Experimental investigation of single slope solar still using different wick materials: a comparative study

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Abstract. Solar still play an important role in mitigating potable water scarcity mainly in developing countries because of its low-cost and easy design. One major concern regarding solar still is the low productivity. Using a wick in still basin decreases active water depth and increases the evaporation rate of basin water. In the present work, a comparative study of single slope solar still using different wick materials is performed. Bamboo cotton, jute, wool, and cotton are used as wick materials. To carry out experiments, two single slope solar stills of similar dimensions are designed and constructed. Wick is placed over the rectangular shaped fins installed in the still basin. The experiments are conducted for 25 days and data collected on the clearest sunshine days are presented in this work. Water depth is kept constant at 1 cm throughout the experiments. Experimental results showed that maximum still productivity and efficiency is obtained using bamboo cotton wick as 3.03 l/m²day and 34.5% respectively. This is 16.9%, 20.7%, 37.8% and 51.9% higher than jute, cotton and wool wick and conventional still. It is evident from the experimental results that bamboo cotton is the most suitable wick material in comparison to others.

Keywords: solar still, water depth, bamboo cotton, still productivity, efficiency

1. Introduction
Freshwater is the most essential component for healthy and sustainable life. Now-a-days freshwater scarcity is an extremely important problem which needs to be tackled immediately. Mostly in developing countries this problem has become severe due to rapidly increasing population, lack of cognizance in people, uncontrolled consumption and wastage of freshwater. Also, major portion of the available freshwater resources existing in developing countries are polluted due to continuous disposal of agricultural waste, industrial waste and human sewage. Therefore the need of potable water is increasing exponentially in developing countries.

Water desalination and distillation using solar still is very advantageous in this respect due to its low-cost and easy fabrication. Low productivity is the main drawback regarding solar still. Different research works are being carried out to increase the still productivity. The use of a finned absorber plate fitted in still basin increases the exposed heat transfer area and a 15.5% increase in still productivity is achieved by Ayuthaya et al. [1]. Rajaseenivasan and Sritheer [2] concluded that use of square fins is more effective in terms of productivity and efficiency than circular fins. Still productivity is defined as the total amount of freshwater obtained from the solar still and solar still efficiency is defined as the ratio of total distillate output to the total input energy to the solar still. Rababa’h [3] compared the performances of yellow sponge, black painted sponge, black coal and black steel used in the still basin. In spite of higher heat absorption the use of black painted sponge
resulted in lower productivity than yellow sponge. This is due to the decreased capillary rise as some of the voids get blocked by black paint. The use of various thermal energy storage materials enhances the night time productivity as they absorb sun’s heat and gets charged during daytime and provides heat during night time. Kabeel and Abdelgaid [4] used paraffin wax as latent heat storage material in a single slope solar still and observed 67.18% increase in productivity. Sensible heat storage materials like servotherm oil and sand were used under the still basin by Deshmukh and Thombre [5]. The results showed a small decrease in daytime productivity but a good increase in night time productivity. Cooling of glass cover increases condensation rate and enhance the still productivity. Water flowing over the glass surface resulted in productivity enhancement [6]. The use of internal and external reflectors in a solar still ensures maximum trapping of solar radiances inside the still. This helped in achieving maximum water temperature and evaporation rate. El-Swify and Metias [7]; Omara et al. [8] applied internal reflectors on the side walls and back wall of still and increased the still productivity to a good extent. Tanaka and Nakatake [9] theoretically analyzed the effect of using internal and external reflectors on the still performance. The total amount of radiations reflected by both reflectors were calculated and a productivity rise of 48% is obtained in the analysis. The use of a wick in still basin also enhances the still productivity. It reduces the water depth, slows down the water movement and thus allows more heat absorption and enhances the evaporation rate of basin water. Karthick Munisamy et al. [10] studied the effect of using different wick materials namely polyester, Terry, jute and fur in an inclined solar still. It was concluded that the use of fur fabric wick material resulted in better productivity in comparison to others. Sakthivel et al. [11] utilized jute cloth as wick material and fixed it on the inner surface of back wall and vertically upwards in the middle of still basin. This modification enhanced the still productivity by 20%. Murugavel and Srithar [12] enhanced the still productivity to 3.58 kg/m².day by using black cotton cloth wick material over rectangular fins made of Aluminium. Jute, woven and linen cloths stitched to a plane wick used by Omara et al. [13], wood pulp paper, water coral fleece and polystyrene sponge used by Hansen et al. [14] are some other wick materials that resulted in productivity enhancement of a still.

