Determination of absorption properties of natural sorbents under dynamic conditions

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Abstract. The relevance of research on the absorption properties of sorbents is due to the need for an individual approach in the selection of filter media for wastewater treatment, depending on their chemical composition. In the presented article sorption properties of sorbents were studied under dynamic conditions. For this purpose, a laboratory-experimental installation for the treatment of natural and waste water was mounted. In the research three types of filtering loads were used: 1 - homogeneous load from activated carbon of BAU-A mark; 2 - combined load from activated carbon and zeolite with particle size of 5 mm; 3 - zeolite with fraction of 5 mm, 3 mm, and 1 mm. Among the studied samples of sorbents, zeolite loading with particle sizes of 5 mm, 3 mm, and 1 mm showed the best performance. Other types of loadings, such as activated carbon BAU-A and combined carbon loadings with zeolite were ineffective, because the sorption coefficient did not meet the MAC requirements.

1 Introduction

Leading industrial enterprises of the national economy need efficient treatment of their wastewater. Outdated methods and technologies of water treatment are not always able to cope with large volumes of wastewater generated as a result of production growth\cite{[1-8]}. This negative factor poses new challenges to science, which consist in the development of new approaches to increase the efficiency of technological processes of water treatment\cite{[9]}. Technical wastewater treatment equipment must meet a number of requirements, the key ones being:

- Simplicity and reliability of designs.
- High productivity.
- Sufficient efficiency of treatment up to the MAC level.
- Low price of purchased materials and equipment operation.

Currently, the majority of enterprises use lagoons-cottlenecks and storage ponds, where industrial and domestic wastewater is discharged and dried \cite{[10]}. Other enterprises give preference to biological treatment methods. However, the bona fide wastewater treatment
can be achieved only with the inclusion of sorption filters in the production cycle of water treatment.

Sorption method is one of the highly effective methods of natural and waste water treatment [11-15]. The efficiency of purification depends largely on a properly selected filtering sorbent. In turn, the sorbent is selected depending on the harmful ingredients included in the composition of wastewater and the required parameters of treated water.

The sorption process will largely depend on the physical properties of the sorbent used in the treatment: natural origin, fraction, crystal structure, water resistance and vibration wear. The external factors that have no small influence on the absorption properties of sorbents can include the pH of the medium, pressure, volume capacity and contact time with the treated liquid [10].

2 Materials and methods

In our research the absorption properties of sorbents were studied under dynamic conditions. For this purpose, a laboratory-experimental installation for natural and waste water treatment was mounted (Figure 1).

Fig. 1. Laboratory and experimental plant for natural and wastewater treatment. 1 - flasks; 2 - reservoir with source water; 3 - pump; 4 - receiving tank; 5 - flow meter.

The presented laboratory-experimental installation for purification of natural and waste water consists of three sorption filters 1 (flasks with the volume of 5 liters), the constructive interrelation of which allows to carry out filtration, as a cascade method, and in parallel operation of all filters.

Untreated wastewater was poured into the source water tank 2, from where it was pumped by pump 3 through pipelines to the filtering equipment 1. The filtered liquid was
collected in the receiving tank 4, from where samples were taken for analysis. The volume of supplied effluent was controlled by flow meter 5. Sampling for analysis was carried out for every 10 liters of treated effluent.

Zeolite-containing rocks of Ilovinsky deposit of Volgograd region and activated carbon of BAU-A brand were used as sorption material. From the sieved samples for the experiment 3 combinations of filter loading distribution were formed. The first combination included homogeneous loading from activated carbon. The second combination was formed from activated carbon placed in the first two flasks and zeolite of 5 mm fraction in the third flask. The third combination consisted of sieved zeolite with a particle size of 5 mm in the first flask, 3 mm in the second flask and 1 mm in the third flask.

