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Research Article

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Performance Improvement of Single Basin Solar Still by Evaporating Surface Enhancement

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Abstract The performance of single basin solar still containing vertical water absorbing textile walls within the basin has been investigated. The textile absorbs water from the basin and evaporates it because of the absorbed solar energy. Two experimental sets (one without textile walls and another with textile walls) were conducted in this study. The productivity and thermal efficiency of the still in both cases were analyzed. It was observed that the average daily yield of distilled water is 10% higher when textile walls are used whereas the average thermal efficiency is 1.6 % higher. The quality of the distilled water was verified through water quality tests, which confirmed its suitability for the domestic use.

Keywords single basin solar still, textile walls, thermal efficiency, yield, water quality

1. Introduction

Many countries suffer from shortages of drink water because of the continuous increase of the population.

Various desalination techniques have been developed to meet out the increased demand of fresh water such as electro dialysis, multi-effect evaporation, and reverse osmosis. However most of the developed techniques consume large amounts of energy and they require intensive maintenance. The use of fossil fuels to drive a desalination unit has also negative environmental impact because of the carbon dioxide emissions [1-3].

Solar energy is abundant in most countries which suffer from fresh water shortage; therefore solar distillation is a very attractive technique for those countries. Additionally this technique is environment friendly and simple compared to other desalination techniques. When saline or brackish or contaminated water is kept in a closed container under the open sky, it gets evaporated. The solar energy is used to accelerate the process of evaporation in the solar still [4-5]. The function of a solar still is to collect the evaporated water vapour by condensing it on a cool surface.

Solar stills are classified broadly into two categories namely passive and active solar stills. Passive solar stills require solar energy for evaporation of saline water whereas active solar stills require an additional thermal energy by external mode for faster evaporation [6-8]. The passive solar still is the most economical solar still to provide drinking water for domestic applications at decentralized level. This is due to the fact that it is simple in design and fabrication, easy to handle, long life and low production cost [9-12]. Passive solar stills are available in different configurations like basin type solar still, wick type solar still, tubular solar still, spherical solar still, parabolic solar still; fibre reinforced plastic solar still, vertical solar still, cascade solar still, staircase solar still, etc. Basin type solar stills are widely used for domestic purposes in the arid and semi-arid areas due to their economic advantages like low investment cost, low maintenance cost and low production cost [13-15].

Numerous factors affect the performance of a solar still. The design factors such as absorbing material, absorbing area, condensing cover material, cover slope, cooling of cover, water depth, insulation material, insulation thickness, geographical position of the still, sun tracking system, etc. Also the climatic factors such as solar intensity, ambient temperature, wind velocity, etc affect thermal efficiency and the productivity of the solar still [16-18]. Generally, the production of fresh water by solar still is quite low. However, it can be improved with the proper control of most significant factors like absorbing material, water depth, condensing cover material, etc [19-20]. The objective of this study is to improve the performance of single basin passive solar still by increasing the evaporating area using textile walls inside the water basin.

2. Experimental Setup

The passive solar still was fabricated with a basin made up of 5 mm thick galvanized steel. The basin was covered with 4mm thick glass which acts as a solar collector. The joining surfaces were tightly sealed with silica gel to make the basin entirely closed. The inlet and outlet for brackish water and desalinated water were made on the side of the basin as shown in fig. 1. The basin was placed on a mild steel frame and was insulated thermally to avoid heat loss from the sides and the bottom. A reflective mirror was mounted on the inner back side of the basin in order to maximize the solar radiation intensity fallen on the bottom of the basin. The schematic of the single basin passive solar still is shown in Fig. 1. The specifications of the solar still are given in Tab. 1.

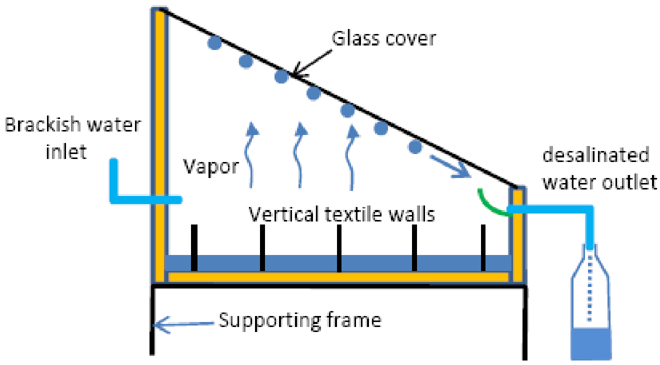

Figure 1: Schematic of the used solar still with vertical textile walls

The experiments were conducted in Damascus (Syria) with Latitude of 33.51 and Longitude 36.28. The experiments were started on 9:30 a.m. and completed on 16:30 p.m.. Two sets of experiments were conducted in this study. First set was conducted using the experimental setup without the vertical textile walls for three consecutive days, whereas the Second set of experiments was conducted using the same experimental setup including the black textile walls for another three consecutive days.

