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Review of membrane nanofiltration for treatment of water and wastewater

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A B S T R A C T

Today, a technology membrane nanofiltration has made significant progress in the treatment of pollutants from water and wastewater. This high-pressure technology has been able to produce high amounts of high-quality water. Features such as good pollutant removal capacity, low-cost membrane, reduced energy consumption, and long life of the nanofiltration membranes compared to reverse osmosis and environmentally friendly have made this technology popular in the world. Key features of nanofiltration membrane rejection are the low yield of monovalent ions, high return of divalent ions, and higher flux values compared to the membrane of reverse osmosis. These properties make nanofiltration membranes suitable for water and wastewater treatment, pollutants removal, pharmaceuticals, biotechnology, and foodstuffs engineering. Disposal of the nanofiltration membranes depends on a set of spatial effects, Donnan potential, dielectric, and conduction. Donnan's classical effect describes the balance and potential membrane interaction between a charged species and the interface of the charged membrane.

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1. Introduction

Water pollution by heavy metals, salts, and dyes is known as toxic and dangerous pollutants for human health and the environment. With the increase in human population, water and wastewater pollution cannot be prevented due to human activities in various sectors such as industry, agriculture, and services (Suhalim et al., 2022). Therefore, removing these pollutants should be considered an essential issue in pollution control and water and wastewater treatment using new water treatment technologies. Nanofiltration technology has attracted much attention due to the advantages of producing promising water fluxes at relatively low operating pressures and excellent separation against divalent salts. Today, nanofiltration technology has made significant progress in desalination, separation, and removal of heavy metals, and purification of organic dyes from water and wastewater (Yuan et al., 2017; Mehrjo et al., 2021).

Nanofiltration, a pressurized membrane procedure, is customarily applied in drinking water and wastewater treatment due to its cost, great proficiency, absence of secondary pollutants in the environment, gentle conditions and environmentally friendly properties. In particular, nanofiltration has excellent properties in selective conditions of rejection or rejection of some different organic dyes, salt ions, and heavy metals due to the separation of physical separation, electrostatic interaction, and Donnan deflection. In this procedure, smaller molecules such as water passage across the membrane, and bigger molecules similar to salts, organic dyes, and ions of metals are prevented from passing. The promising membrane material must have high penetration acceleration, very selective reflux or rejection, enhanced mechanical properties, and high stability in rough chemical solutions. In addition, this technology must have great antifouling properties pending the operation procedure (Chen et al., 2018; Guo et al., 2020; Cao et al., 2021).

Therefore, nanofiltration membranes are a promising technology that has been developed by impregnating a charged polymer on a porous polymer matrix and has attracted much attention. Wang et al. (2019) investigated the composition of attapulgite nanorods in GO nanofiltration membranes for performance dye wastewater purification and concluded that membrane thickness, dye concentration, and separating species in feed solutions affect membrane separation performance. Kamari and Shahbazi (2021) examined high-performance nanofiltration membranes by Fe_3O_4@SiO_2-CS bionocomposite for efficient removal of salts, dyes, and heavy metals and proved that this biocompatible and low-cost technology was very suitable for treating polluted industrial water and wastewater. Zheng et al. (2022) investigated the easy fabrication of nanofiltration membranes with high permeability and selectivity in removing heavy metals and dyes. The modified membrane had increased surface hydrophilicity, surface roughness, and positive charge surface. They concluded that the easy fabrication procedure could accelerate the development of positively charged nanofiltration membranes in potential applications of heavy metal removal and positively charged dyes from wastewater in the industry. Nanofiltration was first introduced in the late 1980s. This membrane has properties between ultrafiltration and reverses osmosis. When contacted with the aqueous solutions, they become some charged due to the separation of the surface groups and or the adsorb charege solution. For instance, nanofiltration polymer membranes possess ionized groups similar to sulfonic and carboxylic, which leads to a charged surface in attendance of feed solution. These membranes have a high resistance to the segregation of tiny organic molecules and mineral salts. Key features of nanofiltration membrane detection are a high rejection of divalent ions, low receptivity of monovalent ions, and higher flux content in comparison reverse osmosis. These attributes allow nanofiltration membranes to be applied in a multitude of fields, In particular for wastewater and water treatment, pharmaceuticals, foodstuffs engineering, and biotechnology (Mohammad et al., 2015). Therefore, the purpose of this paper is to investigate membrane nanofiltration technology for the treatment of water and wastewater pollutants.

