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Effect of water mass on triangular pyramid solar still using phase change material as storage medium

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Abstract

In this paper the effect of water mass on the performance of triangular pyramid solar still with and without latent heat energy storage was experimentally investigated. For comparing the productivity of solar still with and without LHTESS a solar still is designed, fabricated. Experiments are conducted in hot and humid climate of Chennai, India. It is found that there is an increase of production of fresh water with decrease in water mass. There is an increase of about 35% in production of fresh water with LHTESS than that of solar still without LHTESS. Also it was found that during the off shine period the fresh water produced from the still is higher compared to higher water mass. The solar still with and without LHTESS were found to be 5.5 L/m^{2}day and 3.5 L/m^{2}day.

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Keywords: Enhancement; Phase change material; hourly variation; Efficiency

Nomenclature

LHTESS	Latent heat thermal energy storage system
PCM	Phase change Material

1. Introduction

Water is the primary need for human life and it is the most important problem which humans are facing. All ecosystems are depending upon clean water for their daily use. World's water resources are depleting

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due to the increase in population and industrialization. The uses of water from the sources like rivers, lakes were being utilized for the growth of industries and agriculture. Also these sources are polluted by industries. So there is a lack of clean water for the current years. Solar desalination is one of the widely used techniques in producing portable drinking water [1]. Tabrizi et al [2] investigated the effect of built-in latent heat thermal energy storage on a weir-type cascade solar still. It has been reported that the solar still without PCM is well suited for sunny days and still with PCM was suited for cloudy conditions. Tabrizi et al [3] experimentally investigated the effect of water flow on internal heat and mass transfer on a weir cascade solar still. This study aims in developing a solar still for domestic use. The use of paraffin wax acts as an excellent heat recovery unit by storing the heat energy during the day times and releasing its latent heat during the off-shine period (night hours) [4]. Ravishankar et al [4] investigated the effect of PCM as storage to improve the productivity on a triangular pyramid solar still under constant water mass of 20 kg. Results show that the production of fresh water is about 4.2 kg/m^2/day with PCM. Ravishankar et al [6] also investigated the effect of fresh water production during summer and winter conditions. Also Ravishankar et al investigated fresh water production with minimum water depth [5] and the factors affecting the fresh water production[7] under different depth of water and wind velocity over the glass surface. This study also aims to improve the performance of solar still. This experimental setup was designed, installed and tested in the outdoor testing facility, Chennai, Tamil Nadu, India. The whole experimental setup was kept in the North–South direction, with the inclination of 13^o north, which is the latitude of Chennai.

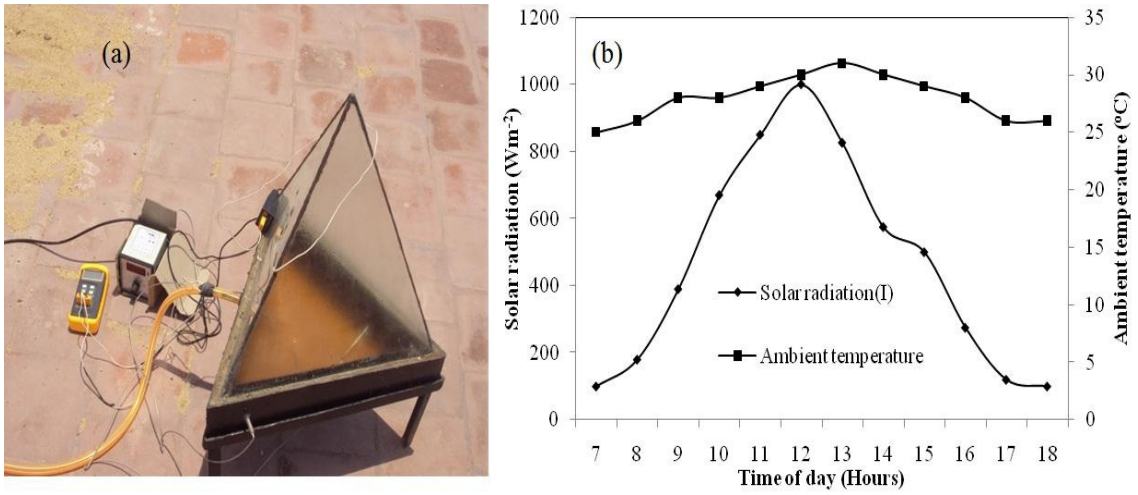

Fig.1. (a) Pyramid type distiller (b) Hourly variation of solar radiation and ambient temperature

2. Experimental Setup

Fig.1. (a) shows the experimental setup of triangular pyramid solar distiller. Experiments were carried out from 6 am- 6 am. Water from the storage tank enters the still through flexible hoses and a valve V, to maintain constant water level in the still. Poly vinyl chloride (PVC) hoses were used for greater flexibility. A small glass piece obstruction was fixed on the inside surface of the glass cover, to facilitate the deflection of the condensate return in to the collection channel, which in turn affixed with the still. The gliding water from the channel was transferred in to the measuring jar through the flexible piping.

