Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2017.20443

67 (2017) 11–15
March

An experimental comparative performance study of semi-cylindrical and double slope solar still

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Received 6 October 2014; Accepted 16 December 2016

ABSTRACT

This paper investigates the performance of a semi-cylindrical solar still and compares it with a conventional single-basin double slope solar still. The transparent cover is made of semi-cylindrical shape glass and referred as semi-cylindrical solar still. Another still is made as a normal double slope single-basin solar still and tested under the same climatic conditions. The experiments were conducted with various depths of water, different wick materials, energy absorbing material and heat storing material in basin. The results show that the condensation rate is always higher in the semi-cylindrical solar still than in the conventional. For the same basin conditions, semi-cylindrical still produces around 56% more than the single-basin double slope still with black cotton cloth in basin. The maximum productivity of 2.87 and 1.985 kg/m^2/d is received in semi-cylindrical and double slope solar still, respectively, with mild steel pieces in basin.

Keywords: Solar still; Solar distillation; Double slope solar still; Semi-cylindrical solar still; Performance

1. Introduction

Solar still is a simple device that can be used for freshwater production in arid areas. It is relatively cheap to construct and easy to maintain. Conventional single or double slope single-basin solar still is not economical because of its lower productivity. Their performances can be improved by incorporating design modifications on cover and basin [1]. Malaiyappan and Elumalai [2] studied the various factors affecting the performance of the still. Manokar et al. [3] reviewed the works on improving the rate of evaporation and condensation process in the passive still.

Conventional solar still has single flat basin with single or double slope transparent cover. To improve the performance, the still different basin and cover plate configurations were designed and tested by different researchers. Durkaieswaran and Murugavel [4] discussed the various special designs, and Sathyamurthy et al. [5] discussed various physical configuration stills tried by different researchers to improve the still performance. Ensafisoroor et al. [6] experimentally compared the performance of different configuration basin solar stills. Dhiman [7] mathematically modeled and analyzed the thermal performance of a spherical solar still. The results show that spherical solar still efficiency is 30% more than the conventional solar still. Ismail [8] experimentally studied a simple transportable hemispherical solar still and evaluated its performance under local climatic conditions. The daily average efficiency of the still reached as high as 33% with a corresponding conversion ratio near 50%. Ahsan et al. [9] studied the effect of cover material of a tubular solar still. Transparent vinyl chloride sheet and polythene film were used as cover materials. Arunkumar et al. [10,11] designed a new solar still with a hemispherical top cover for water desalination with and without flowing water over the cover. The daily distillate output

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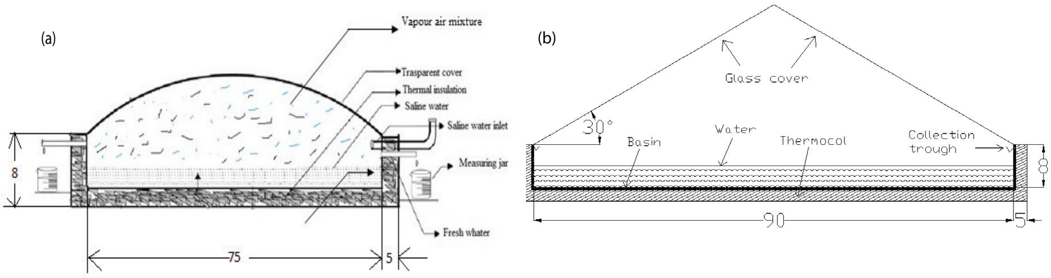

Fig. 1. Schematic drawing of (a) semi-cylindrical solar still and (b) single-basin single slope (dimensions in cm).

