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ORIGINAL ARTICLE

Activated carbon-doped polystyrene fibers for direct contact membrane desalination

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Abstract

Membranes for direct contact membrane distillation were produced from electrospun polystyrene microfibers doped with activated carbon. The addition of activated carbon reduced the hydrophobicity of the fibers. Therefore, desalination membranes were fabricated in a multi-layer construction with undoped polystyrene as the outer layers and activated carbon-doped polystyrene as an inner layer. Membranes including activated carbon-doped layers showed a 20× greater specific surface area as compared to undoped membranes. The vapor flux of the membranes containing layers doped with activated carbon (6.3 ± 0.7 kg/m^2/h) was not statistically different from that with an all polystyrene construction (8.1 ± 1.2 kg/m^2/h). The membranes retained their desalination capabilities despite the addition of the activated carbon.

Keywords Electrospinning · Polystyrene · Activated carbon · Membrane distillation · Volatile organic compounds

1 Introduction

The need for fresh water is an ever-present issue in many regions of the world. As many as 785 million people (one-in-nine) lack access to safe water [1]. One solution is the desalination of seawater using one of the several technologies such as flash distillation, reverse osmosis, or membrane distillation [2]. All of these technologies excel at separating dissolved solids (e.g., salt) from water. However, in today's industrialized world, waterways are becoming increasingly polluted with organic compounds from oil spills, industrial waste, fertilizer and insecticide runoff, and the accumulation of pharmaceuticals [3]. Many desalination methods fail to remove organic molecules from the water resulting in the need for a secondary treatment method, typically involving activated carbon [4–7]. Incorporating the activated carbon directly into a membrane for desalination is seen as one way to simultaneously address different types of contamination [8–10].

Direct contact membrane distillation (DCMD) is a water distillation process using a porous hydrophobic membrane to physically separate wastewater or seawater (the feed) from the fresh water (the permeate). The reclamation of water is facilitated by the vapor pressure difference between the feed and the permeate across the porous membrane [11]. In contrast to reverse osmosis (RO), mass transport occurs in the vapor phase resulting in much higher ion rejection rates [12]. The effectiveness of the hydrophobic membranes depends on the physical properties of the materials and as well as the structural design. While DCMD still faces many challenges such as low flux, pore wetting, and fouling, it holds incredible potential in its ability to utilize low-quality heat for wastewater reclamation from oil and gas production [13], as well as reverse osmosis concentrate [14].

However, like other methods, DCMD is limited in its ability to reject high volatility and low molecular weight organic compounds which typically have to be removed with an adsorption pretreatment. There have been many studies looking at the use of activated carbon (AC) concurrently with DCMD, RO, and ultrafiltration [15–19]. These studies have shown that AC can serve as an effective adsorbent for removal of many different pollutants. However, they also require additional layers, leading to reduced effectiveness in both flux and cost.

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