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Abstract

An attempt has been made for improving the performance of single basin passive solar still through double glazing effect in this study. Two sets of experiments (without double glazing and with double glazing) have been conducted to investigate the effect of double glazing on the performance of the still. Each experiment has been conducted for three clear sky days. The similar trend of solar intensity has been noted in the experiment days. It has been noticed that the solar still with double glazing has utilized the higher amount of solar radiation during the day, which increased the overall fresh water yield from 2.5-3 L and overall thermal efficiency from 25-31.7%. By means of double glazing effect, the overall yield and thermal efficiency of the solar still were improved by 20% and 26% respectively compared to the solar still without double glazing.

Keywords: Single basin solar still, solar intensity, double glazing, yield, thermal efficiency.

Introduction

The decrease of rainfall and the increase of population create water scarcity in many countries. There exists a worldwide imbalance between supply and demand of fresh water. To manage the demand of fresh water, many seashore countries make use of desalination techniques such as multi-effect evaporation, multi-stage flashing, reverse osmosis and electro dialysis. Most of the desalination plants make use of hydrocarbon fuels to drive these techniques which result in negative impact on the environment (Tabrizi and Sharak, 2010; Kabeel and El-Agouz, 2011). The distillation using solar energy is an environment friendly and simple technique compared to other desalination techniques (Kalogirou, 1997). It is quite suitable at the places where solar energy is abundant. When seawater or brackish water is kept in the basin of the still under the open sky, it gets evaporated. The process of evaporation is accelerated by means of solar energy. The solar still captures the evaporated water vapour and condenses it on the glass surface (Samee et al., 2007; Sakthivel and Shanmugasundaram, 2008). There are two types of solar stills i.e. passive solar stills and active solar stills. Passive solar still requires solar energy for the evaporation of seawater whereas active solar still requires an external thermal energy for higher rate of evaporation. The passive solar still is simple in design, easy to handle, long life and low production cost (Tiwari, 1987). It is available in different configurations like basin type, wick type, tubular type, spherical type, parabolic type, cascade, staircase, etc. Out of them, basin type solar stills are extensively used for domestic purposes in the arid and semi-arid regions due to the economic advantages like low investment cost, low maintenance cost and low production cost (Abdallah et al., 2009; Sakthivel et al., 2010; Murugavel and Srithar, 2011).

The design parameters (energy storage medium, condensing cover, cover slope, water depth, insulation thickness, geographical position of the still, etc.) and the ambient parameters (solar intensity, ambient temperature, wind velocity, etc.) affect the performance of the solar still (Khalifa and Hamood, 2009). Generally, the productivity of solar still is quite low. However, it can be improved with the energy storage medium, double glazing effect, sun tracking system etc. Double glazing is a glazing process in which a solar still is covered with two panes of condensing glass with a space between them. It offers more insulation to heat reflection from the water surface in the still basin to the atmosphere. Since the effect of double glazing leads to the reduction of heat loss, the performance of the solar still can be significantly improved. Considering the above facts in view, the objective of this study is to improve the performance of single basin passive solar still through double glazing effect.

Materials and methods

Experimental setup: The solar still was fabricated with single basin made up of 5 mm thick fiber glass material. The basin was covered with two plastic covers (glazing of area 80%). The joints of the still were tightly sealed with silica gel to make the basin as closed container. The provisions were made for the supply of seawater into the basin, collection of fresh water from the still and cleaning of the salt concentrated seawater from the basin. The basin was supported over a mild steel frame and was insulated with polyurethane foam to reduce the heat loss from the basin. The inner side of the basin was painted black to absorb more heat during sun radiation. The specifications of the solar still are given in Table 1.
First set of experiments was started on 13\textsuperscript{th} April 2014 and completed on 17\textsuperscript{th} April 2014. The solar intensity was recorded for 1 h interval. The fresh water yield was measured on hourly basis. Every day, the salts and other contaminants left in the seawater were flushed out and basin was filled with 50 L of fresh seawater before starting the next experiment. The experiments were repeated on second and third day under the same experimental condition. With the presence of double glazing, the second set of experiments was started on 19\textsuperscript{th} April 2014 and completed on 23\textsuperscript{rd} April 2014. The solar intensity was recorded for every 1 h interval. The fresh water yield was measured on hourly basis. The end of each day, the concentrated salt and other contaminants in the seawater were cleaned and fresh seawater of 50 L was filled into the basin before starting of next experiment. The performance of the solar still was estimated based on the measured solar intensity and yield.

The performance of a solar still is generally determined by its overall fresh water yield and thermal efficiency. The yield of a solar still indicates the amount of water produced by the still. The fresh water yield of the solar still is measured with a measuring jar on hourly basis. The daily yield is calculated by summing up the hourly yield of the particular day. Then, the overall yield is calculated by averaging daily yield of all experiment days. The overall thermal efficiency ($\eta_o$) of a solar still indicates the solar energy utilized for making the fresh water during a particular time interval. It is estimated from the ratio of the amount of energy used for the production of fresh water and the average solar intensity received in a day. It depends upon solar intensity ($I$), basin area ($A_b$), latent heat of water evaporation ($H_L$) and production rate of fresh water ($m_w$).

$$\eta_o = \frac{m_wH_L}{IA_b} \times 100$$  \hfill (1)

Where, $H_L$ is 2257 kJ/kg.

