Published in the Russian Federation
European Journal of Technology and Design
Has been issued since 2013.
ISSN: 2308-6505
E-ISSN: 2310-3450
Vol. 6, No. 4, pp. 164-168, 2014

DOI: 10.13187/ejtd.2014.6.164
www.ejournal4.com

UDC 69

Experimental Investigation of Thermal Performance of Closed Solar Still

[1] Farshad Farahbod
[2] Hasan Abedi

[1] Islamic Azad University, Firoozabad, Fars, Iran
Department of Chemical Engineering, Firoozabad Branch
E-mail: mf_fche@iauf.ac.ir
[2] Islamic Azad University, Lamerd, Fars, Iran
Department of Chemical Engineering, Lamerd Branch
E-mail: abedi.hasan63@gmail.com

Abstract

Performance of a closed solar desalination pond, which is jointed to photovoltaic cell for producing sweet water from effluent saline water of refinery industry, 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.

Keywords: Solar pond; insolation rate; Waste water; Potable water.

Introduction

Moreover several regions of the world including Iran are already encountering the problem of freshwater shortage [1 and 2]. Therefore, the transformation of seawater, saline ground water, polluted, and wastewater to fresh water has become indispensable [3 and 4]. These days, many new technologies such as desalination and water-treatment, which mostly based on fossil fuel consumption, are popular in the market [5]. However the problem of lack of fresh water can be solved by using these technologies especially desalination, but it face both unlimited amount of nonrenewable energy sources and the global warming of climate change. In addition electrical energy sources using coal, wood, gas and oil generate large amounts of pollution or carbon dioxide emissions, thereby posing health risks. Under these circumstances, alternate method for producing sweet water from effluent saline water and generating electricity from renewable energy sources for both using and saving must be explored. The desalination technique which is joined with Photovoltaic cells is the most promising technology which is introduced due to the growing global demand of potable water; on the other hand, environmental pollution from fossil fuels, lack of nonrenewable resources, wastewater and electricity neediness that is every day becoming more expensive and economical benefits from utilizing renewable energy resources such as solar energy [6 and 7]. Investigation and improvement in these issues will be useful and constructive to meet the continuously increasing appeal of freshwater in a cost-effectively sustainable way. It also can be helpful in mitigating global climate change (i.e. reduce carbon dioxide emission). Solar energy is one of the renewable energy sources, which is the most important supplier of energy for the earth and at the same time it is the most environmentally friendly, pollution-free, self-contained, reliable, quiet, long-term, maintenance-free, year-round continuous and unlimited operation at moderate costs form of all energies can be used for desalination [8 and 9]. It is really amazing to produce drinking water from effluent saline water and generating electricity from photovoltaic cells without burning any fossil fuels or producing fresh water from effluent wastewater instead of discharging wastewater into the sea, or desert, which is really harmful to the ecosystem, moreover polluting the atmosphere will be prevented seriously [10 and 11].

Materials and methods

1. Solar pond

The thickness of glass roofs and walls is 4 mm to enhance transmissivity coefficient. The net evaporation rate area of solar desalination pond is $1\,m^2$, facing south with an inclination of 35.7° (the latitude of Tehran City) to achieve the most solar radiation. Insolation rate is the amount of radiant energy from the Sun which impacts upon a unit surface area. This depends upon the angle of the Sun with respect to the vertical over the surface. According to the literatures the maximum amount of insolation rate is received when the inclination of the glass roof equals to the latitude of area. So, the inclination of glass roof for this experiment is chosen 35.7° with respect to the latitude of Tehran City. Also, the surface of solar pond bottom is dyed black. The solar pond area consists of 3 parts which are separated by means of 2 long rectangles. The middle part is filled with the concentrated brine waste water and its level is 10 cm. This set up is located on a table about 70 cm higher than the ground. The thickness of table is 4 cm and acts as an insulating layer to storage solar energy in waste water. The space between the table and base of solar desalination pond is filled with sawdust for insulation purpose. So, the maximum amount of solar insolation rate is absorbed in these conditions. The feed is conveyed into the pond through a 2 cm diameter hole, the distillate is collected into a vessel and concentrated brine waste water is drained through another 2 cm diameter hole.

2. Methods

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, approximately. 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. The average temperature of wastewater is 38.4°C, 60.1°C, 65.1°C and 44.92°C in winter, spring, summer and autumn, respectively. Density of layers of waste water is illustrated in Figure 1.

