Original Research Article

ENERGY ANALYSIS OF PASSIVE SOLAR DISTILLATION UNIT

Abstract

The present research involved the energy and exergy analysis of a passive solar distillation unit. A developed unit of solar distillation of 40 litres of holding capacity was optimized for desired output of 5 litres of distilled water. Performance of the developed unit was observed during 8AM to 5PM. The solar still produced 4.5 litres of freshwater per day per m^2 *in 0.01 m depth of the basin. According to the thermal evaluation of the solar still, the maximum daily energy efficiency was found 38.27%.*

Key words: *Passive solar still, Solar desalination, Distilled Water, Energy efficiency*

Introduction

The sun is the great wellspring of energy. Being a tropical country, India is honored with a lot of daylight. The normal clear radiant days are nearer to 300 days a year with sun light of 8 hours per day. The normal sun-oriented radiation fluctuates between 4-7 kWh per square meter each day in various pieces of the country. From this load of computations, India has an expected capability of around 900 GW for sustainable power and 750 GW for sun-oriented force (Kaushal A, 2010).

Water is a chemical substance that is used in home, industrial, and agricultural applications. Clean water is the most important aspect in determining and driving economics. Fresh water for drinking is still a serious concern in desert, remote places in both developed and developing countries around the world. In the ocean, it is estimated that 97 percent of the water is saline (Ranjan, K.R. 2013). There are distinctive desalination measures utilized worldwide to eliminate salts from seawater (66%), bitter water (19%), waterway water (8%), wastewater (6%) and different sources (1%) (Delyannis E. 2003). Distilled water is widely used in hospitals to clean medical tools during procedures and laboratory test (Tiwari G.N, 2007).

Researchers have proposed several designs, materials, and operating settings for solar stills to increase their performance in varied weather situations. Different types of solar stills are described by Kaushal et al. (2010) for producing potable water from brackish or saline water. It was hypothesised that by combining cooling film characteristics, the still efficiency might be increased by 20%. With the use of a reflector, instead of a cooling film, the volume of distillate water from the still can be enhanced by around 14%. Ahmed et al. (2010) designed a solar still system that uses solar energy to produce drinking water from the sea in the Gulf state environment. The efficiency of the solar still with cooling tube was found to be roughly 4% lower than the efficiency of the solar still without a cooling tube. According to Samee et al. (2007), the efficiency and daily productivity of the simple basin type solar still developed are 30% and 3.1 lit/m2, respectively. Eltawil, M.A. (2009) discovered that the output of the still is proportional to the amount of solar radiation reaching it and the ambient temperature.

A thermodynamic analysis is required for accuracy in any solar energy system (Petela R. 2010). Engineers utilize thermodynamic analysis to determine how energy influences the performance of thermal and mechanical systems (Bejan A., 2006). The primary goal of the solar distillation process is to use available solar energy while minimizing heat losses in the system to achieve maximum output in terms of distilled water (Kapurkar, P.M. 2013). Hence a study is conducted to evaluate energy efficiency of a passive solar distillation unit in southern part of Rajasthan.

Materials and Methods

The performance evaluation of a developed Passive solar distillation unit was carried out in April 2021 at the Department of Renewable Energy Engineering, College of Technology and Engineering, Udaipur. The experiments were conducted between sun shine hours 8:00 AM to 05:00 PM. Details of developed solar distillation system is mentioned in Table.1.

Gunny bags were used on the surface of basin area to increase the surface area of basin which helps to evaporate water. The solar distillation unit was poured with a quantity of 4.55 liters of water daily (Fig.1.) to evaluate energy efficiency of unit with the help of equation 1. (Cooper P.I. 1973).

$$\eta_{energy} = \frac{q_{ew} \times A_b}{I_{sb}A_b + I_{sc}A_{etc}} \text{ .... Eq.1.}$$

Where,

A_b = Absorber area of the basin, m^2

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A_{etc} = Absorber area of evacuated tube collector, m^2
I_{sb}, I_{sc} = Insolation on the sloping surface of solar still and solar collector, W/m^2

