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АНАЛІТИЧНИЙ ОГЛЯД СУЧАСНИХ ПРОЦЕСІВ ВОДОПІДГОТОВКИ ТА ВОДООЧИЩЕННЯ

Г.В. Дейниченко, З.О. Мазняк, В.В. Гузенко, В.О. Даниленко

Висвітлено існуючі процеси водопідготовки та водоочищення для харчової промисловості. Подано характеристику різних способів традиційної і мембранної підготовки та очищення води для харчової промисловості. Визначено переваги застосування мембранних процесів водопідготовки та водоочищення в різних галузях харчової промисловості. Запропоновано способи використання мембранних процесів із метою розробки енергозберігаючих технологій водопідготовки та водоочищення.

Ключові слова: *вода, процес, мембрана, розділення, очищення, підготовка.*

АНАЛИТИЧЕСКИЙ ОБЗОР СОВРЕМЕННЫХ ПРОЦЕССОВ ВОДОПОДГОТОВКИ И ВОДООЧИСТКИ

Г.В. Дейниченко, З.О. Мазняк, В.В. Гузенко, В.О. Даниленко

Освещены существующие процессы водоподготовки и водоочистки для пищевой промышленности. Представлена характеристика различных способов традиционной и мембранной подготовки и очистки воды для пищевой промышленности. Определены преимущества применения мембранных процессов водоподготовки и водоочистки в различных отраслях пищевой промышленности. Предложены способы использования мембранных процессов с целью разработки энергосберегающих технологий водоподготовки и водоочистки.

Ключевые слова: *вода, процесс, мембрана, разделение, водоочистка, водоподготовка.*

ANALYTICAL CHARACTERISTICS OF MODERN PROCESSES WATER TREATMENT

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This article is devoted to the questions of the modern processes of water treatment and water purification in food industry. The analysis of theoretical researches concerning the main methods of water treatment and water purification for their further application in different sectors of food industry is presented. The characteristics of different methods of traditional and membrane preparation and purification of water for food industry are presented. The literature analysis demonstrated that for a primary processing of water used in the food industry sedimentation, coagulation, softening processes (membrane distillation, electro dialysis, thermal and ion exchange methods), and for decontamination – chlorination, ozonation, microfiltration, anodic oxidation and so on.

The special consideration the characteristics of the main types of the baromembrane methods and their application during the process of water treatment and water purification is devoted. Membrane processes (microfiltration, ultrafiltration, Nano filtration, reverse osmosis) allow improving the processes of treatment and purification of water for food industry without the application of reagent methods, and improving quality (physical-chemical, microbiological, etc.) indexes of water as a raw material in the technologies of different food products. Analysis of the article data relating to the characteristics of baromembrane processes of preparation and purification, allows us make the conclusion that during the use of membrane processes, compared to other conventional methods of water removed weighty substances, viruses, bacteria without losing additional energy. Application of membrane processes for the treatment and purification of different kinds of water resources is important for technical, ecological and social objectives of the food industry.

Keywords: *water, process, membrane, filtration, treatment, purification.*

The general formulation of the problem. Today we can distinguish the phenomenon which is relevant for all regions of Ukraine – the uneven distribution of fresh water, which leads to certain problems related to water supply enterprises of food, microbiological and pharmaceutical industries. Intensive development of food industry in Ukraine causes a significant increase in the consumption of drinking water. Equally rapid development of energy in metallurgy, agricultural and chemical industries over the last century led to an environmental disaster in the country. After the introduction of more demanding quality standards for drinking water treatment of surface waters by traditional technology under the controlled growth of their contamination is recognized in the developed countries unsatisfactory because of inadequate drinking water chlorination, presence of organic substances, pesticides and other hazardous substances [1].

The necessity for compliance of specific requirements for water quality used in food industries requires introduction of technologies for the purification of drinking water in industry. In addition, people suffer from poor-quality food products, manufactured with the use of inefficiently purified drinking water.

Analysis of recent research and publications. Today, strict requirements are claimed to the water used in the process of food production defined by special technological instructions. They established maximum allowable number of substances, which liquid may contain. For this reason, water used directly in the process of food production, is treated specially [2].

The quality of the research and environmental safety of the treated water is determined primarily by quality projects of processes and treatment facilities. Therefore, under the economic crisis in Ukraine the research and development of modern environmental technologies prevent pollution of the surface and ground waters either leads to a significant reduction or requires the fastest implementation. Today, economists and technologists need to understand that technology is economical and safe when it is ecological [3].

The purpose of the article is to analyze the characteristics, advantages and disadvantages of applying modern water treatment processes for defining future directions in the development of energy-saving technologies to produce high quality treated water for technological needs in food industry.

The main material of the research. In modern conditions, the majority of industrial enterprises in all sectors of food industry uses water resources to cool process equipment (reverse water), its heating (heating water) as well as for the main process (technological water) [5].

