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Direct integration of a vacuum membrane distillation module within a solar collector for small-scale units adapted to seawater desalination in remote places: Design, modeling & evaluation of a flat-plate equipment

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Abstract

Aiming to design a small-scale compact seawater desalination unit for remote coastal areas or islands, an integrated module coupling vacuum membrane distillation (VMD) and a solar flat-plate collector (FPC) was modeled and studied in the present work, with an extensive description of simultaneous mass and heat transfer for the hybrid solar-VMD module. The VMD model was built both at the scale of the membrane (membrane pore model) and at the scale of the module (feed bulk longitudinal model), and was then coupled with a detailed solar energy model. Effects of various solar and VMD parameters on daily water production, energy consumption and gained output ratio (GOR) were analyzed through several series of simulations. Results showed that without condensation heat recovery, lower operating temperatures were more favorable where a daily water production of 8 $kg \cdot m^{-2}$ of the collector or the membrane area for domestic drinking could be obtained over a 12-hour operation. GOR was found to be above 0.7, which is quite comparable to simple-effect single-stage membrane distillation systems driven by indirect supplied heat. Further evaluations also revealed that the introduction of condensation heat recovery facility could markedly improve the daily water production up to 40 $kg \cdot m^{-2}$ for the same operation.

Abbreviations: AGMD, Air gap membrane distillation; CP, circulation pump; CPC, Compound parabolic collector; DCMD, Direct contact membrane distillation; ETC, Evacuated tube collector; FPC, Flat-plate collector; GOR, Gained output ratio; MD, Membrane distillation; SGMD, Sweeping gas membrane distillation; SGSP, Salinity gradient solar pond; VMD, Vacuum membrane distillation; VP, vacuum pump