UNIVERSITY OF FLORIDA

Clean Drinking Water using Advanced Solar Energy Technologies

PI: James Klausner

Students: Fadi Alnaimat/ Ph.D

Description: Water and energy scarcity poses a future threat to human activity and societal development around the world. The state of Florida is vulnerable to fresh water shortages. Florida ground water is contaminated in many locations from leaky underground tanks, agricultural pesticides, and other chemicals. Although it is possible to desalinate sea water, conventional systems are energy intensive. Solar energy utilization for desalination systems is being investigated to provide adequate fresh water for the state's needs. Solar diffusion driven desalination (DDD) system has been developed for both bulk water desalination and small community needs/disaster response. Solar DDD may be a competitive method for small scale seawater desalination.

Budget: $252,000
Universities: UF

Progress Summary

This work concerns the development of a cost effective, low power consumption, and low maintenance desalination process that is powered by solar energy. The solar diffusion driven desalination (DDD) process is most suitable for decentralized applications. While theoretical models have been developed to analyze the evaporation and condensation processes of the solar DDD under transient operating conditions (Alnaimat et al., 2011), experimental investigations have been conducted to validate the theoretical models. In this reporting period, the overall distillation performance of the solar DDD has been investigated under different design and operating conditions. The best operating modes have been proposed to improve the water production and reduce the specific energy consumption.

The solar DDD performance is primarily dependent on the solar heat input, saline and fresh water tank sizes, and evaporator and condenser inlet water temperatures and flow rates. A parametric study is conducted to examine the influence of these parameters under transient operating conditions. In the study, it is found that water production can be improved significantly by increasing the evaporator inlet water temperature. It is also found that increasing the evaporator inlet water temperature reduces the specific energy consumption. The evaporator water temperature is dependent on the solar heat input, saline water and air flow rates, initial saline water tank size and temperature, and the condenser inlet water temperature.

While the saline water storage tank enables the solar DDD system to operate in a re-circulating mode, the initial volume and temperature of the saline water tank impact the system performance. The study shows that small saline water tanks result in a small time delay for the system, which increases the evaporator inlet water temperature and water production rate. At the same time, small saline water tanks store lower thermal energy than larger saline water tanks, thus the fresh water production rate deteriorates more quickly when the solar flux is diminished or not active.

The study shows that decreasing the condenser inlet water temperature reduces the system water production efficiency. This is due to the fact that reducing the condenser inlet water temperature results in reducing the condenser exit air temperature. Since the air is re-circulated back to the evaporator, the evaporator air and water temperature reduction inhibits vapor production. The specific energy consumption can be minimized by running the system with a delayed operating time. This indicates that the system can be run without a cooling requirement. It is found that the solar DDD is best operated with the delayed operating time method. The electrical energy consumption can be reduced to 1.65 kWh/m^3, which is small compared to other small scale desalination processes. The system fresh water production rate is approximately 7.5 L per solar collector surface area per day. An economic cost analysis on a small scale solar DDD unit has been carried out, and it is revealed that the fresh water production cost of the solar DDD is on the order of $\$7/m^3$.

While fresh water production rate and specific energy consumption are essential to evaluate the performance of desalination processes, other factors such as simplicity, ease of operation, and low maintenance requirement are also important practical factors especially for decentralized desalination applications. It is believed that the solar DDD process, with its low power consumption and low maintenance requirement is a competitive desalination technology that is well suited for small scale and decentralized applications. Commercialization of the solar DDD process is being perused.

Alnaimat, F., Klausner, J.F., Mei, R., "Transient Analysis of Direct Contact Evaporation and Condensation Within Packed Beds," Int. J. Heat Mass Transfer, in press, 2011.