For the treatment of water, food industry uses such processes as sedimentation, coagulation, softening (thermal, ion exchange, membrane distillation and electrodialysis), and for disinfection – chlorination, ozonation, microfiltration, anodic oxidation, etc. [6; 7].

The level of water purification is very low today. Existing treatment facilities, even in the case of biological treatment remove only 10...40% of inorganic substances (40% – nitrogen, 30% – phosphorus, 20% – potassium) and virtually remove heavy metals, so each industry should establish its own innovative technologies, which provide measures for the prevention of water source contamination.

Classification of some separation processes by the separating components' chemical and physical properties are presented in Table 1. According to Table 1, the differences in size of molecules, vapor pressure, affinity, charge or chemical nature of molecules help to fulfil membrane separation of water with different levels of contamination [8].

How can we choose the separation process for the solution of this problem? Several common factors can affect this solution, which, however, cannot be applied to all situations. Therefore, some specific criteria, which are to satisfy the substantiated choice of the process, can be considered. Simultaneously, two general criteria can be applied to all separation processes. These criteria can be divided by technical and economic factors.

The first criterion is quite understandable, since two main requirements are put forward to the process of water resources separation: the need to achieve the required degree of extraction and quality (purity) of the resulting water. Sometimes these needs require a combination of two or more separation processes. However, economic opportunity of the process depends largely on the value of target products [9].

Table 1

The separation processes based on molecular properties of water resources subjected to processing

Molecular properties	The process of separation
Size	Filtration, microfiltration, ultrafiltration, dialysis, gas separation, gel permeation chromatography
Steam pressure	Distillation, membrane distillation
Freezing temperature	Crystallization
Affinity	Extraction, adsorbing, absorbing, reverse osmosis, gas separation, pervaporation
Charge	Ion exchange, electrodialysis, electrophoresis
Density	Centrifugation
Chemical nature	Complexation, liquid membranes

Compared to existing conventional methods demanding large areas, multi-step processing technology, large operating costs and a significant number of operational personnel, increasing recognition baromembrane acquire technology for high quality purified water.

Among existing technologies used for water purification in the manufacture of drinks, the technology of hyper-filtration is one of the most effective. This technology is realized due to the installation of treatment systems based on membrane filtration processes. Consequently, the company gets clean water that does not contain any hazardous substances, harmful to human health.

The value of membrane technology in Ukraine and abroad has recently increased primarily as a technology with the ability to bridge the gulf separating industry and the environment. Membrane technology acquired the status of national critical technology as well as catalysis, molecular design, new materials, genetic engineering and other global priorities [10].

Desalination of seawater is an example illustrating the membrane separation problem whose solution can use the competing processes based on different principles of separation, and consuming different amounts of energy.

Today, in water treatment process two basic types of filtration – conventional filtration and membrane filtration – are used. Schematically, Fig. demonstrates the variety and relative position of these processes. The major classification features of baromembrane processes are the average pore size of the membrane, the value of the operating pressure of the process and size of the particles delayed or skipped by the filter. Thus, different methods of membrane processing: filtration, microfiltration, ultrafiltration, Nano-filtration, reverse osmosis are used for water treatment of various types of preparation in food manufacturing enterprises.

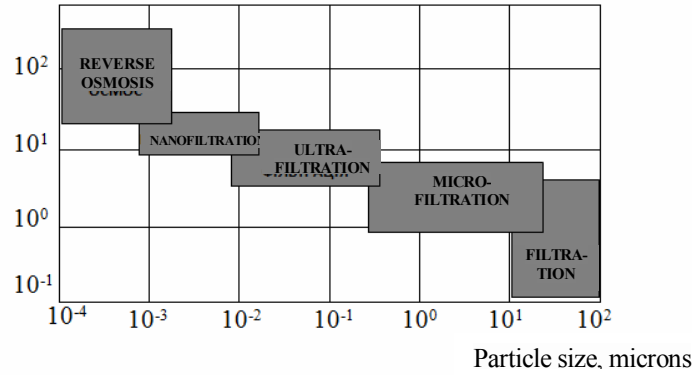

Fig. Types of filtration processes used for water treatment

Normal filtering designed to discharge particles larger than 10 microns from the treated water; membrane filtration separates dispersed phase particles whose size is less than 10 microns [11].

Microfiltration (MF) is intermediate between conventional ultrafiltration and filtration. Microfiltration is used for water purification from colloidal particles, suspended solids, bacteria, with the size of 0,1...10 mm. The working pressure process according to various sources ranges from 0,03...0,1 MPa to 0,01...0,2 MPa. In the process of MF polymer and ceramic membranes with a pore size of 0,05…10 microns and thickness of 10...150 microns are used.

