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Performance Evaluation of Triangular Pyramid Solar Still for Enhancing Productivity of Fresh Water.

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ABSTRACT

In this study, the effect of geometry on the performance of a tetrahedral solar still was experimentally investigated on Chennai climatic conditions. In this work, a solar still of area 0.95 m^2 and a glass cover in a triangular form was designed and fabricated. Environmental parameter includes solar intensity, ambient temperatures, and wind speed. Operational parameters are feed water quantity and orientation. Tests were conducted in Hindustan Institute of Technology and Science, Kelambakkam, Chennai, India. The maximum distillate output found was 4.3 $lm^{-2}day^{-1}$. The results shows that the production of fresh water was increase up to 40% compared to that of other conventional solar stills.

Keywords: Natural convection, solar still, orientation, desalination

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INTRODUCTION

People living in remote areas or islands, where fresh water supply by means of transport is expensive, face the problem of water shortage every day. Solar still presents some specific advantages for their use in these areas due to its easier construction using locally available materials, minimum operation and maintenance requirements and friendliness to the environment. It is really very fortunate that, in times of high water demand, solar radiation is also intense. It is therefore beneficial to exploit solar energy directly by installing solar stills. Two major advantages that favour the use of solar stills are: clean and free energy, and friendly to the environment. Their main disadvantage, however, is the lower output of distilled water in comparison with other desalination systems. The production capacity of a simple type still is in the range of 2–5$lm^{-2}day^{-1}$only. This makes the system highly uneconomical. In solar desalination process, the productivity of the solar still is very less compared to other conventional desalination systems.

Conventional solar still are usually air tight that contains the saline water which has to be purified, a inclined cover of transparent material (usually glass) and metallic frame walls. Various literature reviews are made using forced convection and natural convection in the solar stills. With the increase in the heat and mass transfer co-efficient and due to turbulence the air-mixture motion the productivity of fresh water is enhanced which was experimentally carried out by Ali [6]. The effect of forced convection is caused by fan, water depth in the solar still, and wind velocity which was experimentally investigated by Mashhad, Iran [9].Results showing that with the help of negligible power consumption is a best way to increase the productivity up to 56% with a Reynolds number of 35,000. Yazan Taamaneh [5] investigated a solar still with a basin area of 0.95 m^2 and a glass cover in the form of pyramid has been designed and constructed. Experimental results illustrated that use of fan with the help of a solar photovoltaic cells are cost effective and viable enhancing in the production of fresh water and increase the evaporation rate. Based on the performance evaluation, the daily productivity of fresh water increased by 25% compared to free convection solar still. The daily distillate output has been found to be 2.99 litres day^{-1} with forced convection. In this paper, a triangular shaped solar still with a basin area of 0.95m^2 has been designed, constructed and tested in Chennai, India.

Design of solar still

Experimental investigations are performed to evaluate the performance of solar still under outdoor climatic conditions of Chennai.

The Fig.1 Shows the schematic diagram of triangular pyramid solar still and its various heat flow. It consists of a metallic container, which is occupied by the saline water up to a certain level and below the exit collecting area where the fresh water flows to the collecting jars kept at three corners of the solar still. The solar radiation is transmitted through a 2 mm thick triangular glass cover with a transmissivity of 0.88. The bottom plate is black coated which absorbs the heat. With an allowable energy absorbed by the water, a phase transformation takes place in water. The evaporated water rises and reaches the inner surface of glass in inclined position. Vapor once again undergoes phase change from vapor to liquid. The condensed water flows through the channel made of MS sheet which connected to the outlet. The contaminated water which contains the impurities is removed by desalination process. Un dissolved particles such as salts left behind in the basin itself. The still was filled with saline water to a height of 0.05 m. Thermocouples are kept at different positions to measure the temperatures. Fig 2 shows the heat flow circuit of a triangular pyramid solar still.

