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Obtaining Import-Substituting Effective Adsorbents and Study their Adsorption Properties

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ABSTRACT. As a result of the investigations, the adsorbents of activated coal at different temperatures and with water vapor were extracted from plane-tree, ash-tree, Cherry, Apricot,nut stems were received and their physico-chemical and adsorption properties were determined. The results have shown that the adsorption efficiency and adsorption properties of the plane-tree adsorbents are significantly higher than those of other trees. It can be seen that heating the resulting coal adsorbents from 400 to 800°C, that is, thermal activation, almost has double their pore volume.

KEYWORDS: charcoal, adsorption, isotherm, benzene, adsorbent, single layer capacity, saturation adsorption, comparative surface, porosity, apricot‘s tree activated coal (ATAC), nut’s tree activated coal (NTAC), cherry‘s tree activated coal (ChTAC), plane-tree activated coal (PTAC), ash-tree activated coal (AshTAC).

I. INTRODUCTION

At present activated coal is obtained from various coal materials: wood and cellulose [1, 2], peat [3], brown and coal [4], liquid and gaseous hydrocarbons [5], synthetic polymers [6], plant waste [7] and other raw materials (waste, asphalt, bitumen, car tires, polyvinyl chloride and other synthetic polymers).

About 99% of the total trunk of the tree consists of organic substances. The chemical composition of the wooden part of different tree trunks is almost the same. Part of the dry wood of trees consists of 49% coal, 44% oxygen, 6% hydrogen, 0.1–0.3% nitrogen. These elements mainly form organic compounds such as cellulose, lignin and hemicellulose. In addition to these organic substances tree trunks also contain small amounts of volatile resins, pectins, oils, and other organic compounds soluble in water, alcohol or ether. When wood is burned, inorganic substances as ash are formed. It is known that ash contains mainly calcium, potassium, sodium, magnesium and other elements. By this reason the ash content of charcoal is lower than that of other coals (coal, lignite).

Today many industrial enterprises of the republic; the food industry, the pharmaceutical industry, as well as the field of drinking water and industrial wastewater treatment, have used adsorption methods. Most of the carbons adsorbents used in these processes are imported from abroad.

II. SIGNIFICANCE OF THE SYSTEM

As a result of the investigations, the adsorbents of activated coal at different temperatures and with water vapor were extracted from plane-tree, ash-tree, Cherry, Apricot,nut stems were received and their physico-chemical and adsorption properties were determined.The study of literature survey is presented in section III, methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses the future study and conclusion.

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III. METHODOLOGY

Wastes of various fruit and ornamental tree stems, fruit stumps shells, secondary waste of foodstuffs, considered cheap raw materials for the production of activated coal, which is not widely used in industry. It is well known that fruit trees such as apricots, cherries, nuts and plane- tree, ash-tree and other ornamental trees are common in the Republic. Plane, ash-tree, nuts are used in furniture factories. At the same time, when processing the round part of the trunk, a large amount of wood waste and unsuitable parts of the trunk are formed. This wood is also used as fuel.

In addition during the fall and spring season fruit and ornamental trees have processed a large amount of wood waste, which, is often used as fuel.

Based on the foregoing, carbon adsorbents, local raw materials, and also based on wood waste, the intended use is important. For this, angular adsorbents based on wastes of plane-tree, plane, ash-tree, apricot and nut were obtained thermally (400, 600, 800°C), and they were also activated by water vapor during 1.5 hours (800°C) [8]. The obtained coal sorbents were conditionally marked as follows: apricot‘s tree activated coal (ATAC); nut’s tree activated coal (NTAC); cherry‘s tree activated coal (ChTAC); plane‘s tree activated coal (PTAC); ash-tree’s tree activated coal (ATAC).

The adsorption isotherms of benzene vapor in activated charcoal were measured on Mac-Ben-Bakra sensitive quartz spiral instrument. The pressure difference in the “U” shaped mercury manometers and the change in the quartz spring was determined by using a V-630 catheter. The accuracy of the catheter is 0.05 mm. Before measuring the adsorption of benzene in adsorbents the system was evacuated to 1.33×10^{-3} Pa, heated to 110°C for 8 h and adsorption isotherms were obtained. For adsorbents to vacuum with heating physical adsorbtion water and gases has been released.

