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Synthesis of Wastewater Treatment Sorbents Using Local Raw Materials

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ABSTRACT: Nowadays, the growth of industrial enterprises all over the world is leading to an increase in the volume of wastewater discharged from them. At the same time, the areas of application of sorption processes are also expanding. It is urgent to obtain modified sorbents from mineral raw materials and charcoal, which are considered cheap sorbents, to study their surface and sorption properties, and to conduct research on their use for various purposes. Toxic gases generated in industrial enterprises pollute the air, and various heavy metals, oil products, surfactants, and dyes pollute wastewater. This leads to an increase in the amount of polar and non-polar substances that are often found in water. For this reason, the purification of carbon and minerals using sorbents activated by various methods is of great importance.

KEYWORDS: carbon adsorbents, plant waste, polymers, activation, water purification, soybean oil, glycerin.

I.INTRODUCTION

In science all over the world, in scientific research centers, and in higher educational institutions, the issues of obtaining sorbents used in wastewater treatment and determining their sorption properties are being studied as a research object. For example, scientists from the Mongolian Academy of Sciences and the Institute of Chemistry and Chemical Technology are studying sorbents that remove chloroform from drinking water, researchers from the Vestnik Technological University are studying the physicochemical properties of sorbents for wastewater treatment, and scientists from the Tyumen Industrial University and the Tomsk State University of Architecture and Construction in Russia are conducting research on the use of natural sorbents in the treatment of oil products in water resources.

We synthesized adsorbents by treating pine bark with mineral acids and activating them at temperatures of 300-800 degrees.

II. SIGNIFICANCE OF THE SYSTEM

Nowadays, the growth of industrial enterprises all over the world is leading to an increase in the volume of wastewater discharged from them. 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

In our country, high-quality activated carbon sorbents with high sorption properties are widely used for industrial enterprises, especially for water purification. Activated carbon sorbents are mainly used in various technological processes to purify the main products from additives in the form of gas and liquid aggregates. Also, chemical, physicochemical methods are used to purify industrial wastewater and bring it to the required standards for discharge into water bodies.

The sorbents obtained by treating pine bark in 0,1-0,5 M solutions of HCl, HNO_3 and H_2SO_4 acids and then pyrolyzing them in the absence of air form a microporous product with a high carbon content. The composition and structure of these sorbents depend on the pyrolysis temperature and activation method. In most cases, pyrolysis is carried out at 450-550 ºC, resulting in a high-molecular product in an amorphous state. Charcoal mainly has an aliphatic and aromatic structure. It contains 80-92% C, 4-5% N, 5.0-15% N_2O and 1-3% inorganic compounds, i.e. elements such as K, Na, Ca, Mg, Si, Al, Fe, mainly in the form of carbonates and oxides.

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Today, sorption methods are used in many industrial enterprises in our Republic, in the food industry, in the pharmaceutical sector, as well as in the treatment of drinking and industrial wastewater. Most of the carbon sorbents used in these processes are imported from foreign countries.

Waste from the trunks of various fruit and ornamental trees, fruit pits, and secondary wastes of food products are cheap raw materials for obtaining activated carbons that are not widely used in industry. As is known, fruit trees such as apricot, cherry, walnut, as well as ornamental trees such as pine, ailanthus, plane, ash, etc. growing on the territory of our Republic are common. The trunks of pine, alder, maple, ash, and walnut trees are used in furniture manufacturing factories. During the processing of the round part of the tree trunk, a large amount of wood chips and unusable trunks are generated as waste. This wood waste is used as fuel, for example, for smoking meat and meat products and fish products.

IV. EXPERIMENTAL RESULTS

Based on the above, the preparation of carbon sorbents based on local raw materials, including tree trunks and waste, is of particular importance. For this purpose, the pine tree crown growing in our Republic was treated with 0,1-0,5 M concentrated solutions of HCl, HNO_3 and H_2SO_4 acids, and then thermally activated at temperatures of 300, 400, 500, 600, 700, 800°C to prepare carbon sorbents. The obtained coal sorbents were conditionally named activated pine charcoal-FQDK:HCl-1, FQDK:HCl-2, FQDK:HCl-3, FQDK:HCl-4, FQDK:HCl-5, FQDK:HNO_3-1, FQDK:HNO_3-2, FQDK:HNO_3-3, FQDK:HNO_3-4, FQDK:HNO_3-5, FQDK:H_2SO_4-1, FQDK:H_2SO_4-2, FQDK:H_2SO_4-3, FQDK:H_2SO_4-4, FQDK:H_2SO_4-5. Wood waste of a certain size was heated to 300-800°C for 1.5 hours in a pyrolysis device designed for laboratory conditions.

The porosity of coal sorbents obtained by thermal activation methods based on pine cones in terms of acetone was determined using the methodology developed in accordance with GOST 6217-52.

Initially, the porosity of coal samples obtained at 500 °C and imported coal of the BAU-A brand for comparison was determined in terms of acetone. All sorbent samples were taken in the size range of 2-5 mm. The results obtained are presented in Table-1

Table 2.1
Porosity of coal samples in acetone

Sample name	Activation temperature, °C	Porosity in acetone, %
FQDK:HCl-1	500	39,8
FQDK:HCl-2	500	41,0
FQDK:HCl-3	500	42,2
FQDK:HCl-4	500	43,4
FQDK:HCl-5	500	44,6
FQDK:HNO_3-1	500	37,8
FQDK:HNO_3-2	500	39,0
FQDK:HNO_3-3	500	41,2
FQDK:HNO_3-4	500	41,4
FQDK:HNO_3-5	500	41,6
FQDK:H_2SO_4-1	500	29,8
FQDK:H_2SO_4-2	500	27,5
FQDK:H_2SO_4-3	500	25,2
FQDK:H_2SO_4-4	500	23,4
FQDK:H_2SO_4-5	500	21,6

Among the mineral acids used in wood activation (sulfuric, nitric, hydrochloric acids), there are differences in terms of their effect on porosity and sorption properties. The studies were conducted separately for each acid.

