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EFFECT OF WATER FLOW ON THE CONCENTRATOR COUPLED HEMISPHERICAL BASIN SOLAR STILL

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ABSTRACT

This research article briefly epitomizes the augmentation of condensate by adopting enhanced desalination methodology and technological approach pondering extensive limelight on its performance generating revenue added approach to all scale applications. The experiments were conducted to study the water flow over the condensing cover of the hemispherical basin single slope solar still. Two types of measurements were performed; one with cooling and the other without cooling. The hourly and daily productivity are also calculated and reported. The system efficiency ranged between 3% to 33% for experiments without flow and 9% to 43% with flow. It is concluded that the average maximum efficiency is recorded for still with cooling water flow technique. The peak efficiency of the system worked out to be 37.85%. The maximum of total productivity for stills with and without water flow are 1.67 L and 1.5 L respectively which achieved in possible flow rate (0.065 kg/min).

KEYWORDS: Solar Desalination, Efficiency, Productivity, Hemispherical Solar Still

INTRODUCTION

Power and water supply are widely recognized as the two major issues which mankind has to face and solve during this century. While it is clear that, in the next few decades, oil will cease to dominate, it is not yet clear today which source of energy will replace it. At the same time, water security, already a serious global problem will become critical during the first half of this century. Of all the current environmental problems, those related to energy and water is probably the hardest to approach scientifically and those that will have the worst long term consequences. Problems associated with water scarcity, and the gradual destruction and contamination of fresh waters resources are becoming more pressing in many areas of the planet, causing concern even in countries which, so far, have not experienced such problems. Although, more than two-thirds of the Earth is covered by water, shortage of potable water is a serious issue that many countries suffer from. In many small communities, the natural supply of fresh water is inadequate. The worldwide problem of the rapidly dwindling resources of inadequate fresh water supply for an increasing population intensifies.

Studies have been performed by the variation of evaporative heat transfer coefficients in a conventional still and in an inverted absorber solar still by Suneja and Tiwari [1-4]. Boukar and Harmim [5] carried out a comparative study, where they studied the effect of the Algerian south-west desert climatic conditions on the performance of a single basin solar still and a similar one coupled to flat plate solar collector.

The parabolic shaped concentrator or solar collector concentrates the incident solar radiation on large surface and it focuses on a small absorber or receiver area. The performance of concentrators is much affected by the sun tracking mechanism. The tracking mechanism should move the collectors throughout the day to keep them focused on the sun rays to achieve the higher efficiency. These types of solar collectors reach higher temperature compared to flat plate collectors owing to reduced heat loss area.

Various types of concentrators were used over the years based on its applications. To achieve higher yield, the contractor is coupled with solar still by means of increasing water temperature in the basin. Scrivani et al. [6] presented the concept of utilizing through type solar concentration plants for water production, remediation, waste treatment and the system can be used for processing landfill percolate in arid regions where conventional depuration systems are expensive and impractical. Abdel Rahim and Lasheen [7] conducted experimental and theoretical study of a solar desalination system coupled with solar parabolic through with a focal pipe and simple heat exchanger. The results show that, as time goes on, all the temperatures increase and begin to decrease after 4.00 pm with respect to the solar radiation, although the temperature values of the modified system are still higher than the conventional one. In case of the modified design, the fresh water productivity increased an average by 18%. Chaouchi et al. [8] designed and built a small solar desalination unit equipped with a parabolic concentrator. The results show that, the maximum efficiency corresponds to the maximum solar lightening obtained towards 14:00. At that hour, the boiler was nearly in a horizontal position, which maximizes the offered heat transfer surface. The experimental and theoretical study concluded with an average relative error of 42% for the distillate flow rate. This is due to the imperfections in parabolic geometry, the sun manual follow up and especially to the system's tilt variation during the day, which does not make it possible always to keep the absorber surface covered with salted water.

The aim of the present work is to design and test a solar still equipped with a concentrator in order to study the possibilities of its use in desalination. Preliminary results of the performance testing of this system are presented. Furthermore, the effect of flow (0.065 kg/min) rate on total productivity of the stills was investigated in five sunny consecutive days through 23 to 27 of May, 2009 climatic conditions of Coimbatore, India.