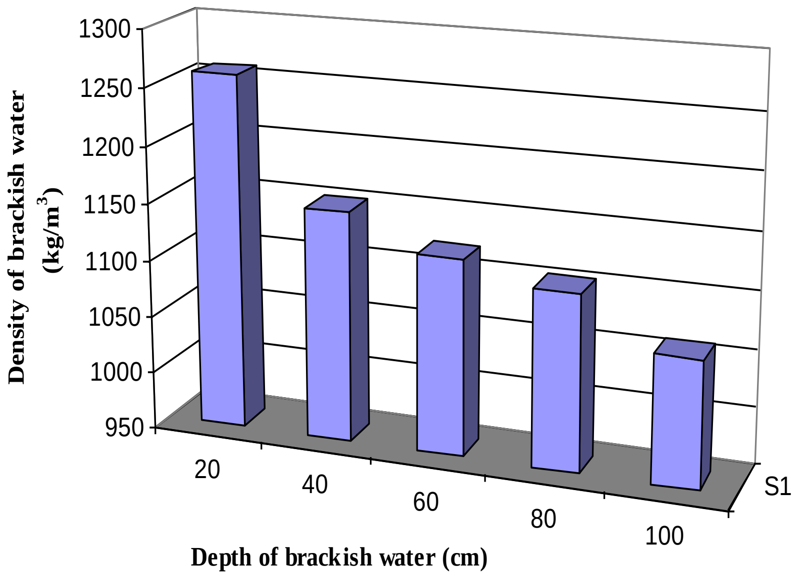

Figure 1. Density of wastewater through the depth.

The increase in the salt concentration increases the density of wastewater. The density of concentrated brine wastewater at the bottom of solar desalination pond reaches to 1260 kg/m^3. The higher concentration decreases the thermal conductivity of wastewater and increases the thermal resistance of lower layers. Floor plate adsorbs irradiation and increases temperature of the adjacent layer of wastewater but higher thermal resistance of the layer decreases the rate of heat transfer to the upper layers. So, the highest thermal energy is saved in this region of solar desalination pond. Experiments show the density of wastewater reduces sharply to 40 cm depth and then has slight reduction to 20 cm. The density reaches 1061 kg/m^3 at the surface of concentrated wastewater.

Figure 2 shows the insolation rate versus hours in 30 June 2013.

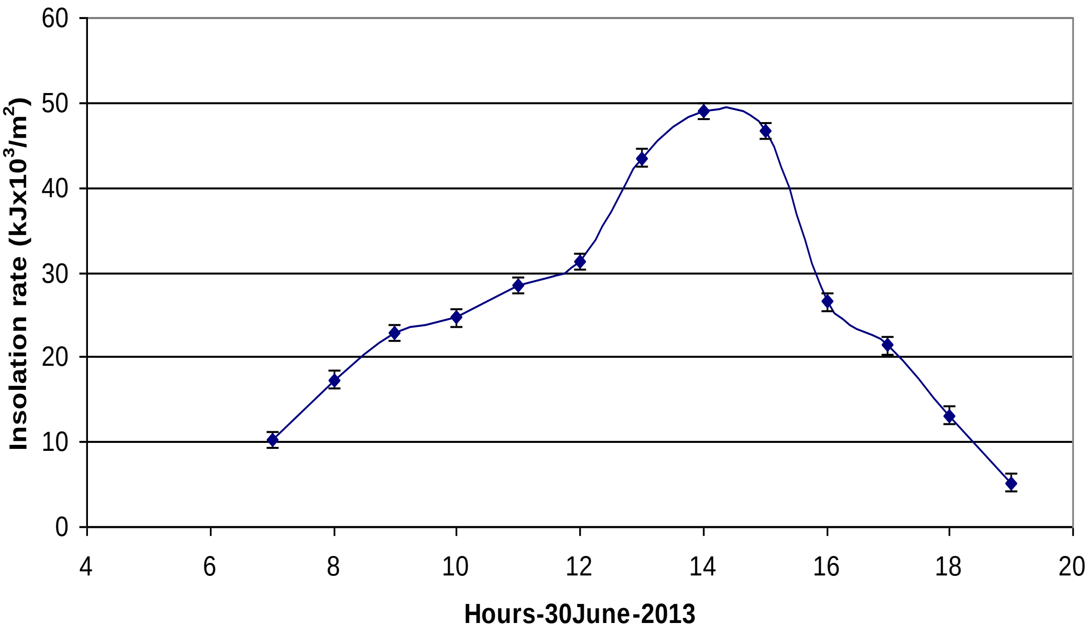

Figure 2. The average temperature of wasterwater in solar pond in 30 June 2013.

The maximum and minimum insolation rate is occurred on 14 and 19 o'clock, respectively.