For all of the above adsorbents (activated with water vapor at 400, 600, 800 and 800°C), benzene vapor adsorption isotherms it can be seen that the adsorption process has increased with increasing temperature, in the process of activating the coal adsorbents obtained at all comparative pressures (P/P_S). The highest amounts of adsorption relate to a sample of coal activated with water vapor.

The comparative surface (S) from the indicator of the adsorption structure of adsorbents was determined by the equation of the theory of Brunauer, Emmett, Teller (BET) [9]. In this case, if the values $P/P_s/a(1 - P/P_s)$ on the ordinate axis and P/P_s on the abscissa axis are formed, directly linear coordinates are formed.

The comparative surface of the adsorbents was calculated by the following equation:

$$S = a_m \cdot N \cdot \omega_0$$

where: S - relative comparative surface (m^2/g);

a_m- the monomolecular layer (mol/kg);

N_A - the Avagadro number;

ω - surface (nm^2), occupied by one molecule.

Based on the adsorption isotherms of benzene vapor, for coal adsorbents, such(important indicators) of adsorbents, as monolayer - α_M, saturation capacity - V_S (or adsorption - α_s), and their relative surfaces – S have been calculated

IV. EXPERIMENTAL RESULTS

For all studied adsorbents (PTAC, ATAC, ATAC, NTAC and CTAC), the relative surface (S) and saturation capacity (a_S) have increased with increasing activation temperature. Plane coal examples, It was determined that increasing the comparative surface of the PTAC-600 was in 1.75 times larger than the PTAC -400, the PTAC -800 was in 1.84 times larger than the PTAC -600 and 3.2 times more than the PTAC -400 [10]. The obtained results are presented in Table 1.

Table 1

Structure - sorption parameters for the adsorption steam of benzol at coal, activated by thermal and water vapor

Adsorbents	Activation temperature, °C	Monolayer capacity, a_m, mol/кg	Comparative surface, $S\cdot 10^{-3}$, m^2/кg	Saturation of adsorption a_s, mol/кg
PTAC	400°C	0,33	79	1,36
	600°C	0,57	138	1,74
	800°C	1,06	255	2,64
	800°C+water vapor	2,0	482	3,86

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AshTAC	400° C	0,31	75	1,28
	600°C	0,53	128	1,68
	800°C	1,01	243	2,52
	800°C+water vapor	1,82	438	3,8
ATAC	400°C	0,32	77	1,23
	600°C	0,47	112	1,56
	800°C	0,7	169	2,1
	800°C+water vapor	1,54	371	3,4
NTAC	400°C	0,25	60	1,20
	600°C	0,48	116	1,58
	800°C	0,69	166	2,2
	800°C+water vapor	1,48	357	3,2
ChTAC	400°C	0,27	65	1,24
	600°C	0,51	124	1,62
	800°C	0,74	178	2,3
	800°C+water vapor	1,46	352	3,1

Activation under these conditions leads to the opening of additional pores in the coal layers of the adsorbent due to the release of various gases and resins in the coal. In comparision with adsorbents obtained at a temperature of 800°C(WVPTAC), the structure – sorption values for a sample activated by water vapor are higher than for other adsorbents. It was found that the comparative surface (**S**) has increased by 1.9 times and the saturation volume (a_s) by 1.5 times in comparison with thePTAC-800 [11]. This is caused by formation of additional pores and cracks owing to the chemical interaction of amorphous coal with water vapor at high temperature (800°C). The data of table 2 have shown that according to the structural sorption indicator, the amount of adsorption of benzene vapors on adsorbents obtained on the basis of plane waste is higher than that by other adsorbents.

