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RESULTS OF REDUCING COD, BOD, SUSPENDED SOLIDS, TURBIDITY AND DRY RESIDUE IN BREWERY WASTEWATER

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Abstract

The article presents the results of evaluating the efficiency of preliminary physicochemical treatment of brewery wastewater according to the main pollution indicators: chemical oxygen demand, biochemical oxygen demand, suspended solids, turbidity and dry residue. The purpose of the study was to determine the technological efficiency of an integrated treatment scheme including mechanical separation of coarse impurities, pH stabilization, coagulation-flocculation and sedimentation. The object of the study was wastewater generated during technological stages of brewing production, including fermentation, filtration, container rinsing, equipment washing and sanitary cleaning of production lines. It was found that the initial wastewater was characterized by a high organic load: COD was 3200 mg/L, BOD was 1800 mg/L, and suspended solids were 950 mg/L. After applying the integrated treatment scheme, COD decreased to 850 mg/L, BOD to 520 mg/L, and suspended solids to 180 mg/L. The removal efficiencies were 73.4, 71.1 and 81.1%, respectively. It is shown that coagulation-flocculation is an important stage of preliminary treatment of brewery wastewater, providing reduction of organic load, removal of dispersed impurities, decrease in turbidity and preparation of wastewater for subsequent biological treatment.

Keywords: brewing industry, wastewater, COD, BOD, suspended solids, turbidity, dry residue.

Introduction

Brewing production is one of the technological processes accompanied by the formation of significant volumes of wastewater with a high organic load. Water is used at almost all production stages: raw material preparation, malt mashing, wort boiling, fermentation, filtration, washing of technological equipment, container rinsing, and sanitary treatment of pipelines and bottling lines. As a result, wastewater of complex composition is generated, containing dissolved, colloidal and dispersed pollutants.

The main sources of brewery wastewater pollution are residues of wort, malt, yeast biomass, sugars, protein substances, alcohols, organic acids, filtering materials, as well as detergents and disinfectants. Therefore, such wastewater is characterized by increased values of chemical oxygen demand (COD), biochemical oxygen demand (BOD), suspended solids, turbidity and dry residue.

COD is an integral indicator of the total organic load of wastewater, whereas BOD reflects the content of biologically degradable organic substances. Suspended solids characterize the amount of

mechanical and dispersed impurities, turbidity indicates the presence of finely dispersed and colloidal particles, and dry residue makes it possible to estimate the total amount of dissolved mineral and organic components.

A specific feature of wastewater from brewing enterprises is the instability of its composition. The concentration of pollutants may vary depending on the production mode, the volume of wort and beer losses, the amount of yeast biomass, the sanitary washing regime, the type of detergents used, and the frequency of technological equipment treatment. Therefore, the selection of a treatment technology should be based on a comprehensive assessment of the physicochemical indicators of wastewater.

Mechanical, physicochemical and biological treatment methods are used to reduce the organic load and the content of dispersed impurities in brewery wastewater. In this context, coagulation-flocculation is considered an important preliminary stage that makes it possible to reduce turbidity, remove a significant part of suspended and colloidal particles, and decrease the load on subsequent biological treatment facilities.

An important direction for increasing the efficiency of physicochemical wastewater treatment is the use of reagent methods based on coagulation and flocculation of dispersed pollutants. Earlier, K. G. Mukhamedov, N. K. Nasirova and co-authors demonstrated the possibility of applying a reagent approach to the treatment of industrial wastewater, which confirms the technological feasibility of preliminary chemical treatment of polluted aquatic systems [2, pp. 51-56]. In addition, the studies of N. K. Nasirova, K. G. Mukhamedov, Sh. A. Mutalov and J. K. Mukhamedov on the flocculation properties of modified polyacrylamide confirm the prospects of using polymer flocculants for the enlargement of dispersed particles and intensification of wastewater clarification processes [3].

The purpose of this study is to assess the efficiency of reducing COD, BOD, suspended solids, turbidity and dry residue in brewery wastewater when applying an integrated preliminary physicochemical treatment scheme.

To achieve this purpose, the following tasks were set: to characterize the main polluting components of brewery wastewater; to assess the initial values of COD, BOD and suspended solids; to determine the efficiency of reducing these indicators after treatment; and to reveal the technological role of coagulation-flocculation in preparing wastewater for subsequent biological treatment.

