Impact of Solar Powered Fountain on The Performance of Conventional Solar Still

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***Abstract*—An experimental analysis of conventional solar still (CSS) and solar-powered fountain when placed in Conventional Solar Still has been carried out and reported in this research article. For this experimentation, two geometrically similar CSS with 1 m^2 basin area from FRP material had fabricated. One of the still was placed without any modification and, the other solar still was set down with the solar-powered fountain. The objective of this experiment was to determine the impact that solar-powered fountain did on the performance characteristics of CSS and see the effect of this on the distillate output. The significant purpose of the solar-powered fountain in this experiment was to increase the evaporation rate and surface area. The distillate output obtained from MSS (Modified solar still) is 35.63% higher than CSS, whereas the average cumulative distillate output of MSS compared to CSS has elevated by 101.34% because of the solar-powered fountain.**

Keywords*— Desalination; Conventional solar still; Solar powered fountain

Nomenclatures:

a	Accuracy
T_w	Temperature of water surface (ºC)
T_ci	Inner glass cover temperature (ºC)
u	Standard Uncertainty

Abbreviations

AC	Total annual cost (Rs.)
AMC	Annual maintenance cost (Rs.)
ASV	Annual Salvage value (Rs.)
AWC	Annual water cost (Rs./l)
CRF	capital recovery factor
CSS	Conventional Solar Still
FAC	First Annual Cost (Rs.)
GI	Galvanized Iron
Rs.	Indian National Rupee
MSS	Modified Solar Still
SFF	Sinking fund factor

I. INTRODUCTION

Human civilization progresses into an age of machines. To attain these developments, we have been polluting our natural resources. One of the highly affected natural resources is water and, also this topic was globally discussed by world leaders. 70% of earth's surface is covered with water but, only 2% of it is freshwater rest is salty and brackish water which is exiguous for the present-day population. Solar desalination is a promising technique that can be applied to transmogrify brackish water into distilled water. The solar still is advantageous to places with less access to water supplies as it is easy to fabricate, requires parts that are within easy reach, and costs less than contrasted to modern water purifiers. Solar still not only purifies salt and dirt but also removes bacteria's in water to make it consumable. The various factors affecting the performance of the solar still are solar radiation intensity, wind velocity, ambient temperature, and the gradient of water surface and glass cover temperature, basin plate area, and glass inclination angle, depth of water. Solar energy is one such energy that is just not only free but renewable, sustainable, and environmentally friendly. Conventional solar still (CSS) is a passive device that works on the greenhouse effect and uses solar energy to desalinate brackish/salty water.

The solar intensity, wind velocity and ambient temperature cannot be controlled as they are metrological parameter whereas the remaining parameters, free surface area of water, absorber plate area, glass cover inclination and depth of water can be varied to enhance the productivity of the solar stills.

Carlos Wilson[1] firstly used the passive solar stills which are also popularly called as conventional solar stills (CSS) to supply fresh water to a nitrate mining community. The major drawback of CSS is its poor distillate output and requirement of a large surface area. A detailed review on the development of conventional solar still (CSS) have been reported by Kabeel et al. [2] and Ayoub et al. [3].

Jamil and Akhtar [4] have reported the influence of characteristic dimension (aspect ratios from 1.94 to 2.67) on the distillate yield of a CSS. Dumka & Mishra have presented a new method to increase the distillate yield of CSS by augmenting it with an ultrasonic fogger/humidifier [5,6], they have also reported a paper on comparative analysis of CSS and MSS (CSS augmented with permanent ferrite ring magnets) [7]. Kumar and Tiwari [8] and Sharshir et al. [9] work aimed to explore a new technique for improving the performance of solar stills (SSs) through utilizing three different types of a new hybrid structure of heat localization materials (HSHLM) floating on the water surface to increase the evaporation rate as well as water production and minimize heat losses. An exergo-economic analysis of a still for near coastal areas has been reported by Dumka and Mishra [10]. Influence of cocopeat augmented with solar still has been reported by Sharma et al. [11].

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The objectives of this research are as follows:

- Experimental analysis of instantaneous thermal efficiency of MSS and CSS.
- Variation in distillate yield of MSS and CSS.

II. EXPERIMENTAL SETUP

For this experiment, two identical CSS with 1m^2 basin area made from FRP material. The thickness of FRP still is 5 mm. Whose higher and lower sides are 0.48 m and 0.2 m, respectively. The inner surfaces of solar still were painted black to achieve higher absorption of solar energy. An iron transparent glass of 4mm thickness has been utilized to cover the still at an angle of 15.6º from the horizontal surface. The solar powered fountain used in this experiment has the dimension of 16cm × 16cm × 3.5 cm. Where, the fountain was placed in the center of the basin plate. The purpose of solar powered fountain was to increase surface area and evaporative cooling. Fig. 1 and 2 shows the photographs of CSS and MSS.