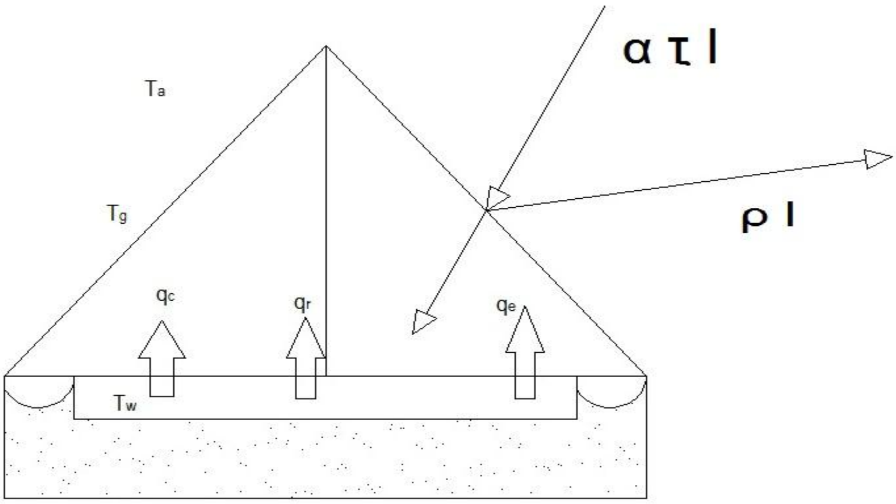

Figure 1: Schematic diagram and various heat flow in triangular pyramid solar still

The bottom of the basin was filled with sawdust up to a height of 0.01 m. The sides of the basin are insulated with the glass wool. Glass wool has a higher insulation value per thickness, but sawdust was used underneath because it had to support the weight of the still. These insulation layers reduce the conduction heat loss through the base and sides of the solar still and variation in the insulation value can have a 10% effect on overall productivity .The parameters used in the experiment are given in Table 1. The still temperature was recorded using K-type thermocouples and digital temperature indicators. The solar radiation intensity was recorded by a precision pyranometer.

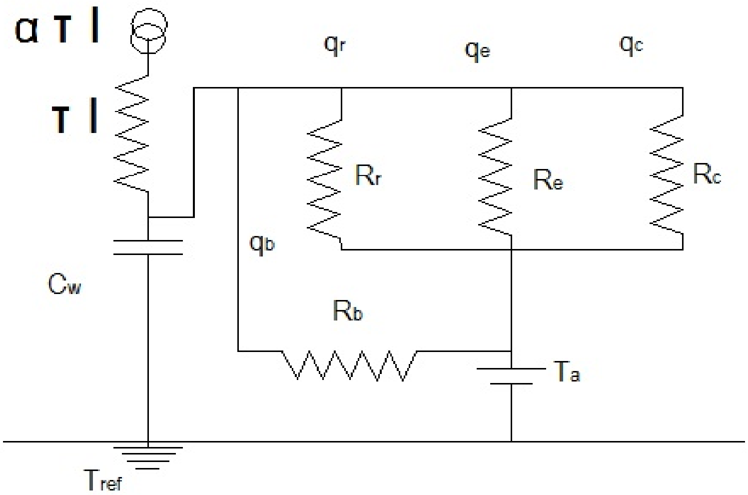

Figure 2: Heat flow circuit of a triangular pyramid solar still

Parameter	Symbol	Value
Transmissivity of glass	τ_c	.88
Emissivity of glass	ε_c	.98
Density of water	ρ	995 kg/m^3
Latent heat of vaporization	h_{fg}	2376 kJ/kg
Latitude	ϕ	11^0 North