FABRICATION DETAILS

A single slope solar still with spherical basin absorber was constructed. The basin is modified to hemispherical shape and it is made up of copper of thickness 4 mm. The diameter of the hemi spherical base is 0.22 m, and the hemispherical absorber is attached at the bottom of the still. The bottom and sides of the inner surface of the basin and the outer surface are painted black and ¼ inch inlet pipe is provided for water inlet. The top surface of the still is covered by a cover of area 0.25 m $\times$ 0.25 m. The top cover is made up of transparent glass sheet of thickness 2 mm of transmittance 90%. Thermocouples were used to measure the temperature inside the still. The top cover is placed over the grooves with uniform resting slope of 16°.A water collection segment is also provided at the respective place. It has a length of 0.27 m and a width of 0.025 m. This entire setup is mounted at focal point of the concentrator.

EXPERIMENTAL SETUP AND PROCEDURE

Brackish or saline water poured into the still to fill it partially, which is then exposed to the sun. The glass cover permits solar radiation to get into still, which is predominantly absorbed by the blackened base. Consequently water gets heated up and hence the moisture content of the air trapped between the water surface and the glass cover increases. Humid air circulation is induced by temperature difference between basin and condensation surfaces causing heat transfer.

Experiments were performed at Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore, Tamil Nadu, India. The experiments were conducted in April- May 2009, to investigate the effect of potable water productivity comparison between concentrator coupled single slope solar still with and without top cover cooling method.

The average ambient temperature recorded during this study was 22.1 °C -34.7 °C during summer and 15.2 °C-32.2 °C during winter.

All experiments started at 10.30 a.m. and terminated at 3.00 p.m. local time. The still is made to face the south and the saline water is poured inside the still in the early morning. The still with hemispherical basin solar still is fixed at the focal length of the concentrator with the help of the iron stand. The experimental setup and the pictorial view of the stills are shown in Fig. 1 and Fig. 2. The feed tank containing the cold water is connected to the channel at the top of the still. The glass cover was cleaned and placed on the basin without any vapor leakage. Based on the previous work by Suneja and Tiwari [4], the flow rate reported as 0.065 kg/min for the inverted absorber solar still. We have adopted the similar water flow rate in our experiments. The flow rate of the water is adjusted to the preferred value. The variations of water temperatures of both units as well as the productivity are recorded with time during the entire experiment. The ambient temperature and humidity were also monitored. The measured temperatures depend on solar intensity, wind velocity and its direction. The temperatures were recorded using K-type thermocouples and digital temperature indicators. The solar radiation intensity on the horizontal surface, along with its beam component is recorded with precision pyranometer and pyrheliometer, respectively.

RESULTS AND DISCUSSIONS

The concentrator coupled solar still is tested under the top cover cooling effect. The efficiency, internal heat transfer coefficients and daily productivity are predicted. It is clear from Fig. 3 shows the variations of ambient temperature and solar radiation with respect to time. The average values of solar intensity and ambient temperature were about 710 W/m^2 and 36°C.

The measured values of water temperature, air temperature and glass temperature are shown in Fig.4 for 0.065 kg/min cooling water flow. Variation in the efficiency of the still stand is depicted in Fig.5. The system efficiency ranged between 3% to 33% for experiments without flow and 9% to 43% with flow. It is concluded that the average maximum efficiency is recorded for still with cooling water flow technique. The peak efficiency of the system worked out to be 37.85%. The cooling performs important function of continuous self cooling of the glass cover. The presence of dirt and other types of contents on the top cover greatly reduce the still performance as well as efficiency. Continuous cleaning of the cover maintains high levels of efficiency.

Fig.6 shows the variations in the hourly output of the purified water versus time. It is clear from the graphical representation; the water flow over the glass cover study gives the higher yield as compared to without flow over the cover. The maximum of total productivity for stills with and without water flow are 1.67 L and 1.5 L respectively which achieved in possible flow rate (0.065 kg/min). This is due to the fact that when the flow rate is low, water has a higher temperature because of the increase in the water residence time. Although, the maximum productivity is obtained in minimum flow rate, however, it should be noted that very low flow rates (Below 0.055 kg/min) cause unsuitable distribution of water and prevent to maintain a uniform water film upon the evaporation surface.

Water Analytical Results

Water quality analysis was performed at the Tamilnadu Agricultural University's, Soil Science and Agricultural Chemistry Department in Coimbatore, India. The results thus obtained are presented in Table 2. Two different water samples were tested. Two parameters, pH and electrical conductivity (dSm^{-1}) were measured before and after these samples were desalinated. Before desalination, the level of electrical conductivity in the water was around 1dSm^{-1} which is ~2% of ocean water, but not drinkable. However, it decreased to 0.10 dSm^{-1}, which is drinkable, after desalination. The typical pH varies from one water sample to another as well as on the nature of the construction materials used in the water distribution system. It is usually in the range of 6.5 to 8.

