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YU. M. FEDENKO
Candidate of Technical Sciences,
Senior Lecturer at the Department of Technology of Inorganic Substances,
Water Treatment and General Chemical Technology
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"
ORCID: 0000-0002-8599-1717

A. O. TKACHUK
Master`s Student at the Department of Technology of Inorganic Substances,
Water Treatment and General Chemical Technology
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"
ORCID: 0009-0006-1473-9131

NEW METHODS OF WATER PURIFICATION FOR USE IN PHARMACY

The principle of membrane separation is widely used for water purification. Water is passed under pressure through a semi-permeable membrane. Membrane technologies differ from filtration. During filtration, particles removed from the water remain on the surface or in the filter media. During membrane filtration, two solutions are formed: filtrate (clean water) and concentrate (a solution with retained substances).

The size of the membrane pores determines the size of the particles that are removed. Based on their size, membrane technologies are classified into the following types: microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. The size of the membrane pores decreases when moving from microfiltration to reverse osmosis. The membrane offers greater resistance to water flow if the pore size of the membrane is small, requiring higher pressure for filtration.

For coarse water purification or preparation for deep purification, microfiltration membranes with a pore size of 0.1-1.0 μm are used, which retain suspensions and colloidal particles that cause water turbidity.

Ultrafiltration membranes with a pore size of 0.01–0.1 μm, which retain trivalent iron, bacteria, viruses, large organic molecules, and colloidal particles, are used for water clarification and disinfection. Such ultrafiltration membranes have an asymmetrical structure, consisting of a porous base that provides mechanical strength and a thin layer of several tens of microns. Ultrafiltration does not retain dissolved salts and does not change the mineral composition of water. It is used in households and industry, providing high-quality purification of water from impurities without the use of chemical reagents. Thanks to this, the use of ultrafiltration is quite promising from an economic and environmental point of view.

High-quality clean water is obtained thanks to nanofiltration membranes with a pore size of 0.001–0.01 microns, which retain dangerous bacteria, viruses, colloidal particles, molecules of heavy metal salts, nitrates, nitrites, and other harmful impurities. Depending on the structure of the membrane, it allows 15-90% of mineral salts to pass through. Pure water from nanofiltration plants is used in the electronic, medical, glass, food, pharmaceutical, and other industries.

Reverse osmosis membranes have the smallest pores, which trap all viruses and bacteria, allowing only water molecules, small organic compounds, and light mineral salts to pass through. Reverse osmosis membranes trap about 97–99 % of dissolved substances. Such membranes are used to obtain high-quality water for bottling, in the food industry, in the production of alcoholic and non-alcoholic beverages, and in seawater desalination. Two-stage reverse osmosis is a good alternative to evaporative distillers and is used in many industries, such as electronics and electroplating.

Different types of membranes have different water quality requirements. Microfiltration membranes and ultrafiltration membranes operate in the pH range of 1–13 and are not affected by chlorine or high suspended solids content. Nanofiltration membranes and reverse osmosis membranes require pretreatment of water, removal of dissolved iron, neutralization of oxidants, and removal of suspended solids. All types of membranes require compliance with operating technologies, despite the high level of automation. They must be periodically flushed and cleaned to avoid irreversible contamination and failure.

Key words: *membrane, permeate, concentrate, reverse osmosis, electrodeionization.*

Ю. М. ФЕДЕНКО
кандидат технічних наук,
старший викладач кафедри технології неорганічних речовин,
водоочищення та загальної хімічної технології
Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського»
ORCID: 0000-0002-8599-1717

ISSN 2078-4481

А. О. ТКАЧУК
студентка магістратури кафедри технології неорганічних речовин,
водоочищення та загальної хімічної технології
Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського»
ORCID: 0009-0006-1473-9131

НОВІТНІ МЕТОДИ ОЧИЩЕННЯ ВОДИ ДЛЯ ВИКОРИСТАННЯ У ФАРМАЦІЇ

Для очищення води широко застосовується принцип мембранного розділення. Вода під тиском пропускається через напівпроникну мембрану. Мембранні технології відрізняються від фільтрування. При фільтруванні частинки, які вилучаються з води, залишаються на поверхні або у фільтруючому завантаженні. Під час мембранного фільтрування утворюється два розчини – фільтрат (чиста вода) і концентрат (розчин із затриманими речовинами).

Розмір пор мембрани визначає розмір частинок, що видаляються. За їх розмірами мембранні технології класифікують на наступні типи: мікрофільтрація, ультрафільтрація, нанофільтрація і зворотний осмос. Розмір пор мембрани зменшується при переході від мікрофільтрації до зворотного осмосу. Мембрана чинить більший опір потоку води, якщо розмір пор мембрани малий, при цьому необхідний більший тиск для фільтрації.

Для грубого очищення води або її підготовки до глибокого очищення використовують мікрофільтраційні мембрани з розміром пор 0,1–1,0 мкм, які затримують суспензії і колоїдні частинки, що є причиною каламутності води.

