Technological Innovation to Reduce the Negative Environmental Impact of Industrial Wastewater

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Abstract. Rational use of natural resources and protection of water bodies is an actual problem of the modern world. Due to the rapidly developing industry, wastewater which contain high concentrations of suspended substances and organic pollutants is discharged to water bodies in a large volume. So design improved treatment facilities that ensure high quality of treated water is an important task.

Biomembrane technology is a promising direction in water treatment, providing high efficiency of treatment at minimal cost. Compared to the traditional treatment scheme, it allows you to avoid the use of secondary settling tanks by separating the active sludge from the treated wastewater on the membranes. Due to the very small size of the membrane pores, almost complete removal of suspended substances and microorganisms is achieved. A bioreactor with an external arrangement of the membrane module provides high specific capacity. The small-bubble aeration system in the aeration tank ensures the maintenance of dissolved oxygen at a concentration of 2-3 mg / l for the correct course of the nitrification and oxidation of organic substances. The combination of biological treatment and membrane separation ensures high operational reliability and durability.

This technology is used in various industries, but it is most widely used in the food and oil refining industries due to the high content of organic pollutants, which are mostly removed by this installation.

The use of biomembrane technology is economically advisable for designing treatment facilities for industrial wastewater treatment from organic pollutants.

1. Introduction

Industrial wastewater is a technogenic factor of environmental pollution. Industrial wastewater is formed during the implementation of the technological process. The composition of wastewater and its contamination content depends on factors such as the type of production, the composition of raw materials, parameters and duration of the technological process. There are these types of pollution: organic pollution of plant and animal origin; mineral pollution, which includes sand, clay, mineral acids, etc.; and biological pollutions - small algae, bacteria, etc. for example, wastewater of the food industry contains a large amount of organic pollution [1, 2].

To reduce the negative impact on the water disposal, the discharged wastewater must satisfy the next requirements:

1) It mustn’t contain combustible impurities, such as gasoline and petroleum products;
2) Wastewater mustn’t contain bacteria;
3) They shouldn't contain large impurities that clog the water disposal;
4) The values of wastewater composition indicators must not exceed the maximum permissible concentrations [2, 3].

As a result, improving existing and implementing innovative water treatment technologies is urgent.

BCC Research: Market Research Report & Industry Analysis shows an annual increase in the use of membrane bioreactors in the global market. It is connect with the effectiveness of this technology [4, 5].

Purpose of the research is to develop a scheme for wastewater treatment using a membrane bioreactor.

To achieve this purpose, you need to solve the next tasks:
1) Study methods of wastewater treatment;
2) Perform a comparison analysis of the traditional treatment scheme and the scheme using a membrane bioreactor;
3) Design a membrane bioreactor for wastewater treatment and provide a description of its construction;
4) Identify the advantages and disadvantages of the proposed wastewater treatment technology;
5) Perform the analysis of the global market for membrane bioreactors.

The object of the research is industrial waste water. The subject of the research is the technology of wastewater treatment using a membrane bioreactor.

2. Materials and methods

There are mechanical, chemical, physico-chemical and biological wastewater treatment methods. The methods of wastewater treatment are presented in figure 1 [6].

![Figure 1. Methods of wastewater treatment.](image_url)

Sand traps, grates, and settling tanks are widely used for mechanical cleaning. Grates hold up large dirt, and the sand trap cleans wastewater from mineral contamination, sand, clay, etc. For cleaning from fats, resins and other contaminants, grease traps, resin traps, and oil traps are used [2, 7].

Physical and chemical methods of purification are divided into regenerative and destructive methods. In the first case, the basis is physical and chemical processes in which the pollution removed from the water does not change its composition and structure. Among regenerative methods, there are coagulation, membrane methods, extraction, etc. Destructive methods are based on chemical and physical processes in which the contaminant passes from one phase state to another. These methods include neutralization, oxidation, reduction, etc. Membrane methods that can provide a high degree of purification are quite promising directions of physical and chemical cleaning [8, 9].

Biological wastewater treatment is based on the process of life of microorganisms, for which the organic pollutants contained in the water are a source of nutrition. Biological purification can be
carried out in natural and artificial conditions. In the first case, the process takes place in biological ponds or filtration fields, in the second, artificial conditions are created – aerotanks and biofilters [2].

3. Results and discussions

Biomembrane technology combines methods of biological purification and membrane separation. Compared to the traditional treatment scheme, due to the separation of activated sludge and treated wastewater in membrane cassettes, use of the secondary settling tanks is not required. The use of a membrane bioreactor ensures the removal of suspended substances, microorganisms, and viruses from the water.

There are 2 types of the membrane bioreactors:
1) the bioreactor with a submerged membrane module;
2) the bioreactor with external arrangement of the membrane module.

In the first case, the membranes are placed directly in the biological treatment zone with activated sludge, in the second - they are located in a separate membrane tank with the installation of pumping pumps [10, 11].

