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Polymer Waste for the Creation of Sorption Materials for Wastewater Treatment

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ABSTRACT: The paper presents an overview of modern approaches to the processing of polymer and plant waste in order to obtain carbon adsorbents. Activation methods that affect the porous structure and sorption properties of materials are considered. Particular attention is paid to the use of the obtained sorbents for the purification of water and organic liquids, such as soybean oil and glycerin.

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

I.INTRODUCTION

Sorption materials play an important role in the purification of water, air and process fluids from pollutants. In the context of growing environmental problems, more and more attention is paid to the development of sorbents based on secondary resources, including polymer waste. High availability, low cost and the possibility of modifying the structure make polymers promising raw materials for the creation of effective sorption systems [1].

Processing of plastic waste, such as polyethylene terephthalate (PET), polypropylene (PP), polyethylene (PE) and polystyrene (PS), allows obtaining carbon materials with developed porosity, capable of effectively adsorbing heavy metals, organic compounds and petroleum products. Methods of chemical activation, alkaline treatment and carbonization allow for targeted changes in the structure of materials and the introduction of functional groups that increase sorption capacity.

The use of polymer waste to obtain sorbents contributes to both solving the problem of their disposal and the development of affordable technologies for environmental purification.

II. SIGNIFICANCE OF THE SYSTEM

The paper presents an overview of modern approaches to the processing of polymer and plant waste in order to obtain carbon adsorbents. 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

Adsorption is the process of concentrating molecules from the gas or liquid phase on the surface of a solid due to intermolecular interactions. Depending on the nature of the forces, a distinction is made between physical adsorption, caused by Van der Waals forces and reversible, and chemical adsorption, accompanied by the formation of strong chemical bonds. Ion-exchange adsorption, based on the substitution of ions between the adsorbent and the solution, also plays a special role [2].

The efficiency of the process is determined by the specific surface area, porous structure and the presence of functional groups on the adsorbent. Microporous materials, such as activated carbons and modified polymers, have high sorption capacity. The behavior of adsorption systems is described by the Langmuir and Freundlich isotherms, reflecting the dependence of the sorbed amount on the concentration of the pollutant.

Adsorption is widely used in wastewater treatment, emissions neutralization, catalysis and separation of mixtures. Improving the structure of adsorbents and their chemical modification allows expanding the scope of application and increasing the efficiency of purification [3-5].

Sorption processes are widely used in industry and ecology due to the high efficiency of removing impurities from liquid and gaseous media. Technologies based on adsorption are used to purify wastewater from heavy metals, organic compounds and petroleum products, as well as to remove polluting gases from atmospheric emissions of industrial enterprises. In the chemical and petrochemical industries, adsorption is used to dry gases, purify and separate hydrocarbon mixtures, regenerate solvents and isolate valuable products [4].

In pharmaceuticals and biotechnology, sorption methods are used in the processes of purifying drugs, separating biomolecules and concentrating active compounds. In the food industry, sorption technologies are used to refine vegetable oils, purify beverages and stabilize taste properties. In the energy industry, adsorption materials are used to store hydrogen and natural gas, capture carbon dioxide, and also in the purification of process gases at power plants. In electronics, sorption processes are used in the production of ultra-pure materials, drying of gases and liquids, and in the development of sensors and membrane technologies. In medicine, adsorption methods are used to purify blood, in the production of medical filters and materials with antimicrobial properties [6-8].

Modern research is aimed at creating new sorbents with controlled porosity, high selectivity and the possibility of repeated use, which allows to significantly expand the scope of application of sorption technologies.

Activated carbons for adsorption purification

Activated carbons are effective adsorbents with a developed porous structure, obtained from carbon-containing raw materials by thermal or chemical activation methods. Their structure and surface composition determine the ability to absorb organic and inorganic pollutants. Modification of the porous structure and functional groups allows to expand the areas of application in adsorption purification. Carbon-containing materials such as hard and brown coals, peat, lignin and wood have natural porosity, but the volume of micropores in them is relatively small. The formation of microporosity is associated with areas of low electron density between macromolecules. Coals of the early (brown, long-flame) and late (anthracite) stages of metamorphism have the maximum specific surface area.