Table 1: Specifications of the solar still

Parameter	Dimension
Length of basin	60 cm
Width of basin	60 cm
Depth of basin in front side	20 cm
Thickness of glass	4 mm
Tilt angle of glass	33°
Height of textile walls	5 cm
Length of textile walls	50 cm
Insulation thickness	5 mm

First set of experiments was conducted using the solar still filled with 5 liters of brackish water. The experiments were started on July 9th 2018 and completed on July 11th 2018. The solar still was placed with the tilted glass facing the sun (facing south) for all times. The solar intensity, perpendicular to the cover glass, and the amount of the distilled water were recorded every hour between 9:30 and 16:30 o'clock. The salts and other contaminants left in the seawater were flushed out and the basin was filled with 5 liters of brackish water on 8:30 o'clock. The experiments were repeated on second and third day under the same conditions.

The second set of experiments was conducted by placing the vertical textile walls in the solar basin. The experiments were started on September 16th 2018 and completed on September 18th 2018. The solar intensity as well as the distilled water quantity was recorded hourly between 9:30 and 16:30 o'clock.

3. Results and Discussion

- **Solar intensity**

The solar intensity perpendicular to the glass cover was measured hourly during the two experimental periods using a measuring instrument from type MacSolar SLM 018c with an accuracy of ± 3 %. The solar intensity curves were almost identical for the three measuring days of each measuring period. Fig. 2 shows the solar radiation intensity on 9 July representative for the first measuring period and the solar intensity on 16 September representative for the second measuring period.

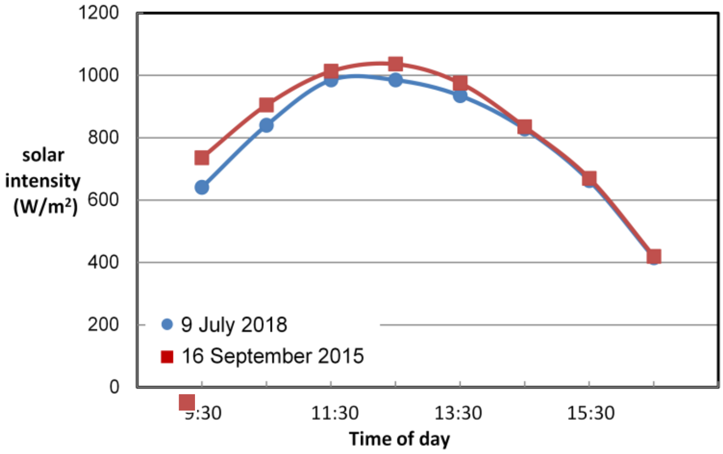

Figure 2: Solar radiation intensity on both measuring periods

- **Distilled water amount**

Fig. 3 shows the hourly distilled water amount in the first experimental period. The hourly distilled water yield is similar in all three days. The light differences are mainly caused by the small variations in the wind velocities and ambient temperatures. Between 8:30 and 9:30 o'clock, no distilled water is produced because the solar radiation is weak and the water in the basin is not warm enough. The maximum produced distilled water was 1055 ml on 11 July, whereas the minimum amount was 1022 ml on 10 July 2018.

Fig. 4 shows the hourly distilled water amount in the second experimental period between the 16th of September and the 18th of September. The average amount of distilled water in the second experimental period was approximately 10 % higher than in the first period. This result can be attributed to two factors; the first one is due to a higher solar intensity in the second period and the utilization of the textile walls represents the second factor.