In the traditional scheme, after biological treatment, the flow of industrial wastewater enters the post-treatment station, where it is settled in a secondary settling tank and ultraviolet disinfection. In the scheme with the use of a membrane bioreactor at the exit from it, we get already treated wastewater that meets the regulatory indicators. It is connected with the fact that membrane separation can replace the secondary settling. On the surface of the membranes, disinfection occurs thanks to the small size of the membrane pores, so in some cases additional disinfection is not required. The traditional scheme and the scheme using a membrane bioreactor is presented in figure 2 [11].

![Figure 2](image)

**Figure 2.** The wastewater treatment scheme: (a) – the traditional scheme; (b) – the scheme using the membrane bioreactor.

The principle of the working of the membrane bioreactor is as follows: industrial water after preliminary mechanical treatment enters the denitrifier. Here, organic pollutants contained in the water are oxidized by active silt with the release of free nitrogen. Then the wastewater flow enters the aerobic zone for the oxidation of organic pollutants. From this zone, the circulating active sludge is sent to the anoxide zone with a denitrifier, and the excess active sludge is diverted to the sludge treatment station [12]. At the final stage, the waste water enters a membrane tank for separating the treated wastewater and activated sludge. Construction of the membrane bioreactor is presented in figure 3.
Figure 3. Membrane bioreactor for wastewater treatment: 1 – the reactor lid; 2 – electromotor; 3 – belt drive; 4 – aerotank; 5 – membrane module; 6 – membrane’s frame; 7 – turbine agitator; 8 – the bioreactor.

Biomembrane technology is based on the ability of microorganisms to absorb organic pollutants contained in wastewater as a source of nutrition, and on the subsequent separation of treated wastewater and activated sludge in a membrane reservoir. A mixture of microorganisms that make up the active sludge is called biocenosis. It consists of bacteria, protozoa, fungi, and yeast. Basically the process of treatment consists of the vital activity of bacteria. Она состоит из бактерий, простейших, плесневых грибов, дрожжей. [13, 14]. The quality of sludge is largely determined by the rate of its deposition, the sludge index, and the age of the sludge.

The favorable effect of the correct flow of biological purification is achieved due to the next properties of microorganisms:

1) The ability to reproduce quickly. On average the number of cells doubles every 30 minutes;
2) They form clumps that can be easily removed after the ending of the treatment process;
3) The ability to oxidize a variety of organic pollutants [15].

The technology of membrane separation is based on the presence of a special permeable barrier between the two phases – the membrane [16]. Due to the rapid development and efficiency of membrane technologies, barometric processes such as micro-, nano - and ultrafiltration and reverse osmosis are now widely used [16]. The main characteristics of barometric processes are presented in table 1 [17, 18].

| Process            | Pore size, micrometers | Pressure, atm |
|--------------------|------------------------|--------------|
| Reverse osmosis    | <0,001                 | 10-100       |
| Nanofiltration     | 0,001-0,01             | 5-10         |
| Ultrafiltration    | 0,01-0,1               | 1-5          |
| Microfiltration    | 0,1-1                  | 0,1-2        |
The developed installation uses ultrafiltration semi-fiber membranes. The developed treatment technology in a membrane bioreactor has a lot of advantages:

1) High efficiency of purification from bacteria, viruses, suspended substances, as well as a significant reduction in BOD and COD indicators;
2) Disinfection on the membrane surface;
3) A small area connecting with a large flow of incoming water;
4) Small capital expenditures;
5) Preventing the removal of activated sludge along with treated wastewater;
6) The Low cost of aeration [10, 19, 20, 21].

Despite the many advantages, the installation also has disadvantages. One of them is the pollution of the membranes. For this purpose, membrane flushing is provided: direct, reverse and flushing with chemical reagents, alkalis or acids.

The developed construction provides semi-fiber membrane modules, which are characterized by high packing density, low material consumption and minimal costs. This technology has a high oxidizing power. This reduces the water retention time in the reactor, and therefore increases productivity. The proposed installation is able to provide the maximum effect of removal of suspended substances, a significant reduction in COD and BOD indicators. To prevent the deposition of activated sludge in the anoxic zone, the design provides a stirrer.

The designed installation can be used not only in the case considered. Parameters can be changed depending on various factors. For example, you can change the parameters of an aeration tank depending on the composition of incoming wastewater and the pollutants contained in it, or change the age of activated sludge.

Thanks to the application of the proposed treatment scheme using a membrane bioreactor, high water quality indicators are achieved with minimal resource and capital investment.

4. Findings

As a result, in the course of the study, a wastewater treatment scheme was developed and the construction of a membrane bioreactor was proposed. The use of a technological scheme with a membrane bioreactor provides high quality indicators of treated water that satisfy regulatory requirements.

The installation is cost-effective, because the membrane bioreactor can replace the "aeration tank + secondary settling tank + post-treatment station" system. In the course of the study the economic efficiency of the installation, including the characteristics of the production process and the calculation of capital expenditure, comprising the cost of construction and installation works and cost were calculated.

Due to the high concentration of activated sludge, the retention time of waste water in the bioreactor is reduced, which in turn increases productivity. The technology also provides almost complete removal of viruses and bacteria (99 %), so in some cases additional disinfection is not required.

The theoretical and practical significance of the research is to optimize the design of bioreactors and improve the efficiency of wastewater treatment.

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