Traditionally, carbon adsorbents are obtained from wood, coal, peat and fruit stones. Modern technologies include the production of activated carbons from polymer resins and carbon black, which makes it possible to obtain mesoporous materials with a narrow pore distribution. The production of activated carbons includes the stages of carbonization in an inert atmosphere and activation to increase the pore volume. The use of chemical activators such as zinc chloride, carbonates and hydroxides improves the mechanical strength and ion-exchange properties of carbon materials. The global consumption of porous carbon materials exceeds 1.1 million tons per year and continues to grow. About 80–85% of activated carbons are produced from non-renewable resources, but interest in recycling wood and agricultural waste is growing. The porous structure of activated carbons includes micropores ($\leqslant$2 nm), mesopores (2 – 50 nm), and macropores (>50 nm), which ensures their high sorption capacity [9 – 10].

IV. EXPERIMENTAL RESULTS

The chemical activity of PUM is determined by the presence of phenolic, carbonyl, carboxyl, ether groups on the surface, as well as nitrogen-, phosphorus-, sulfur- and halogen-containing fragments. PUM is obtained by physical (carbonization and treatment with water vapor or CO_2) and chemical activation methods using reagents such as H_3PO_4, KOH, NaOH, $ZnCl_2$.

Lignin is considered a promising raw material for obtaining sorbents. Pyrolysis and activation of technical lignins allow obtaining microporous carbons with a high specific surface area. Activation with steam, alkalis and salts promotes the formation of a narrow-pore structure and high sorption capacity.

PUM treated with H_3PO_4 or KOH demonstrate high efficiency in water purification from organic pollutants and heavy metals. Carbonization of lignin with subsequent activation allows to obtain activated carbons with a specific surface area of up to 3000 m^2/g, suitable for sorption technologies and lithium batteries.

Lignin-based sorbents are also used in medicine and veterinary science as effective enterosorbents. Processing of plant raw materials (birch bark, willow, aspen) allows to obtain sorbents with high oil capacity and the possibility of multiple regeneration. Fibrous composite materials with plant fillers and modified polystyrene foam expand the use of sorbents for the elimination of oil spills and cleaning of polluted environments [11. 12].

Adsorbents based on polymers and their waste

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Efficient waste management is crucial for maintaining environmental sustainability and protecting public health. Improper disposal of plastic waste leads to soil and water pollution, destruction of ecosystems and a threat to wildlife. Every year, millions of tons of plastic end up in oceans and landfills, where they persist for centuries, breaking down into microparticles that enter the food chain and have negative impacts on human health. As the population and consumption levels increase, the need to effectively manage plastic waste is becoming increasingly important to prevent long-term environmental damage and reduce greenhouse gas emissions [11-13].

Fig. 1. Polymer waste in nature.

The accumulation of polymer waste remains a serious problem: since the 1950s, global plastic production has reached 8.3 billion tons, of which 6.3 billion tons have become waste. Only 9% were recycled, 12% were incinerated, while 79% accumulated in landfills or in the environment.

The main sources of plastic waste are packaging, construction materials, household products, textiles, transport and electronics. In 2018, their volume exceeded 343 million tons, of which 90% was post-consumer waste. The high resistance of plastics to biodegradation leads to their long-term accumulation in ecosystems. Traditional disposal methods, such as landfill and incineration, are accompanied by serious environmental risks. Recycling is considered the most promising direction, the effectiveness of which depends on separate collection systems and the level of technological development. One effective solution is to process plastic waste into activated carbon, which is produced by physical or chemical activation methods. Plastic-based activated carbon is used for water purification, membrane separation, electrochemical devices, sensors, energy storage systems, and solar panels due to its high specific surface area, electrical conductivity, and structural stability. Research shows that plastic waste can be converted into sorbents with competitive characteristics, but processing complex mixtures remains a technologically challenging task [1-5]. Since the mass production of plastics, their total volume has reached 6.3 billion tons, of which only 9% has been recycled, while 79% has accumulated in the environment. If current trends continue, the volume of plastic waste could reach 33 billion tons by 2050. One of the serious problems remains the pollution of the world's oceans, where it is predicted that the mass of plastic will exceed the mass of fish.