Table 1: Experimental Parameter

The daily production was obtained as a summation of day and night production. However, the solar radiation was only measured over an eight hour period, so this underestimates the solar radiation and therefore overestimates the efficiency. Experimental steady state efficiency was calculated using the formula,

$$\eta = \frac{m\, h_{fg}}{A_b I_s \Delta t} \qquad (6)$$

Water sample analysis

The quality of water is analyzed at Tamil Nadu agricultural University's soil science and agricultural chemistry department in Madurai, India. Results are represented in Table 2. Three different samples are chosen and tested. Parameters like pH, electrical conductivity (dSm^{-1}) and Total dissolved solids (TDS) were measured before and after desalination process. Electrical conductivity of the sample before desalination was found to be 1.2 dSm^{-1} which is not acceptable for drinking purpose. After desalination is was found to be 0.08 dSm^{-1} which is drinkable. The pH value of water before and after desalination is found to be 7.5 and 6.9 respectively. The range of pH value of drinkable water varies from 6.5 to 8.

Table 2: Water sample analysis

Sample	TDS (mg/liter)		pH Value		Electrical Conductivity (dSm^{-1})	
	Before	After	Before	After	Before	After
A	370	35	7.5	6.9	1.2	.08
B	375	38	7.2	6.7	1.12	.093
C	360	42	7.3	6.87	1.3	.095

Global Radiation and Ambient temperature

Global radiation and ambient temperature is shown in fig 3 and Fig 4 Maximum radiation and temperature are found to be 34^0 C and 1000 W/m^2 respectively in the months of September and November.

Tests are conducted between 7:00 am to 6:00 pm and temperatures are noted every 1 hour time interval.

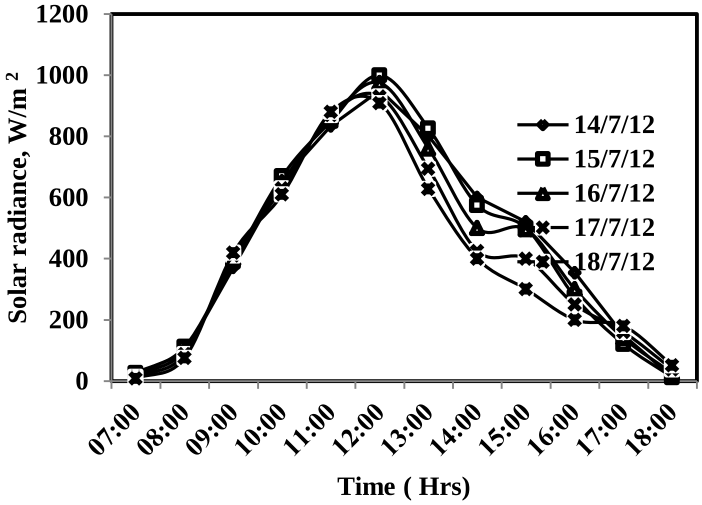

Figure 3: Hourly variation of solar radiation during test days

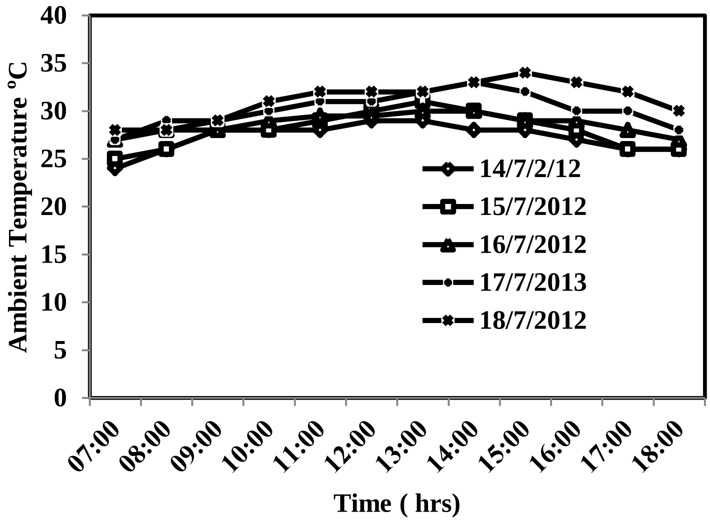

Figure 4: Hourly variation of ambient temperature

RESULTS AND DISCUSSION

Fig. 5 and 6 shows the experimental results of the hourly variation of the wind velocity, saline water temperature, glass cover temperature during test days of solar still testing. From fig 6, the temperature of saline water and the glass cover temperature increases in the morning hours to reach maximum value around midday before it start to reduce late in the afternoon. It can be noted that the glass cover attains the maximum temperature faster than saline water. This is in fact because the saline water has higher thermal heat capacity than that of glass cover.