Table.1. Specification of developed solar distillation unit-

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

Fig.1 Developed Passive solar distillation unit

Result and discussion

The experimental investigation was carried out at Department of Renewable Energy Engineering, College of Technology and Engineering, Udaipur. The study area lies at 24° 38' N- latitude, 73° 43' E- longitude at an altitude of 582.5m above mean sea level. Several experiments were conducted to evaluate energy efficiency of passive solar still. The energy efficiency was found in the range of 2% to 38% during the experiment period as shown in Table.2 and fig.2 to fig.5. The average energy efficiency of the developed solar still was 22%. It was observed that the maximum energy efficiency of the passive still is 38.27% on 1st April 2021 as shown in Fig.2. During the experiment wind velocity of 5-8 km per hour was observed.

Table.2 variation in energy and exergy efficiency of passive solar still unit

Date	Energy efficiency		Distilled water at 2 p.m. (ml)	Cumulative distilled water (ml)
	Maximum	Minimum		
1st April 2021	38.27	2.48	980	4540
5th April 2021	35.99	5.06	920	4798
6th April 2021	36.76	5.97	960	4380
7th April 2021	37.72	7.35	960	4400

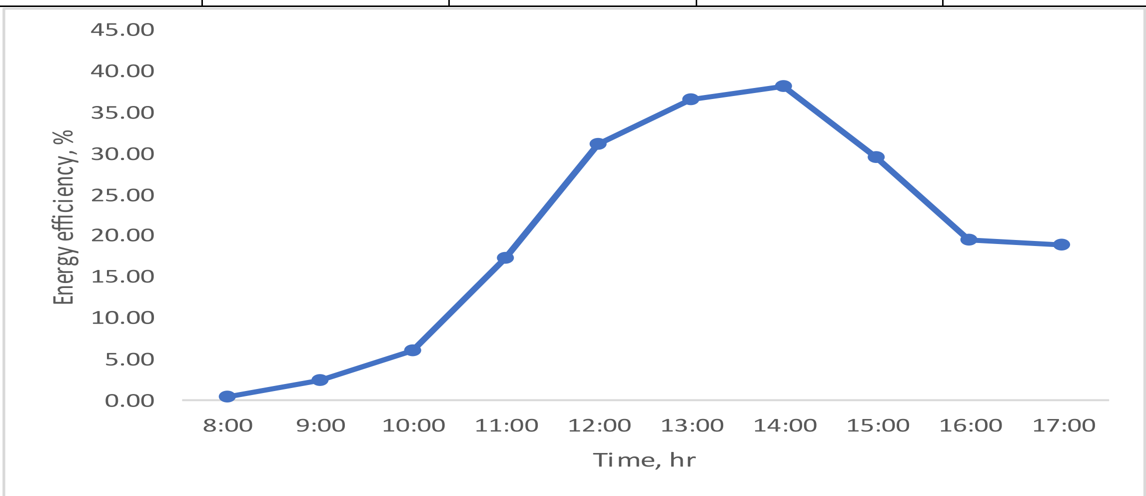

Fig.2. Hourly variation of the energy efficiency on 1st April 2021

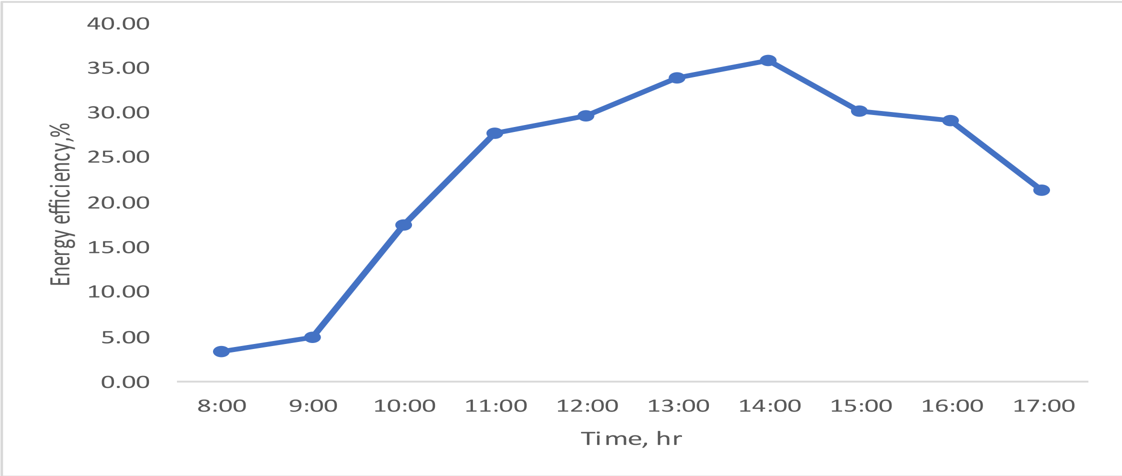

Fig.3. Hourly variation of the energy efficiency on 5th April 2021

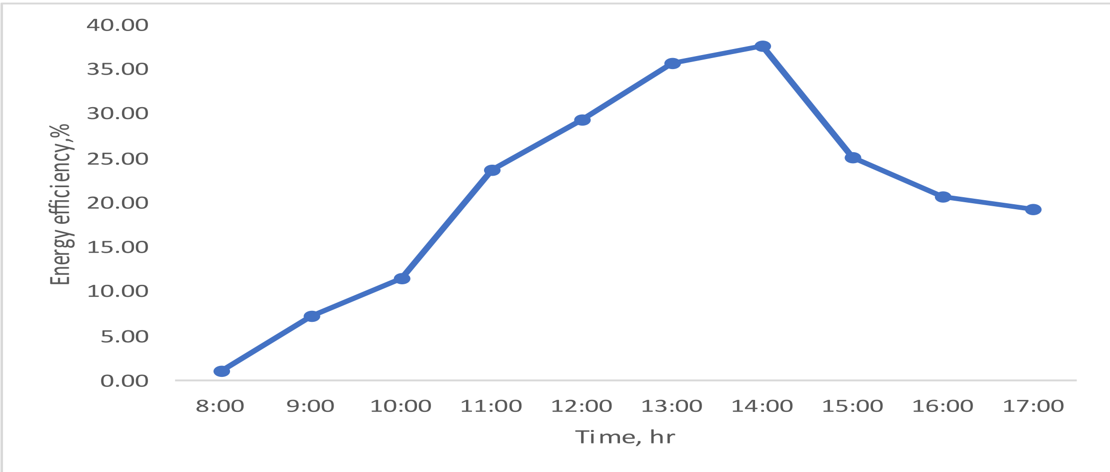

Fig.4. Hourly variation of the energy efficiency on 6th April 2021

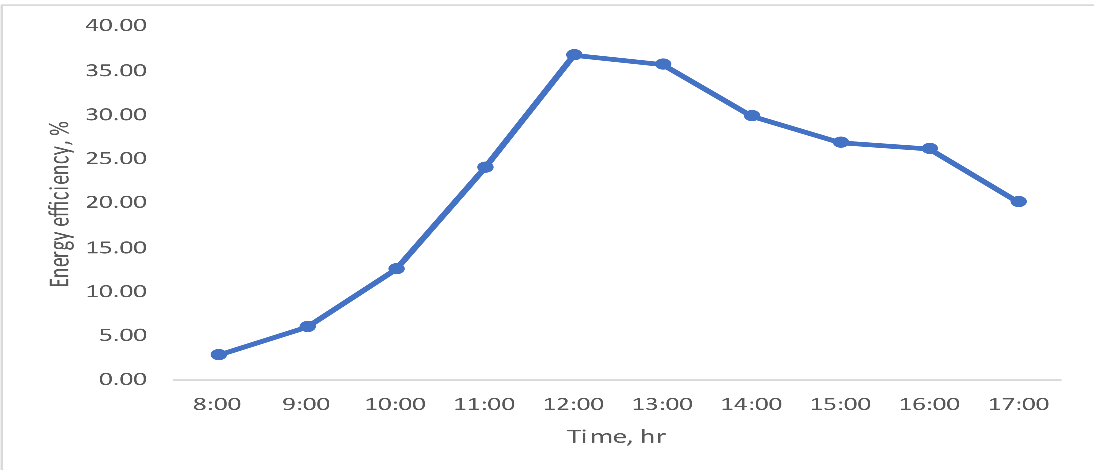

Fig.5. Hourly variation of the energy efficiency on 7th April 2021

Results of experiment conducted showed that water temperature increases with solar radiation and reaches it maximum at 2 p.m. After that it starts loosing it temperature and production. Similar trend of temperature variation also described by Barden *et. al.* (2007) and Abdenaces*et. al.* (2007).

