Energy Analysis of Passive Solar Distillation Unit

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

ABSTRACT

The energy analysis of a passive solar distillation unit was the focus of this study. A 40-liter solar distillation plant was constructed and adjusted for the intended output of 5 liters of distilled water. The developed unit's performance was monitored from 8 a.m. to 5 p.m. Even so, the solar produced 4.5 liters of fresh water per m² each day. According to the solar still's updraft assessment, the maximum daily energy efficiency was found to be 38.27 percent.

Keywords: Passive solar still; solar desalination; distilled water; energy efficiency.

1. INTRODUCTION

Water is an extremely important component for the survival of humans and other living creatures. In both urban and rural locations, safe water is crucial for human civilization. Because of a lack of adequate drinking water, billions of people are suffering from health problems. As a result, there is a compelling need to develop powerful, viable techniques for providing safe water at a cheap cost [1].

With the growth of the global population and the rise of industry, the need for freshwater production is growing. To accommodate this need, desalination technology is becoming more widely used. Solar energy is the most low-maintenance and cost-effective desalination technology; nevertheless, its output is restricted [2-4]. This page aims to give a comprehensive overview of the numerous varieties of solar stills, including passive and active designs, single and multi-effect types, and
various performance enhancements. Capacity [5].

Solar energy is extremely cost-effective when compared to other forms of energy generation. They're also highly versatile and may be used in a variety of ways [6-9]. The solar power system's maintenance costs are similarly minimal. The primary downside is that they are susceptible to weather interference, necessitating the need for an energy storage device, which would raise the overall cost of technology [10].

Water is a chemical substance that is used in a variety of applications including residential, industrial, and agricultural. The most crucial factor in determining and driving economics is clean water. Drinking water is still a major issue in deserts and rural areas of both developed and developing countries around the world. It is estimated that 97 percent of the water in the ocean is saline [11].

Ahmed et al. [12] In the Gulf state environment, he created a solar still system that harnesses solar energy to produce drinking water from the sea. The efficiency of a solar still with a cooling tube was found to be around 4% lower than that of a solar still without a cooling tube. According to Samee et al. [13]. The straightforward basin type solar still produced has a 30 percent efficiency and daily productivity of 3.1 lit/m2. For solar stills, experts have investigated a variety of designs, technologies, and operation parameters to improve their effectiveness in a variety of meteorological conditions.

Different types of solar stills are described by Kaushal et al. [14] for producing potable water from brackish or saline water. The still efficiency might be raised by 20% by adding cooling film properties, according to the theory. The volume of distillate water from the still can be increased by nearly 14% by using a reflector instead of a cooling film.

Eltawil, M.A. [15] discovered that the output of the still is proportional to the amount of solar radiation reaching it and the ambient temperature.

Alwan et al. [16] The amount of water vapour that condenses on the aluminum plate is the biggest (about 46%), while the rest condenses on the glass plate. This indicates that the spontaneous flow of moist air (free convection) through the aluminum sheet has effectively increased productivity (its surface temperature is lower than that of the glass).

A thermodynamic analysis is required for accuracy in any solar energy system [17]. The thermodynamic analysis is used by engineers to determine how energy affects the performance of thermal and mechanical systems [18].

The major purpose of the solar distillation process is to maximize the amount of distilled water produced while using available solar energy and reducing heat losses in the system [19]. Hence a study is conducted to evaluate the energy efficiency of a passive solar distillation unit in the southern part of Rajasthan.

2. MATERIALS AND METHODS

In April 2021, the Department of Renewable Energy Engineering, College of Technology and Engineering, Udaipur, evaluated the performance of a designed Passive solar distillation unit. The studies were carried out between the hours of 8:00 a.m. and 5:00 p.m. Table 1 shows the details of the developed solar distillation system.

