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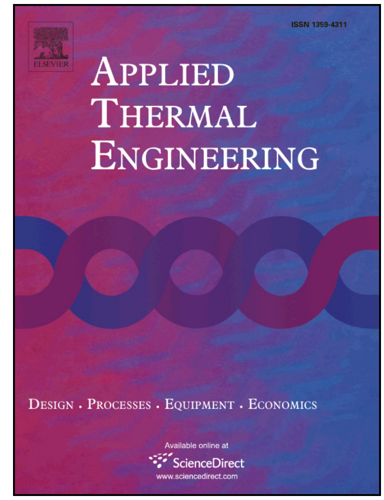

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Simulation study of flat-sheet air gap membrane distillation modules coupled with an evaporative crystallizer for zero liquid discharge water desalination

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Abstract

A flat sheet air gap membrane distillation (AGMD) model and evaporative crystallizer were developed for the designing and optimization of the lab-scale zero liquid discharge (ZLD) water desalination experimental plant. The models were validated by comparing with published experimental data. Univariate analysis was utilized to investigate the influences of thirteen operating and dimensional parameters of single stage and multi-stage AGMD modules on the permeate flux, evaporative efficiency, water recovery, and gained output ratio (GOR). Optimization of the parameters were conducted aiming to maximize the permeate flux, water recovery, and GOR of the AGMD module. Membrane distillation and crystallization (MDC) process was then altogether modeled in Aspen Plus software based on the parameter studies of the single and multi-stage AGMD model. The effects of water removal ratio in the crystallizer and NaCl mass fraction of the MD retentate stream on the heat duty of the system were analyzed. The operating condition with the minimum input energy for the current MDC design was determined, and the input energy is 1651.5 kJ/kg-H_2O. The process can be further optimized to tremendously reduce the required input energy when the heat stored in the evaporated vapor from the crystallizer is recovered.

Keyword: flat sheet AGMD; zero liquid discharge; desalination; evaporative crystallizer; MDC

1. Introduction

Water scarcity problem becomes severer in recent years as the world population increases. In order to meet the increasing requirement of fresh water, many water treatment strategies have been proposed, among which desalination method is increasingly popular and has drawn greater attention. The desalination plants operated worldwide produced 78.4 million cubic meters water per day by the year 2013, and the number continues increasing [1].

Sea water or salt water desalination is a process that separates the saline water into two streams: a fresh water stream with low salt content, and a concentrated brine stream. Currently, the most popular commercially used desalination approach is reverse osmosis (RO) modules which can produce high-quality potable water [2]. However, the concentrated brine stream emitted by the desalination method will adversely affect the ecosystem if it is discharged directly to the rivers, lakes, or oceans. Therefore, zero liquid discharge (ZLD) becomes essential to mitigate the negative influence of desalination on the environment. The ZLD method can be integrated with the existing desalination approach to establish a hybrid desalination technology.

Membrane distillation (MD) coupled with crystallization (MDC) process is an important ZLD method which has attracted the interest of many scholars and institutes [3–9]. Membrane distillation module is able to enrich the brine to a higher concentration than RO module. Hydrophobic porous membrane is the

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