\textbf{Results and discussion}

The solar intensity observed in the first set of experiment days and second set of experiment days are shown in Fig. 2 and 3 respectively. It was observed that the radiation from the sun increased continuously from 6:00 a.m. and reached the maximum about mid of the day. Then, the solar radiation started to decrease and the trend continued up to the sunset. Almost the same trend was observed in the 6 experiment days. Figure 4 shows the hourly yield of the solar still with the absence of double glazing. The hourly yield measured for the 3 d was noted to be a similar pattern of increasing and decreasing depending upon the amount of solar intensity. It was observed that the hourly yield increased as the solar intensity increased during the day. The solar intensity reached its maximum about mid of the day but the yield reached its maximum about 2.00 p.m.

<table>
<thead>
<tr>
<th>Geometrical parameter</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the basin</td>
<td>1 m</td>
</tr>
<tr>
<td>Width of the basin</td>
<td>1 m</td>
</tr>
<tr>
<td>Thickness of glass cover</td>
<td>5 mm</td>
</tr>
<tr>
<td>Glass cover area</td>
<td>0.8 m$^2$</td>
</tr>
<tr>
<td>Inclination of glass cover</td>
<td>22$^\circ$</td>
</tr>
<tr>
<td>Insulation thickness</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

Table 1. Specifications of the solar still.

The experimental setup used for the conduct of experiments in this study is shown in Fig. 1. The basin of solar still was filled with fresh seawater to the depth of 50 mm and 25 kg Omani rock stone bed. When the still was placed under the sun radiation, the incident solar radiation was transmitted through the condensing glass cover. The seawater was thus heated and water was evaporated. The water vapour was condensed on the glass covers and the condensate (fresh water) was collected in a storage container. The fresh water yield was measured using a measuring jar with an accuracy of 10 mL. The solar intensity was measured with a TES133 pyranometer with an accuracy of ± 1W/m$^2$. The experiments were conducted in Muscat, Oman (Latitude 23.617/Longitude 58.583). The experiment was started on first day 6:00 a.m. and completed on next day 6:00 a.m. The solar still was placed with the tilted glass facing the sun (facing south) during the conduct of experiments. Two sets of experiments were conducted in this study. First set of experiments were conducted using the experimental setup with the absence of double glazing for three consecutive days. Second set experiments were conducted using the same experimental setup with the presence of double glazing for another three consecutive days.
It was due to the time lag between the energy supplied for vaporization and condensate collected. During the time from 1.00 p.m. to 2.00 p.m., the reduced solar intensity increased the temperature difference between the seawater and glass cover and resulted in more condensation of water vapour. During evening and night (non-sunshine period) hours also, water production was continued because of the energy stored in the seawater and the stone bed, but the rate of production was very minimal compared to the sunshine period.

Figure 5 shows the variation of yield of solar still with the presence of double glazing. The energy stored in the stone bed was given to the seawater during late evening hours, which increased the yield of the still. There was a steep increase in yield of the still till 12.00 p.m. and there was a steep decrease in yield of the still after 2.00 p.m. The increase and decrease in the yield of the still exactly followed the variation of solar intensity during that period. It was observed that hourly yield was increased during the time from 11.00 a.m. to 12.00 p.m. and reached maximum at 2.00 p.m. As the solar intensity received by the still was increased, the yield was also increased.

The increase of the yield was due to the reduction of energy loss from the still to the atmosphere through the condensing glass covers. Figure 6 shows the average fresh water collection for both cases. During the morning hours, the hourly yields were increased due to increase in solar intensity received by the still and started to decrease in the afternoon and evening hours. In the night time, average yield was very small compared to morning hours 10 a.m. to 12 p.m. The still was making the water throughout the day, even during night hours because of the energy released by the water and the stone bed. It was observed that the solar still with double glazing produced more fresh water compared to the conventional still (without double glazing) throughout the day. The increase of the yield was due to the reduction of energy loss to the atmosphere through the condensing glass covers. Figure 7 shows the daily yield of solar still and Fig. 8 shows the overall yield obtained in the day time and night time for both cases. It was noted that the overall yield was more during day time due to the direct utilization of the maximum available solar energy in the day time. In the night time, the fresh water was formed due to the heat stored in the water and stone bed.
The day time and night time yield were noted to be high in the case of solar still with double glazing, because more heat energy from solar radiation was utilized for making the fresh water. The overall thermal efficiency of the still was calculated based on the average yield using the Eqn. 1. Figure 9 shows the overall thermal efficiency of the solar still. The efficiency of the still with double glazing was noted to be 31.7% whereas the efficiency of the still without double glazing was noted to be 25%. The efficiency of the solar still was improved by 26% by means of double glazing. The increase of overall efficiency was due to reduction of energy loss by the still and larger temperature difference maintained between the basin seawater surface and inner surface of the condensing glass covers.

**Conclusion**

The performance of single basin passive solar still was improved through double glazing effect in this study. The solar still with double glazing utilized the higher amount of solar radiation during the day and increased the fresh water yield from 2.5 to 3 L/day and thermal efficiency from 25 to 31.7%. By means of double glazing effect, the overall yield and overall thermal efficiency of the solar still were improved by 20% and 26% respectively in comparison with the conventional solar still.

**References**