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Theoretical investigation of thermal performance of closed solar still

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ABSTRACT

Performance of a closed solar desalination pond, which is jointed to photovoltaic cell for producing sweet water from effluent saline water of the Mobin petrochemical complex, is studied in this paper. Also, capability of photovoltaic cells to generate electricity is reported due to insolation rate during a year. Highest and lowest amounts of fresh water are reported to present design parameters of solar pond capacity.

INTRODUCTION

Water resources cover about three-quarters of the earth's surfaces; just 3% of the whole resources are clean and potable water and among approximately, 1% of the whole resources are available[1, 2, 3]. So, water treatment is usually needed and desalination process is the most efficient for formation of drinking water from brackish and/or seawater, certainly[4]. However, desalination process is energy intensive, so the required capital, fixed and operational cost will be high if fossil fuel energy is used. Fortunately, in regions of greater potable and drinking water shortage like Middle East, renewable energies such as solar energy is more abundant during the year. So, solar desalination systems have been applied for many generations especially production of sweet water[5]. Solar ponds, solar still and photovoltaic powered reverse osmosis (PVRO) systems are two kinds of famous technologies based on solar energy to purify sea water and surface water and produce clean drinking water, respectively[6]. However, the costs and energy consumption in a PVRO system can be significantly increased by minimizing water production and maximizing the effects of membrane degradation to extend system life.

MATERIALS AND METHOD

Generally, the evaporation rate is defined as the amount of liquid evaporates per square meter per day. The properties of air such as moisture content and temperature, insolation rate and wind velocity affect on this rate. Distilled water is accumulated in side parts of the solar pond and is drained into collector vessels ultimately. The produced water is generally potable; the quality of the distillate is very high because all the salts, inorganic and organic components are left behind in the pond. Experiments show the average temperature of wastewater varies from 37.28°C to 68.96°C during a year while the annual ambient temperature is 12.5°C to 34.8°C, approxi-

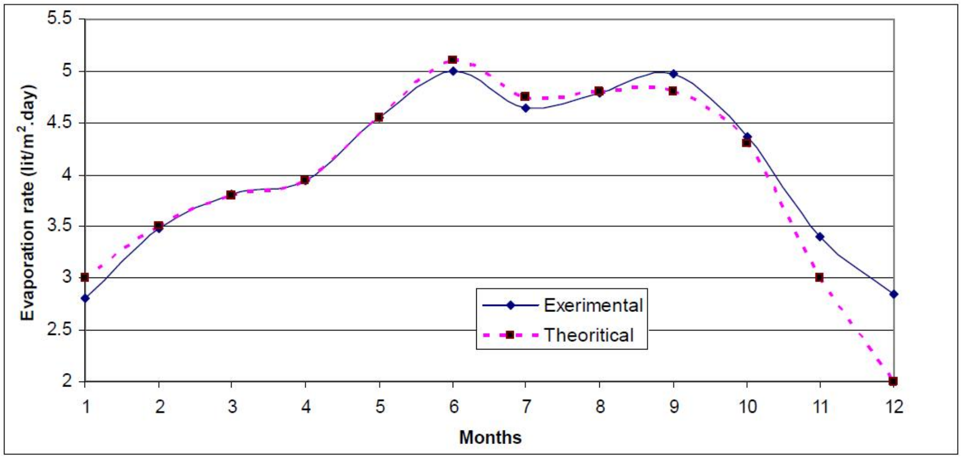

Figure 1 : The difference between experimental data and theoretical model

mately. The bottom layer in the solar pond, called the storage zone, is dense and is heated up more than surface layer. The ambient temperature changes from 12.5°C to 34.8°C. The experimental results indicate maximum amount of absorbed solar energy is on July since the temperature differences between ambient and average temperature of wastewater is 34.16°C. So, thermal efficiency of solar desalination pond may be improved on July comparing with the other months.

RESULTS AND DISCUSSION

The energy conservation equations are written for the absorber plate (base of solar desalination pond), brackish water and glass covers to find temperature profiles. Energy gained by the base of solar pond (from sun and convective heat transfer between brackish water and the base of solar pond) is calculated by equation 1. Brackish water in the solar pond receives energy from sun and base of solar pond which is equal to the summation of energy lost by convective heat transfer between brackish water and glass covers, evaporative heat transfer between brackish water and glass, irradiative heat transfer between brackish water and glass covers. So, energy gained by brackish water is written as equation 2:

Energy gained by glass covers (from sun and convective, irradiative and evaporative heat transfer from brackish water to glass covers) is equal to the summation of energy lost by irradiative heat transfer between glass covers and sky. So, energy gained by glass is written as equation 3.

$$I\alpha_{ba}A_{ba} - Q_{c,b-ba} - Q_{loss} = m_{ba}c_{ba}\left({dT_{ba}}/{dt}\right) \quad (1)$$

$$I\alpha_{b}A_{b} + Q_{c,b-ba} - Q_{c,b-g} - Q_{r,b-g} - Q_{e,b-g} = m_{b}c_{b}\left({dT_{b}}/{dt}\right) \quad (2)$$

$$I\alpha_{g}A_{g} + Q_{c,b-g} - Q_{r,g-s} - Q_{c,g-a} + Q_{r,b-g} + Q_{e,b-g} = m_{g}c_{g}\left({dT_{g}}/{dt}\right) \quad (3)$$

Finally, calculation for brackish water temperature and glass temperature conducts to the total condensation rate which is presented in equation 6.

$$dm_{c}/dt = h_{e,b-g}(T_{b} - T_{g})/h_{lv} \quad (4)$$

$$dm_{c}/dt = h_{e,b-g}(T_{b} - T_{ave})/h_{lv} \quad (5)$$

$$T_{ave} = 0.8T_{g} + 0.2T_{ba} \quad (6)$$

Amount of condensation rate shows the productivity of solar pond as a performance index of solar desalination pond, so calculated values are compared with experimental data in various salinities considering the amounts of solar flux during a day.

Figure 1 shows the difference between experimental and theoretical model to predict the evaporation rate.

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