CONCLUSIONS

In this experiment, an attempt has been made by the cooling the top cover. The average daily output of the still was around 1.67 L for with flow and 1.5 L for without flow the condensing cover. Flowing cooling water on the top cover increased the solar still productivity. It was absorbed that the evaporative heat loss coefficient is a strong function of the operating temperature range, while the convective and radiative heat loss coefficients are more or less temperature independent. The overall approach of this design and construction of the concentrator coupled hemispherical solar still with top cover cooling methodology appears to be good as indicated by its efficiency 38.85%, which is comparatively more than that of without cooling effect. This system offers a viable alternative to the single basin solar still connected to a flat plate collector for high temperature passive solar distillation.

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APPENDICES

Table 1: The Values Obtained for Constant Flow Rates During the Study

	For Flow Rate	
	With Water Flow (0.065 kg/min)	**Without Water Flow**
Values of C	1.38	0.21
Values of n	0.26	0.24
Average of h_{cw} (W/m^2 °C)	129.61	116.74
Average of h_{ew} (W/m^2 °C)	366.57	594.88

Table 2: Tested Water Quality Results

Sample No.	TDS (mg/litres)		pH		Conductivity(dSm^{-1})	
	Before Desalination	After Desalination	Before Desalination	After Desalination	Before Desalination	After Desalination
Samples A-B	320	40	7.60	7.32	1	0.10

