Productivity and Efficiency of Modified Solar Still Using Convex Lenses on the Glass Cover and Radiating Surfaces Inside

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Abstract

There is a problem of potable water shortage in many parts of the world nowadays. For many developing countries, desalination using solar energy is the solution to overcome this issue. This paper investigates the performance of a solar still using the convex lenses on the glass cover, and radiating surfaces below the lens to increase the solar radiation inside the solar still. The results of this investigation indicate that using of a convex lens and radiating surfaces can significantly increase the daily productivity and the efficiency of the single basin solar still. Experiments were carried out during March 29 to June 6, 2016, at Sabratha Engineering College, Libya. The amount of distilled water was measured starting from 10 A.M to 4 P.M each day. The results showed that the maximum daily productivity and efficiency of the new still with a convex lens and radiating surfaces was 2.248 L/day and 63.64% respectively at 4:00 PM on May 26, 2016.

Keywords: Solar still; productivity; solar radiation; convex lens

1. Introduction

The drinking water shortage is one of the biggest problems in developing countries. It is known that the fresh water represents only 3% of water on the earth. Only 1% is available for human use, and the rest is polar ice[1]. Nowadays the industrial effluents and sewage disposal resulted in pollution in rivers and lakes which led to a scarcity of fresh water in many big cities around the world. Sea water is the only available source for a large amount of water, but it contains high salinity, so it needs to desalination. Desalination methods use a large amount of energy to remove a portion of pure water from a salt-water source. Solar stills are widely used in solar desalination. The single-slope solar still is the most popular due to its simple design, lower cost, better performance, and easy in operational and constructional procedures when compared to other types of solar stills but has low pro-ductivity per unit area. Different experimental and theoretical investigations were conducted by many researchers on the single basin solar still to increase the productivity[2], [3]. During last decades, many researchers around the world presented a lot of mathematical modeling, theoretical analysis, and computer simulation of different designs of solar stills in some articles[4]–[6]. They also tested a number of designs and modifications to the conventional solar still. Many researchers studied the design and operational factors affecting the solar still productivity such as glass cover cooling[7], glass cover inclination[8], basin insulation, basin water depth[9], [10], and absorbing materials[11], [12]. Other researchers studied the effect of local factors such as solar radiation[13], ambient temperature[14], wind velocity[15], on the productivity of the solar still. To increase the heat transfer rate inside the solar still, many researchers used fins for[16],[17]. Adding fins in the basin of a conventional single basin still

accuracy of 3% is used for measurement of solar irradiance manually every 15 minutes. The distilled water is collected and measured on an hourly basis using a calibrated flask provided below the basin. The wind velocity is measured by using anemometer TM-401 with an accuracy of ± 0.1 m/s.

Figure 2.1: Modified solar still with radiating surface and convex lenses on the cover glass

Figure 2.2: Modified solar still with Radiating Surfaces inside the basin

3. Results and Discussion

The variation of the solar radiation (I) , the ambient temperature (T_{amb}) , the basin temperature at upper side (T_{bu}) , the basin temperature at lower side (T_{bl}) , the upper glass temperature (T_{gu}) , the Lower glass temperature (T_{gl}) , the brine inlet temperature (T_{win}), the brine outlet temperature (T_{wou}) , the temperature of the radiating surface (T_{rsur}) and the Temperature of the vapor inside the still (T_{vap}) on 4th of June 2016 are shown in Figure (3.1) It is noticed that all temperatures increase as the time increase till they reach their maximum values at noon, then they start to decrease after that. The reason is that solar radiation intensity increases in the morning, and its reaches its

maximum value at the noon, then it starts to decrease by the afternoon, and it is dependent on the wind velocity. The variation of ambient temperature is between 26–29 °C and solar radiation received during the study is between 708–998 W/m². The convex lenses concentrate the solar radiation at their focii on the surface of the radiating plate, and this increases the water temperature and decreases the glass cover temperature. Thus the temperature difference between the water and glass increases.
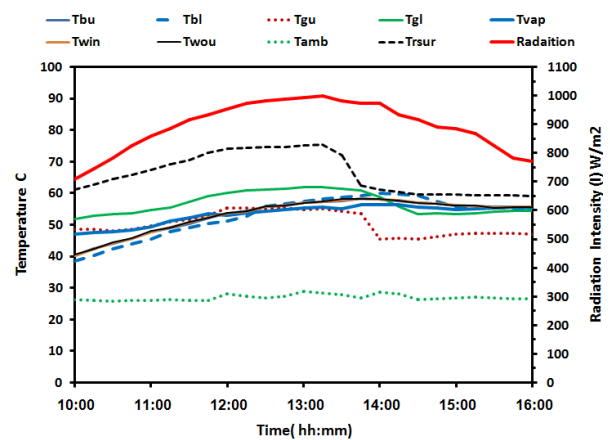
Figure 3.1: Hourly variation of the solar radiation and temperature of the modified solar still on June 4, 2016