The results were determined.

1. Studies have shown that hydrochloric acid (HCl) has a mainly disintegrating effect, that is, it dissolves mineral salts and some hydrophilic components in wood. This increases the porosity of the sorbents - in particular, it contributes to the formation of mesoporous ones. In addition, the sorption properties of the sorbents are improved, but sometimes there may not be enough functional groups on the surface.

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The concentration of acids used in wood activation significantly affects the structure and adsorption properties of the sorbent. The optimal concentration for each acid and their compositional suitability can be summarized as follows:

1. The optimal concentration for wood activation is 5–15% (by mass).

This range is sufficient to dissolve mineral impurities in the wood, loosen cell walls, and increase porosity without causing damage. At higher concentrations (20%+), excessive erosion of the structure, pore closure, or non-activated areas may occur.

5–10% HCl solutions are widely used on an industrial scale, and are therefore economically viable.

2. Nitric acid (HNO_3) is a strong oxidizing acid that breaks down the carbon structures in wood and forms many carboxyl, carbonyl and hydroxyl groups. The porosity of the sorbents can increase, but excessive oxidation, i.e., acid concentration, destroys the structure. In addition, the sorption properties of the sorbents increase the number of oxygen groups useful for sorption of heavy metals and polar molecules, but the overall porosity is low.

Studies have yielded good results when carried out with a 1–5% (mass) concentration solution of nitric acid (HNO_3).

Since nitric acid has a very strong oxidizing property, it should be used in low concentrations, i.e., 1–3% solutions have been shown to be sufficient to form functional groups on the surface and partially increase porosity.

In wood processing, at high concentrations (10%+), it excessively breaks down the wood structure, preventing the formation of an effective porous skeleton. In industry, the cost of nitric acid is higher than that of HCl. Although the economic damage is not great due to its use at low concentrations, it is not very useful for mass production.

3. The studies were conducted on the basis of sulfuric acid (H_2SO_4), a strong dehydrating and carbonizing acid. It converts the wood structure into a solid carbon skeleton. Sulfuric acid formed micropores in terms of porosity. Due to its very strong effect, it can densify the structure. The sorption property is good at sorbing gas or small molecules through micropores, but is less effective for large molecules.

The optimal concentration of sulfuric acid (H_2SO_4) was used in the study, 1–5% (mass). Due to the strong dehydrating effect of sulfuric acid (H_2SO_4), a low concentration is recommended. A microporous structure is best formed in the range of 2–3%. When sulfuric acid (H_2SO_4) is used at a high concentration (10%+), the wood structure is carbonized, the porosity is sharply reduced, and a dense structure is formed. Economically, it is slightly more expensive than HCl, but cheaper than HNO_3. It is economically acceptable when used at low concentrations.

The results of the studies showed that sorbents activated by treatment with hydrochloric acid (HCl) and low concentration nitric acid (HNO_3) at a temperature of 500 ^{o}C showed high porosity and good sorption properties (balanced).

The pine dome sorbent activated by treatment with nitric acid enabled high sorption of heavy metals or ionic substances.

Table 2
Determination of the sorption capacity of pine bark by activating it with mineral acids

№	Acids	Optimal concentration	Activation effect	Static exchange capacity mg·ekv/g
1	HCl	5-15%	High porosity, stable structure	4-5
2	HNO_3	1-5%	Many functional groups on the surface, but structural hazards	4-6
3	H_2SO_4	1-5%	Microporous dense structure	3-4

The most optimal choice is 5–10% HCl: good porosity, cheap and suitable for industry. For special adsorption purposes (heavy metals, ions) – 1–3% HNO_3 is recommended. If micropores are required – 2–3% H_2SO_4 is used.

The properties required for obtaining a sorbent for adsorption of petroleum products (e.g. diesel, gasoline, oil, fuel oil) from water are high hydrophobicity and a wide mesoporous (large-pore) structure. Since the molecules of petroleum products are large and poorly soluble in water, the following conditions are important for their effective capture:

Wide mesoporous and macroporous (⩾2 nm) structure - due to the large size of the oil molecules, microporous (1－2 nm) is not enough. With a high surface area, but relatively few functional groups - petroleum products are non-polar substances, therefore, adsorption with polar (carboxyl, carbonyl) groups is not strong. It has hydrophobic properties - it should adsorb organic matter (oil), not water. Hydrochloric acid (HCl) is the best choice. Treatment with 5–10% HCl removes soluble impurities from wood.

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V. CONCLUSION AND FUTURE WORK

To effectively adsorb petroleum products from water, the developed sorbents must possess high hydrophobicity and a well-developed mesoporous structure. These requirements are due to the large and non-polar nature of petroleum molecules. A mesoporous (⩾2 nm) or even macroporous structure allows for the deep penetration of oil molecules, while a high surface area enhances adsorption efficiency. At the same time, a low content of polar functional groups on the sorbent surface is preferable, since petroleum products are non-polar and do not interact strongly with polar groups. The most suitable chemical treatment is with 5–10% hydrochloric acid (HCl), which effectively removes water-soluble impurities from the wood-based raw material and helps to develop the desired porous structure. Additionally, this method is cost-effective, technologically simple, and suitable for industrial applications.

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