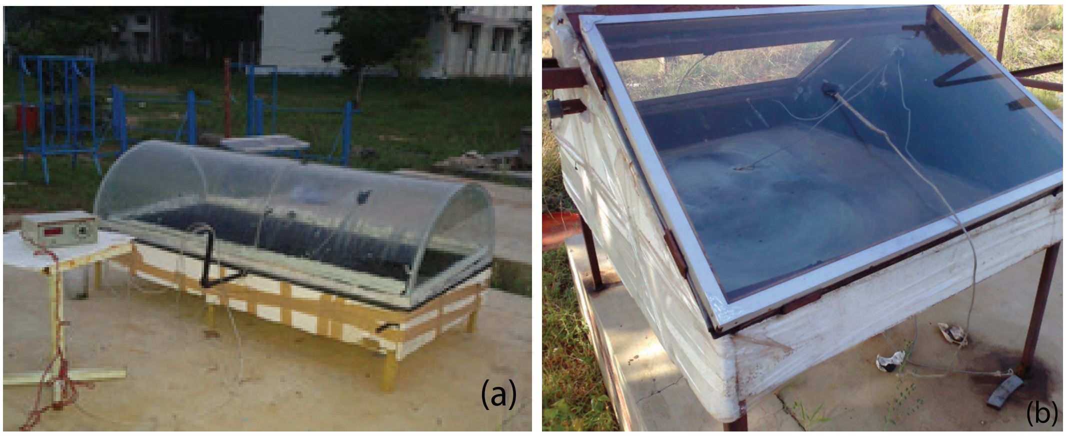

Fig. 2. Photographic view of (a) semi-cylindrical solar still and (b) single-basin double slope still.

Table 1
Accuracy and error limits for various measuring instruments

S.No.	Instrument	Accuracy	Range	% Error
1	Thermometer	+1°C	0°C–100°C	0.25%
2	Thermoouple	+0.1°C	0°C–100°C	0.50%
3	PV-type sun meter	+1 W/m^2	0–2,500 W/m^2	2.50%
4	Anemometer	+0.1 m/s	0–15 m/s	10.00%
5	Measuring jar	+10 mL	0–1,000 mL	10.00%

of the system is increased by lowering the temperature of the cover by water flowing over it. The daily distillate output of the system is increased by lowering the temperature of water flowing over it. Taamneh and Taamneh [12] experimentally investigated the effect of forced convection on the performance of pyramid-shaped solar still. It was found that usage of fan that works with energy from small photovoltaic panels improves the vapor flow and evaporation rate.

The above study reveals that varying the transparent cover configuration resulted in considerable improvement in productivity of the basin still. To validate this claim, the performance of the still with different cover configuration has to be tested simultaneously with conventional still and compared. In this work, single-basin solar still with hemi-cylindrical

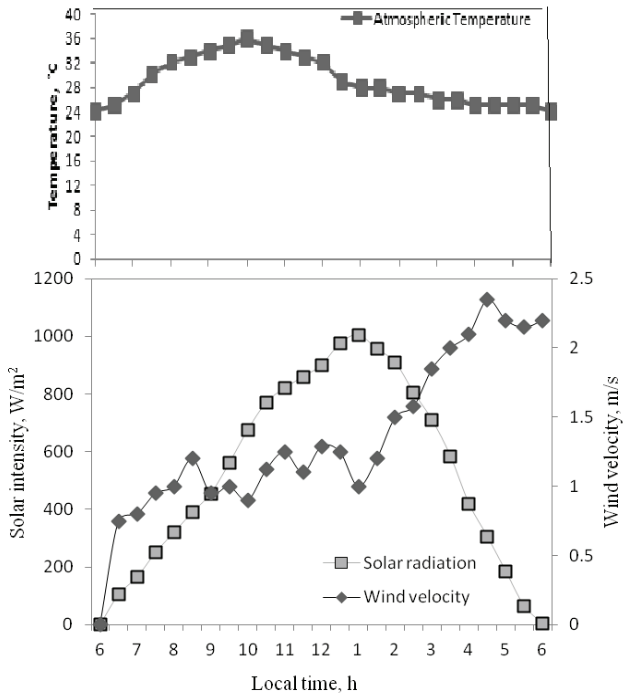

Fig. 3. Variation of solar radiation, wind velocity and atmospheric temperature.