Table 2
Pore size indicators for adsorption of charcoals activated by thermal and water vapor of benzene vapor

Adsorbents	Activation temperature, °C	$W_0 \cdot 10^3$	$V_s \cdot 10^3$	$W_{me} \cdot 10^3$	Average radius of porer$_{av}$, Å
PTAC	400°C	0,093	0,121	0,028	30,6
	600°C	0,138	0,155	0,017	22,5
	800°C	0,213	0,235	0,022	18,4
	800°C+water vapor	0,295	0,343	0,048	14,2
AshTAC	400°C	0,091	0,114	0,023	30,3
	600°C	0,115	0,150	0,035	23,4
	800°C	0,204	0,224	0,020	18,4
	800°C+ water vapor	0,295	0,338	0,043	15,4
ATAC	400°C	0,089	0,110	0,021	28,7
	600°C	0,115	0,139	0,024	22,2
	800°C	0,151	0,187	0,036	22,1
	800°C+ water vapor	0,269	0,303	0,034	16,3
NTAC	400° C	0,081	0,107	0,026	35,7
	600° C	0,120	0,141	0,021	24,3
	800° C	0,170	0,196	0,026	23,6
	800°C+ water vapor	0,257	0,285	0,028	16,0
CTAC	400°C	0,082	0,110	0,028	33,7
	600°C	0,117	0,144	0,027	23,2
	800°C	0,170	0,205	0,035	23,0
	800°C+ water vapor	0,251	0,276	0,025	15,7

Based on the adsorption isotherm of benzene vapor in coal adsorbents, as well as micropores, equations of the theory of volume saturation (MXTH), adsorption micropores (W_0), for saturated states, the adsorption volume (V_S) and mesopore

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sizes were determined by the formula $W_{me} = V_S - W_0$. The average pore radius was calculated by the equation $r_{ÿp} = \frac{2 \cdot V_s \cdot 10^4}{S}$.

It was found that with increasing in temperature of thermal activation of micropores (W_0) of charcoal, as well as for their saturated states, the adsorption volume has increased, and the average pore radius has decreased. With an increasing activation temperature, increasing in the number of micropores than the number of mesopores was observed therefore the average pore radius of the adsorbent has decreased. Heating the PTAC from 400 to 800°C, that is thermal activation means that their pore size was incrused almost double, and activation with water vapor has increased 3.2 times. The comparison of the amount of mesopores to the adsorption volume (V_S) wasequaled corespondenlyfor:PTAC-400 - 23.1%, PTAC -600 - 11%, PTAC -800 - 9.4%, PTAC-800 - 14%.

The thermodynamic quantities of the interaction of adsorbent-adsorbate molecules were studied using the example of coal adsorbents of plane. The average free energy of interaction of the adsorbent-adsorbatewas determined by the following equation:

$$\Delta g^m = \Delta\mu_1 \omega_1 + \Delta\mu_2 \omega_2$$

Graphical dependencies $\Delta g^m = f(W_2)$ are compiled according to the calculated value Δg^m for all pairs pressure values. It is possible to find, from graphical data, the Gibbs thermodynamic potential, which is the boundary of the proximity of adsorbates and adsorbents. The obtained results are presented in table 4.

The adsorption of benzene vapor on coal adsorbents, which were activated by thermal and water vapor, was studied. According to the results of benzene vapor adsorption, adsorbents by their, adsorption capacity, specific surface (S) and saturation adsorption (a_s) can be dipesed in following:

Table 3

Thermodynamic parameters of the interaction of coal adsorbents with benzene molecules

№	Adsorbents	The awarage free of interaction in system adsorbent-adsorbate, Δg_{max}^m, J/mol	Gibbs Thermodynamic Potential ΔG_i, J/mol
1	PTAC -400	-3,4	-3,9
2	PTAC -600	-5,51	-6,3
3	PTAC -800	-9,77	-11,9
4	WVPTAC	-29,11	-37,5

V. CONCLUSION AND FUTURE WORK

We can say that heating the obtained coal adsorbents from 400 to 800°C, that is, by thermal activation, led to a doubling of their pore size. The amount of adsorption of benzene vapor does not significantly differ due to the composition, structure and nature of the obtained adsorbents. The amount of adsorption of benzene vapor on the PTAC is characterized by a higher than that of other adsorbents, as well as by the size of cracks and porosity between the layers of the adsorbent in comparison with other adsorbents.

According to the results of the adsorption of benzene vapors on adsorbents obtained in 1.5 hours from water vapor at various temperatures, from the above-studied trees from which grow in our country, in order to clean coal adsorbents in various industries from organic compounds can be used as adsorbent.

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