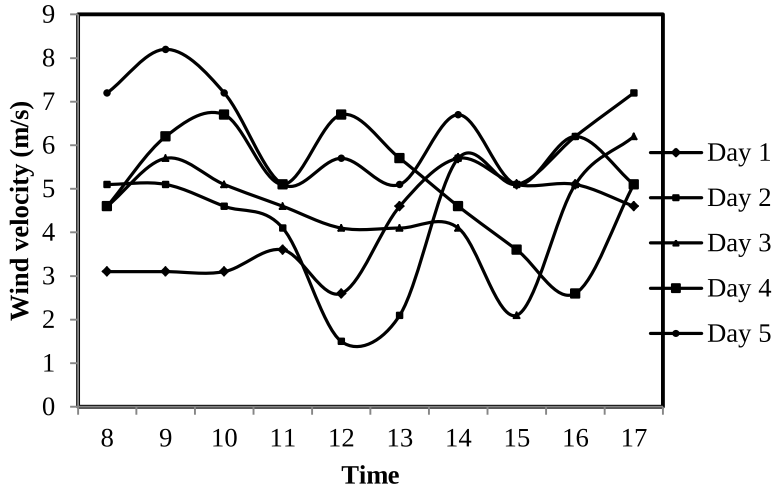

Figure 5: Variation of wind velocity with respect to time

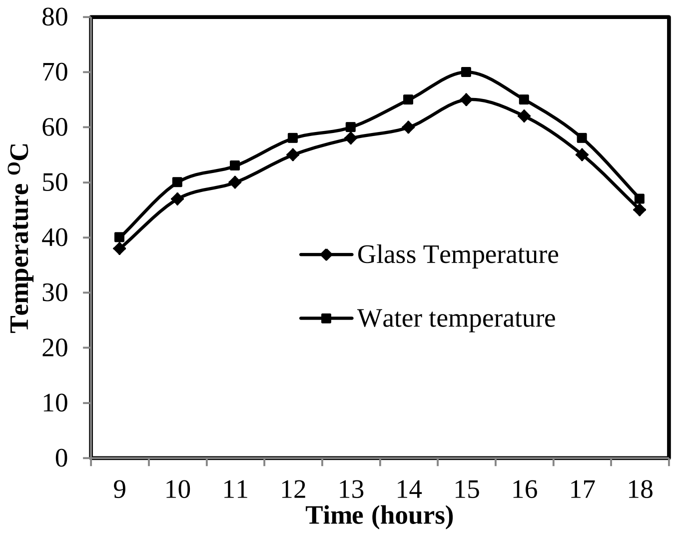

Figure 6: Hourly variation of water and glass temperature

Fig 7 shows the hourly variation of still efficiency based on free convection of wind blown over the glass surface during the test conducted. It can be noted that the still efficiency increases in the morning and reaches the maximum efficiency value till mid day and then decreases at a slower rate. It is clear that the still efficiency profiles follow the similar trends as of those for solar radiation as shown in fig 7. The experimental results in this study are presented to assess the effect of natural convection on the productivity of fresh water.

Fig. 8 shows the comparative analyses of the freshwater production rate for solar still based. The fresh water production based on natural convection was 4.33 l per day. The difference between the free convection and conventional solar still fresh water production was found to be 40%. The increase in the freshwater production is due to the circulation of the air inside the solar still and hence the evaporation rate that has been increased by the wind velocity over the glass surface.