Ультрафільтраційні мембрани з розміром пор 0,01–0,1 мкм, які затримують тривалентне залізо, бактерії, віруси, великі органічні молекули, колоїдні частинки, використовують для освітлення і знезараження води. Такі ультрафільтраційні мембрани мають асиметричну структуру, складаються з пористої основи, яка забезпечує механічну міцність, і тонкого шару в кілька десятків мкм. Ультрафільтрація не затримує розчинені солі і не змінює мінеральний склад води. Вона застосовується в побуті та промисловості, високоякісно очищає воду від домішок без використання хімічних реагентів. Завдяки цьому, застосування ультрафільтрації досить перспективне з економічної та екологічної точок зору.

Чисту воду високої якості отримують завдяки нанофільтраційним мембранам з розміром пор 0,001–0,01 мкм, які затримують небезпечні бактерії, віруси, колоїдні частинки, молекули солей важких металів, нітратів, нітритів та інших шкідливих домішок. Залежно від структури мембрани, вона пропускає 15–90 % мінеральних солей. Чиста вода з нанофільтраційних установок застосовується в електронній, медичній, скляній, харчовій, фармацевтичній та інших галузях промисловості.

Зворотноосмотичні мембрани мають найменші пори, які затримують всі віруси і бактерії, пропускаючи лише молекули води, невеликих органічних сполук і легких мінеральних солей. Зворотноосмотичні мембрани затримують близько 97–99 % розчинених речовин. Такі мембрани використовують для отримання води високої якості при розливі води, в харчовій промисловості, виробництві алкогольних і безалкогольних напоїв, опрісненні морської води. Двоступеневий зворотний осмос є хорошою альтернативою дистиляторам-випарникам і використовується на багатьох виробництвах, таких як, наприклад, електроніка і гальваніка.

Різні види мембран мають різноманітні вимоги до якості води. Мікрофільтраційні мембрани і мембрани ультрафільтрації працюють в діапазоні pH 1–13, не бояться хлору і високого вмісту зважених речовин. Для нанофільтраційних мембран та мембран зворотного осмосу необхідна попередня обробка води, видалення розчиненого заліза, нейтралізація окисників і видалення зважених частинок. Всі види мембран вимагають дотримання технологій експлуатації, незважаючи на високий рівень автоматизації. Їх необхідно періодично промивати і очищати, щоб уникнути незворотного забруднення і виходу з ладу.

Ключові слова: *мембрана, пермеат, концентрат, зворотний осмос, електродеіонізація.*

Statement of the problem

The principle of membrane separation is widely used for water purification. Water is passed under pressure through a semi-permeable membrane. Membrane technologies differ from filtration. During filtration, particles removed from the water remain on the surface or in the filter media. During membrane filtration, two solutions are formed: filtrate (clean water) and concentrate (a solution with retained substances) [1].

The size of the membrane pores determines the size of the particles that are removed. Based on their size, membrane technologies are classified into the following types: microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. The size of the membrane pores decreases when moving from microfiltration to reverse osmosis. The membrane offers greater resistance to water flow if the pore size of the membrane is small, requiring higher pressure for filtration [2,3].

Analysis of recent research and publications

Reverse osmosis is a baromembrane method of water purification. It is based on the phenomenon of osmosis, a process in which a solvent with a lower salt concentration passes through a semipermeable membrane toward a solution with a higher concentration to equalize the concentrations on both sides of the membrane.

In the reverse osmosis method, the opposite process to osmosis occurs. It is based on the process of transferring a solvent with a higher concentration through a membrane towards a solvent with a lower concentration under pressure that significantly exceeds osmotic pressure. Thus, the water passing through the membrane forms a permeate, while the dissolved salts remain on the side of the concentrated solution and form a concentrate [4–6].

The factor that plays a key role in the application of the reverse osmosis method is the working pressure. As the working pressure increases, its permeability increases, but only in cases where the membrane does not deform when the pressure increases [7].

The dependence of membrane selectivity on pressure is similar to the dependence of permeability. In the low-pressure zone, selectivity increases almost linearly with increasing pressure, but as the pressure increases, the rate of increase slows down and reaches a maximum determined by the properties of the membrane itself and the dissolved substance. This is because at low pressures, the flow of water increases more intensively, while the flow of the dissolved substance remains almost unchanged. Subsequently, even with a decrease in permeability due to membrane compaction, selectivity is maintained due to a decrease in the transfer of the dissolved substance [8–10].

Purpose of the study

The purpose of this article is to provide a comparative description of the latest methods of water purification for use in pharmacy, namely reverse osmosis and electrodeionization.

Presentation of the main research material

The reverse osmosis water purification method involves the use of a semi-permeable membrane, to which water is supplied under pressure exceeding osmotic pressure. The source water is fed into the membrane module, where part of the flow passes through the membrane to a tube in the center of the module and forms a permeate, while the dissolved substances remain in the other part of the flow and form a concentrate that is removed from the system. An example of a reverse osmosis membrane is shown in Fig. 1. This method provides a high degree of removal of dissolved ions from water [11,12].