2. Material and Methods

2.1. Fabricate methods of nanofiltration membranes

Polymer nanofiltration membranes may be fabricated by several methods including surface polymerization, phase inversion, and after treatment more porous support. The phase inversion method has been used to form commercial and experimental nanofiltration membranes more than other methods. The benefit of this method is that it is lower complex and needed fewer stages than surface polymerization. Provides easy formation of hollow fiber membranes in addition to flat sheet geometry. In the phase inversion procedure, a thermodynamically constant polymer solution separates into a polymer-rich phase and a polymer-free phase, finally Leading to a bi-continuous porous solid. This method of mixing liquid and liquid can be done in different manners. Immersion deposition occurs when a polymer solution (consisting of at least one polymer and one solvent) is immersed in a coagulation bath including a non-solvent (for polymer) in which solvent and insolvent are miscible. The solvent moves around the polymer towards the non-solvent, causing the phase to separate. 2) Phase separation due to evaporation occurs when the polymer concentration increases with the evaporation of the polymer solvent. 3) Phase separation due to vapor is achieved when the polymer solution is exposed to a non-solvent (usually water). Adsorption of this non-solvent causes precipitation or mixing. 4) Heat-induced phase separation is performed by changing the temperature (generally reduced) so that the polymer dissolves lower in the solvent. The solvent is removed from the resulting polymer matrix by evaporation, freeze-drying, and extraction (Paul and Jons, 2016; Bastin et al., 2021). The fabrication of the nanofiltration membrane using the phase inversion method is indicated in Figure 1.

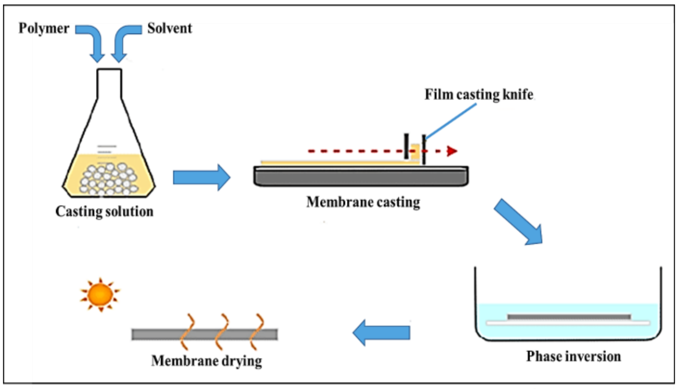

Fig . 1. The fabrication of the nanofiltration membrane using the phase inversion method

3. Results and discussion

3.1. Separation mechanism

Nanofiltration is a very complex procedure that depends on the surface microhydrodynamic conditions that occur on the surface and membrane nanopores. The rejection of nanofiltration may be due to factors such as the effects of spatial, dielectric, conductivity, and Donnan potential. The transfer of neutral salts takes place through the mechanism of esterification (size-based deprivation). The Donnan classic effect investigates the balance and potential membrane interaction between the charged membrane interface and a charged species. Membrane load arises from the separation of adjustable groups at the membrane surface and inside the structure of the membrane cavity. These groups may be alkaline or acidic in nature and or a composition of both due to the specific materials used in the production procedure. The separation of these surface groups is impressed with the pH of the contact solution and the membrane may show an isoelectric spot with a special pH, while the surface chemistry of the membrane is naturally amphoteric. In addition to surface groups of Ionizable, nanofiltration membranes have a weak ion-exchange, and ions in contact with the solution may be adsorbed to the membrane surface, and cause a little change in the charge of the membrane. Attraction or repulsion of electricity occurs because of the ionic capacity and constant charge of a membrane, which can change depending on the ionic condition as a result of the upper phenomena. The dielectric deprivation phenomenon is less understood and there are two basic competition hypotheses due to the interaction's precise nature. These phenomena are the so-called "image forces" and "energy-saving barrier" mechanisms. Both deprivation mechanisms are resulting from intense spatial range and nanoscale that exist in nanofiltration membrane separation and are efficiently charge-based deprivation phenomena (Vezzani and Bandini, 2002; Mohammad et al., 2015). The membrane nanofiltration system is schematically indicated in Figure 2.