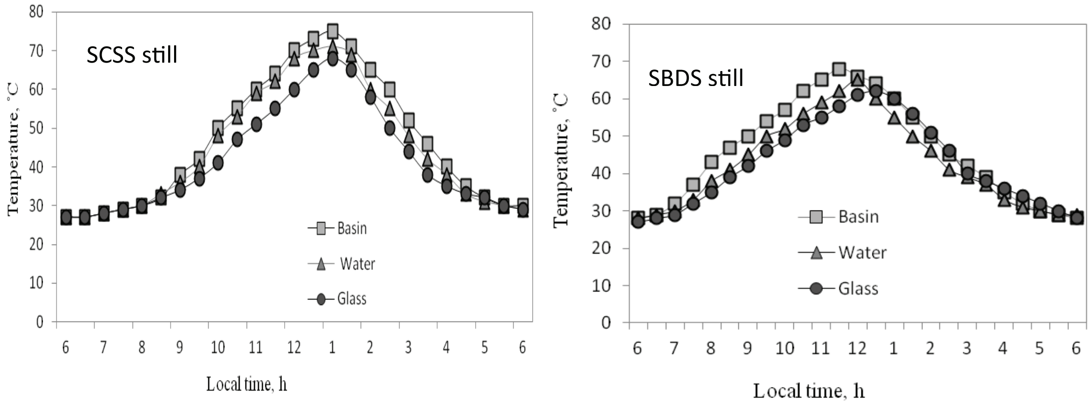

Fig. 4. Variation of temperature at different locations for 2 cm depth.

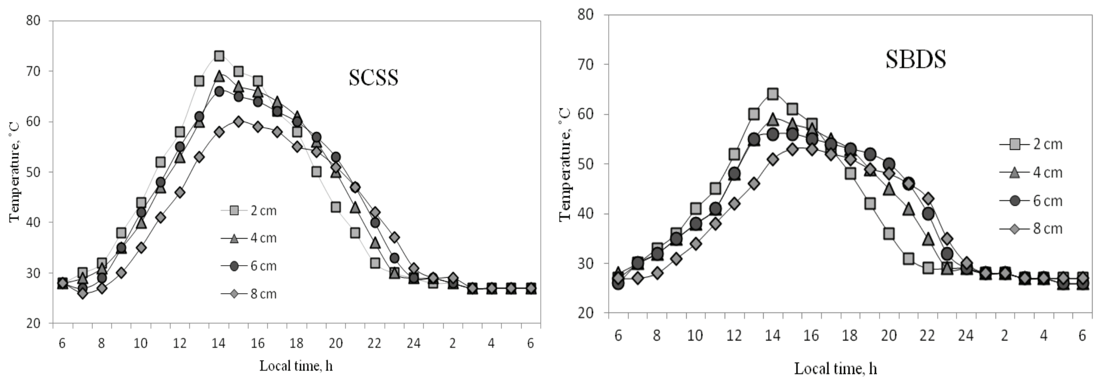

Fig. 5. Variation of water temperature for different depths.

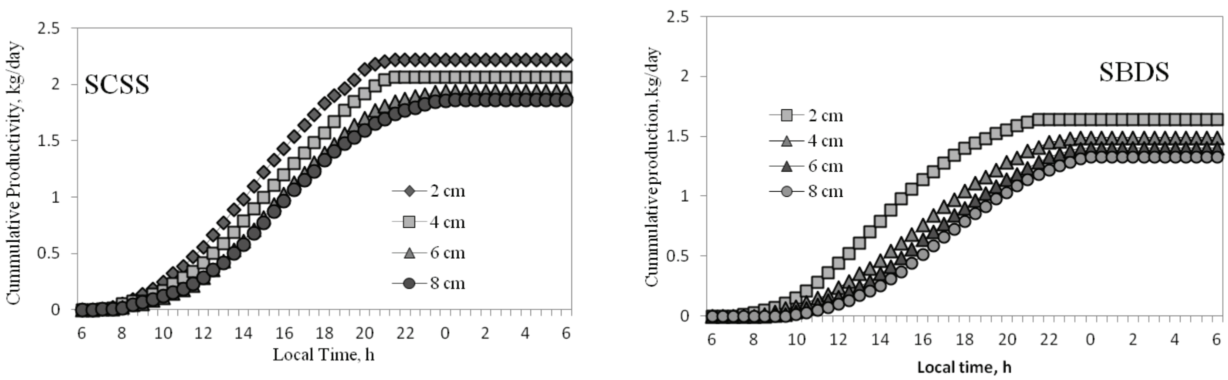

Fig. 6. Variation of cumulative water production for different depths.

transparent has been fabricated and tested simultaneously with conventional double slope solar still. Their performances were compared for different depth of water in the basin and with different energy storing, absorbing and wick materials in the basin.