Materials and Methods

The object of the study was wastewater from brewing production formed as a result of technological operations including equipment washing, fermentation, filtration, container rinsing and sanitary treatment of production lines. The investigated wastewater represented a general flow containing organic substances of varying degrees of dispersion, yeast biomass, wort residues, protein compounds, sugars, alcohols, organic acids, as well as mechanical and colloidal impurities.

COD, BOD, suspended solids, turbidity and dry residue were selected as the main monitored indicators. COD was used to assess the total organic load of wastewater; BOD was used to characterize the biologically degradable fraction of organic substances; and suspended solids were used to determine the amount of insoluble impurities. Turbidity was considered as an indicator of the presence of finely dispersed and colloidal particles, whereas dry residue was used as an indicator of the total content of dissolved mineral and organic substances.

Wastewater treatment was carried out according to a scheme that included mechanical separation of coarse impurities, pH stabilization, coagulation-flocculation and sedimentation. Mechanical separation ensured the removal of large particles of malt, yeast mass and other coarse-

dispersed impurities. At the coagulation-flocculation stage, aggregation of colloidal and finely dispersed particles occurred with the formation of larger flocs, which were subsequently removed during sedimentation.

Coagulants and flocculants that promote destabilization of colloidal particles and formation of settling aggregates were considered as reagents for treatment. The technological effect of coagulation-flocculation was evaluated by the reduction in COD, BOD, suspended solids and by the degree of wastewater clarification.

The efficiency of pollutant reduction was calculated using the following equation:

eta = ((C0 - C1) / C0) x 100%,

where eta is the treatment efficiency, %; C0 is the concentration of the indicator before treatment, mg/L; and C1 is the concentration of the indicator after treatment, mg/L.

This approach allows the quantitative assessment of changes in each indicator and makes it possible to determine the technological significance of the applied preliminary treatment scheme.

Results and Discussion

The initial brewery wastewater was characterized by a high degree of organic pollution. Before treatment, COD was 3200 mg/L, BOD was 1800 mg/L, and suspended solids were 950 mg/L. These values indicate the presence of a significant amount of organic compounds formed due to residues of wort, malt, yeast biomass, proteins, sugars, alcohols and organic acids.

The high COD value indicates a significant total organic load in the wastewater. At the same time, the high BOD value shows that a substantial part of the organic pollution is represented by biologically degradable substances. This creates prerequisites for the use of biological treatment; however, the direct supply of such wastewater to the biological stage without preliminary preparation may lead to overloading of treatment facilities and a decrease in the stability of biological processes.

After applying the integrated treatment scheme, COD decreased from 3200 to 850 mg/L. The COD reduction efficiency was 73.4%. Such a decrease is explained by the removal of part of the colloidal and finely dispersed organic substances that aggregated, formed flocs and passed into the sediment during coagulation-flocculation. In addition, mechanical separation and sedimentation contributed to the removal of part of the coarse-dispersed organic impurities.

The BOD value before treatment was 1800 mg/L and decreased to 520 mg/L after treatment. The BOD reduction efficiency was 71.1%. The decrease in BOD indicates the partial removal of biologically degradable organic substances at the physicochemical treatment stage. At the same time, the residual BOD value after treatment shows that a subsequent biological stage is required to achieve a deeper reduction of the organic load.

The content of suspended solids in the initial wastewater was 950 mg/L and decreased to 180 mg/L after treatment. The removal efficiency of suspended solids was 81.1%. This was the highest value among the considered parameters, which confirms the effectiveness of coagulation-flocculation and sedimentation in removing dispersed impurities. During treatment, yeast cells, malt particles, protein-polyphenol complexes and residues of filtering materials enlarged and separated from the aqueous phase in the form of sediment.

Table 1

Changes in the main physicochemical indicators of brewery wastewater before and after treatment

№	Indicator	Before treatment	After treatment	Reduction efficiency, %
1	COD, mg/L	3200	850	73.4
2	BOD, mg/L	1800	520	71.1
3	Suspended solids, mg/L	950	180	81.1
4	Turbidity	Decreases due to aggregation of colloidal and finely dispersed particles	Determined after instrumental control	Calculated based on measurement results
5	Dry residue	Characterizes dissolved mineral and organic components	Decreases to a limited extent during reagent treatment	Decreases to a limited extent during reagent treatment

As can be seen from Table 1, the most pronounced reduction was observed for suspended solids. This is explained by the fact that the major part of mechanical and colloidal impurities in brewery wastewater is in a dispersed state and is effectively removed by combining coagulation, flocculation and sedimentation.

