Mechanical Engineering Doctoral Defense

Direct Solar-powered Membrane Distillation for Small-scale Desalination Applications

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Abstract

Water desalination has become one of the viable solutions to provide drinking water in regions with limited natural resources. This is particularly true in small communities in arid regions, which suffer from low rainfall, declining surface water and increasing salinity of groundwater. Yet, current desalination methods are difficult to be implemented in these areas due to their centralized large-scale design. In addition, these methods require intensive maintenance, and sometimes don't operate in high salinity feedwater. Membrane distillation (MD) is one technology that can potentially overcome these challenges and has received increasing attention in the last 15 years. The driving force of MD is the difference in vapor pressure across a microporous hydrophobic membrane. Compared to conventional membrane-based technologies, MD can treat high concentration feedwater, does not need intensive pretreatment, and has better fouling resistance. More importantly, MD operates at low feed temperatures and so it can utilize low–grade heat sources such as solar energy for its operation. While the integration of solar energy and MD was conventionally indirect (i.e. by having two separate systems: a solar collector and an MD module), recent efforts were focused on direct integration where the membrane itself is integrated within a solar collector aiming to have a more compact, standalone design suitable for small-scale applications. In this dissertation, a comprehensive review of these efforts is discussed in Chapter 2. Two novel direct solar-powered MD systems were proposed and investigated experimentally: firstly, a direct contact MD (DCMD) system was designed by placing capillary membranes within an evacuated-tube solar collector (ETC) (Chapter 3), and secondly, a submerged vacuum MD (S-VMD) system that uses circulation and aeration as agitation techniques was investigated (Chapter 4). A maximum water production per absorbing area of 0.96 kg m^{-2} h^{-1} and a thermal efficiency of 0.51 were achieved. A final study was conducted to investigate the effect of ultrasound in an S-VMD unit (Chapter 5), which significantly enhanced the permeate flux (up to 24%) and reduced the specific energy consumption (up to 14%). The results add substantially to our understanding of integrating ultrasound with different MD processes.

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Zoom Link: https://asu.zoom.us/j/84596772822