3. Results and Discussions

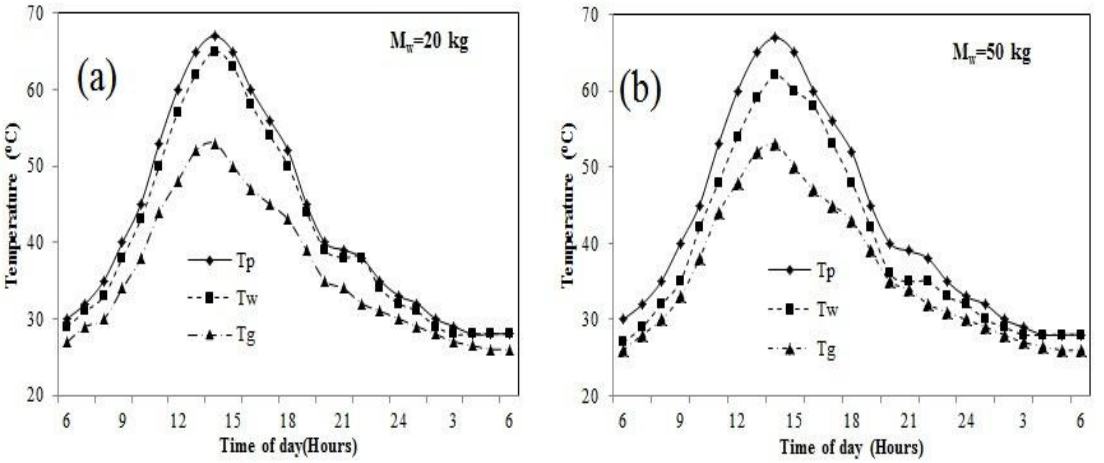

Fig.2. Hourly variation of basin, water and glass temperature without PCM (a) M_w=20kg (b) M_w=50kg

Fig. 1(b) showing the hourly variation of solar intensity from which it is observed that the maximum in the afternoon. The average ambient temperature was found to be 30 C during the month of April. The still performance is mainly depending on the various factors such as depth of water, inclination, water mass and ambient conditions. Thus various experiments were conducted on the still with and without PCM on two different water masses. The hourly variation of basin temperature, water temperature and glass temperatures were shown in fig 2(a) and (b) with water mass of 20 kg and 50 kg. Fig .2(a) shows the water temperature, basin temperature and glass temperature were higher in case of 20 kg and the maximum was found to be 65, 68 and 54 ^{o}C respectively. When comparing the still with 50 kg water mass its temperatures were 60, 65 and 52 ^{o}C respectively.

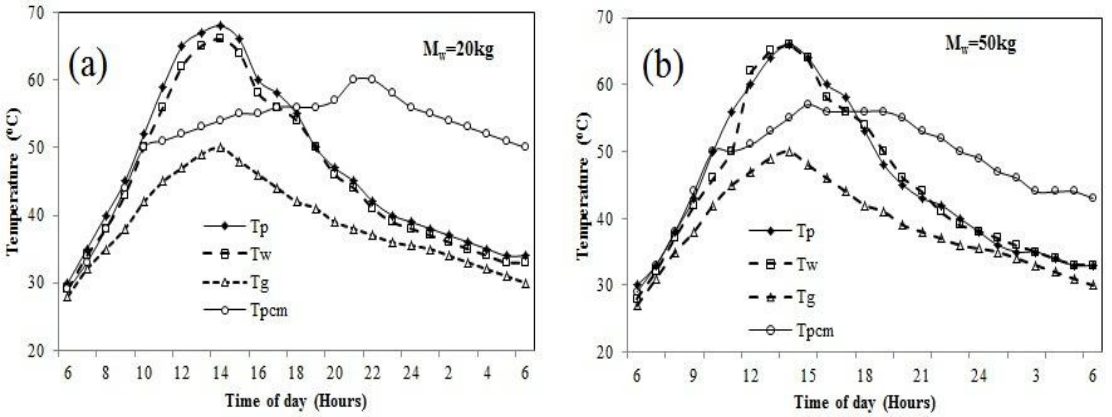

Fig.3. Hourly variation of basin, water and glass temperature with PCM (a) M_w=20 kg (b) M_w=50 kg

Fig .3. (a) showing the hourly variations of plate temperature, water temperature, glass temperature and PCM temperature. It is clear the basin liner temperature is very close to the PCM temperature at the starting time. After 12:00 pm the temperature of PCM remains constant due to its melting point. Due to the increase in solar intensity the PCM temperature is increased. During the night time it releases its heat to water. It is obvious that the temperature of basin is decreasing during night time due to the ambient condition. With higher water mass in the basin, the temperature of PCM is decreasing rapidly faster while

comparing to that of lower water mass. Also water having the higher thermal conductivity in which the thickness of water will be an important criterion.