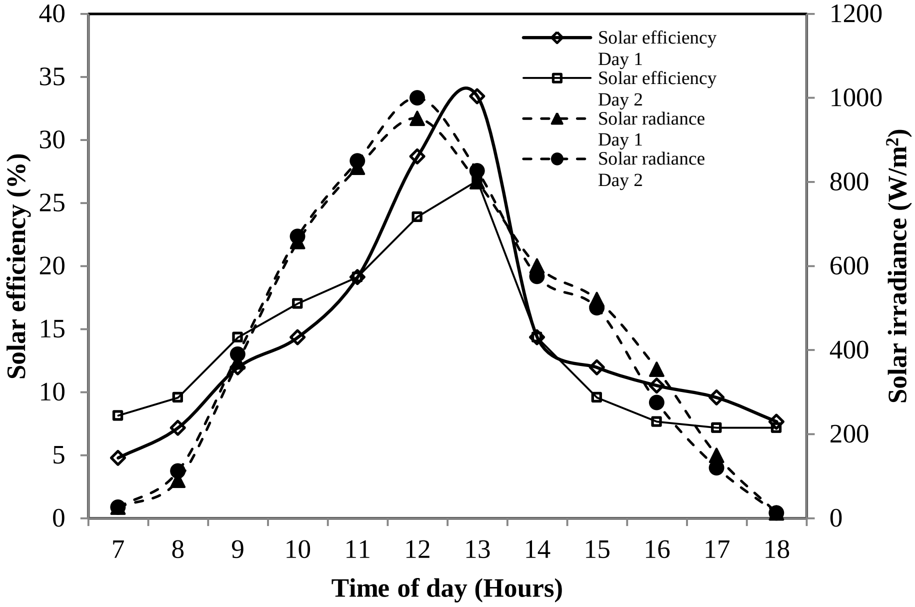

Figure 7: Variation of solar efficiency of still with respect to time

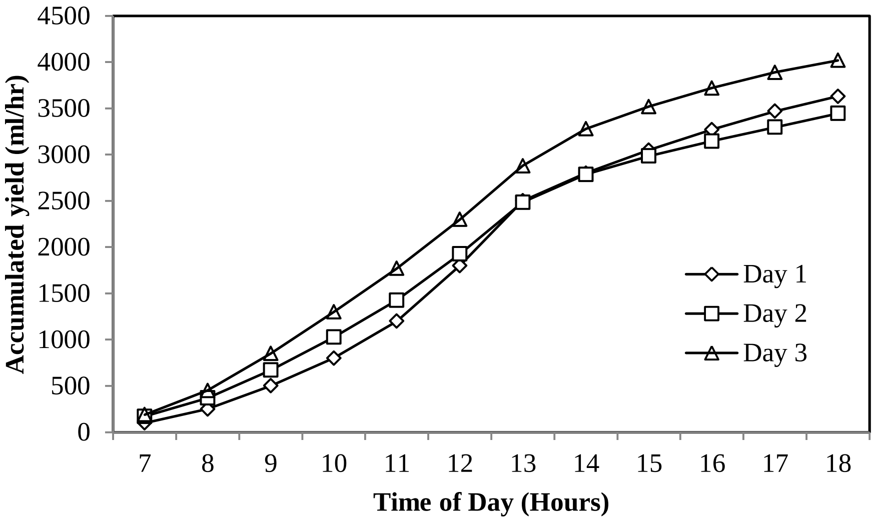

Figure 8 Accumulated yield of fresh water from the solar still during test days

CONCLUSION

In this work, the effect of natural convection on the performance of triangular pyramid-shaped solar still is investigated experimentally under outdoors of Chennai City (south India) climatic conditions. The daily distillate production has been found to be 4.3 l per day for a solar still with forced convection, i.e. 40% increase in freshwater productivity compared to conventional solar still. In further work a solar assisted thermo-electric cooler may be used to enhance the evaporation rate and therefore fresh water production.

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