Use of municipal vegetative waste as raw material for sorbent production

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Abstract. The most important direction of waste management is to reduce the resulting environmental impact. One of the promising ways of waste recycling is their use as a raw material for the production of sorbents. The paper presents the results of studies on the possibility of using ChL 250, i.e. modified municipal vegetative waste for cleaning the storm runoff of service stations from petroleum products and associated pollutants. It was found that the sorption capacity of the material for petroleum products is 194 mg/g. The trials carried out on real sewage confirmed the viability of this sorbent for use in water treatment.

1. Introduction

The problem of municipal waste management is very relevant around the world. The most important direction of waste management is to reduce the resulting environmental impact. This environmental impact is expected to be limited by minimizing waste formation, reuse, recycling and regeneration. It is necessary to form the concept that waste is at the same time a resource, and not just a collection of hazardous and unnecessary substances and compounds [1].

In 2016, there were more than 2 billion tons of municipal wastes worldwide. Figure 1 presents approximate data on the annual amount of municipal waste generated [2].

Figure 1. Annual municipal solid waste generated per capita (kilograms/capita/day).
Despite a wave of interest in the problem of recycling, most of them are still taken to landfills for disposal, which has a negative impact on the environment and leads to the alienation of large areas. Thus, in the United States, the percentage of waste to be disposed of was 55% in 2003, 47% in Korea, and 72% in the United Kingdom [3].

The tightening of environmental legislation forces enterprises to look for ways to use waste that was previously to be disposed of [4].

One of the promising ways of recycling is their use as a raw material for the production of sorbents and coagulants, which allows us to solve several important problems at once:

- to dispose of waste;
- to produce high-quality sewage treatment;
- to reduce the cost of water treatment [5-8].

Among the municipal and agricultural wastes, vegetative residues constitute a significant proportion [3,9].

Such cellulose-containing materials make it possible to obtain effective sorption materials, which are an alternative to active coals, which have a fairly high cost, which limits the possibilities of their industrial use [10-12].

Currently, there are many studies on the preparation of sorbents from vegetative residues using various technologies and modification methods that increase the sorption properties of the feedstock with respect to various pollutants [5, 6, 13–19]. This suggests that chestnut leaves i.e. the vegetative waste of urban households can serve as raw material for obtaining promising sorption material.

2. Materials and methods

Sorbent samples were prepared by roasting dry chestnut leaves (Aesculus hippocastanum L.) in a muffle furnace in open containers at different temperatures.

The chemical composition of the samples was studied using the scanning electron microscope of high resolution "TESCAN MIRA3 LMU”.

Infrared spectra were obtained on a The Vertex 70 FTIR spectrometer instrument, and then decoded using reference and scientific literature [20-24].

For the preparation of model waters containing petroleum products, spindle oil brand I-20A was used, \( \rho = 890 \text{kg/m}^3 \) at 20 °C [25]. In real sewage the composition of petroleum products is not specified.

3. Results and discussion

As a result of heat treatment of cellulose-containing material (chestnut leaves), the percentage of chemical elements changes (Figure 2).

As it can be seen from the given data, the largest amount of carbon from the samples under study is from CTW\textsubscript{250}, which is explained by the high content of cellulose and other organic components of the leaf, together with the removal of moisture.

Figures 3-5 show the IR spectra obtained in the study of samples of the sorption material.

The main components of the leaves are cellulose and lignin, which differ in the complexity of the structure and a large number of different types of bonds.

The most intense peaks in the oscillation range of 3100-3600 cm\(^{-1}\) indicate OH groups of cellulose and lignin, as well as fluctuations of water adsorbed on the surface of the material.

Oscillations 2750-3000 cm\(^{-1}\) indicate the group \( \text{CH}_2, \text{CH}_3 \); the range of 1800–1500 cm\(^{-1}\) belongs to the \( \text{C} = \text{O} \) and \( \text{C} = \text{C} \) bonds; 1200–950 cm\(^{-1}\) \( \text{C} – \text{O} \) and \( \text{C} – \text{C} \) bonds. The frequency range of 1330-1325, 1235-1230 indicates the presence of a lignin syringyl ring.

After heat treatment at 250 °C, the main structure of the peaks is preserved, since cellulose and lignin were not subjected to decomposition, however, hemicellulose [26] and tannins began to decompose. Thus the amount of carbon-containing compounds with double bonds (1626 ± 50 cm\(^{-1}\)) increases.
Figure 2. The percentage of chemical elements in CTW at different processing temperatures.