2. Experimental setup and procedure

Fig. 1 presents schematic diagrams of single-basin and semi-cylindrical solar stills that are used in this study. The single-basin single slope solar still was having basin area of 0.9 m × 0.7 m, and semi-cylindrical solar still having basin area of 1.47 m × 0.75 m. Both the still basins are made up of 1.4 mm thickness mild steel plate. The basin is black coated to increase radiation absorption. The semi-cylindrical still transparent cover is made of semi-cylindrical glass. Window glass of 4 mm thickness is used as transparent cover with inclination of 30° in double slope solar still. The cover is fixed 10 cm above from the bottom of the basin. Both stills were insulated by the 50 mm thermocol.

The condensed water is collected in the V-shaped drainage provided below the glass lower edge on both sides of the still. The condensate collected is continuously drained through flexible hose and stored in a measuring jar. Solar radiation is measured by PV-type sun meter, and wind velocity and ambient temperature (T_a) is measured by digital anemometer and thermometer, respectively. The basin (T_b), water (T_w), glass (T_g) and condensate (T_c) temperatures were measured for the single-basin double slope and semi-cylindrical solar still using the K-type thermocouples. The minimum error that occurred in any instrument is equal to the ratio between its least count and minimum value of the output measured. The accuracies and error for various measuring instruments are given in the Table 1.

Both stills were installed, and experiments were conducted at Energy Park, National Engineering College, Kovilpatti (9°11′ N, 77°52′ E), Tamil Nadu, India, during March 2014. The readings were taken from morning 6 am to next day 6 am, for every 30 min interval. Experiments were conducted with different depth of water (2, 4, 6 and 8 cm), different wick materials (black cotton cloth, waste cotton pieces, jute cloth and polystyrene sponge), energy absorbing material (black dye) and energy storing material (mild steel pieces). Fig. 2 shows the photographic view of the single-basin double slope still and semi-cylindrical still with temperature measurement systems. The experimental results of the days with average radiation conditions were considered for analysis.

Fig. 7. Photographic view of materials used.
Note: 1 – Mild steel pieces; 2 – polystyrene sponge; 3 – lack dye; 4 – black cotton cloth; 5 – waste cotton pieces and 6 – jute cloth.

3. Results and discussion

3.1. Effect of different depth of water

The variation of different parameter of the stills for different depths of water in the basin is discussed in this section. Fig. 3 shows the average variation of solar radiation, wind velocity and atmospheric temperature during March 2014. The radiation reaches the maximum around 1.00 pm, and wind velocity is low in morning hours and increases during evening hours. Fig. 4 shows the variation of different temperature of single-basin double slope and semi-cylindrical solar still at 2 cm depth. It can be seen that for semi-cylindrical solar still, all temperatures are higher than single-basin double slope solar still. Result shows maximum temperature was reached at 1.00 pm for semi-cylindrical solar still and single-basin double slope still. This is due to higher amount of solar radiation received through semi-cylindrical cover than double slope cover.

Fig. 5 compares the variation of water temperature in semi-cylindrical solar still and single-basin double slope solar still. It can be seen that semi-cylindrical solar still water temperature is higher than the single-basin double slope solar still water temperature for all depth. The water temperature increase is depending upon the amount solar radiation received at the basin of the still. The semi-cylindrical cover facilitates in admitting more amount of solar energy into the still.

Fig. 6 shows the variations of actual cumulative production rate for different depth of water in the basin. For semi-cylindrical still, the production rate variation is uniform for all depths. But, for double slope still, the production variation is high at lower depth of 2 cm and lesser for higher depths.

