International Core Journal of Engineering Volume 8 Issue 1, 2022
ISSN: 2414-1895 DOI: 10.6919/ICJE.202201_8(1).0033

Research Progress of Reverse Osmosis Membrane for Seawater Desalination and Investigation of Membrane Pollution

Hongyu Meng

College of Environmental Science and Engineering, Tiangong University, Hexi district, Tianjin, 300200, China

Abstract

Nowadays, membrane technology has been applying in sewage disposal and desalination. This paper describes the development background of membrane technology and membrane equipment. It is emphasized that reverse osmosis (RO) membrane plays a dominant part in the advanced disposal of industrial wastewater and seawater desalination. Secondly, the research progress of RO membrane was summarized by investigating a large number of articles. Finally, the fouling of RO membrane is discussed.

Keywords

Seawater Desalination, Reverse Osmosis Membrane, Membrane Pollution, Antifouling.

1. Introduction

In the seawater desalination technology development, its core technology lies in membrane technology and membrane equipment innovation development. The rapid development of membrane technology has led to its application in energy, food, biological engineering and other industries and plays an important role[1]. Membrane materials are currently considered as a practical water disposal technology and a credible and valid way to alleviate the global water resources lack. There are three kinds of membrane separation by driving force: electrically driven membrane separation, thermal driven membrane separation and pressure driven membrane separation. Depending on the separation performance, pressure driven membranes include: RO membrane, nanofiltration membrane, microfiltration membrane and ultrafiltration membrane[2]. Among them, the RO membrane has a better interception result on most composition of industrial wastewater except water molecules. Therefore, RO membrane plays a dominant role in the advanced disposal of industrial wastewater, with wide application potential and high commercial value.

2. Research Progress of RO Membrane

2.1 Evolution and Industrialization of RO Membrane

RO membrane is the central part of RO filtration process, so it has significant to develop a new RO membrane with high separation performance, good chemical stability and strong antifouling performance. Cellulose acetate RO membrane and aromatic poly-amide RO membrane are two important milestones in the history of RO membrane[3]. It is worth noting that poly-amide RO membrane has become the most widely used RO membrane. The team of many domestic researches institutions is mainly committed to the development of aromatic poly-amide RO composite membrane. From 1960s to 1970s, researchers made great progress in the design and industrialization of the hollow fiber RO membrane of tricellulose acetate. They also developed aromatic poly-amide RO membranes in the 1980s and 1990s, following the functional identification of poly-amines in composite membranes and the realization of trimethylchloroyl synthesis. The fact proved that aromatic poly-amide RO membrane has good practical value.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202201_8(1).0033

In the past ten years, researchers in colleges and universities have been developing the production and employ of composite RO membranes. Progressive RO membranes are prepared by adding functionalized additives (inorganic nano-particles or organic compounds)[4],[5] and designing monomer structures (hydrophilic or hyper-branched molecules)[6][7]. In particular, functionalized nanoparticles (such as carbon nanotubes[8], silver nanoparticles[9], nano-clays[10], molecular sieve[11]) are introduced into the ultra-thin skin layer of poly-amide membrane to form water channels and increase the surface hydrophilicity of the membrane to improve the separation performance. Besides, some innovative strategies have been proposed to regulate the performance of RO membranes. For example, the anti-fouling properties of poly-amide membranes are enhanced by constructing an ultra-thin layer of amphoteric ions on their upper surface[12], while the chlorine resistance is realized by sacrificial layer construction or surface modification[13]. Compared with foreign countries, domestic RO membrane types are relatively limited. Therefore, the commercialization of domestic RO membrane needs more research investment to find different membrane types suitable for seawater quality in different regions.

2.2 Investigation on Surface Modification of RO Membrane

The main purpose of membrane surface modification is to transform the surface characteristics of the membrane and make it less susceptible to contamination. In general, the flatness and charge of thin film surface is the two most general surface properties. A smooth film has a lower potential for contamination than a rough film surface because smooth surfaces are not conducive to dirt deposition. In addition, if the film surface is opposite to the charge of the dirt, the strong electrostatic interaction will lead to a larger area of membrane contamination. Therefore, surface modification of RO membrane is beneficial to alleviate membrane pollution[14].

The general method to promote the anti-pollution ability of RO membrane is to apply a protective layer on the membrane surface to inhibit the accumulation and adsorption of pollutants on the membrane surface. For example, Son team converted the RO membrane into a commercially valuable commercial RO membrane by adding two poly-electrolyte protective layers to the membrane[15]; Halakoo and Feng changed the surface of the film composite poly-amide membrane by adding cat-ionic polyimine and anionic go particles to the substrate and spraying them layer by layer[16]. The modified membrane was tested by NaCl, Na2SO4, MgSO4 and MgCl2 salt solutions, and the desalination rate of the membrane was as high as 99.9% at different temperatures and concentrations.

