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Performance of vacuum poly(propylene) membrane distillation (VMD) for saline water desalination

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A B S T R A C T

In this study, commercial poly(propylene) (PP) hollow fiber membrane was used for desalination of highly saline water via VMD. The effect of operational conditions, such as feed temperature (i.e., 45–64 °C), feed flow rate (i.e., 0.4–0.6 L/min), feed concentration (i.e., 35–100 g/L), and vacuum pressure (i.e., 12.7–28 kPa (abs)), on hollow fiber performance was studied. The hot brine was circulated through the lumen side of the hollow fibers.

The results demonstrated that the water permeate flux of about 66 (kg/m^2 h) was achieved at the operating conditions defined by 35 g/L, 65 °C, 0.6 L/min (pertaining to feed concentration, temperature, and flow rate, respectively) under 12.7 kPa (abs) vacuum pressure, whereas salt rejection was 99.99% and the conductivity of the permeate was less than 10 (μS/cm). In order to minimize the number of experiments and optimize the influence of operating conditions on permeate flux, Taguchi method was used and ANOVA was implemented to determine the contribution of each factor to the observed output. The findings revealed that the feed temperature was the most influential factor in determining the permeation flux, followed by vacuum pressure, feed concentration and feed flow rate.

1. Introduction

The scarce drinking water and the rapid global population growth necessitate the use of modern techniques to purify seawater and identify the factors affecting the increase in production and meeting the shortfall in drinking water. Membrane distillation (MD) is one of those modern techniques for seawater or even highly saline water desalination [1,2]. MD is a thermally driven separation technique utilizing a hydrophobic porous membrane to separate the hot saline water into two streams concentrated solution and permeate water [3,4]. Presently, four configurations of the MD technique are in use, namely Direct contact membrane distillation (DCMD), Air-gap membrane distillation (AGMD), Sweeping gas membrane distillation (SGMD), and Vacuum membrane distillation (VMD) [5]. The importance of using membrane technology stems from the ability to obtain a high permeation flux with appropriate separation performance. In that respect, VMD is the most suitable configuration for water desalination. The advantages of VMD mainly stem from the high pure water permeability under lower operating temperatures (less energy consumption), lower heat loss by conduction through the membrane wall, negligible heat transfer by conduction due to low pressure on the permeate side and no temperature polarization on the permeate surface because the water vapor is withdrawn immediately from the permeate side during the VMD process [6–9]. VMD has been a subject of numerous studies focusing on the ground, underground, brackish and seawater desalination with moderate permeate flux. For example, Cabassud and Wirth [10] employed VMD with hollow fiber module for desalination of seawater. The authors reported that the VMD process feasibility for seawater desalination primarily depends on the membrane material. Xu et al. [11] used poly(propylene) (PP) hollow fiber membrane for desalination of seawater by VMD and studied the effect of operating conditions, such as feed temperature and desalting degree, on the permeate flux. More recently, Mohammadi and Safavi [12] investigated a new membrane module to improve the desalination of high concentration NaCl aqueous solution by using VMD process. The effect of operating parameters on the membrane performance was also studied.

In their work, Pangarkar et al. [13] studied the influence of operating conditions, such as feed temperature, flow rate, concentration, vacuum pressure and PTFE membrane fouling, on groundwater permeate flux by using VMD. More recently, Sivakumar et al. [14] used hollow fiber VMD technique to study mine water treatment approaches and discussed the effect of operating parameters on permeate flux. They found that the vacuum pressure was the most influential parameter among those investigated in their work. In their study, Zhang et al. [15] fabricated porous silicon nitride (Si_3N_4) hollow fiber membrane via combined phase inversion and sintering method. The prepared

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