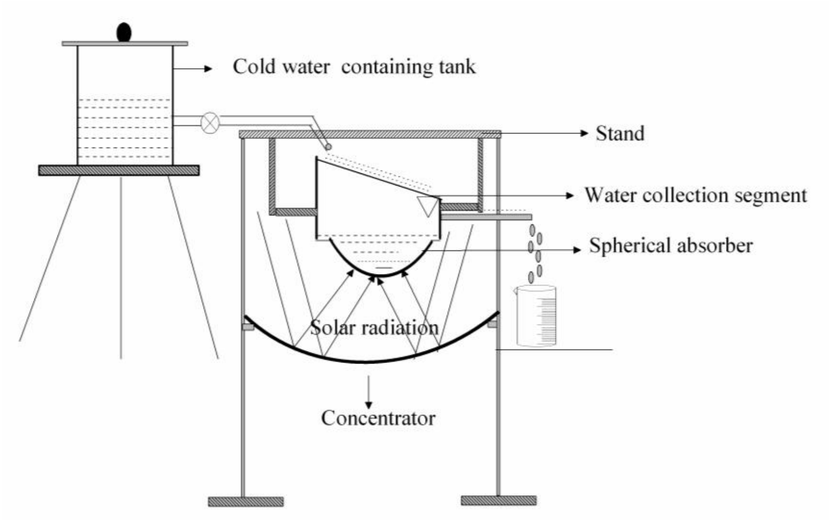

Figure 1: Schematic Diagram of the Experimental Setup

Figure 2: Pictorial View of the Experimental Setup

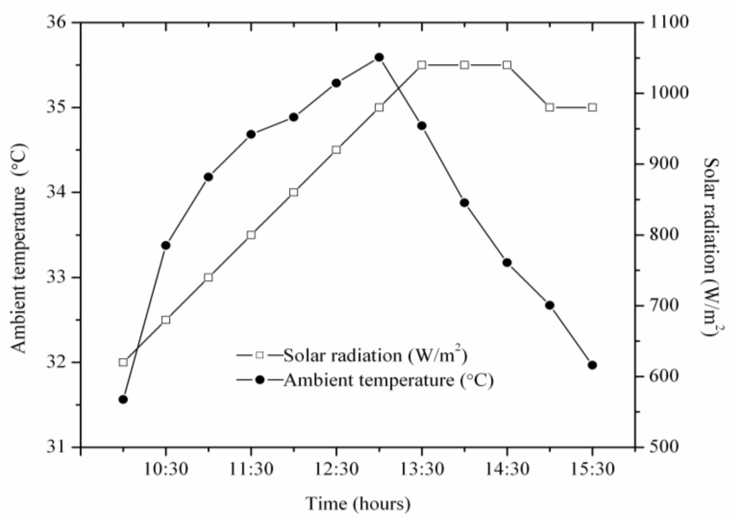

Figure 3: Variation of Solar Intensity and Ambient Temperature

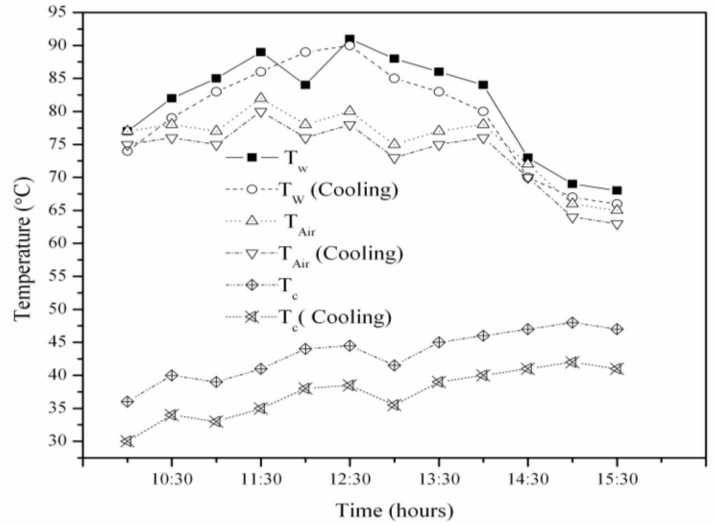

Figure 4: Progress of Most Characteristic Temperature with Time

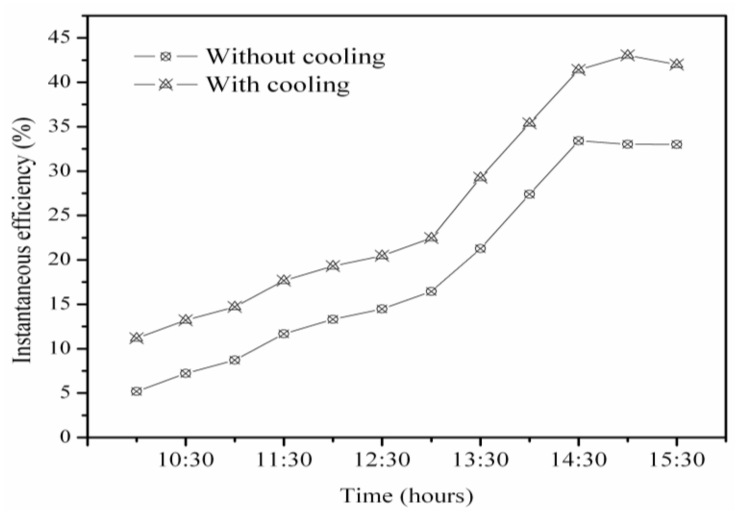

Figure 5: Variation of Efficiency of Solar Still with Time

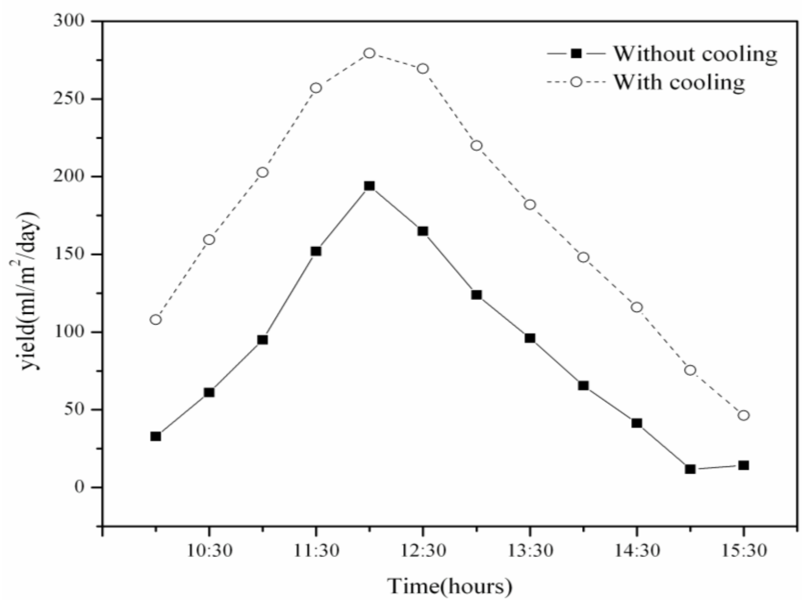

Figure 6: Comparison of Distillate Yield per Hour with Time