V. CONCLUSION AND FUTURE WORK

Polystyrene and polycarbonate are widely used, but their processing is complicated by the content of toxic components such as styrene and bisphenol A. A promising direction is the production of sorption materials based on polymer waste, in particular hyper-crosslinked polymers (HCPs), which have high stability, specific surface area and adjustable porosity. Polymer waste that is resistant to decomposition is a valuable raw material for the creation of effective sorbents, especially after chemical modification and the use of thermal treatment methods, which allows you to regulate the density and improve the sorption characteristics of materials.

REFERENCES

1. Azizian S., Eris S. Adsorption isotherms and kinetics // Interface Science and Technology / ed. by Mehrorang Ghaedi. - Elsevier, 2021. - Vol. 33. - P. 445-509. - ISBN 978-0-12-818805-7. DOI: https://doi.org/10.1016/B978-0-12-818805-7.00011-4.
2. Dąbrowski A. Adsorption - from theory to practice // Advances in Colloid and Interface Science. - 2001. - Vol. 93, № 1-3. - P. 135-224. DOI: https://doi.org/10.1016/S0001-8686(00)00082-8.
3. Rafatullah M., Sulaiman O., Hashim R., Ahmad A. Adsorption of methylene blue on low-cost adsorbents: A review // Journal of Hazardous Materials. - 2010. - Vol. 177, № 1-3. - P. 70-80. DOI: https://doi.org/10.1016/j.jhazmat.2009.12.047.
4. Foo K.Y., Hameed B.H. Insights into the modeling of adsorption isotherm systems // Chemical Engineering Journal. - 2010. - Vol. 156, № 1. - P. 2-10. DOI: https://doi.org/10.1016/j.cej.2009.09.013.
5. Gupta V.K., Suhas. Application of low-cost adsorbents for dye removal - A review // Journal of Environmental Management. - 2009. - Vol. 90, № 8. - P. 2313-2342. DOI: https://doi.org/10.1016/j.jenvman.2008.11.017.
6. Tóth J. Uniform interpretation of gas/solid adsorption // Advances in Colloid and Interface Science. - 1995. - Vol. 55. - P. 1-239. DOI: https://doi.org/10.1016/0001-8686(94)00226-3.
7. Cheung C.W., Porter J.F., McKay G. Sorption kinetics for the removal of copper and zinc from effluents using bone char // Separation and Purification Technology. - 2000. - Vol. 19, № 1-2. - P. 55-64. DOI: https://doi.org/10.1016/S1383-5866(99)00073-8.
8. Azizian S., Bashiri H., Volkov A.G. Derivation of Azizian-Volkov (AV)-isotherm based on statistical thermodynamics // Colloids and Surfaces A: Physicochemical and Engineering Aspects. - 2009. - Vol. 335, № 1-3. - P. 28-32. DOI: https://doi.org/10.1016/j.colsurfa.2008.10.030.
9. Azizian S., Eris S., Wilson L.D. Re-evaluation of the century-old Langmuir isotherm for modeling adsorption phenomena in solution // Chemical Physics. - 2018. - Vol. 513. - P. 99-104. DOI: https://doi.org/10.1016/j.chemphys.2018.06.022.
10. Sohn S., Kim D. Modification of Langmuir isotherm in solution systems - definition and utilization of concentration dependent factor // Chemosphere. - 2005. - Vol. 58, № 1. - P. 115-123. DOI: https://doi.org/10.1016/j.chemosphere.2004.08.091.
11. Azizian S., Eris S., Wilson L.D. Reply to "Comment on 'Re-evaluation of the century-old Langmuir isotherm for modeling adsorption phenomena in solution'", published by Kopinke et al. [Chemical Physics (2018)] // Chemical Physics. - 2019. - Vol. 517. - P. 268-269. DOI: https://doi.org/10.1016/j.chemphys.2018.10.008.
12. Azizian S., Volkov A.G. A new isotherm for nondissociative gas adsorption with two different states of an adsorbate // Chemical Physics Letters. - 2008. - Vol. 454, № 4-6. - P. 409-414. DOI: https://doi.org/10.1016/j.cplett.2008.02.049.
13. Plazinski W., Rudzinski W., Plazinska A. Theoretical models of sorption kinetics including a surface reaction mechanism: A review // Advances in Colloid and Interface Science. - 2009. - Vol. 152, № 1-2. - P. 2-13. DOI: https://doi.org/10.1016/j.cis.2009.07.009.