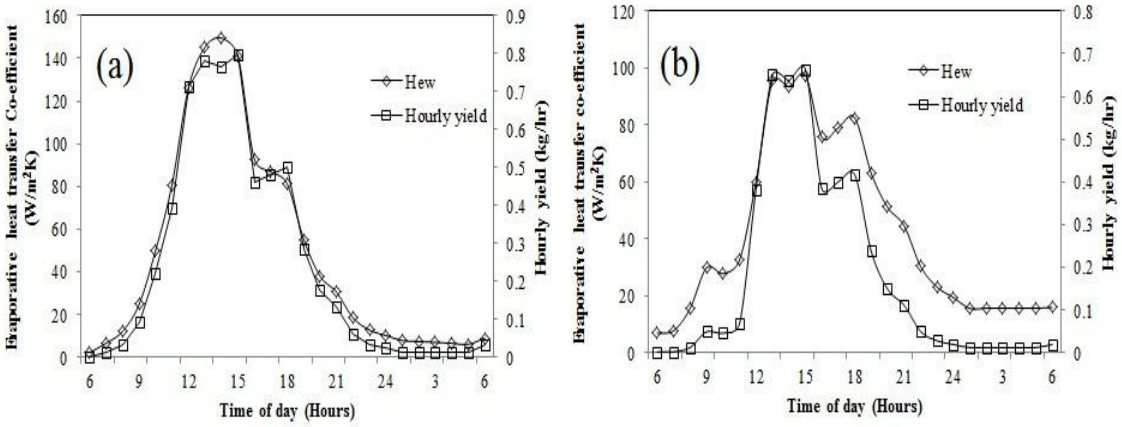

Fig.4. Variation of hourly yield and evaporative heat transfer co-efficient with PCM (a) M_w=20kg (b) M_w=50kg

Fig.4. (a) and (b) shows the hourly variation of evaporative heat transfer co-efficient with PCM as storage with different water masses. It is observed that the maximum value of 140 W/m^{2}K with a water mass of 20 kg. While comparing with higher water mass it is seen that the vale is reducing. Also the hourly variation of yield is reduced by 0.2 kg/m^2. It is due to the effect of higher evaporation rate of water in the basin. Fig.5. (a) and (b) shows the comparative analysis of solar still with and without PCM storage. The accumulated yield of solar still is maximum for solar still is higher in case of still with minimum water mass. The maximum yield was found to be 6.5 l/m^2/day and 3.5 l/m^2/day.

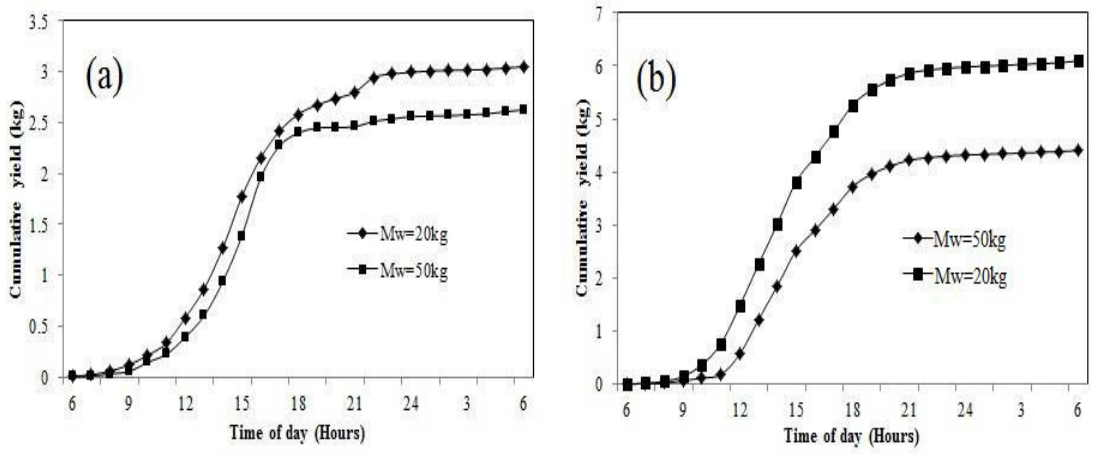

Fig.5. Cumulative yield of solar still (a) without PCM (b) with PCM

Also Fig 5 (a) and (b) shows that the utilization of PCM on the basin increases the fresh water production by 100% when compared to the solar still with water mass of 20 kg.

4. Conclusions

From the present experimental results of the triangular pyramid solar still under different water masses the following conclusions were drawn

- The productivity of fresh water from solar still was higher at 20 kg water mass.
- The augmentation of daily production was increased from 3.5 to 5.5 l/m^2/day.
- The efficiency of solar still was increased by 35% with PCM as storage.
- Also it is found that the effect of mass of PCM plays an important factor in designing the solar still.

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Biography

Ravishankar Sathyamurthy graduated his Bachelor in Mechanical Engineering and pursued his Post graduation in Thermal Engineering at Anna University of Technology Thirunelveli in 2012. Presently he is a research associate in the Department of Mechanical Engineering, Hindustan Institute of Technology and Science, Chennai. His area of interest includes solar desalination, renewable energy technologies, thermal energy storage, and nano materials. He is currently a reviewer in the Renewable and sustainable energy: A review, Journal of Applied fluid mechanics, International Journal of Renewable energy research, Institute of Engineers (Inida) :Series C Case studies in thermal engineering, Journal of Solar energy, Journal of Energy research.