Fig. 1: Photograph of CSS

Fig. 2: Photograph of MSS

Five K-type thermocouples (K 7/32-2C-TEF) have utilized for measuring atmospheric temperature, inner glass surface and outer glass surface temperature, basin temperature, and water temperature in both CSS and MSS during the experiment. Temperatures have documented with the help of the DTC324A-2 temperature indicator during the experiment.

TABLE I: Measuring instruments accuracy, range and standard uncertainties

Instrument	Accuracy	Range	Standard uncertainty
Graduated Cylinder	±1 ml	0 - 250 ml	0.6 ml
Thermocouple	±0.1ºC	-100 - 500ºC	0.06ºC
Solar Power meter	±10 W/m^2	0 - 1999 W/m^2	5.77 W/m^2

The standard uncertainty is evaluated with the following expression [12]:

$$u = a / \sqrt{3} \quad (1)$$

where, a is the accuracy of the instruments. TABLE I shows the range, accuracy, and uncertainty of experimental instruments.

The experiments have been performed in the month of May-June 2021, at Jaypee University of Engineering and Technology, Guna, India. The duration of the experiments was 7 hr. After every hour, the following observations were made during the experiments:

- Glass, basin water and atmospheric temperatures.
- Solar radiation intensity.
- Distillate per hour.

III. OBSERVATIONS, RESULTS AND DISCUSSIONS

Fig. 3 shows the variation of solar radiation intensity and ambient temperature as a function of time. At the start of the experiment, solar radiation intensity and ambient temperatures were 690 W/m^2 and 26.6ºC, respectively. The maximum solar radiation intensity was recorded to be 995 W/m^2 at 13:30 h and, the maximum ambient temperature was 32.9ºC at 13:30 h. At the end of the experiment, solar radiation intensity was 330 W/m^2 at 17:30 h however the minimum ambient temperature was 29.1ºC at 17:30 h. The average solar radiation intensity and ambient temperature have been observed to be 764.375 W/m^2 and 29.775ºC respectively.

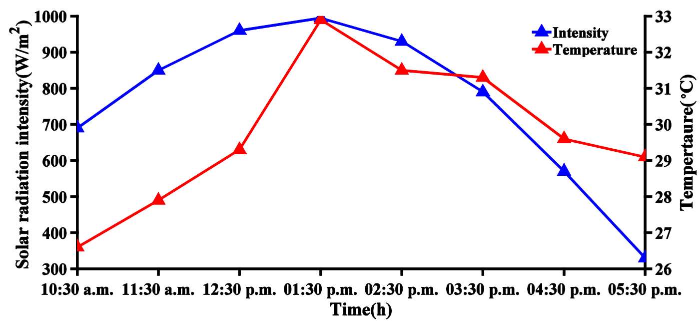

Fig. 3: Variation of solar radiation intensity and ambient temperature as a function of time

The Variation of basin water temperature as a function of time in CSS and MSS has depicted in Fig. 4. As T_w of CSS leads MSS throughout the experiment, this is due to the evaporative cooling caused by the solar-powered fountain, the peak value of T_w recorded for CSS was 44.7ºC at 13:30 h whereas MSS recorded a value of 41.2ºC at 14:30 h an hour delayed from CSS. Basin water temperature undergoes a total increment of 49.79% and 38.39% for CSS and MSS respectively. The average increment of basin water temperature of CSS in comparison to MSS has been observed to be 12.94%.

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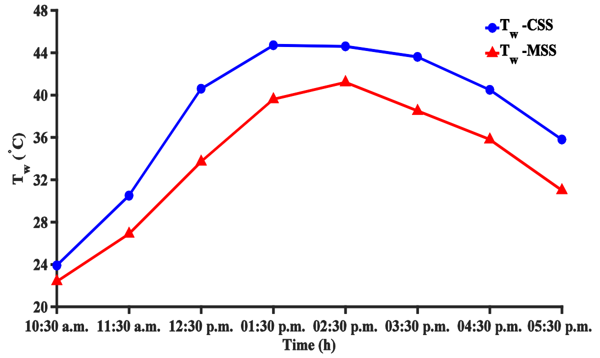

Fig. 4: Variation of basin water temperature as a function of time

Fig. 5 shows the variation of temperature of inner condensing glass cover as a function of time. T_{ci} of MSS leads CSS from the start of the experiment till 16:30h after that, CSS leads till the end. The CSS lead MSS in the end due to the evaporative cooling effect caused due to solar powered fountain placed in it. Peak value of T_{ci} recorded was 38.6ºC at 14:30h and 36.3ºC at 15:30 h for MSS and CSS respectively. The average glass cover temperature for CSS was 32.64ºC and for MSS was 34.78ºC. Increment from average temperature to peak temperature has been observed to be 11.2217% and 10.99% for CSS and MSS, respectively.

