TETRABUTYL ORTHOSILICATE POLYSULFONE SUPERHYDROPHOBIC MEMBRANE FOR DIRECT CONTACT MEMBRANE DISTILLATION DESALINATION

Background of Study

The sustainable development of each society is hinges on the availability of freshwater in the area [1]. This because fresh water is the important element to sustain the life system on the Earth. Nonetheless, billions of people do not have access to drinkable water because many freshwater systems from lakes and rivers are too polluted and are drying up day by day at an alarming rate [2]. Scientists and engineers have been looking into unconventional water resources such as seawater, industrial waste water and municipal brine [3]. In this regard, seawater desalination appears to be a highly feasible option due to the ubiquity of seawater [4]. There are two main desalination processes that are commercially exploited, namely thermal and membrane processes [5]. membrane distillation (MD) is a membrane-based non-isothermal process which utilizes a suitable hydrophobic microporous membrane, primarily used to desalinate seawater [6]. For the manufacture of nanostructured polymeric materials for use in a variety of applications, such as MD membrane engineering, the electrospinning technique is used [7].

There are two fundamental technological approaches to desalinating water: thermal and membrane approaches [8]. Reverse osmosis (RO), nanofiltration (NF), multiple-effect distillation (MED), mechanical vapour compression (MVC), and membrane distillation (MD) are a few of the technologies that have been applied to the desalination process over time [9]. In the process of thermal desalination, water from seawater is evaporated using heat energy, leaving behind only pure water after condensation. Because of the Middle East's plentiful fossil fuels, poor quality seawater, and appropriateness for electricity cogeneration, thermal desalination systems are commonly utilized there [5]. Even while thermal approaches generate more water with the total dissolved solids ranging from 5 to 50 parts per million, the system has the drawback of requiring a significant quantity of energy to complete the removal process, leading to high operational costs [10].

Technically, there are two primary methods for desalinating water: the thermal method and the membrane method [8]. MED, also known as multiple effect evaporation (MEE), and MSF desalination, are examples of thermal techniques. The former, known as MED, is the most traditional desalination method today and is also one of the most thermodynamically effective. It is made up of many cells that operate at lowering pressures and temperatures while recapturing heat from steam condensation. However, because it is regarded as being extremely dependable and sturdy, MSF is the thermal technique that is most frequently employed globally. Water is heated in a brine heater after passing through a number of heat exchangers in this procedure. It goes through several stages of abrupt decompression that result in vapor ("flashes" into steam) [11].

William Gilbert first observed the development of a cone-shaped water droplet in the presence of an electric field in a study he did in 1600. This observation inspired him to develop the idea of electrospinning. Stephen Gray discovered the electrohydrodynamic atomization of a water droplet, which produced a very fine stream, around a century later. The first known electrospraying experiment was carried out in 1747 by Abbé Nollet, who showed that water could be sprayed as an aerosol while passing through an electrostatically charged vessel that was positioned adjacent to the ground. The behavior of charged droplets was then thoroughly investigated by Lord Rayleigh. In order to establish how many charges a liquid droplet could contain before ejecting liquid jets from the surface, he performed a theoretical calculation in 1882. High voltage is used in both the electrospinning and electrospraying processes to eject liquid jets, making them identical procedures. When electrospinning, the jet can be kept in a continuous shape to create fibers rather than breaking up into droplets (for the generation of particles) as with electrospraying [12].

A hydrophobic membrane is used as a separating layer in the new thermally powered desalination method known as MD. Since there is currently no commercially available membrane for MD, numerous research organizations are constantly making significant attempts to synthesize or produce novel membranes [13]. Although commercial microfiltration membranes are suitable for MD, they still have poor permeation flux and are prone to wetting problems. Electrospun nanofiber membranes were taken into consideration for MD applications because of their high hydrophobicity, high porosity, and suitable pore diameters. Since the initial use of a nanofiber membrane for MD was reported in 2008, other research teams have produced nanocomposites and other distinctive hybrid designs, such as dual-layer and triple-layer, to construct and enhance the properties of nanofiber membranes [14] , doing post-treatment methods such as hot-pressing and applying surface modification techniques. When compared to commercial membranes, findings in the literature generally showed improved permeation flux and salt rejection efficiency for nanofiber membranes; nevertheless, difficulties with longterm stability and fouling formation are still not thoroughly examined [15].

In DCMD, the surface of the hot membrane side is in direct contact with the hot solution (feed). Then, the feed side is connected to the permeate side, water vapor is transported and condenses. Due to the difference in vapor pressure, the vapor gradient moves the water vapor across the membrane. Unless otherwise specified, DCMDrefers to the default MD setup [16]. This arrangement, which incorporates several NPs types (such as SiO_2NPs) onto MD membranes, has been thoroughly studied for its use in the purification of various types of fluids (such as oilfield and salty), juice concentration,and the extraction of metals and ammonia [17].

Problem Statement

Membrane distillation MD is although a prominent process in various applications such as water treatment and desalination but the low rate of flux and fouling creating resistance for this process to be used in Industry.

In this work, it is suggested that the fabrication of electrospun novel superhydrophobic PolyethERsulfone (PES) hybrid membrane containing tetrabutyl orthosilicate (PVDF-TBOS) as nanofillers. The study aims to increase the mechanical strength for higher flux and reduced fouling of the membrane. However, the optimal composition and electrospinning conditions of PES-TBOS IS still unknown. Also, the physicochemical properties and the desalination performance of the membranes need to be characterized.

