Sewage treatment in megacities by modified chestnut tree waste

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Sewage treatment in megacities by modified chestnut tree waste

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Abstract. The greater the density of urban building, the more sewage is produced per unit area, so in megacities, where residential block of flats are built everywhere then the issue of water treatment is particularly acute. The paper presents the results of researches on the purification of urban municipal sewage using modified chestnut tree waste. This material has a great potential for use in water treatment, having universal accessibility and high sorption properties. The conducted researches made it possible to establish that the optimum temperature for carrying out the process of modification of tree waste is about 450°C. In this case, the material is notably carbonized, but the active ignition doesn't happen.

Researches carried out in model and municipal sewage showed that modified chestnut tree waste allows reducing COD values by 92%, reducing the content of suspended substances by 90%, nickel ions by 87%, oil products by 88%.

Production tests on real sewage showed that with the aid of the obtained sorption material it is possible to conduct pre-or post-purify of the wastewaters effectively.

1. Introduction

The population of the planet is steadily increasing. Cities are expanding and more and more new territories are being built up while the height of buildings and the density of population per unit area are increasing. Urban residents, like all people, need water and food and municipal utilities pump daily thousands of cubic meters of water to meet the needs of the population.

Globally, 3.6 billion people live in urban areas. The next few decades will be the most rapid period of urban growth in human history, with 2.6 billion additional urban dwellers expected by 2050. This increase in total municipal water demand is driven not just by the increase in urban population, but also by a tendency for economic development to increase the fraction of the urban population that uses municipal supply rather than other sources such as local wells or private water vendors. The economic development increases per-capita water use, as new technologies such as showers, washing machines, and dishwashers increase residential use of water [1].

Data on freshwater consumption per person in some European countries are provided in Table 1 [2].

Table 1. Freshwater consumption per person in some European countries, m^3/year

Country	Years		
	2011	2012	2013
Russia	480	463	454
Bulgaria	866	780	751
Poland	313	302	295
Slovakia	110	123	118
Czech Republic	180	175	157

The functioning of large cities is connected with the formation of huge amounts of sewage, for example, in the metropolitan city of Moscow, in 2014, 862.86 million m^3 of sewage was supplied to treatment plants [2].

Data on the amount of urban sewage formed in some European countries are shown in Table 2 [3].

Table 2. The amount of urban wastewater generated in some European countries, million m^3 per year

Country	Time		
	2012	2013	2014
Bulgaria	483.31	513.78	500.67
Czech Republic	834.5	929.4	809.9
Latvia	141.04	150.14	111.16
Netherlands	1,826.6	1,722.466	1,695.209
Hungary	431.647	484.885	475.34
Lithuania	162.93	159.68	151.83
Romania	985.5	947.5	918.8

Domestic sewage contains organic substances, fats, proteins, synthetic surfactants, suspended substances, petroleum products, some heavy metals in high concentrations. Such drainages have a high level of bacterial danger [4–6].

In conditions of dense urban building, sewage treatment is a serious problem. Huge volumes of polluted water require intensive and uninterrupted operation of all water treatment systems.

After collection and equalization, domestic sewage is removed by sewage systems to urban treatment facilities. As a rule, they consist of the following water treatment devices: grates, sand traps, settling tanks, aerated tanks and disinfection devices.

To increase the efficiency of urban treatment facilities work, additional devices are used as local treatment and post-treatment. In particular, adsorption purification plants are widely used because they have high efficiency and allow extracting a wide range of pollutants from aqueous media simultaneously [7–9].

Taking into account the large volumes of treated sewage, the sorption materials at the same time should have a low cost price providing the high purification efficiency.

The purpose of the researches was to determine the possibility of using modified chestnut tree waste for domestic sewage treatment.

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2. Experimental section

Thermal modified tree waste (MTW) of conifer chestnut trees (Aésculus hippocastanum L.), which is widely distributed in Europe, was used to purify model waters [10]. It is a large rapidly growing tree with sessile leaflets that can reach more than 30 meters in height [11].

Samples of tree waste were collected in the urban area of Belgorod (Russian Federation).

Muffle furnace Liop LF-7/13-G2 was used for burning of tree waste.

The indicator of chemical oxygen demand (COD) in model emulsions was determined according to the standard procedure [12]

Nickel ions were determined by the photocolorimetric method with an indicator of dimethylglyoxime at a wavelength of 445 nm [13].

3. Results section

Tree waste is formed everywhere, and within the boundaries of settlements, as a rule, is collected by city services and exported to landfills. At the same time, this material has a high sorption potential, based on its physico-chemical properties. Vegetable waste is often the object of research as a potential raw material for the production of sorption materials [14–24]. So, the works on the use of the leaves of trees of the genus Acacia are known for purification model waters from various pollutants such as dyes, phenol, and oil [16]. In the article [17] the research results are given according to removal of heavy metal ions from aqueous solutions using tobacco leaves as a sorbent. According to the experimental results, the tobacco leaves sorbent is an effective, low cost, and alternative sorbent precursor for the removal of lead, zinc, and cadmium ions from sewage.

We carried out researches on the treatment of model waters using a thermally modified chestnut tree waste. The modification was carried out in such a way: leaves dried for 3 days at a temperature of 20–23°C, air humidity of about 30%, were ground in a mortar up to a particle size D <0.5 cm, and then they were burnt in a muffle furnace at different temperature interval of 50.

At temperatures from 100 to 300°C the leaves do not undergo noticeable visual changes. In the temperature range from 350 to 400 the leaves noticeably darken, after 400 they begin to carbonize, after 550°C they burn into ashes.