3. Investigation on Fouling of RO Membrane

Fouling generally refers to pollutants temporarily or permanently deposited on the membrane surface or membrane hole. Pollutants mainly include biological pollutants, inorganic pollutants, organic pollutants and particle pollutants. Membrane fouling, which occurs mainly inside or on the surface of membranes, is also a major challenge for RO desalination, as it deteriorates membrane performance, reduces membrane life, and inevitably leads to increased operating and investment costs. The fouling of membrane was discussed according to the types of pollutants.

3.1 Colloid Dirt

Colloids can be split into organic colloids and inorganic colloids according to their properties. Inorganic colloids in water are silt, sulfur, colloidal silica, etc. Organic colloids include oils, proteins, fat, etc.[17]For particle contamination of membranes, in general, photosynovials with stronger hydrophilic properties and low-charge surfaces are less susceptible to particle contamination, however, hydrodynamic pressure operating environments with high membrane flux or low cross-flow velocity can result in severe membrane damage[18].

3.2 Organic Dirt

Organic fouling result from the accumulation and deposition of relatively dense organic matter such as proteins, nucleic acids, lipids and amino acids, including natural organic compounds, complex compounds and soluble microbial items. Natural organic matter is the heterogeneous mixture formed

ISSN: 2414-1895 DOI: 10.6919/ICJE.202201_8(1).0033

naturally after the decomposition of animal and plant remains. complex compounds are synthetic dissolved organic compounds that are artificially added or produced in disinfection[17]. Soluble microbial products, however, are by-products of biological processes in which organic matter is biobroken down. Traditional pretreatment methods can not fully remove the organic matter in the solution, so organic pollution is a challenge in the treatment and desalination of RO membrane wastewater.

3.3 Inorganic Dirt

Inorganic scaling is formed by calcium carbonate, silica, calcium phosphate and other inorganic substances in water. They form supersaturated solution and finally precipitate out of the solution to reach the surface of the membrane, resulting in membrane contamination. Inorganic fouling is affected by many chemical and physical parameters, such as surface temperature, etc.

3.4 Biological Dirt

Biological dirt refers to the attachment and accumulation of microorganisms accompanying biofilm formation on solid host materials during RO filtration, which can account for 40% of the total dirt[19]. Biological pollution is the most challenging pollutant in RO membrane pollution of seawater desalination. There are two main reasons for this. First, the soluble organic matter in seawater cannot be fully dislodged in the pretreatment stage, the biological pollution potential of seawater desalination RO membrane is very large[20]. Second, because water is rich in nutrients, proliferating microorganisms form mature biofilm[21]. Biological contamination refers to the continuous accumulation of organisms or biopolymers on the membrane surface, resulting in the taking shape of biofilm. It is generally believed that due to the formation of biofilm, resistance of water through the membrane increases, resulting in reduced flux.

4. Conclusion

RO membrane process is an attractive technology, which has been widely used in seawater desalination. In the coming years, the separation technology of RO membranes will keep leading the way of desalination and industrial sewage disposal. In this paper, research progress and pollution problems of RO membrane is investigated, and the problem that seawater desalination RO membrane is easy to be polluted is emphasized. In order to make the RO membrane better applied in desalination, so as to further promote the application of RO technology, on the one hand, it is necessary to further study the pollution mechanism of RO membrane, figure out the root cause of membrane pollution; On the other hand, the synthesis and preparation of new monomers and the modification process of membrane materials need to be improved.

References

[1] N. Misdan, W. J. Lau, and A. F. Ismail, “Seawater Reverse Osmosis (SWRO) desalination by thin-film composite membrane-Current development, challenges and future prospects,” Desalination, vol. 287, pp. 228-237, 2012, doi: 10.1016/j.desal.2011.11.001.

[2] S. F. Anis, R. Hashaikeh, and N. Hilal, “Reverse osmosis pretreatment technologies and future trends: A comprehensive review,” Desalination, vol. 452, no. October 2018, pp. 159-195, 2019, doi: 10.1016/j.desal. 2018.11.006.

[3] S. F. Anis, R. Hashaikeh, and N. Hilal, “Functional materials in desalination: A review,” Desalination, vol. 468, no. July, 2019, doi: 10.1016/j.desal.2019.114077.

[4] P. Taylor, H. Dong, L. Zhang, and H. Chen, “Desalination and Water Treatment Preparation and characterization of surface- modified zeolite-polyamide thin film nanocomposite membranes for desalination Preparation and characterization of surface-modifi ed zeolite-polyamide,” no. March 2013, pp. 37–41, 2012.

[5] Y. Zeng, L. Wang, L. Zhang, and J. Qiming, “An acid resistant nano fi ltration membrane prepared from a precursor of poly (s-triazine-amine) by interfacial polymerization,” J. Memb. Sci., vol. 546, no. October 2017, pp. 225–233, 2018, doi: 10.1016/j.memsci.2017.10.022.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202201_8(1).0033

[6] X. Wei, Z. Wang, J. Chen, J. Wang, and S. Wang, "A novel method of surface modification on thin-film-composite reverse osmosis membrane by grafting hydantoin derivative," vol. 346, pp. 152–162, 2010, doi: 10.1016/j.memsci.2009.09.032.

