Wastewater treatment technology with modified sorbent from the complex of household services

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Abstract. The composition and characteristics of wastewater from the complex of household services and the method of wastewater treatment from the surfactants have been studied. To increase the efficiency of local treatment of the wastewater, a method of neutralization on a carbon sorbent modified with sulfuric acid has been analyzed. Wastewater treatment technology with a high content of organic substances having an increased alkaline reaction is a pretreatment of coal with sulfuric acid solutions, which then serves as a resin charge for filters. The spent resin charge is regenerated with a hydrogen peroxide solution. These results have been obtained using artificially prepared and natural wastewater from the complex of household services and form the basis for the development of wastewater treatment facilities for laundries located in hotels, health centers and recreation facilities. The conclusions on the efficient use of the proposed method are made. Keywords: Treatment facilities, resource-saving technology, wastewater, surfactants.

1. Introduction
A complex of household services is an integral part of a modern city. The necessity of local treatment of its wastewater is determined by the discharge capacity of the city sewage system, its location, the capacity of the reservoir that is the receiver of the treated wastewater, the requirements of local sanitary authorities for the level of wastewater treatment, etc.

At present, the problem of wastewater treatment from the surfactants is a relevant one, since they are in the wastewater of many enterprises, such as numerous car washes, motor depots, urban household waters, as well as in the networks of public services, which include laundry facilities of various types. Numerous compositions of detergents are used for their activity, including surfactants that are resistant to biochemical oxidation and inhibit the vital activity of bacteria in urban wastewater treatment plants and enter the environment, polluting it. Thus, the priority task in the wastewater treatment of these enterprises (including those with a circulating water supply cycle) is the extraction of surfactants, which are the greatest danger [1].

In world practice, various methods of wastewater treatment of this type are used, including those with the use of sorbents. The main difference of the proposed method is the use of sulfuric acid as a modifier. Based on the analysis of the references, this modification method for the wastewater treatment from the complex of household services has not been used [2-3].
2. Materials and methods

2.1. Composition and characteristics of wastewater

Wastewater from washing machines used in the complex that provides household services to the population, after each operation: washing, primary rinsing, second rinsing, spinning, is discharged from the machines in the form of volley sewage. At the same time, wastewater after each such operation has a different level of pollution, including surfactants (the highest concentration of surfactants is observed after washing, and decreases with each rinse), in this regard, before the supply of wastewater to local treatment facilities we need the average wastewater flow rate and concentration.

Wastewater from the laundries contains process detergents, contaminants removed from fabrics, and mineral salts contained in the original tap water.

The pollutants can be soluble and insoluble in water: sugar, starch, flour, urea, organic acids and salts, protein substances, inorganic salts contained in the original tap water. Detergents are the following: fatty soap (laundry soap with 60...72% of fatty acids) and synthetic detergents (synthetic detergents, which are based on synthetic surfactants (15...40%)); in the production of detergents, anionic and nonionic surfactants are used.

Regardless of which class the surfactant belongs to, its molecule consists of two parts: hydrophobic (water-insoluble), represented by a hydrocarbon chain of the general formula $\text{C}_n\text{H}_{2n+1}$ (n = 10...18 carbon atoms), and hydrophilic (water-soluble), represented with a sulfate or sulfonate group in anionic surfactants, and with a polyoxyethylene chain in nonionic surfactants.

The dual character of the molecules of surfactants determines their main property that is an oriented adsorption at the interface (the hydrophilic part is facing the polar phase, which is water; whereas the hydrophobic part is facing the less polar phase, which is air, oil, etc.), which causes the foaming, emulsifying, and suspending ability of these substances.

In the solution the surfactants at high concentrations are oriented in the form of micelles, which the solubilizing ability of detergents is related to. In general, all of the above properties of surfactants determine their detergency.

Powdered detergents for washing woolen and silk fabrics contain mainly up to 40% of surfactants, up to 10% of condensed phosphates and up to 47% of sodium sulfate. Mixtures of surfactants are also used, but usually contain up to 50% of alkyl sulfates.

Apart from detergents, additional bleaching and bluing agents, as well as finishing materials are mainly used for washing white cotton and linen fabrics. Hydrogen peroxide (perhydrol), perborate and sodium hypochlorite are used as bleaching agents, and ultramarine, dry or liquid blue, is used to bluish linen. Potato or corn starch, sodium carboxymethyl cellulose, or polyvinyl alcohol are used to improve the appearance of washed products and increase their service life [4].

Wastewater generated in the technological process of the complex is an integrated polydisperse heterogeneous system. The dispersed phase is represented by emulsions and suspensions; the dispersion medium is water with dissolved organic and mineral substances.