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Particular</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absorber area of the basin, m²</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>Basin area, m²</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>Area of the glass cover, m²</td>
<td>1.16071</td>
</tr>
<tr>
<td>4</td>
<td>Insulation thickness, m</td>
<td>0.025</td>
</tr>
<tr>
<td>5</td>
<td>The angle of inclination of the glass</td>
<td>30°</td>
</tr>
<tr>
<td>6</td>
<td>Width of the basin, m</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>The thickness of glass cover, m</td>
<td>0.005</td>
</tr>
<tr>
<td>8</td>
<td>Dimensions of gunny bag, m</td>
<td>1.12 ×0.68</td>
</tr>
<tr>
<td>9</td>
<td>Total absorber area, m²</td>
<td>1.32</td>
</tr>
</tbody>
</table>

Gunny bags were placed on the basin's surface to enhance the surface area, which aids in the evaporation of water. The solar distillation unit was poured with 4.55 liters of water every day (Fig. 1) to determine the unit's energy efficiency using equation 1. [20].
Fig. 1. Developed Passive solar distillation unit

\[ \eta_{\text{energy}} = \frac{q_{\text{ev}} \times A_b}{I_{sb} A_b + I_{sc} A_{etc}} \]  

(1)

Where,

- \( A_b \) = Absorber area of the basin, m²
- \( A_{etc} \) = Absorber area of evacuated tube collector, m²
- \( I_{sb}, I_{sc} \) = Insolation on the sloping surface of solar still and solar collector, W/m²

3. RESULT AND DISCUSSION

The experiment was carried out at Udaipur's College of Technology and Engineering's Department of Renewable Energy Engineering. At a height of 582.5m above mean sea level, the data analysis area is located at 24° 38' N latitude and 73° 43' E longitude. Several tests were carried out to determine the energy efficiency of passive solar still. During the experiment period, the energy efficiency was found to range from 2% to 38%, as shown in Table.2 and Fig. 2 to Fig. 5. The evolved solar still had a 22 percent average energy efficiency. On April 1, 2021, the maximum energy efficiency of the passive still was found to be 38.27 percent, as illustrated in Fig. 2. During the experiment, a wind speed of 5-8 km/h was recorded.

Fig. 2. Hourly variation of the energy efficiency on 1st April 2021
Fig. 3. Hourly variation of the energy efficiency on 5th April 2021

Fig. 4. Hourly variation of the energy efficiency on 6th April 2021

Fig. 5. Hourly variation of the energy efficiency on 7th April 2021
Table 2. Variation in the energy efficiency of passive solar still unit

<table>
<thead>
<tr>
<th>Date</th>
<th>Energy efficiency</th>
<th>Distilled water at 2 p.m. (ml)</th>
<th>Cumulative distilled water (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st April 2021</td>
<td>38.27, 2.48</td>
<td>980</td>
<td>4540</td>
</tr>
<tr>
<td>5th April 2021</td>
<td>35.99, 5.06</td>
<td>920</td>
<td>4798</td>
</tr>
<tr>
<td>6th April 2021</td>
<td>36.76, 5.97</td>
<td>960</td>
<td>4380</td>
</tr>
<tr>
<td>7th April 2021</td>
<td>37.72, 7.35</td>
<td>960</td>
<td>4400</td>
</tr>
</tbody>
</table>

Fig. 6. Hourly variation of the distilled output and solar insolation on 1st April 2021

Fig. 7. Hourly variation of the distilled output and solar insolation on 5th April 2021

The results of the experiment revealed that water temperature rises with sun energy and peaks around 2 p.m. It then begins to lose warmth and output. Temperature fluctuation follows a similar pattern by Barden et al. (2007) and Abdenaces et al. (2007).
The temperature of glass from inside and outside is found the same which indicates negligible energy absorbance of glass [21]. The temperature of the glass was found to be lower than that of the water, causing vapor condensation on the inside surface of the glass. Hourly measurements of daily generated distilled water were taken, and a relationship between sun radiation is shown in Figs. 6 to 9.

Due to weaker sun radiation, the output of the passive solar distillation unit was lower in the morning early hours. The largest discharge of freshwater was noted between the hours of 1 and 2 p.m. The output of passive solar still has a direct link with sun insolation, as evidenced by Ahmed, H. M.’s findings [12].

4. CONCLUSION

Parametric research was carried out to determine the impacts of solar radiation on the production of distilled water at given parameters such as saline water depth, insulation thickness, and glass cover angle of inclination. The highest instantaneous total energy efficiency and yield were found to be 38.27 percent and 5.44 L, respectively [22]. For test-1, test-2, test-3, and test-4, the total production of the still were determined to be 4.54, 4.79, 4.38, and 4.4 l/m2/day, respectively. The solar distillation
process, on the other hand, is one of the most basic and extensively used methods for transforming salt water or water into distilled water. Low operating and maintenance expenses, plenty of sunshine, and all-day operation.

COMPETING INTERESTS
Authors have declared that no competing interests exist.

REFERENCES

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/83035