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REMOVAL OF ORGANIC IMPURITIES FROM SEWAGE BY EVAPORATION THROUGH POLYMER MEMBRANES

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Pervaporational nonporous membranes are obtained on the basis of synthetic rubber. The possibility of using the method of evaporation through the obtained membrane is considered for treatment of sewage resulting from styrene, polysterene, polycarbonate, and polysulfone production.

Conservation of nature resources, electric energy saving, and contamination of the environment are acute problems of modern industrial production. In this respect we are pinning our hopes on membrane methods of separation.

The use of membrane methods makes it possible to solve many problems facing modern chemical technology, including problems of removal of organic impurities from industrial sewage.

At present, most industrial sewage is treated by the traditional methods of flotation, distillation, and evaporation. However, implementation of these methods often cannot provide high quality of treatment without complex apparatus or considerable energy supply. The use of biochemical methods requires thorough control of maintenance of conditions in cleaning facilities that are optimum for providing for the vital activity of active microorganisms, whereas the method of ultrafiltration used abroad in the majority of operating industrial facilities does not ensure removal of organic solvents from sewage [1].

Thanks to its simplicity, the absence of reagents, environmental safety, and low power consumption the process of evaporation through a semipermeable membrane (pervaporation) allows one to replace traditional technologies of sewage treatment at the enterprises of the chemical, petroleum refining, fuel-power engineering, food, and pharmaceutical industries and those related to them, ensuring high-quality treatment at low cost of its implementation.

Pervaporation is a membrane process that combines permeation of volatiles of a liquid mixture through a selective membrane with their evaporation from the surface of the latter. This means that separation of different components from liquid mixtures is determined not only by the pressure difference of their vapors but also by the permeation flow through the membrane. It is customary to assume that the gradient of the chemical potentials of the separated substances is the moving force of separation.

The term "chemical potential" is used here in the sense formulated by Hougen and Watson in [2]. By this they mean the "tendency toward transfer" (escaping tendency) of substance from each separate phase or instability of the phase mixture. For an ideal gas or vapor this escaping tendency is equal to its partial pressure, and therefore, it depends strongly on the total pressure in the system. For a liquid the change in the escaping tendency depends slightly on the pressure and is mainly determined by the temperature and concentration of the components in the system.

The mechanism of mass transfer in pervaporation includes three successive stages: 1) sorption of the components from the liquid mixture by the surface of a polymeric membrane that possesses selective permeability; 2) diffusion of the sorbate in the polymer of the membrane; 3) evaporation of the sorbate to the vapor phase from the opposite side of the membrane.

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TABLE 1. Results of Investigations on Removal of Organic Impurities from Chemical Industries Sewage

Substance	Concentration of impurities in sewage, mg/liter		
	in initial mixtures	after treatment	maximum permissible [3]
Acetone	100.0	1.00	3.0
Benzene	14.0	traces	0.5
Xylene	18.3	0.14	0.5
Methylene chloride	200.0	5.0	7.5
Perchloroethylene	7.0	0.07	0.5
Styrene	72.0	0.10	0.1
Toluene	36.0	traces	0.5
Trichloreethylene	9.4	traces	0.5
Triethylamine	10.0	traces	2.0
Phenylic acid	0.7	absence	0.001
Chlorobenzene	1.5	traces	0.02
Benzyl chloride	3.2	absence	0.001
Chlorotoluene	5.3	0.01	0.02
Carbon tetrachloride	60.0	0.18	0.3
Ethyl benzene	3.60	0.01	0.01

The efficiency of the pervaporation process depends mainly on the internal properties of the polymers used in membrane production. The choice of these polymers is therefore the key problem in improvement of pervaporation apparatuses.

On the basis of the studies conducted, new pervaporation membranes based on synthetic rubber were developed in the Department of Machines and Apparatuses of the Chemical Industry of "Kiev Polytechnic Institute" National Technical University of Ukraine. The employment of these membranes will allow one to substantially broaden the possibilities of membrane technology, since they can be used in treatment of liquid mixtures with a pH from 1 to 13 in the temperature range from 10 to 120°C.

The membranes obtained are classified as diffusion nonporous polymeric membranes. This means that they do not possess pronounced pores and, consequently, are insensitive to contamination.

The process of diffusion permeation in these membranes can be interpreted qualitatively as the migration of sorbate molecules through a tangle of polymer chains and vacancies. As in simple liquids, in a polymer at a temperature higher than its vitrification temperature vacancies constantly disappear and form again under the effect of thermal fluctuations. Diffusion occurs due to migration of sorbate molecules from vacancy to vacancy under the effect of the gradient of chemical potentials and the cooperative action of the surrounding complex of molecules and polymer links.

Permeability, as the ability of the membrane to transmit a substance, is determined in this case by the ability of the penetrating molecules to increase the number of migrating polymer links by weakening the bonds between them. In other words, most gases and liquids that are soluble in the membrane polymer can pass through such membranes.

The developed membranes possess good resistance to inorganic acids, alkalis, and the most solvents, which makes them suitable for treating organic solutions, in contrast to many traditional membranes. They possess high mechanical strength and elasticity, which permits using them without a substrate.

We developed a technology for producing different modifications of the membranes and manufactured test batches.

To choose the optimum technological schemes of treatment and temperature and hydrodynamic regimes, experimental setups for tubular and plane membranes with a mass transfer surface 0.25 and 0.08 m^2, respectively, were manufactured in the Department. The principle of thermopervaporation was realized in the setups. According to this principle vapors of substances that pass through the membrane condense on a cold wall inside the membrane module.

Experiments on removing organic impurities from sewage of styrene, polystyrene, polysulfone, and polycarbonate production were conducted on these setups. Results of the experiments are given in Table 1.

It is found in the experiments that:

1. Tubular diffusion membranes based on synthetic rubber possess high stability in all the components of the sewage studied.

2. All organic components of the sewage studied can be removed by evaporation through diffusion membranes, with the values of the maximum permissible concentrations being attained for all components.

3. The increase in the concentration of organic impurities with a volley discharge of waste waters does not affect normal operation of the setups.

4. The most admissible is to carry out the process at atmospheric pressure and to maintain the working temperature within the limits of $50 \pm 5^{\circ}C$.

On the basis of these conclusions we suggested three types of membrane modules that make it possible to carry out pervaporation on a commercial scale.

Two commercial membrane setups of the module type with a working surface of the membranes of 20 and 100 m^2 were designed. These setups can be used to treat and recirculate sewage, separate azeotropic and thermolabile mixtures, concentrate solutions, and return valuable organic substances to a technological cycle.

A setup with a working surface of the membranes of 20 m^2 was introduced at the "Zarya" Production Association (Dzerzhinsk, Nizhegorodskii Region, Russia). It is used to remove methyl chloride, acetone, phenylic acid, and triethyl amine from sewage of polycarbonate production. The setup capacity is 15 m^3/day.

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