Objectives

- To establish the optimal composition of PES-TBOS nanofibrous superhydrophobic membrane.
- To identify the optimal electrospinning conditions of PES-TBOS nanofibrous superhydrophobic membrane.
- To characterize the physicochemical properties of electrospun PES-TBOS and nanofibrous superhydrophobic membrane.
- To evaluate the desalination and anti-fouling performance of the electrospun PES-TBOS nanofibrous superhydrophobic membrane in the reverse osmosis (RO) of brine by direct contact membrane distillation (DCMD).

Scope of Study

The membranes containing PES-TBOS will be prepared containing different percentages of TBOS and PES to investigate the rheological behavior of the dope solutions. Moreover, the effect of molecular weight, concentration of solvent including dimethyl sulfoxide (DMSO) along with acetone and the effect of temperature on the viscosity of the dope solution will be studied.

The second phase of study will investigate the optimal conditions of the electrospinning process by using response surface methodology for the fabrication of electrospun nano fibrous membranes.

The third phase of the study characterized the physicochemical properties of the electrospun nanofibrous PES-TBOS membranes by Contact angle analysis, porosity, Differential Scanning Calorimetry (DSC), Thermogravimetric analysis (TGA), Scanning electron microscopy (SEM), Energy dispersive X-ray (EDX), X-ray diffraction analysis (XRD), Atomic force microscopy (AFM), Pore Size, Liquid entry pressure (LEP).

The last phase of study involves the evaluation and antifouling performance of the membranes by keeping the temperature of the feed at 70°C and 20°C for the permeate using RO brine.

Significance of study

The finding of this study will bring out anti fouling with high flux and good mechanical strength membrane overcome the shortcomings of desalination of sea water which produces low flux and rapid fouling.

References

1. Twibi, M.F., et al., *Development of high strength, porous mullite ceramic hollow fiber membrane for treatment of oily wastewater.* Ceramics International, 2021. **47**(11): p. 15367-15382.
2. Brza, M., et al., *Metal framework as a novel approach for the fabrication of electric double layer capacitor device with high energy density using plasticized Poly (vinyl alcohol): Ammonium thiocyanate based polymer electrolyte.* Arabian Journal of Chemistry, 2020. **13**(10): p. 7247-7263.
3. Ravi, J., et al., *Polymeric membranes for desalination using membrane distillation: A review.* Desalination, 2020. **490**: p. 114530.
4. Tai, Z.S., et al., *Ceramic membrane distillation for desalination.* Separation & Purification Reviews, 2020. **49**(4): p. 317-356.
5. Greenlee, L.F., et al., *Reverse osmosis desalination: water sources, technology, and today's challenges.* Water research, 2009. **43**(9): p. 2317-2348.
6. Baghel, R., et al., *A review on membrane applications and transport mechanisms in vacuum membrane distillation.* Reviews in Chemical Engineering, 2018. **34**(1): p. 73-106.
7. Khayet, M., et al., *Dual-layered electrospun nanofibrous membranes for membrane distillation.* Desalination, 2018. **426**: p. 174-184.
8. Shengquan, Y., et al., *Separation of carcinogenic aromatic amines in the food colourants plant wastewater treatment.* Desalination, 2008. **222**(1-3): p. 294-301.
9. Pinto, F.S. and R.C. Marques, *Desalination projects economic feasibility: a standardization of cost determinants.* Renewable and Sustainable Energy Reviews, 2017. **78**: p. 904-915.
10. Ghaffour, N., T.M. Missimer, and G.L. Amy, *Technical review and evaluation of the economics of water desalination: current and future challenges for better water supply sustainability.* Desalination, 2013. **309**: p. 197-207.
11. Saidur, R., et al., *An overview of different distillation methods for small scale applications.* Renewable and sustainable energy reviews, 2011. **15**(9): p. 4756-4764.
12. Xue, J., et al., *Electrospinning and electrospun nanofibers: Methods, materials, and applications.* Chemical reviews, 2019. **119**(8): p. 5298-5415.
13. Tijing, L., et al., *1.16 Electrospinning for membrane fabrication: strategies and applications.* Comprehensive Membrane Science and Engineering; Elsevier: Oxford, UK, 2017: p. 418-444.
14. Feng, C., et al., *Production of drinking water from saline water by air-gap membrane distillation using polyvinylidene fluoride nanofiber membrane.* Journal of Membrane Science, 2008. **311**(1-2): p. 1-6.
15. Shan, H., et al., *Nanocoated amphiphobic membrane for flux enhancement and comprehensive anti-fouling performance in direct contact membrane distillation.* Journal of Membrane Science, 2018. **567**: p. 166-180.
16. Tomaszewska, M., *Membrane distillation-examples of applications in technology and environmental protection.* Polish Journal of Environmental Studies, 2000. **9**(1): p. 27-36.
17. Nthunya, L.N., et al., *A review of nanoparticle-enhanced membrane distillation membranes: membrane synthesis and applications in water treatment.* Journal of Chemical Technology & Biotechnology, 2019. **94**(9): p. 2757-2771.