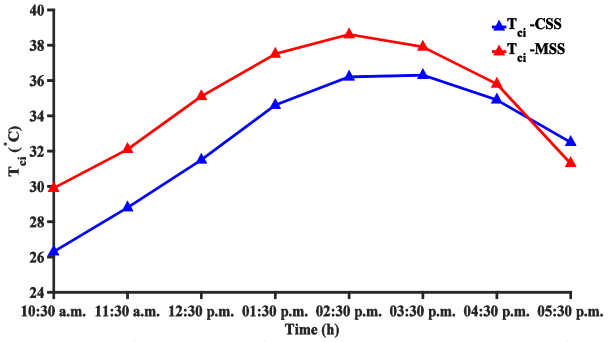

Fig. 5: Variation of temperature of inner condensing glass cover as a function of time

The variation of distillate yield obtained from CSS and MSS has shown in Fig. 6. The cumulative yield recorded from CSS and MSS is 0.811 and 1.1 liters, respectively. An increment in cumulative yield of 1108.33% and 200% was recorded for CSS and MSS, respectively. The distillate output obtained from MSS (Modified solar still) is 35.63% higher than CSS. The average cumulative yield increment of MSS was recorded to be greater than 101.34% from CSS.

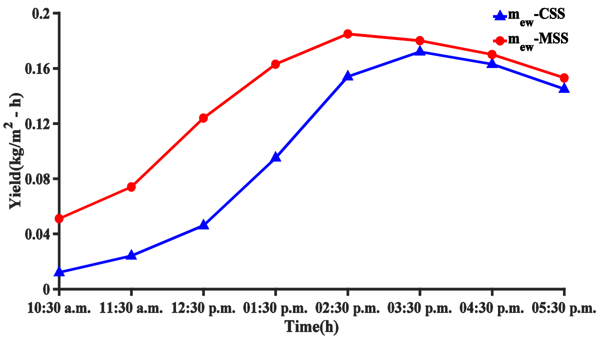

Fig. 6: Variation of distillate yield as a function of time

The variation of efficiency of CSS and MSS has shown in Fig. 7. During the entire experiment, MSS has been more efficient than CSS. MSS lead CSS by 5.83% in instantaneous efficiency recorded at 17:30 h. Instantaneous efficiency of CSS and MSS at 17:30 h was observed to be 29.53% and 31.26%, respectively. The mean overall efficiency for CSS and MSS has been recorded as 10.87% and 13.79% consequently. Augmentation of still with solar-powered fountain resulted in increment of overall efficiency by 26.86%. With the help of cost analysis as shown in TABLE II and TABLE III, one can understand how solar fountain helps in the reduction of cost per liter (CPL). The CPL in MSS has decreased by 20.34% in comparison to CSS.

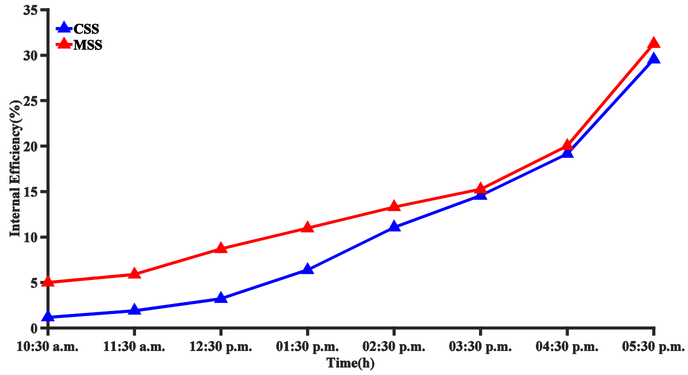

Fig. 7: Variation of instantaneous thermal efficiency as a function of time.

TABLE II: Installation cost and salvage value of different components of CSS and MSS (in Rs.)

	CSS	MSS	Salvage value
FRP Solar Still	6000	6000	600
Glass	500	500	0
Putty	100	100	0
Bubble wrap	100	100	0
Solar Fountain		1000	1000
Total Cost	**6700**	**7700**	**1600**

TABLE III: Values of different cost and factors for CSS and MSS.

	CSS	MSS
CRF	0.1468	0.1468
	0.0268	0.0268
SFF		
FAC	983.7224 Rs.	1130.5 Rs.
ASV	13.4121 Rs.	40.2364 Rs.
AMC	147.5584 Rs.	169.582 Rs.
AC	1117.9 Rs.	1259.9 Rs.
AY	202.75	275
CPL	**5.5135Rs./l**	**4.5814Rs./l**

All the above factors have been evaluated by the formulas given by Dumka et al. [12].

IV. CONCLUSIONS

Based on the theoretical and experimental analysis of CSS and CSS augmented with solar power fountain, the following conclusions drawn were:

- Due to evaporative cooling caused by the solar-powered fountain, the basin water temperature of CSS is higher than MSS.
- The average value of increment of basin water temperature of CSS in comparison to MSS is 12.94\%.
- The average value of increment of condensing inner glass cover temperature of MSS compared to CSS is 6.55\%.
- The average cumulative distillate output of MSS compared to CSS has been increased by 101.34\% because of the solar-powered fountain.
- The distillate output obtained from MSS is 35.63\% higher than CSS.
- The increment of overall efficiency is 26.86\% higher of MSS than CSS.
- The CPL for CSS was 5.5135Rs./l and MSS was 4.5814Rs./l.

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