[7] J. Qin, S. Lin, S. Song, L. Zhang, and H. Chen, "4-Dimethylaminopyridine promoted interfacial polymerization between hyperbranched polyesteramide and trimesoyl chloride for preparing ultralow-pressure reverse osmosis composite membrane," ACS Appl. Mater. Interfaces, vol. 5, no. 14, pp. 6649–6656, 2013, doi: 10.1021/am401345y.

[8] H. Zhao, S. Qiu, L. Wu, L. Zhang, H. Chen, and C. Gao, "Improving the performance of polyamide reverse osmosis membrane by incorporation of modi fi ed multi-walled carbon nanotubes," J. Memb. Sci., vol. 450, pp. 249–256, 2014, doi: 10.1016/j.memsci.2013.09.014.

[9] C. Dong, Z. Wang, J. Wu, Y. Wang, J. Wang, and S. Wang, "A green strategy to immobilize silver nanoparticles onto reverse osmosis membrane for enhanced anti-biofouling property," Desalination, vol. 401, pp. 32–41, 2017, doi: 10.1016/j.desal.2016.06.034.

[10] H. Dong, L. Wu, L. Zhang, H. Chen, and C. Gao, "Clay nanosheets as charged filler materials for high-performance and fouling-resistant thin film nanocomposite membranes," J. Memb. Sci., vol. 494, pp. 92–103, 2015, doi: 10.1016/j.memsci.2015.07.049.

[11] H. Huang et al., "Acid and multivalent ion resistance of thin film nanocomposite RO membranes loaded with silicalite-1 nanozeolites," J. Mater. Chem. A, vol. 1, no. 37, pp. 11343–11349, 2013, doi: 10.1039/c3ta12199b.

[12] S. Lin, Y. Li, L. Zhang, S. Chen, and L. Hou, "Zwitterion-like, Charge-Balanced Ultrathin Layers on Polymeric Membranes for Antifouling Property," Environ. Sci. Technol., vol. 52, no. 7, pp. 4457–4463, 2018, doi: 10.1021/acs.est.7b06183.

[13] G. Hamdy and A. Taher, "Enhanced chlorine-resistant and low biofouling reverse osmosis polyimide-graphene oxide thin film nanocomposite membranes for water desalination," Polym. Eng. Sci., vol. 60, no. 10, pp. 2567–2580, 2020, doi: 10.1002/pen.25495.

[14] P. S. Goh, W. J. Lau, M. H. D. Othman, and A. F. Ismail, "Membrane fouling in desalination and its mitigation strategies," Desalination, vol. 425, no. August 2017, pp. 130–155, 2018, doi: 10.1016/j. desal. 2017.10.018.

[15] M. Son, W. Yang, S. S. Bucs, M. F. Nava-Ocampo, J. S. Vrouwenvelder, and B. E. Logan, "Polyelectrolyte-Based Sacrificial Protective Layer for Fouling Control in Reverse Osmosis Desalination," Environ. Sci. Technol. Lett., vol. 5, no. 9, pp. 584–590, 2018, doi: 10.1021/acs.estlett.8b00400.

[16] E. Halakoo and X. Feng, "Layer-by-layer assembly of polyethyleneimine/graphene oxide membranes for desalination of high-salinity water via pervaporation," Sep. Purif. Technol., vol. 234, no. September 2019, p. 116077, 2020, doi: 10.1016/j.seppur.2019.116077.

[17] C. Liu, W. Wang, B. Yang, K. Xiao, and H. Zhao, "Separation, anti-fouling, and chlorine resistance of the polyamide reverse osmosis membrane: From mechanisms to mitigation strategies," Water Res., vol. 195, p. 116976, 2021, doi: https://doi.org/10.1016/j.watres.2021.116976.

[18] C. Y. Tang, T. H. Chong, and A. G. Fane, "Colloidal interactions and fouling of NF and RO membranes: A review," Adv. Colloid Interface Sci., vol. 164, no. 1-2, pp. 126-143, 2011, doi: 10.1016/j.cis.2010.10.00 7.

[19] S. Kalafatakis, A. Zarebska, L. Lange, C. Hélix-Nielsen, I. V. Skiadas, and H. N. Gavala, "Biofouling mitigation approaches during water recovery from fermented broth via forward osmosis," Membranes (Basel)., vol. 10, no. 11, pp. 1–18, 2020, doi: 10.3390/membranes10110307.

[20] W. Yin, J. S. Ho, E. R. Cornelissen, and T. H. Chong, "Impact of isolated dissolved organic fractions from seawater on biofouling in reverse osmosis (RO) desalination process," Water Res., vol. 168, p. 115198, 2020, doi: 10.1016/j.watres.2019.115198.

[21] J. S. Ho et al., "In-situ monitoring of biofouling on reverse osmosis membranes: Detection and mechanistic study using electrical impedance spectroscopy," J. Memb. Sci., vol. 518, pp. 229–242, 2016, doi: 10.1016/j.memsci.2016.06.043.