The productivity of the modified solar stills on an accumulative hourly basis for different days is presented in Figure (3.2). The results showed that the productivity of the modified still with lenses and radiating surface starts from zero in the morning when the experiment is started, then it increases gradually as the solar radiation starts to increase. This increase in the solar radiation results to increase in the water evaporation and condensation due to the temperature difference between the water the glass cover. The results indicated that the highest daily productivity for modified and conventional solar stills is 2.228 L/day and 2.216 L/day on 24th and 26th of June 2016 respectively. The efficiency of the modified solar stills on an hourly basis for different days is shown in Figure (4.1). The hourly and daily efficiency are calculated from the following relation:

$$\eta_h = \frac{M_{w,h} * L_{w,av}/3600}{(A_b * I + P_{pump})} \qquad (3.1)$$

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$$\eta_d = \frac{M_{w,d} * L_{w,av}/3600}{\sum_{1}^{n} (A_b * I + P_{pump})} \qquad (3.2)$$

Where

(η_h) and (η_d) are the hourly and the daily efficiency respectively.

$(M_{w,h})$ and $(M_{w,d})$ are the hourly and the daily productivity respectively in (kg/hr).

(A_b) is the basin area $(1.0m^2)$.

(P_{pump}) is the power of pump in (W).

(I) is the incident solar radiation on the horizontal surface in (W/m^2).

(n) is the number of effective running hours.

$(L_{w,av})$ is the average of the latent heat of vaporization of water in (J/kg).

$(L_{w,av})$ depends on the Basin water temperature (T_w) by the following correlation:

$$L_{w,av} = 10^3 * (2501.9 - 2.40706T_w +$$

$$1.192217T_w^2 - 1.5863 * 10^{-5}T_w) \qquad (3.3)$$

It is noticed that the efficiency of the modified solar still depends mainly on the productivity which depends on the solar radiation and the convex lens and the radiation surfaces. The highest value obtained for the efficiency is 63.64% on 26th June 2016.
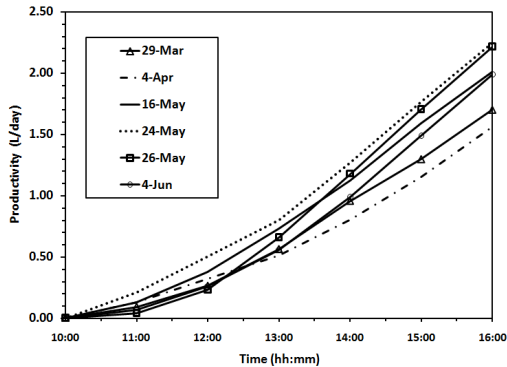

Figure 3.2: The productivity of the modified solar stills on hourly basis for different days

4. Conclusion

In the present study, the performance of the modified solar still using lenses and the radiating surface is investigated experimentally. The performance is expressed in terms of the maximum productivity and efficiency gained during the experiment time. Based on the obtained results, the following conclusions can be drawn:

1. The highest productivity of the modified still with a convex lens and radiating surface is 2.248 L/day at mass water 20 kg.

2. The maximum efficiency of the modified still with a convex lens and radiating surface is 63.64% at mass water 20 kg.
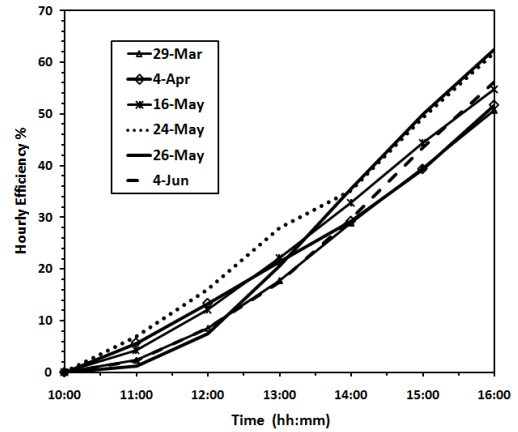
Figure 4.1: The efficiency of the modified solar stills on hourly basis for different days

Acknowledgment

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