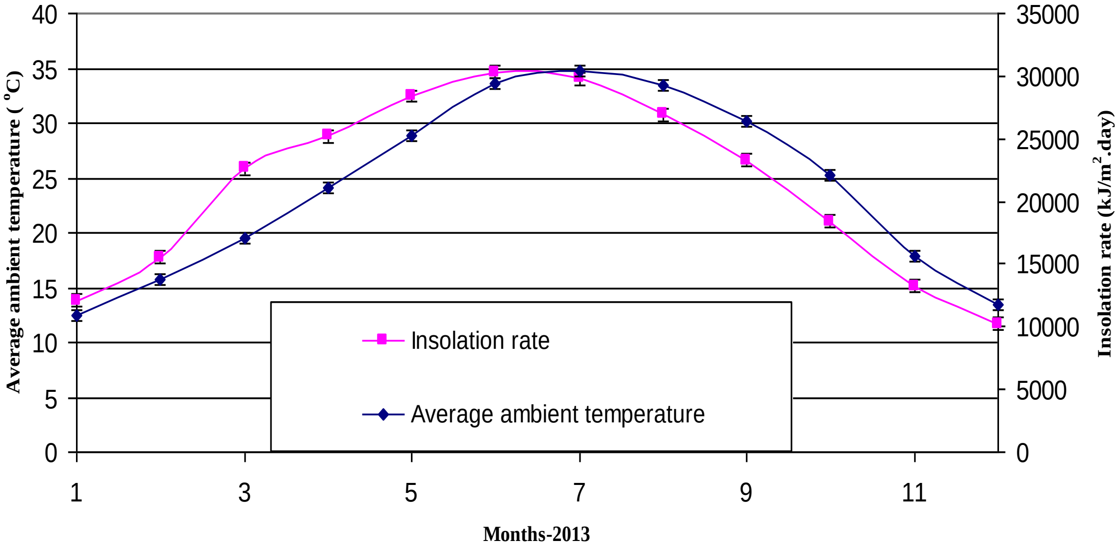

Figure 3. Evaluation of average ambient temperature and insolation rate versus different months of 2013.

Amounts of insolation rate versus average ambient temperature in each month are shown in Figure 3. According to the experimental results the maximum value of average ambient temperature is seen on July and also maximum amount of insolation rate is seen on June, in spring. During summer maximum insolation rate and average ambient temperature is on July.

October and March show higher insolation rate during autumn and winter, respectively. Also, the maximum values of average ambient temperatures are obtained on October and March.

Conclusion

The effect of using solar cell in performance of one solar desalination pond is investigated experimentally in this research. Application of solar energy in fresh water production and also electricity generation from wastewater of desalination unit in one refinery industry is considered during a year. Insolation rate, ambient temperature, average temperature of wastewater, density of wastewater in pond, amount of produced water, electrical energy is produced.

References:

1. Farshad Farahbod, Dariush Mowla, M. R. Jafari Nasr, Mohammad Soltanieh, 2013, Experimental study of a solar desalination pond as second stage in proposed zero discharge desalination process, Sol. Energy, 97, 138–146.

2. El-Sadek, A., 2010. Water desalination: An imperative measure for water security in Egypt. Desalination. 250, 876–884.

3. Farahbod, F., Mowla, D., Jafari Nasr, M. R., Soltanieh, M., 2012. Experimental study of forced circulation evaporator in zero discharge desalination process. Desalination. 285, 352-358.

4. Garmana M. A., Muntasser M.A., 2008. Sizing and thermal study of salinity gradient solar ponds connecting with the MED desalination unit. Desalination. 222, 689–695.

5. Giesta, M. C., Pina, H. L., Milhazes, J. P., Tavares, C., 2009. Solar pond modeling with density and viscosity dependent on temperature and salinity. Int. J. Heat Mass Transfer. 52, 2849–2857.

6. Mittelman, G., Kribus, A., Mouchtar, O., Dayan, A., 2009. Water desalination with concentrating photovoltaic/thermal (CPVT) systems. Sol. Energy. 83, 1322-1334.

7. Farahbod, F., Mowla, D., Jafari Nasr, M.R., Soltanieh, M., 2012. Investigation of Solar Desalination Pond Performance Experimentally and Mathematically, J. Energy Resour. Technol., 134, 041201.

8. Karakilcik, M., Kıyma, K., Dincer, I., 2006. Experimental and theoretical temperature distributions in a solar pond. Int. J. Heat Mass Transfer. 49, 825–835.

9. Roca, L., Berenguel, M., Yebra L., Alarcón-Padilla, D.C., 2008. Solar field control for desalination plants. Sol. Energy. 82, 727-786.

10. Alarcón-Padilla, D. C., García-Rodríguez, L., Blanco-Gálvez, J., 2010. Design recommendations for a multi-effect distillation plant connected to a double-effect absorption heat pump: A solar desalination case study. Desalination. 262, 11–14.

11. Caruso, G., Naviglio, A., Principi, P., Ruffmi, E., 2001. High-energy efficiency desalination project using a full titanium desalination unit and a solar pond as the heat supply. Desalination 136, 199-212.