The composition of the total wastewater from the complex of household services is characterized by a high content of organic pollutants (chemical oxygen consumption is up to 2000 mgO$_2$/l), an alkaline reaction (pH 8...10) and an increased content of fat (up to 80 mg/l) (Table 1).

2.2. Wastewater treatment methods

There are many ways to clean water from surfactants, in particular, they are coagulation, pressure flotation, foam separation, which can reduce the concentration of the surfactants in water to 50-100 mg/l. The disadvantage of these methods is the necessity to dispose foam condensate and a relatively low degree of purification. As a rule, adsorption and destructive methods are used for water purification that is biochemical purification and, more recently, oxidation with strong oxidants, such as ozone and hydrogen peroxide. The disadvantage of adsorptive cleaning methods is the periodic regeneration of the used adsorbents. Requiring high energy consumption oxidative methods do not...
additionally pollute the water with their decay products, but contribute to its saturation with oxygen, which is formed during the decomposition of the above oxidants [5-9].

Compared to ozone, hydrogen peroxide has the advantage that it makes it easy to create practically any concentration of an oxidant in the water being purified.

However, it is known that a high rate of oxidation of contaminants with hydrogen peroxide can be achieved only when catalysts for its decomposition are used. Such catalysts are also adsorbents that are activated carbons [10-13].

Table 1. Characteristics of the total average wastewater from the laundry.

| Characteristics                  | Value          |
|----------------------------------|----------------|
| pH                               | 8.10           |
| Temperature, °C                  | 31             |
| Content of, mg/l:                | 290            |
| suspended substances             | 200–464        |
| dissolved solids, mgO₂/l         | 1384           |
| chemical oxygen demand           | 1020           |
| biochemical oxygen demand₅      | 334            |
| biochemical oxygen demand₃₀     | 490            |
| total nitrogen                   | 36             |
| ammonium nitrogen                | 1.5            |
| lipoid                           | 400            |
| surfactants                      | 130            |

The aim of this research is to study the efficient use of modified active carbons in the adsorption-catalytic process of water purification from surfactants with hydrogen peroxide. Coals should act as both catalysts for the decomposition of hydrogen peroxide and adsorbents of surfactants and products of their destruction.

At present, in the world practice, the method of modifying the coal charge with inorganic acids is being tested in order to improve its adsorption-catalytic properties in the process of water purification [14-18].

This technique consists of adding inorganic acids to the carbonaceous material, the surface area of the activated carbon matrix being at least about 5 times the surface area of the carbonaceous material.

Thus, we obtain a new composition containing acid-modified activated carbon, which can be obtained by converting a carbonaceous substance into an activated carbon matrix and adding an inorganic acid to the resulting matrix [19-20].

2.3. Materials Used for Wastewater Treatment

In this work, sulfuric acid has been selected as the strongest and most economically profitable acid available for the modification of activated carbon.

In a number of experiments, Carbonut WT coal has been used, since, according to the manufacturer, this grade of coal is most effective in the processes of cleaning wastewater from laundries from such pollutants as various solvents (including chlorine), hydrocarbons, halogenated hydrocarbons, pesticides (atrazine, simazine), herbicides, detergents and various organic substances that give the water tastes and odors.

Activated carbon Carbonut WT is produced from the coconut shells and is thermally activated by water vapor under special technological conditions. Coconut activated carbons Carbonut WT are distinguished by an exceptional purity of the final product, high mechanical strength, activity and low dust formation (Table 2).

This activated carbon is analogous to products such as BAU-A and BAU-MF (GOST (State Standard) 6217-74, produced by Sorbent JSC, Karbokhim JSC, UralHimSorb), OU-A, OU-B and OU-
V (GOST (State Standard) 4453-74, produced by Sorbent JSC, Karbokhim JSC, UralHimSorb), and in terms of the quality of adsorption and service life, it is several times superior to domestic analogues.

### Table 2. Characteristics of Carbonut WT 124 E coal.

| Parameter                      | Value                  |
|--------------------------------|------------------------|
| Coal shape                     | Granulated             |
| Size of particles, mesh USS    | 12x40                  |
| Size of particles, mm          | 0.4-1.7                |
| Specific surface area, m²/g    | 1150                   |
| Iodine index, mg/g             | 1100                   |
| CTC adsorption, %              | 60                     |
| Pour density, kg/m³            | 500                    |
| Moisture content, %            | 4                      |
| Ignition residue, %            | 3                      |
| pH                             | 10                     |
| Resistance, %                  | 99                     |
| After-treatment processing     | Washed with water      |

#### 2.4. Course of research

Let us consider the course of experiments on filtration of wastewater from public service enterprises through a column filled with activated carbon previously modified with sulfuric acid.