Temperature of glass from inside and outside found same which indicates negligible energy absorbance of glass (Kwatra HS. 1996). Temperature of glass observed less to the water temperature which causes condensation of the vapor on the inner surface of the glass. Daily produced distilled water was measured hourly and a relation between solar radiation is show in fig 6 to fig.9.

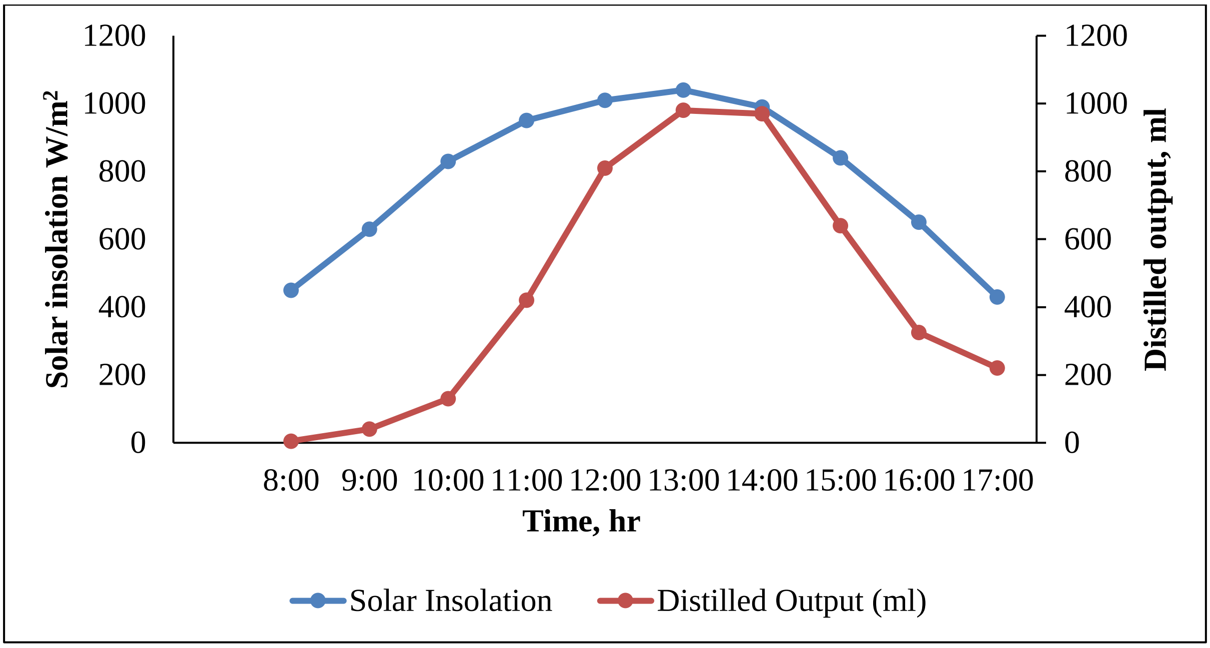

Fig.6. Hourly variation of the distilled output and solar insolation on 1st April 2021