The use of bamboo cotton fabric as a wick material in solar still does not exist in the present literature. Main aim of the present study is to enhance the productivity of a single slope solar still using bamboo cotton wick. Moreover, an experimental comparative study of jute, cotton and wool fabrics with bamboo cotton as wick materials used in still basin is carried out in this work.

2. Experimentation

2(a) Experimental set-up and instrumentation

Two single slope solar stills of same dimensions and basin area 0.36 m² are fabricated and experimentally tested in the climatic conditions of National Institute of Technology Kurukshetra, India having coordinates (29.9490° N, 76.8173° E). Basin of both solar stills is made up of galvanized iron and is painted in black colour for maximum heat absorption. A 4 mm thick glass cover is inclined at an angle equal to latitude angle of the location. The bottom plate, side walls and back wall of the still is insulated with 5 mm thick glass wool to minimize heat losses to the surroundings. Silicon is applied around the sides of the inclined glass cover to avoid any vapour leakage from the solar still. A storage tank of 100 litre capacity is used to feed brackish water inside the still and to maintain the desired water depth in the basin. PT-100 thermocouples of accuracy ± 0.1 °C and range up to 200 °C are installed at different points for measuring basin water, glass cover and ambient temperature values. All these temp values are indicated by a digital temperature indicator. Solar intensity is measured by a pyranometer of accuracy ± 1 W/m² and range 0-5000 W/m². Wind velocity is measured by an anemometer with accuracy ± 0.1 m/s and range 0.2-30 m/s. Hourly productivity is measured with the help of a calibrated plastic cylinder with accuracy ± 1 ml and range 0-1000 ml. An error of ±2.9% in experimental results is calculated by following the procedures presented by Barford [15].

2(b) Experiment procedure

The experiments are conducted in the winter months of January and February. The schematic diagram of experimental set-up is shown in figure 1. Four different types of wick materials namely bamboo
cotton, wool, jute and cotton as shown in figure 2. are used in the experiment. All wick materials are dyed black to ensure maximum absorption of solar radiations. The experimentation is performed for 25 continuous days with two solar stills using different wick materials. The data collected on days with maximum sunshine hours is presented in this work. Experimental testing of jute wick and bamboo cotton wick in still basin is performed on dated 06-02-2018 and testing of cotton and wool wick in still basin is performed on 15-02-2018. The testing and data collection for conventional still is done on 18-02-2018. Brackish water was collected from a small pond in Dayalpur village in Kurukshetra district. The glass of solar still was cleaned before the sunshine hours and experimental set-up was made ready before 8 A.M. The various measuring instruments namely pyranometer thermocouples, digital temperature indicator, and anemometer are checked for their smooth functioning before the start of readings. The brackish water was fed to the still basin from storage tank to keep water depth to 1cm. The entire set-up was made ready up-to 8.30 A.M. The experimental data in the form of basin water, ambient, glass cover temperature, solar radiation intensity, wind velocity, productivity were collected every hour from 9 A.M. till 5 P.M. on all testing days.

This brackish water in still basin was evaporated inside solar still by absorbing solar radiations and condensed on the comparatively cool inner portion of inclined glass cover. The rate evaporation depends on the amount of solar radiations entering the solar still and absorbed by the basin water. The rate of condensation totally depends on the temperature difference between water vapors and inner surface glass cover. The higher the temperature difference the better the rate of condensation achieved. The condensate is collected in a trough and then in container located outside the solar still. The photograph of distilled water and brackish water are shown in figure 3.

Figure 1. Schematic diagram of experimental set-up.
3. Results and discussion

All experiments are conducted at a constant water depth of 1 cm. Bamboo cotton has remarkable hygroscopic properties and the results from experiments proved it a better wick material when compared with others. The variation of solar radiation intensity on testing days with time is shown in figure 4. The maximum radiation intensity is observed at 1 P.M. on both testing days. Solar intensity increases in the morning up to 1 P.M. and decreases afterwards. The variation of basin water temperature with time for solar still using different wick materials and conventional still is shown in figure 5.