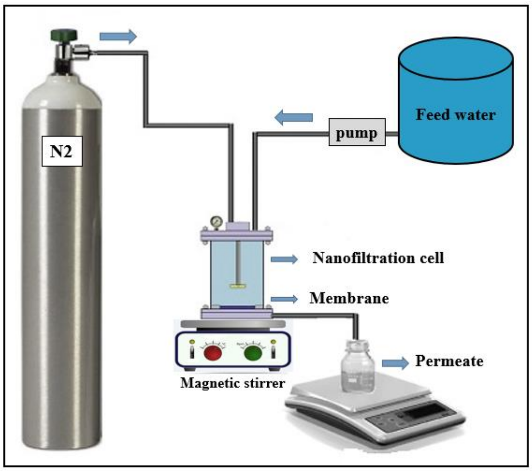

Fig. 2. The membrane nanofiltration system

3.2. The application of nanofiltration

The high-pressure nanofiltration membrane procedure is able of producing greater quantities of water with high quality. The high ability to remove pollutants, reduce membrane cost, reduce energy consumption and increase membrane life compared to reverse osmosis has made nanofiltration widely accepted and popular all over the world (Pontie et al., 2008). Nanofiltration has been used by many researchers in environmental applications to treat groundwater, wastewater, and surface water. Aside from the goal of removing small organic matter and divalent salts, recent research has indicated that nanofiltration is applied in some attractive new environmental applications, including contaminated groundwater and surface water, wastewater, desalination, and medicines. Nanofiltration has also been used to remove heavy metals, persistent organic pollutants (POPs), pharmaceutically active compounds (PhACs), organic dyes, and hormones (Saitua et al., 2011; Mohammad et al., 2015; Kabbani et al., 2021). The problem of arsenic in groundwater has received a great deal of attention around the world. For nanofiltration, various studies have been conducted with the aim of elimination. However, many of these studies have been performed on a laboratory or bench scale, using contaminated or natural artificial water as a model solution. Saitua et al. (2011) studied the removal of 5-valent arsenic from a naturally occurring polyamide nanofiltration membrane pilot from polluted groundwater. The membrane indicated a similar selectivity for artificial and natural polluted groundwater. This technology can also be a new approach without fouling and high selectivity with a pre-oxidation unit to convert 5 to 3 valence arsenic and an effective stabilization unit for arsenic recovery. Fluoride removal from some fluoride-affected areas in groundwater was also investigated. Simulation and modeling studies were performed along with economic assessment in addition to membrane proficiency in different operating conditions. So that the performance of nanofiltration membrane technology was very effective in the removal of fluoride from polluted groundwater in affected areas of the world. The focus of nanofiltration has been increasingly on the elimination of POPs, pesticides, disinfectants, and hormones (Mohammad et al., 2015; Owusu-Agyeman et al., 2019). Desalination technology, in particular the membrane-based procedure, is identified as one of the best candidates for dehydration. Membrane nanofiltration has indicated a high power that is one of the cases to decrease membrane fouling barriers and energy consumption in the desalination procedure. In principle, nanofiltration has proven its usefulness as a pre-treatment of seawater desalination, an alternative to reverse osmosis in the procedure of water treatment, and can be integrated with other procedures for superior overall proficiency. Beginning in the late 1990s, nanofiltration was tested as a pre-treatment procedure in a heat and membrane desalination plant. Which reduced the total soluble solids or salts in the reverse osmosis feed water and the multi-stage distillation unit. The reduction of total soluble solids caused the desalination unit for operating at higher temperatures and distillation recovery rates. The integration of nanofiltration as a section of the pretreatment procedure also resulted in more water production (about 60%) and a reduction of about 30% in cost for desalination and reverse osmosis units (Mohammad et al., 2015; Wu et al., 2021).

4. Conclusion

According to the research content, the following results can be stated:

1) Membrane nanofiltration technology has become popular all over the world with features such as good pollutant removal capacity, cheap membrane, reduced energy consumption, and long life of nanofiltration membranes compared to reverse osmosis and environmentally friendly.

2) The phase inversion method has been used to fabricate of nanofiltration membranes compared to other methods due to its less complexity, the possibility of easy formation of hollow fiber membranes, and the flatter geometry of the sheet.

3) In nanofiltration technology, smaller molecules, such as water, pass through membranes, while larger molecules, such as dyes, salts, and heavy metal ions, are prevented from passing through.

4) Nanofiltration membranes can be used in many fields, especially for wastewater and water treatment, pharmaceuticals, biotechnology, and foodstuffs engineering.

5) The rejection of nanofiltration membranes depends on factors such as spatial effects, Donnan potential, dielectric, and transfer.

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