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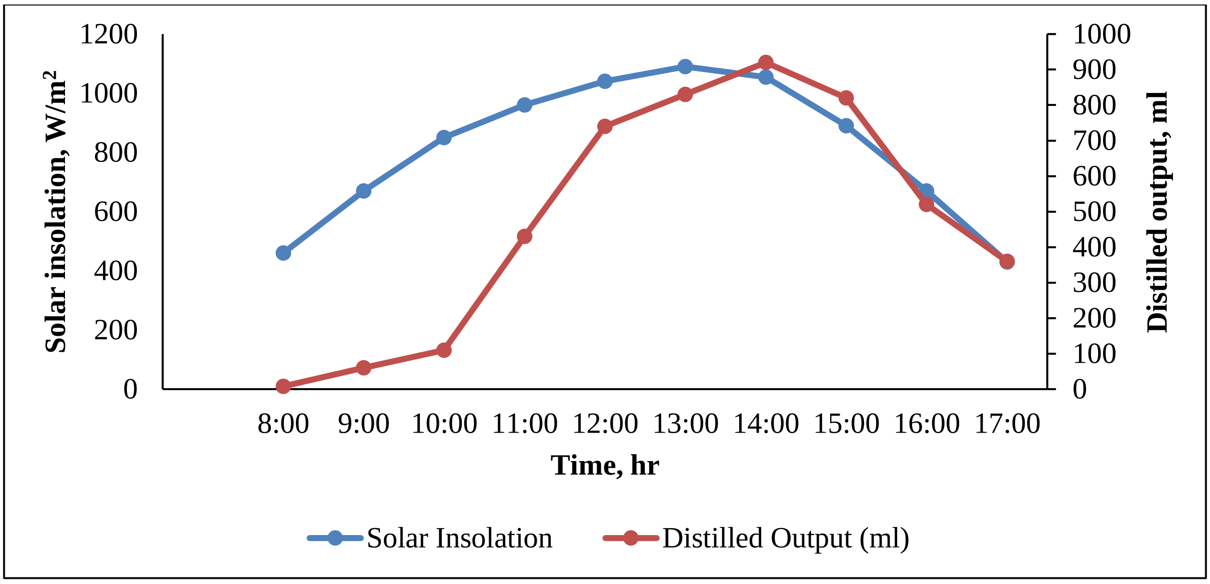

Fig.7. Hourly variation of the distilled output and solar insolation on 5th April 2021

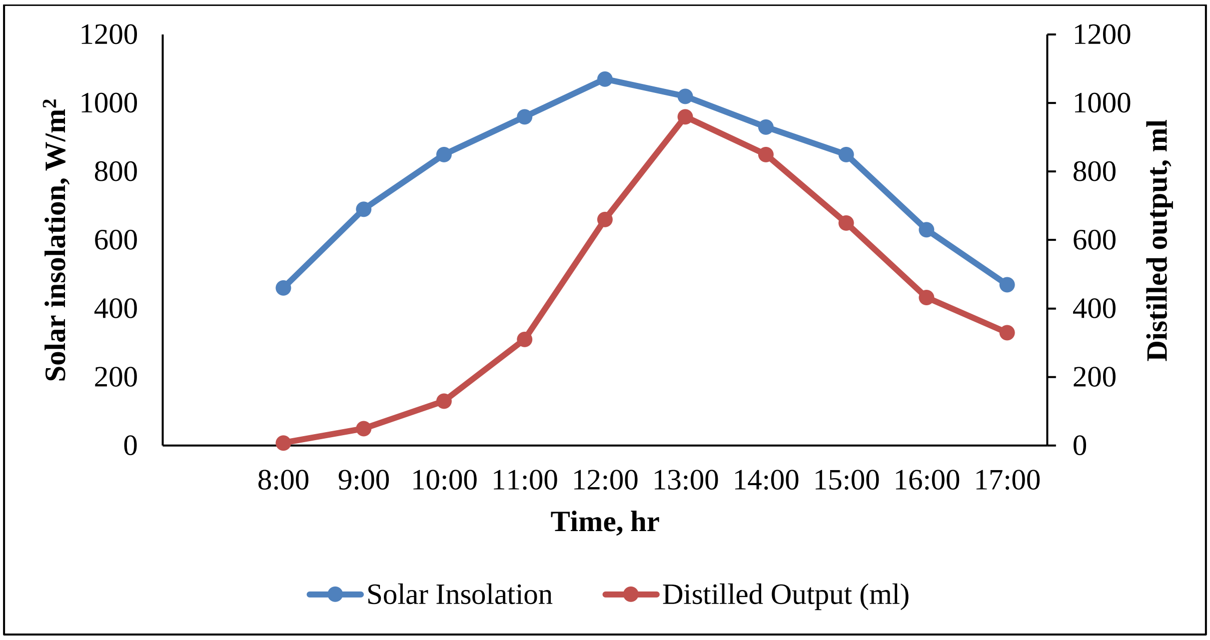

Fig.8. Hourly variation of the distilled output and solar insolation on 6th April 2021

