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Exploitation of solar energy collected by solar stills for desalination by membrane distillation

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Abstract

The aim of this work was to evaluate the technical feasibility of producing potable water from simulated seawater by integrating a membrane distillation module with a solar still. The relatively hot brine in the solar still was used as a feed to the membrane module. The synergistic action of the solar still and the membrane module in the production of potable water was quantified. For this purpose, two types of experiment were conducted, indoor experiments and outdoor experiments. The sensitivity of the permeate flux to the brine temperature, flow rate, salt concentration and solar irradiation were all investigated. Overall, the flux of water from the solar still was no more than 20% of the total flux. The brine temperature significantly affected the flux of both the solar still and the membrane module, while the effect of salt concentration was marginal. The effect of these process parameters was more noticeable in the membrane module than in the solar still.

Keywords: Desalination; Membrane distillation; Solar still

1. Introduction

The demand for good-quality drinking water is increasing steadily world-wide. Increasing population, with the desire to improve standards of living, contribute to the increased demand. The severity of the problem is more pronounced in the Middle East region, especially in countries such as Jordan, which suffers from a shortage of running surface water, scanty rainfall and rapid population growth. Although over

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Nomenclature

h	brine depth
P_w^*	water vapor pressure
Re	Reynolds number
T	temperature
w	mass fraction of salt
x	mole fraction of salt

Subscripts

c	cold side
h	hot side

two-thirds of the planet is covered with water, 99.3% of the total water is either too salty (seawater) or inaccessible (ice caps). Since water is potable if it contains less than 500 ppm of salt, much research has gone into finding efficient methods of removing salt from seawater and brackish water. These are called desalination processes [1].

Process technologies for the treatment of saline water are consequently increasing in importance and developing at a rapid pace. Desalination processes can broadly be divided into two categories: processes with a phase change such as distillation and freezing, and processes without a phase change such as reverse osmosis (RO) and electrodialysis (ED).

Membrane distillation (MD) is a hybrid of thermal distillation and membrane processes. The concept of MD was first described in the technical literature in 1967 [2]. Numerous research groups around the world have contributed to the understanding of the process. Its technical feasibility has been shown in such applications as the desalination of seawater [3–6], the removal of alcohols from aqueous streams [7], and the concentration of juices [8], bovine blood [9] and mineral acids, such as hydrochloric [10] and sulfuric [11] acids. The number of commercial applications of membrane distillation is small but growing. Desalination plants were built in Florida and the Cayman Islands but are no longer operated [12]. Recently, a Swedish company began marketing the process for water purification in nuclear plants.

Membrane distillation can best be described as trans-membrane evaporation. It is a thermally driven process in which a hydrophobic membrane is in contact with a hot or warm feed solution. Vapor evolved from the feed solution passes through the pores of the membrane and is collected on the other side. Methods for collecting the vapor permeate include immediate condensation within a colder liquid flowing on the second side of the membrane [Fig. 1(a)], or condensation on a cold surface located at some distance from the membrane [Fig. 1(b)]. In the latter situation, vacuum can be applied to draw more vapor through the membrane.