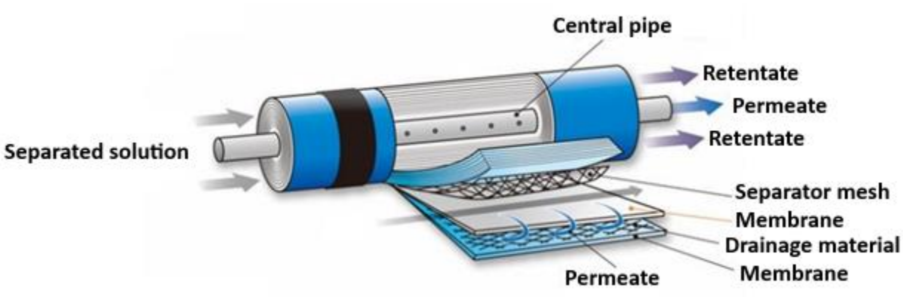

Fig. 1. Scheme of a roll membrane module

To achieve higher quality purification, a second stage of purification is envisaged, which includes the installation of an additional reverse osmosis membrane or an electrodeionizer. The second reverse osmosis membrane removes residual dissolved salts from the permeate, while the electrodeionization module demonizes the water using ion-exchange resins under the action of an electric current. Since membrane filtration cannot achieve absolute microbiological purity, additional water disinfection methods are used [13–15].

The water supplied to the membrane must undergo preliminary purification from mechanical impurities, chlorine, organic pollutants, and hardness salts, which can cause damage to the membrane and fouling on its surface. Also, to prevent bacterial growth on the membrane surface, regular sanitization of the filter elements is required [16].

This method of water purification provides significant energy savings compared to distillation, making it economically attractive for companies that require large amounts of water for injections. Membrane filtration also produces less waste compared to distillation, making the process more environmentally friendly. The flexibility in the design of the membrane system allows it to be adapted to the production area of the enterprise and occupy a small area, and the absence of the need for heating ensures greater productivity of the installation [17–19].

Electrodeionization is usually used for further purification of pre-desalinated water. This method is based on the use of ion exchange resins and electric current. The electrodeionization module consists of a cathode and an anode between which there are cation-selective and anion-selective membranes, forming chambers filled with ion exchange resin. The feed water enters the module and passes through H-cationic and OH-anionic resins, which retain the ions of dissolved salts, and the purified water is discharged from the system. However, under the action of a constant electric field, the ions retained by the resin continue to move towards the electrodes and pass through the ion-exchange resin to the concentrate chambers, where they accumulate and are discharged from the system or can undergo a second demineralization stage [20].

The main advantage of this method is that there is no need for periodic chemical washing of the resin layer, since in the electrodeionization module, the exchange properties of the resin are constantly regenerated by electrical energy. This also makes it possible to use the unit in continuous operation [21].

However, for the application of electrodeionization, water must undergo preliminary purification from mechanical impurities, hardness salts, and dissolved carbon dioxide, which can impair the operation of the module. Also, due to the peculiarities of the module's operation, the cost of maintaining the system can increase significantly due to the constant use of electrical energy [22,23].

The water deionization scheme is shown in Fig. 2.

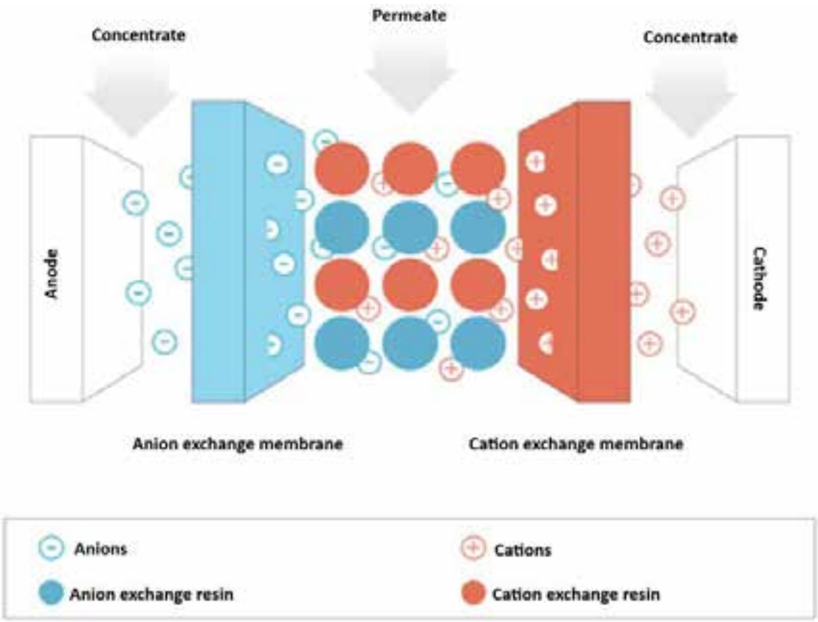

Fig. 2. Scheme of water deionization

Conclusions

Obtaining water for injections using reverse osmosis is a modern method which, when the system is designed correctly, fully complies with the requirements of the State Pharmacopoeia and pharmacopoeias of other countries.

The main advantages of this method are the production of high-quality water for injections using significantly less energy and operating costs, as well as the compactness of the equipment and the possibility of continuous operation. Compared to traditional distillation methods, reverse osmosis is the optimal choice for pharmaceutical companies.

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