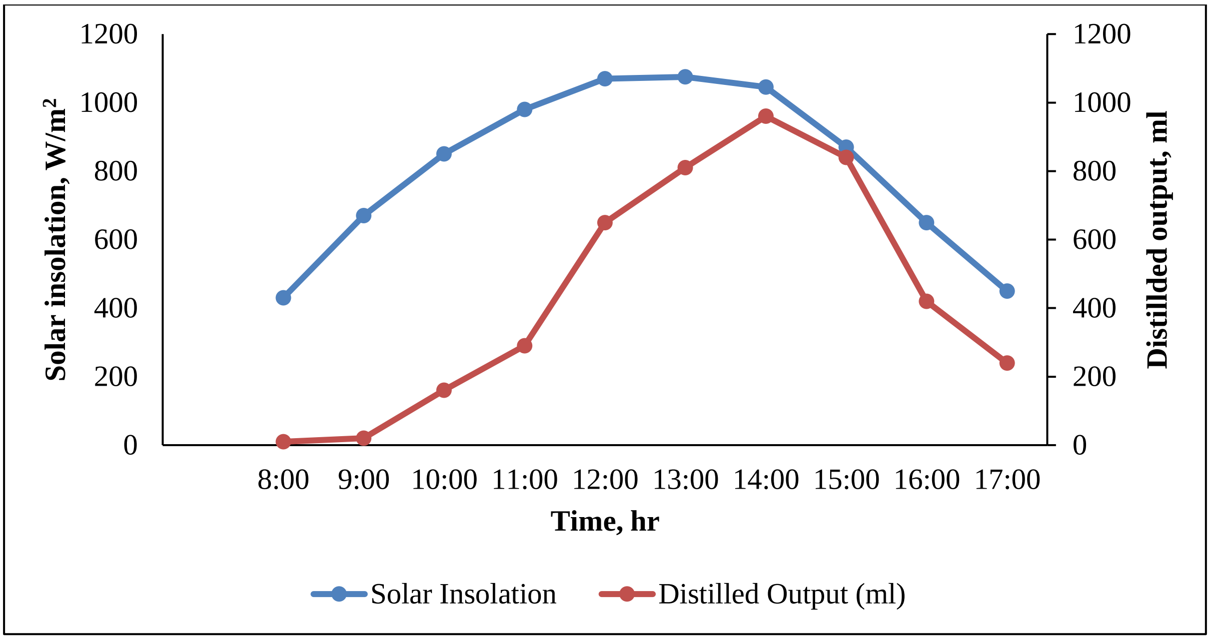

Fig.9. Hourly variation of the distilled output and solar insolation on 7th April 2021

The output of the passive solar distillation unit was lower during morning early hours due to lower solar radiation. The fresh water output was observed maximum at time period between 1.00 to 2.00 P.M. The yield of the passive solar still has a direct relationship with solar insolation and the results was supported by Ahmed, H. M. (2010).

Conclusion

A parametric study has been conducted to find out the effects of solar radiation on production of distilled water at fixed parameters such as saline water depth, thickness of insulation and angle of inclination of the glass cover. The maximum instantaneous overall energy efficiency and hourly yield were 38.27 % and 5.44% respectively observed (Singh, B. P. 2011). The total output of the still was found 4.54, 4.79, 4.38 and 4.4 l/m^2/day respectively for test-1, test-2, test-3 and test-4. However, the solar distillation process is one of the simplest and most widely used technologies for converting seawater or water into distilled water. Good economy, low operating and maintenance costs, enough sunlight and all-day operation.

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