Ultrafiltration (UF) is the process of membrane separation from the aqueous solution of macromolecular compounds (particle size of 0,001...0,02 microns; the value of working pressure is 0,1...1,0 MPa) and their fractions. UF process is used when the molecular weight of the dissolved components is much larger than the molecular weight solvent.

Polymer composite asymmetric membranes formed by phase inversion are used for the UF process. The minimum pore size of UF-membranes according to various sources is 0,001 microns, 0,003 microns or 0,01 microns. The maximum size of UF pore is 0,1...0,2 microns.

Reverse osmosis (RO) is a liquid-phase baromembrane process in the process of which selective solvent transfers against its osmotic pressure gradient under the influence of the applied operating pressure to the membrane. The essence of the process is reverse osmosis solutions filtration under the pressure through semipermeable membranes, which leek the solvent (water) and delay all or some of the molecules or ions of the dissolved substances. RO grounds on the phenomenon of osmosis – free transfer of a solvent through a semipermeable membrane into solution until equilibrium is achieved.

The main distinguishing RO feature from other baromembrane processes is a very small pore size and, consequently, high operating pressure. The diameter of the membrane pore for RO ranges from 0,0001 microns to 0,01 microns. Thus, very dense membranes causing much greater hydrodynamic pressure compared with the other types of membranes are used for reverse osmosis.

Under current conditions, RO is mainly used for membrane separation of true solutions. The main area of its application is desalination of seawater to obtain of drinking and highly purified water for various sectors of food industry.

The key characteristics of baromembrane processes used in water treatment are presented in Table 2.

From the data presented in Table 2, it is evident that Nano-filtration – a mediating process between ultrafiltration and reverse osmosis – refers to

baromembrane processes. The amount of particles held by Nano-filtration is about 1...2 microns, the value of working pressure is 0,8...3,0 MPa.

Nano-filtration is used for the purification of water from organic substances and mineral mixtures at the stages preceding the final water purification by ion exchange or electrodialysis. Nano-filtration treats natural and industrial water at low operating pressure, ensuring the retention of high organic matters and colloids, microorganisms, hardness, and reduces water coloration.

Analysis of these data (Table 2) allows us conclude that compared to other membrane processes while using MF and UF, the suspended solids, viruses, bacteria are removed from water without the high electricity costs. In addition, application of MF and UF for the purification of surface water is especially promising because these methods allow us obtain clean drinking water without any chemicals.

UF water treatment is applied at the previous stage of natural and wastewater before subsequent desalination by membrane or other physical and chemical methods.

Table 2

The main parameters and characteristics of different types of membrane filtration of surface water

Characteristic	Microfiltration	Ultrafiltration	Nano-filtration	Reverse osmosis
1	2	3	4	5
Material	Polyamide, polypropylene, poly-sulfone, ceramics	Cellulose, polysulfone, ceramics	Cellulose, thin film composite materials	Cellulose, thin film composite materials, polysulfone
Pore size, microns	~0,01–1,0	0,001–0,01	0,0001–0.001	< 0,0001
Size of molecule that are removed (κDalton)	> 100,0	2,0–100,0	0,3–1,0	0,1–0,3
Working pressure, bar	> 2,0	1,5–7,0	3,5–20,0	15,0–70,0
Removal of suspended solids	Yes (large colloids, emulsion)	Yes (colloids)	Yes	Yes

Table 2

1	2	3	4	5
Removal of dissolved organic matter	No	Yes	Yes	Yes
Removal of dissolved inorganic matter	No	No	20,0–85,0%	95,0–99,0%
Removal of microorganisms	Cysts, large bacteria, seaweed	Cysts, large bacteria, seaweed, viruses	All microorganisms	All microorganisms
Chemical water composition	Doesn't vary	Varies partially	Varies	Varies
Consumption of energy, $кW \cdot h/m^1$	Low	Low	Low-moderate	Moderate

The use of UF in the process of water preparation has several advantages: low energy absorption capacity and high process does not require the use of chemicals, water pH remains constant.

For further water treatment by means of membrane methods it is reasonable to use RO and electrodialysis, which are currently used mostly for the purification of water, desalination of salt and brackish water to produce drinking water with low salt content . During the RO, fluoride ions are to be trapped by the membrane with other ions.

Thus, the application of baromembrane processes for the preparation and purification of food products has significant advantages comparing with the other traditional methods.

Conclusions. Analysis of the above data let us make the conclusion that the usage of membrane processes for the treatment of water resources is an important technical, environmental and social task for food industry development. During the application of membrane processes, all suspended solids, viruses, bacteria are removed from water without electricity power costs. In addition, the use of baromembrane technology in water treatment is especially promising because these methods allow for high-quality purified water with the strongly marked physical, chemical and microbiological parameters without any chemicals.

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