Figure 3. IR spectrum of ChL initial components.

Figure 4. IR spectrum of components ChL250
After heat treatment at 500 °C, the peak of the greatest intensity indicates the presence of carbonates (1450 ± 50 cm⁻¹), which is in good agreement with the data of energy dispersive analysis given earlier.

Despite the fact that the material obtained as a result of heat decomposition of cellulose may have high sorption capacity, such intensive heat treatment seems to be irrational, since the amount of the resulting solid residue is a small part of the initial mass of leaves (about 5-7%), and the energy costs for heat modification are quite large. In view of the above mentioned, it was decided to carry out the further research on the modification of the initial ChL at temperatures not exceeding 250 °C.

The study of the adsorption of petroleum products from model waters was carried out in a static mode using ChL initial, and ChL₁₀₅ . ChL₂₅₀. Initially, the equilibrium concentration of dissolved petroleum products was determined after 40 min of interaction of sorption materials weighing 0.5 g with 1 dm³ of a model solution with a concentration of 0.1 g/dm³ at a temperature of 20 °C. Then the values of the sorption capacity and the cleaning efficiency of the model solution with the studied materials were calculated (Table 1).

| Name        | Sorption capacity, mg/g | cleaning efficiency, % |
|-------------|-------------------------|------------------------|
| ChL initial | 154                     | 75                     |
| ChL₁₀₅     | 134                     | 67                     |
| ChL₂₀₀     | 186                     | 93                     |
| ChL₂₅₀     | 194                     | 97                     |

As it can be seen from the obtained results, the sorption capacity of the obtained materials is expected to be lower than that of activated carbons, but it is comparable with similar materials obtained from waste.

To determine the effectiveness of the treatment of real sewage using CTW₂₅₀ material, further studies were carried out.

Sewage samples were taken from storm water runoff from service stations of Oskol Roads, Belgorod Region, Russia. In addition to petroleum products, such waters contain associated pollutants that influence the process of water purification, which must be taken into account when developing the technology for using a sorption material.

When carrying out the research on the purification of storm waters using a sorption material, polluted waters were taken into conical flasks, where appropriate sample weights of sorption material were added, stirred for 10 min, after which the liquid was filtered through a filter paper, then analyzed to find contaminated matter. The research results are presented in table 2.
Table 2. Test results of CTW\textsubscript{250} in storm waters of a service station.

| Substance                  | Concentration | To cleaning | After cleaning | Cleaning efficiency, % |
|----------------------------|---------------|-------------|----------------|------------------------|
| Additive 1 g/dm\textsuperscript{3} | Suspended substances, mg/dm\textsuperscript{3} | 274.2 | 149.9 | 45.3 |
|                            | COD, mgO/dm\textsuperscript{3}        | 125.3 | 43.6 | 65.2 |
|                            | Petroleum products, mg/dm\textsuperscript{3} | 9.8 | 2.7 | 72.4 |
| Additive 2 g/dm\textsuperscript{3} | Suspended substances, mg/dm\textsuperscript{3} | 274.2 | 129.7 | 52.7 |
|                            | COD, mgO/dm\textsuperscript{3}        | 125.3 | 39.1 | 68.8 |
|                            | Petroleum products, mg/dm\textsuperscript{3} | 9.8 | 2.0 | 79.4 |
| Additive 3 g/dm\textsuperscript{3} | Suspended substances, mg/dm\textsuperscript{3} | 274.2 | 82.5 | 69.9 |
|                            | COD, mgO/dm\textsuperscript{3}        | 125.3 | 30.9 | 75.3 |
|                            | Petroleum products, mg/dm\textsuperscript{3} | 9.8 | 1.1 | 88.7 |

It was found that in the studied sewage, the highest values of the cleaning efficiency of the aquatic environment are achieved by adding CTW\textsubscript{250} in an amount of 3 g/dm\textsuperscript{3}.

4. Conclusion

Studies of the sorption material at various stages of its modification showed that at a treatment temperature of 250 °C, the material contains the greatest amount of carbon, the amount of carbon-containing compounds with double bonds also increases due to the destruction of hemicellulose and tannins. Sorption capacity LK\textsubscript{250} for petroleum products is 194 mg/g. Sewage treatment of service stations showed that the resulting sorbent is promising for use in sewage treatment from petroleum products and related pollutants.

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