Preliminary researches made it possible to establish that from the indicated temperature range processing the optimum one is about 450°C. So, significant carbonization of the material takes place, but active ignition of the foliage doesn’t happen. The efficiency of pollutants extraction is high for foliage treated at both 450°C and 500°C, but choosing a lower temperature is rational in terms of reducing the cost on initial the source material.

The purification of model solutions and emulsions was carried out in a static manner by mixing the samples of the ground MTW with an aqueous system followed by the filtration of the spent sorption material. The contact time was 30 minutes and the temperature of the medium was 21°C.

The concentrations of substances before (C1) and after (C2) of water purification were determined in accordance with the previously mentioned procedures, then the purification efficiency (E) was calculated according to the formula:

$$E = \frac{C1 - C2}{C1} * 100\%$$

The results of researches of the effectiveness of COD reduction in model systems are shown in Figure 1. Model systems were prepared by diluting cow milk in water, because milk is a complex multicomponent system containing basic groups of organic substances.

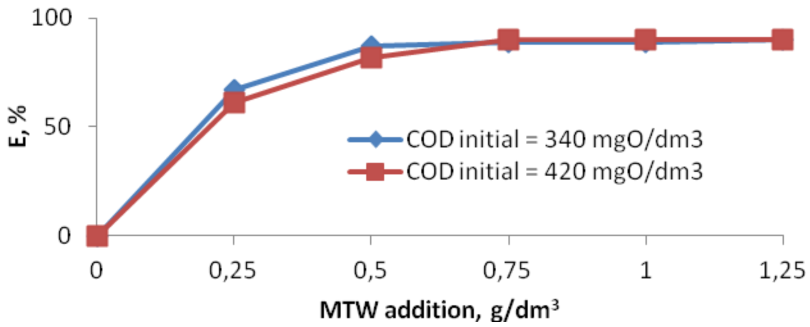
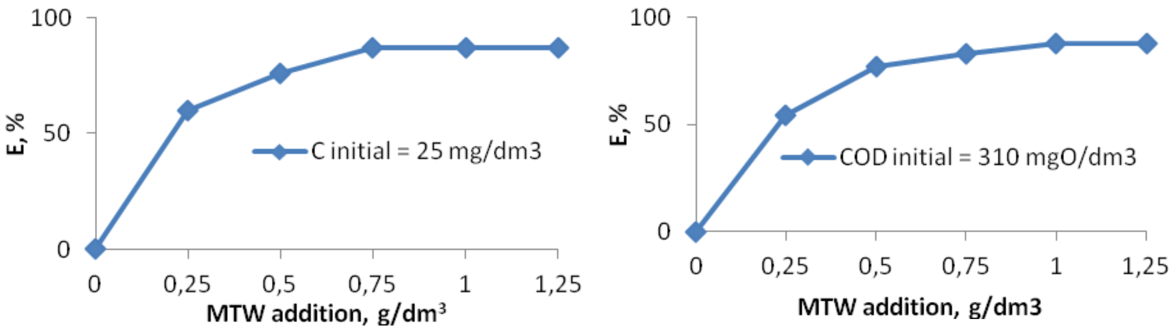


Figure 1. Efficiency of reducing COD values in model water systems using MTW

Data on the purification of model waters from nickel and petroleum ions are given on the Figure 2.



a b

Figure 2. Efficiency of purification of model waters from nickel ions (a) and petroleum products (b) in model water systems using MTW

With initial COD values of 340 and 420 mgO / dm^3 model waters prepared by diluting milk, the optimum amount of sorption material added is 0.5 g / dm^3. When purifying model waters from nickel ions with an initial pollutant concentration of 25mg / dm^3, the greatest efficiency is achieved with the addition of MLO from 0.75 g / dm^3, when extracting petroleum products from model emulsions with a starting COD value of 310 mgO / dm^3, the rational amount of added material is also 0, 75 g / dm^3.

As it can be seen from the given data, the obtained sorption material decreases the COD values effectively and allows extracting nickel ions and oil products from model water systems.

To confirm the results obtained in the model waters, researches were carried out in the conditions of the laboratory of urban treatment facilities (Table 3). The amount of sorption material added was 1 g/dm^3, the temperature of the aqueous medium was 18°C, and the reaction time was 25 minutes.

The purification efficiency in this case was slightly lower than in the treatment of model waters from individual components, which is explained by the interaction of the sorption material with several contaminants present in the sewage simultaneously.

Table 3. Efficiency of domestic wastewater treatment

Indicator	Sewage composition of Municipal Unitary Enterprise "Gorvodokanal", Alekseevka city (Russian Federation), mg/ dm^3		Purification efficiency, %
	before cleaning	after cleaning	

Suspended substances	192.4	18.5	90
COD, mgO / dm^3	395.0	92.3	77
Petroleum products, mg / dm^3	2.6	0.33	87

The obtained data show that MTW is an effective sorption material in conditions of multi-component sewage, which allows purifying water systems from various pollutants.

Conclusions

The conducted researches made it possible to establish that thermally modified chestnut tree waste is a perspective material for use in the treatment of domestic sewage.

The obtained sorption material is widely available, has a low cost and allows reducing COD values by 92%, reducing the content of suspended substances by 90%, nickel ions by 87% and oil products by 88%.

Production tests on real sewage showed that with the aid of the obtained sorption material it is possible to effectively pre-or post-purify the wastewaters.

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