3 Results

The study of absorption properties of sorbents was carried out after filtration of preliminarily clarified wastewater of cattle breeding complex used for irrigation. The chemical analysis of livestock wastewater presented in Table 1 shows the exceeding of MPC of two indicators: ammonium nitrogen - by 20.1%, potassium - by 88.3%. Thus, the required sorption coefficient of ammonium nitrogen to MAC values is 16.7 %, potassium sorption coefficient - 46.9 %.

Table 1. Chemical analysis of wastewater from a cattle breeding facility.

<table>
<thead>
<tr>
<th>No.</th>
<th>Indicator</th>
<th>Concentration mg/l</th>
<th>MPC, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>7.5</td>
<td>6.0-8.5</td>
</tr>
<tr>
<td>2</td>
<td>Dry residue</td>
<td>1527.7</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>Biochemical oxygen uptake</td>
<td>802.0</td>
<td>850</td>
</tr>
<tr>
<td>4</td>
<td>Chlorides</td>
<td>73.8</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Nitrates</td>
<td>0.28</td>
<td>0.5</td>
</tr>
<tr>
<td>6</td>
<td>Ammonium nitrogen</td>
<td>120.1</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>Magnesium</td>
<td>28.6</td>
<td>330</td>
</tr>
<tr>
<td>8</td>
<td>Calcium</td>
<td>135.9</td>
<td>450</td>
</tr>
<tr>
<td>9</td>
<td>Potassium</td>
<td>141.2</td>
<td>75</td>
</tr>
<tr>
<td>10</td>
<td>Sodium</td>
<td>62.7</td>
<td>200</td>
</tr>
<tr>
<td>11</td>
<td>Soluble iron</td>
<td>0.5</td>
<td>20</td>
</tr>
</tbody>
</table>

At the end of the experiment, graphs of ammonium nitrogen and potassium sorption dynamics were plotted and presented in Figures 2 and 3.

Fig. 2. Dynamics of ammonium nitrogen sorption.
4 Discussion

The graphs presented in Figures 2 and 3 show that the absorption capacity of zeolite-containing rocks of 5 mm, 3 mm and 1 mm fraction under dynamic conditions is significantly higher than that of activated carbon of BAU-A grade and combined loading from activated carbon and zeolite.

The dynamics of ammonium nitrogen sorption shows that the sorption coefficient, satisfying the MPC, in the conditions of filtration through zeolite loading was observed during filtration of 70 liters of liquid, and the absorption process ended after treatment of 100 liters of wastewater. The volume of treated effluent with permissible content of impurities, filtered through the combined loading of activated carbon and zeolite, as well as through a homogeneous loading of activated carbon, decreased relative to the volume of effluent treated with zeolite by 57.1 % and 85.7 %, respectively. The sorption process in the combined load was terminated at 60 liters of treated effluent, in the charcoal load - at 50 liters.

At sorption of potassium in coal and combined loading, the content of impurities in the effluent after treatment did not reach MAC values, and equilibrium was reached at 30 and 40 liters. In zeolite loading sorption was completed after treatment of 90 liters of wastewater, and the volume with effective extraction of pollutants was not more than 40 liters.

The research was carried out within the framework of the fulfillment of the state task ordered by the Ministry of Science and Higher Education of the Russian Federation in 2024-2025. "Technological convergence of robotic systems and methods of automated control of filter equipment regeneration processes in land reclamation and water management".

5 Conclusion

Summarizing the results of our research we can say with certainty that preliminary clarification of livestock effluents for irrigation does not give the required result, because the content of ammonium nitrogen exceeds MAC by 20.1 %, and the content of potassium by 88.3 %. In this case it is necessary to include sorption method of treatment in the technological process of water treatment.

Among the studied samples of sorbents zeolite loading with particle sizes of 5 mm, 3 mm and 1 mm proved to be the best. Other types of loadings, such as activated carbon
BAU-A and combined carbon loadings with zeolite were ineffective, because the sorption coefficient did not meet the requirements of MPCs.

References
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