The maximum water temperature of 64.2 °C is achieved with bamboo cotton wick. This is due to good water absorption by bamboo cotton leaving less amount of water in still basin leading to more heat absorption by basin water. The variation of glass cover temperature with time is shown in figure 6. The maximum glass cover temperature of 43.1 °C is achieved with bamboo cotton wick due to high latent heat of condensation absorbed by the glass surface. The maximum ambient temperature is achieved between 1 P.M. to 2 P.M. due to the availability of maximum solar radiations during this time interval. The variation of hourly still productivity with time is shown in figure 7. Due to high rate of water absorption and water release from bamboo cotton, the evaporation rate is high. The maximum hourly productivity of 222 ml is achieved at 1 P.M. at the time of maximum solar intensity using bamboo cotton wick.
bamboo cotton wick. The variation of accumulative productivity with time is shown in figure 8. The maximum accumulative productivity of 1091 ml is achieved with bamboo cotton. Some output is obtained after 5 P.M. as well with bamboo cotton still due to heat storage. Figure 9 shows the accumulative productivities of still using bamboo cotton, jute, cotton, wool wicks and of conventional still. Solar still using bamboo cotton wick delivered maximum yield of 3030 ml/m²d that is approximately 52% higher than conventional still. Also, the still productivity using bamboo cotton wick is 16.9%, 20.7%, 37.8% higher than jute cotton and wool wicks respectively.

![Figure 6. Variation of glass temperature with time.](image)

![Figure 7. Variation of hourly productivity with time.](image)

Figure 10 shows the values of daily efficiencies for different still modifications. The maximum daily efficiency of 34.5% is obtained for the still with bamboo cotton wick which is 1.7%, 4.4%, 4.7% and 6.4% higher than still using jute wick, cotton wick, wool wick and conventional still respectively.

![Figure 8. Variation of accumulative productivity with time.](image)

![Figure 9. Accumulative productivity using different wick materials.](image)

Some important experimental data in the form of maximum water temperature ($T_{mw}$), maximum glass temperature ($T_{mg}$), accumulative productivity ($P_a$) along with meteorological data in form of maximum solar intensity ($I_m$), maximum ambient temperature ($T_{ma}$) and average wind velocity ($V_a$) is presented...
in Table 1. The brightest sunshine hours were obtained on two testing days 06-02-18 and 15-02-18 and still using jute wick, bamboo cotton wick and wool wick, cotton wick were tested on these days respectively. The maximum efficiency obtained in different modifications is also mentioned in Table 1. It is observed from the table that maximum solar intensity and ambient temperature on both testing days are approximately same. Also the best results were obtained in case of bamboo cotton wick.

![Graph](image)

**Figure 10.** Daily efficiency using different wick materials.

**Table 1.** Experimental and meteorological data collected from the experiments.

| Wick material       | Experiment date | Experimental data | Efficiency, $\eta_d$ (%) | Meteorological data |
|---------------------|-----------------|-------------------|--------------------------|---------------------|
|                     |                 | $T_{mw}$ °C | $T_{mg}$ °C | $P_a$ (l/m² day) |                     | $I_m$ (W/m²) | $T_{ma}$ °C | $V_a$ (m/s) |
| Jute                | 06-02-18        | 62.0       | 41.9       | 2.59             | 32.8                | 743       | 22.7       | 1.42       |
| Bamboo cotton       |                 | 64.2       | 43.1       | 3.03             | 34.5                |           |            |            |
| Wool                | 15-02-18        | 58.1       | 40.5       | 2.20             | 29.8                | 742       | 23.5       | 1.82       |
| Cotton              |                 | 60.9       | 41.4       | 2.50             | 31.1                |           |            |            |

**4. Conclusions**

The effect of using bamboo cotton wick in a single slope solar still is experimentally investigated in this study at a constant water depth of 1 cm. To enhance the rate of heat exchange, aluminium fins of rectangular shape are installed in the still basin. All wick materials were placed over the rectangular fins and experimental performance of bamboo cotton wick is compared with jute wick, cotton wick, wool wick and conventional still. The following results are drawn from the experiments conducted:

- Using wick in still basin enhances still productivity and efficiency considerably with maximum values of 3.03 l/m²d and 34.5% obtained for a bamboo cotton wick respectively followed by
2.59 l/m²d productivity for jute wick, 2.50 l/m²d for cotton wick and 2.19 l/m²d for wool wick. The productivity obtained for a conventional still is 1.99 l/m²d.

- The use of rectangular fins in still basin increases the heat transfer rate between water and basin liner thereby increasing the evaporation rate of water.
- The maximum basin water temperature of 64.2°C is obtained for a bamboo cotton wick still.
- The daily still efficiencies with jute wick, cotton wick, wool wick and conventional still is averaged at 32.8%, 31.1%, 29.8% and 28.1% respectively.

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