3.2. Effect of using wick, porous and energy storing materials

From the above results, it can be concluded that minimum mass of water increases the productivity. Hence, the further experiments were conducted in semi-cylindrical solar still for 2 cm water depth along with different wick and energy storing materials in the basin. Fig. 7 shows the different materials used in this study, such as polystyrene sponge,

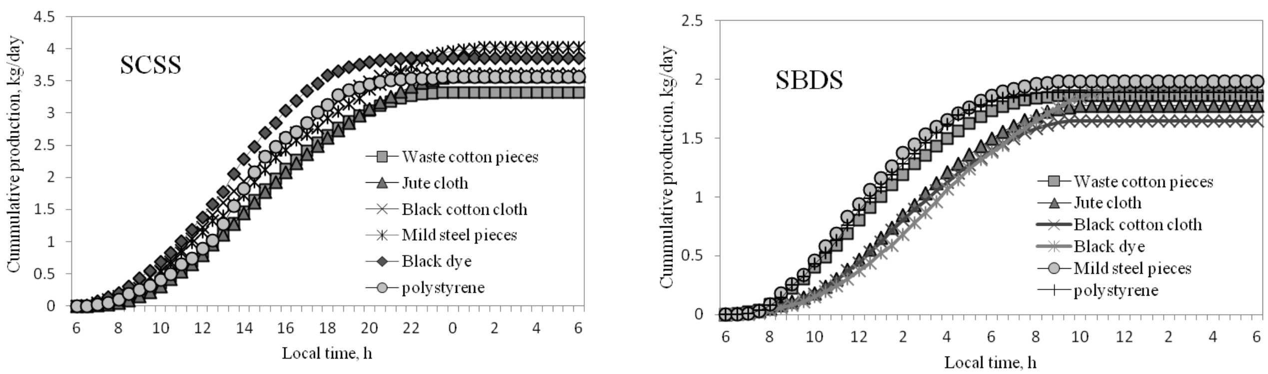

Fig. 8. Variations of cumulative production for different materials.

Table 2
Comparison of productivity in semi-cylindrical solar still and single-basin double slope solar still at different basin condition

S.No.	Basin condition	Total production				
		Semi-cylindrical still		Single-basin double slope still		
		kg/m^2/d	% Increase	kg/m^2/d	% Increase	% Increase (with single-basin double slope still)
1	8 cm	1.865	Reference value	1.300	Reference value	43.46
2	6 cm	1.935	3.753351	1.400	7.69	38.21
3	4 cm	2.065	10.72386	1.510	16.15	36.75
4	2 cm	2.215	18.76676	1.640	26.15	35.06
5	Waste cotton pieces	2.370	27.07775	1.860	43.07	23.71
6	Jute cloth	2.560	37.26542	1.775	36.5	44.22
7	Black cotton cloth	2.580	38.3378	1.650	26.9	56.63
8	Polystyrene sponge	2.545	36.46113	1.890	45.38	34.65
9	Black dye	2.755	47.72118	1.930	48.46	42.74
10	Mild steel pieces	2.870	53.8874	1.985	52.69	44.58

black cotton cloth, waste cotton pieces and jute cloth, having higher wicking properties, which enhances area of contact between water and air. Usage of black dye increases solar radiation absorption by the basin water. Mild steel will store the excess heat and release it during nocturnal period.

Fig. 8 shows the actual cumulative production variations of both stills for different materials in the basin. The cumulative production was higher through the entire day for the still with black dye in the basin than other materials. Polystyrene sponge was having higher production than mild steel pieces in morning hours. Polystyrene sponge contains minute holes; it leads to increase the production rate. But, the overall productivity was less for the sponge in the basin. Heat stored in the mild steel pieces releases in evening time and increases the productivity than any other materials and attains the higher overall productivity. Table 2 compares the productivity and increase in productivity (kg/m^2/d) of the stills for different basin conditions.

4. Conclusion

A semi-cylindrical solar still and a single-basin double slope still have been fabricated and experimentally tested for different depths of water in the basin, and their performances were compared in the same solar condition. These still were also tested with different materials, such as black cotton cloth, waste cotton pieces, jute cloth, polystyrene sponge, black dye and mild steel pieces in the basin along with water in the same solar condition. Both the stills yielded maximum water production at minimum depth (2 cm) of water in basin. Comparatively, semi-cylindrical still yielded more production for all basin conditions. It is also noted that provision of wick and energy storing material in the basin increases the distillate output in both stills. Semi-cylindrical still with mild steel pieces in the basin yielded a maximum of 2.87 kg/m^2/d.

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