The size of the pores of benzene vapor in adsorbents activated under different conditions on the basis of coke

№	Adsorbents	Microporous volume $W_0 \cdot 10^3$, m ³ /kg	Volume of mesocytetes $W_{me} \cdot 10^3$, m ³ /kg	Saturation volume $V_s \cdot 10^3$, m ³ /kg
1	K-1	0.05	0.03	0.053
2	K-2	0.13	0.003	0.133
3	K-3	0.16	0.016	0.176
4	K-4	0.21	0.012	0.222

The volume of micropores calculated using the equation of the theory of micro-pores was found to be 2.6 times higher in K-2, 3.2 times higher in K-3 and 4.2 times higher in K-4 than in K-1.

4. Conclusions

In the adsorbent K-4 obtained on the basis of coke and asphalt, it was found that during the adsorption process ~10% benzene molecules are strongly bound due to the formation of p complexes. In K-4, benzene adsorption is characterized by high adsorbents, cracks between the adsorbent layers, and high porosity compared to other adsorbents. According to the results of benzene adsorption on adsorbents, these adsorbents can be used in various fields, which allows to eliminate to some extent the demand of the Republic for adsorbents.

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