The first stage is the treatment of 250 ml of washed Carbonut WT coal with 1 liter of sulfuric acid solution. The acid concentration has been determined empirically and is 6 mg/l.

The second stage is filtration of natural wastewater from the complex of household service through a column filled with pre-modified coal.

The third stage is biochemical purification, namely the oxidation of the sorbed contaminants with a hydrogen peroxide solution until the adsorbent charge is completely cleaned from organic contaminants.

#### 3. Results

Estimation of the treatment efficiency has been carried out according to the most critical and basic indicator of the level of pollution for this type of wastewater that is the indicator of the content of organic substances in water - chemical oxygen demand (COD) (Table 3, 4).

### Table 3. Filtration of natural wastewater on modified activated carbon.

| No. of experiment | Received filtrate volume, l | Input COD, mgO₂/l | End COD, mgO₂/l | Sorbent COD = End COD – Input COD, mgO₂/l | % of wastewater treatment |
|-------------------|-----------------------------|--------------------|-----------------|---------------------------------------------|--------------------------|
| 1                 | 0.5                         | 839±15             | 67±8            | 772                                         | 92%                      |
| 2                 | 1                           | 839±15             | 143±12          | 696                                         | 83%                      |
| 3                 | 1.5                         | 839±15             | 185±11          | 654                                         | 78%                      |
| 4                 | 2                           | 839±15             | 243±18          | 596                                         | 71%                      |
| 5                 | 2.5                         | 839±15             | 361±12          | 478                                         | 57%                      |
| 6                 | 3                           | 839±15             | 428±9           | 411                                         | 49%                      |
| 7                 | 3.5                         | 839±15             | 495±6           | 344                                         | 41%                      |
| 8                 | 4                           | 839±15             | 571±10          | 268                                         | 32%                      |
| 9                 | 4.5                         | 839±15             | 638±15          | 201                                         | 24%                      |
| 10                | 5                           | 839±15             | 688±12          | 151                                         | 18%                      |
| 11                | 5.5                         | 839±15             | 738±9           | 101                                         | 12%                      |
| 12                | 6                           | 839±15             | 814±8           | 25                                          | 3%                       |
Table 4. Filtration of natural wastewater on pure sorbent.

| No. of experiment | Received filtrate volume, l | Input COD, mgO_2/l | End COD, mgO_2/l | Sorbent COD = End COD – Input COD, mgO_2/l | % of wastewater treatment |
|-------------------|----------------------------|--------------------|-----------------|---------------------------------------------|--------------------------|
| 1                 | 0.5                        | 839±15             | 67±8            | 772                                         | 66%                      |
| 2                 | 1                          | 839±15             | 143±12          | 696                                         | 59%                      |
| 3                 | 1.5                        | 839±15             | 185±11          | 654                                         | 53%                      |
| 4                 | 2                          | 839±15             | 243±18          | 596                                         | 48%                      |
| 5                 | 2.5                        | 839±15             | 361±12          | 478                                         | 40%                      |
| 6                 | 3                          | 839±15             | 428±9           | 411                                         | 33%                      |
| 7                 | 3.5                        | 839±15             | 495±6           | 344                                         | 28%                      |
| 8                 | 4                          | 839±15             | 571±10          | 268                                         | 22%                      |
| 9                 | 4.5                        | 839±15             | 638±15          | 201                                         | 14%                      |
| 10                | 5                          | 839±15             | 688±12          | 151                                         | 10%                      |
| 11                | 5.5                        | 839±15             | 738±9           | 101                                         | 4%                       |
| 12                | 6                          | 839±15             | 814±8           | 25                                          | 1%                       |

4. Summary

- The research has proven the efficiency of the proposed method of wastewater treatment from the factories of public services;
- It is determined empirically that the most effective concentration of sulfuric acid for the modification of the sorbent is 6 mg/l;
- The modified sorbent shows an increase in wastewater treatment efficiency by an average of 13.8%.

5. Conclusion

The proposed option for wastewater treatment from the complex of public services has proven its validity. Sorbent modification helps to increase the wastewater treatment efficiency by 14%. In addition, data on the effective concentration of sulfuric acid used to modify the coal charge have been obtained.

The final selection of the most effective wastewater treatment process for these enterprises can be made after analysis of the oxidative destruction of absorbed organic substances and decomposition of oxidants on the surface of activated carbons, which is the subject of further research.

References

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