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Recent progress of membrane distillation using electrospun nanofibrous membrane

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ABSTRACT

Rapid population growth has resulted in imbalance in the supply and demand of fresh water for human consumption. As the sources of fresh water from surface water and fresh groundwater have been consistently depleting at an alarming rate, alternative sources such as seawater and brackish water are sought out. Desalination of water is considered as one of the most sustainable and best water resource alternatives. Membrane distillation (MD) is an emerging and promising technology for water desalination and purification. It presents many advantages over the common desalination technologies such as reverse osmosis. The two major factors hindering the application of MD are suitable membrane design and structure, and energy efficiency of the MD process. In recent years, membrane design has seen increasing research and interest. Advances in science and technology have led to new materials and techniques that could find potential application for membranes in MD. In the past few years, electrospinning of nanofibers has gained much interest and attention in their application for MD membrane, and so far has promising results. This review focuses on the recent progress in the application of nanofibrous membrane fabricated by electrospinning for MD application.

Contents

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1. Introduction

Fresh water shortage for human consumption and irrigation is one of the major problems faced globally today. Nowadays, more than 1 billion people lack access to drinking water [1]. Seawater comprises majority of the world's water resources and only 2.5% is fresh water, but only a portion of this fresh water is available for human consumption. Finding alternative ways to provide fresh water is of utmost importance. Since seawater is widely available, many research studies have been focused on converting seawater into drinking water [2,3] or for irrigation [4]. Other alternative ways are to treat brackish or wastewater into potable water [5,6]. Membrane technology plays an important role in desalination, and in water and wastewater treatment. Several membrane-based technologies such as reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF) are currently being used [7]. In desalination, multi-stage flash distillation (MSF) and RO are the most widely used methods globally with a salt rejection higher than 98% [8]. Extensive research about RO has been conducted by several groups [9–13] and many review papers [9,14–16] are widely available in literature. RO presents an efficient way of desalination, however, it is an energy-intensive process, so there is a need for an alternative cost-effective process to turn seawater into drinking water. In recent years, several groups have focused on studying alternative methods for RO such as NF, electrodialysis, capacitive deionization, forward osmosis (FO), and membrane distillation (MD). Among the current water desalination and purification technologies, MD process presents many attractive features compared to other technologies. Increasing array of research is being conducted to optimize the performance of MD in desalination focusing both on theoretical and experimental studies [17–21]. Several experimental parameters are investigated on their effect on MD flux performance such as the feed and permeate temperature, salt concentration, and membrane properties (morphology, hydrophobicity, porosity, pore size and pore size distribution, etc.). There has been a surge of MD studies in the past 10 years (see Fig. 1). In 2013 alone, as of the writing of this paper, the number of MD publications as searched through the Web of Science with the topic 'membrane distillation' is already more than 200 publications, and it still continues to rise. Recently, an increasing number of studies is geared on modifying or entirely changing the MD membrane. Khayet [22] reviewed the fabrication and MD performance evaluation including experimental and theoretical studies of several commercial and laboratory-made MD membranes. Alkhudhiri et al. [23] recently reported a comprehensive review on MD performance addressing membrane characteristics, fouling, heat and mass transfer concepts, and effects of operating conditions.

In the past few years, nanotechnology has been gaining momentum in its application for water and wastewater treatment, and desalination. Many studies are now utilizing nanoparticles and nanofibers to impart additional properties and functionalities to the membrane, and also for membrane preparation, fabrication and modification. A few review articles in literature in the past few years have been dedicated to the application of nanotechnology to water and wastewater treatment [24–26]. Subramanian and Seeram [27] reported the recent developments on the use of electrospun nanofibers for desalination application by NF and MD. Feng et al. [28] reviewed the preparation and characterization of electrospun nanofiber membranes for water treatment and other membrane separation processes. Camacho et al. [29] have

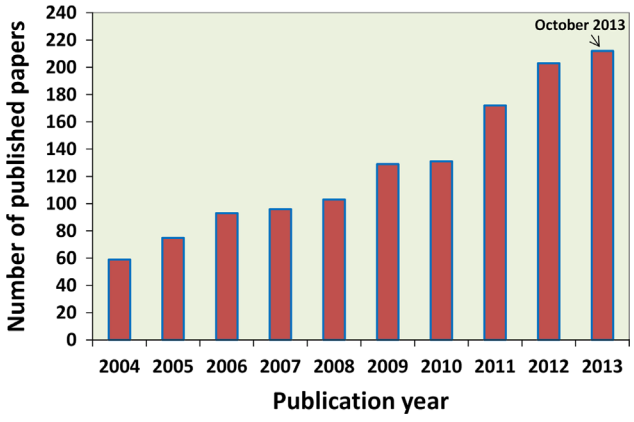

Fig. 1. Annual publication on the subject of membrane distillation for the past 10 years (2004–October 2013) as searched through Web of Science.

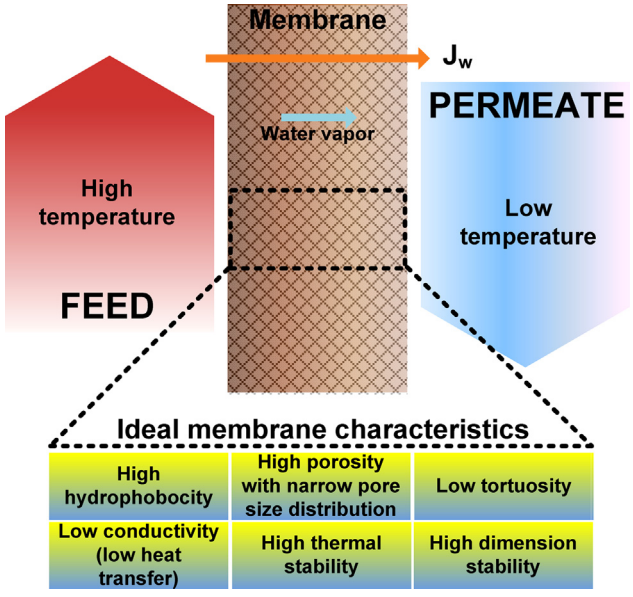

Fig. 2. Schematic layout of the MD process and a list of ideal membrane characteristics for highly efficient MD.