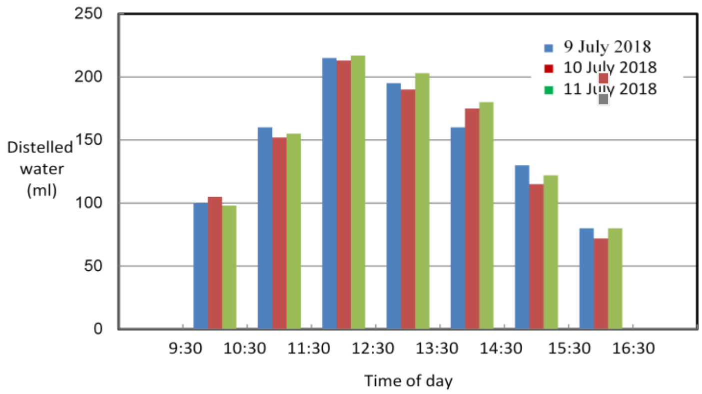

Figure 3: The amount of distilled water hourly on the first experimental period

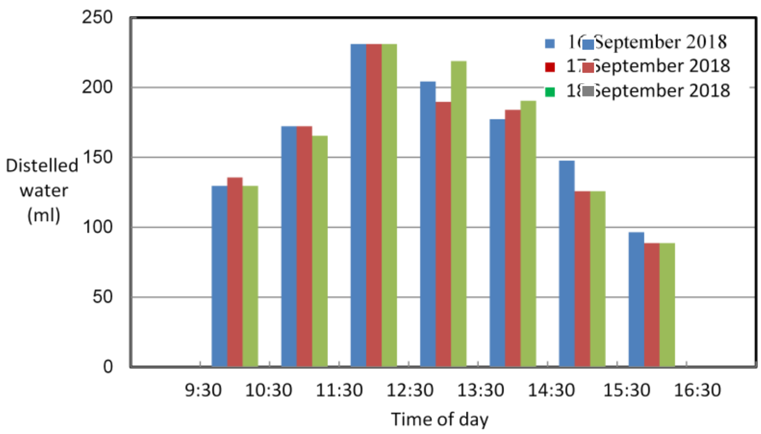

Figure 4: The amount of distilled water hourly on the second experimental period

- **Thermal efficiency**

The thermal efficiency (η) of a solar still represents the part of solar energy which utilized for producing the distilled water during a particular time interval Δt. It depends upon solar intensity (I) perpendicular to the glass cover, glass cover area (Ag), latent heat of water evaporation (H_L) and production rate of water. This efficiency can be estimated from the ratio of the amount of energy used for the production of the distilled water (m_w) and the average solar intensity received in the time interval.

$$\eta = \frac{m_w H_L}{I A_g \Delta t} \quad (1)$$

where H_L is 2257 kJ/kg.

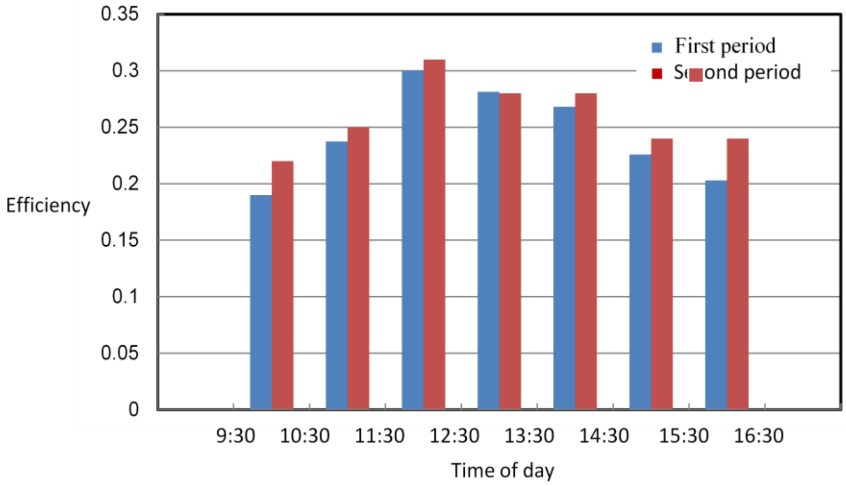

Figure 5: Recorded Thermal efficiency on the first and second experimental periods

Fig. 5 shows the average thermal efficiency during the first and second measuring periods as a function of the day time. A maximal improvement of 3.7 % can be seen as a result of the use of textile walls for enhancing the evaporating surface, whereas the average improvement in the thermal efficiency is 1.6%. The improvement is pronounced at the beginning and the end of the process where the solar radiation has not reached its maximal value. The improvement of the efficiency is minimal at the midday, where the water temperature reaches maximal value.

The improvement of the efficiency is much lower than expected, if we consider that the surface of the textile walls is approximately 2500 cm^2, which means that the enhancing of the evaporating surface is 70%. The low improvement of the efficiency can be attributed to the reaching of a saturation state of vapor inside the solar still above the water in the liquid state. The achievement of the saturation occurs slower at the transition phases at the beginning and end of the process, because the water temperature is not constant, therefore the improvement of the efficiency is maximal in these regions. In contrary, the water temperature is almost constant at the midday and the saturation occurs rapidly, which cause a minimal improvement in the efficiency.

- **Water quality**

Two water samples were chemically analyzed in order to determine the removal of some elements in the water during the distillation process. Table 2 shows the measured values before and after the distillation. The decreasing percentage lies between 87.5 % (Sulphate) and 99.9 % (Magnesium). The large decreasing percentage values indicate the capability of the solar still to produce drinkable water from brackish water.

Table 2: Measured values of some elements

	Undistilled water (mg/l)	Distilled water (mg/l)	Decreasing percentage (%)
Chloride	16.75	0.42	97.5
Fluoride	0.33	<0.01	97
Sulphate	12.5	1.56	87.5
Calcium	45	0.71	98.4
Potassium	1.9	<0.1	94.7
Magnesium	11	<0.01	99.9
Sodium	30	0.23	99.2
TDS	256	12	95.3

4. Conclusion

The performance of a single basin solar still has been improved using textile walls inside the basin. The textile walls absorb the water from the basin leading to increase the evaporation surface and consequently the evaporation rate. The amount of distilled water has been increased by 10 % because of the textile walls, whereas the thermal efficiency has been increased by 1.6 %.

Water quality tests have been performed for samples before and after the distillation. The content of the tested elements and compounds is decreased by 87.5 % to 99.9 % indicating the capability of the solar still to produce drink water from brackish water. Further improvements of the performance of the solar still using energy storage materials inside the basin are under way.

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