The reduction in COD and BOD is also significant; however, the residual concentrations of these indicators remain rather high. This is due to the fact that part of the dissolved organic compounds is not completely removed at the physicochemical treatment stage. Therefore, coagulation-flocculation should not be considered an independent final technology, but rather a preliminary stage that reduces the load on subsequent biological treatment.

Turbidity in brewery wastewater is formed due to yeast cells, malt particles, protein compounds, filtering materials and organic colloids. During coagulation-flocculation, these particles combine into larger aggregates and are removed during sedimentation. Therefore, turbidity reduction is an important technological indicator reflecting the degree of wastewater clarification and the efficiency of removing the colloidal phase.

The dry residue indicator characterizes the total content of dissolved mineral and organic components, including salts, detergent residues and low-molecular-weight organic substances. In contrast to suspended solids and turbidity, dry residue may decrease to a lesser extent during reagent treatment, since a significant part of dissolved substances remains in the water phase. For a deeper reduction in dry residue, additional methods such as filtration, sorption, membrane separation or ion-exchange processes may be required.

Table 2

Technological significance of reducing the main wastewater indicators

No.	Indicator	Reason for high value	Technological significance of reduction

1	COD	Residues of wort, sugars, proteins, alcohols, organic acids	Reduction of the total organic load
2	BOD	Biologically degradable organic substances	Preparation for stable biological treatment
3	Suspended solids	Yeast, malt particles, filtering materials	Reduction of sediment formation and load on treatment facilities
4	Turbidity	Colloidal and finely dispersed particles	Water clarification and improvement of filterability
5	Dry residue	Dissolved salts, detergents, organic residues	Assessment of the need for additional advanced treatment

The obtained results are consistent with the technological characteristics of brewery wastewater. According to the literature, such wastewater is usually characterized by a high concentration of organic substances, suspended particles and nutrients, which requires the use of combined treatment schemes [7, p. 2999; 12, p. 1604; 16, pp. 235-247]. Modern studies also show that coagulation-flocculation is an effective method of preliminary treatment of real brewery wastewater, especially when it is necessary to reduce organic substances and nutrients before further treatment [7, p. 2999].

In this study, the use of the physicochemical stage made it possible to reduce COD by 73.4%, BOD by 71.1%, and suspended solids by 81.1%. This confirms the feasibility of including coagulation-flocculation in the technological scheme of brewery wastewater treatment.

The practical significance of the results obtained lies in the fact that the proposed scheme makes it possible to reduce the load on subsequent biological treatment facilities, increase the stability of the treatment process and reduce the risk of overloading treatment systems with organic pollution. The reduction of suspended solids is particularly important, since their excess may lead to sludge accumulation, deterioration of mass transfer and a decrease in the efficiency of biological processes.

Based on the results obtained, the following technological sequence can be recommended for brewery wastewater: mechanical separation of coarse impurities -> equalization of composition and flow rate -> pH stabilization -> coagulation -> flocculation -> sedimentation -> biological treatment -> filtration -> quality control of treated water.

Conclusion

1. Brewery wastewater is characterized by a high organic load and a significant content of dispersed impurities. Before treatment, COD was 3200 mg/L, BOD was 1800 mg/L, and suspended solids were 950 mg/L.

2. Integrated preliminary treatment, including mechanical separation, pH stabilization, coagulation-flocculation and sedimentation, provided a significant reduction in the main physicochemical indicators.

3. After treatment, COD decreased to 850 mg/L, BOD to 520 mg/L, and suspended solids to 180 mg/L. The reduction efficiencies were 73.4, 71.1 and 81.1%, respectively.

4. The highest efficiency was achieved for the removal of suspended solids, which is associated with the aggregation of yeast cells, malt particles, protein-polyphenol complexes and other dispersed impurities during coagulation-flocculation.

5. The residual values of COD and BOD after physicochemical treatment indicate the need for subsequent biological treatment for deeper removal of dissolved organic substances.

6. Turbidity reduction and dry residue control are important additional indicators that make it possible to assess the degree of water clarification and the need for advanced treatment.

7. The obtained results confirm that coagulation-flocculation is an effective stage of preliminary treatment of brewery wastewater and can be recommended for inclusion in an integrated treatment scheme.

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