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EXPERIMENTAL INVESTIGATION OF BASIN TYPE SINGLE SLOPE SOLAR STILL WITH FLOATING WICKS

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ABSTRACT

In the present study, the conventional single effect basin type solar still has been modified by encorporating wicks inside the basin to enhance its productivity. The float wick helps to make the contact with basin water as the level of basin water reduced with the progress of the day. The rate of evaporation of basin water in modified still increased dur to reduce in inertia of basin water and water gets evaporated when direct sunlight falls on it. Both the stills were fabricated with same material and dimensions for comparison purpose.The performance of modified still has been compared with the conventional still under similar operating and weather conditions. The productivity of modified and conventional still was 4.33 kg/m^2 and 3.48 kg/m^2 respectively when the solar intensity and ambient temperature was 22.32 MJ/m^2 and 35.29 ℃ respectively. The overall and day productivity of modified still was 24.19% and 39.06% respectively higher than that of conventional still.

KEYWORDS: Solar Still, Float Wicks, Desalination & Productivity

Original Article

1. INTRODUCTION

In present time, the amount of fresh drinkable water is decreasing due to contamination of water from industrialization and urbanization. In coastal regions and arid areas, abundant amount of sea water or slightly saline water is available but there is scarcity of potable water. The most economical method to overcome this scarcity of water is use of solar still, which converts brackish water into potable one without using any conventional source of energy. The main drawback associated with solar stills is their low productivity.

In coastal regions and arid areas where sea water or slightly salty water is available but there is scarcity of potable water. There are many ways to treat this impure water by using non-renewable energy. But in the areas where non-renewable energy is costly or not available, the solar distillation is the main technique that can be utilized to get consumable water. In solar distillation, heat energy is given as input which is taken from the sun. Solar stills are very cheap devices which can be used in solar desalination technology. The main advantage of using solar still is that it makes use of clean and free energy due to which this device is eco-friendly.

The percentage of salty water is about 97% on earth surface (Selvaraj & Natarajan, 2017). Desalination of saline and brackish water is very important. Brackish water contains various harmful bacteria. Solar still is a sustainable source for purification of saline water (Kaushal, 2010). Basin type single slope solar still have glass cover, wicks and black liner in the basin. Solar energy passed through glass cover and then enters into the still. The hot basin water gets evaporates and condensed on the glass surface which further collected in a container through a channel fixed on the glass cover.

Productivity of single slope solar still can be increased by using wicks, wax, blacked jute cloth, reflectors etc. Ambient temperature, wind velocity, solar input, water depth are various factors affect the performance of solar still. Daily productivity is to be improved by using wick material such as jute cloth. Jute cloth is cheap and easily available in the market. The performance of solar still is to be increased by modification in their design and convert into active multistage solar still. Now, the productivity of multistage solar still is to be increased up to 100 l/day with black coated basin surface (Sandeep, Kumar, & Dwivedi, 2015). M. Saktivel et al. (2010) have done experimental study and found that the productivity of solar still without wick material was low. The productivity was enhanced by using wicks material like jute, sponge etc. Wick materials used to enhance the production of fresh and pure water. The daily productivity was increased 3.9 kg/m^2 by using jute cloth. Khalifa et al. (2009) experimentally found the effect of basin type solar still with insulation material. The effect of insulation thickness on basin type solar still was found experimentally and the basin type solar still was covered with insulation material having thickness 30 mm, 60 mm and 100 mm respectively. The result showed that the productivity of solar still was enhancing with 60mm insulation. Hansen et al. (2015) found that the productivity of inclined type solar was enhanced by changing different wick materials. The distillation of pure water was also to be increased with stepped absorber, flat absorber and wire mesh. The charcoal cloth has used in solar still at the bottom as absorber, due to this solar still basin absorb more heat and the productivity was increased. Sharon et al. (2017) found that the productivity of solar still was increased by using wick material. The productivity of pure water was 2.5 L/m^2. Distillate water production increased by 90% by using blacked jute wick. The blacked jute wick material absorbs more heat from the sun and due to this water distillation could increase. Phadatare and Verma (2007) experimentally found that the single slope basin plastic solar still performance was found to be enhanced by using insulation of glass wall of 2 mm with black acrylic sheets of 3 mm. The basin water depth was also played a very important role. The experimental study showed that the basin water depth was 2 cm and the productivity of pure water increased. The overall productivity of pure water was found to be 2.1 l/m^2 day. Durkaieswaran (2015) found that the basin type solar still productivity was enhanced with low mass of water, black cloth and aluminium insulation. Solar still performance was increased with aluminium rectangular fin cover due to this there was no heat loss. Black cotton cloth was also enhanced the productivity of desalination in basin type solar still device.

In the present work, a single slope basin type solar still has been modified by placing multiple float wicks in the basin of the still. The float wick was made by wrapping black cotton cloth on thermocol sheet having protective layer of polyurethane foam to avoid any burn out due to high temperature. The solar still contains floating wicks in the basin referred as modified still and whereas the still without paraffin wax in basin referred as conventional still. The performance of modified still has been compared with the conventional basin type still of identical specifications under same ambient conditions. The use of float wicks reduced thermal inertia of the basin leading to early response and higher operating temperatures which resulted in enhanced distillate outputs of the modified still as compared to the conventional still.

2. EXPERIMENTAL SET UP

In this experimental work, there was two solar still fabricated having same geometrical dimensions and size (conventional still and modified still) as shown in Figure 1. In the modified still, there was a use of paraffin wax as an energy storage medium. The basin tray was made up of stainless steel having evaporating surface area of 1.2 m^2. The glass cover was inclined at 30° with the horizontal surface, which is almost equal to latitude of location. The bottom surface of basin is covered with black rubber liner, which helps to improve the absorption of solar radiation.

Figure 1: Pictorial View of Experimental Set up of Conventional and Modified Still.

The float wicks were placed inside the basin having uniform gap between them as shown in Figure 2 to reduce the thermal inertia of the basin water. The float was made from thermocol sheet of thickness 19 mm on which a black cotton cloth of 1 mm thickness was wrapped on it. The length and width of the wicks were 740 mm and 25 mm respectively. Insulation was provided on the sides and bottom of the basin with the help of casing of galvanized iron sheet to prevent the heat losses. The material selected for insulation was rock wool. The condensed distillate was collected in the channel consisted of polycarbonate sheet. Sufficient slope was given to channel for smooth flow of distillate which was further accumulated in the plastic container.

Figure 2: Float Wick in the Basin of Modified Solar Still.

3. EXPERIMENTAL PROCEDURE

The experiments were performed on both modified and conventional still at Thapar University, Patiala, India. The basin type modified and conventional still was placed facing south and kept side by side. Initially, both the stills were calibrated under similar operating and weather conditions. For this, same amount of water was filled in the basin of both the stills and their hourly distillate outputs were measured simultaneously for three days. The similar values of the productivities of both the stills showed that their performance was well in synchronization with each other. Conventional and modified still were run side by side for 24 hours to compare the performance. Every morning at 9 am, the basin water was filled up to depth of 3 cm and the distillate production from 9 am to 5 pm measured hourly basis using a container. The distillate formed during night from 5pm to next morning 9 am was due to the energy stored inside the still during the day time.

Kipp and Zonen pyranometer along with LOGBOX SD data logger was used to measure the solar intensity on the horizontal surface of basin water at an interval of 10 minutes. In order to measure the temperature of still components, T-type thermocouples were used and datalogger was used to lock the temperature readings for 24 hours. The wind velocity was measured using hand held anemometer. Distillate outputs from both the stills were collected hourly in the plastic containers, between 9:00 AM to 5:00 PM and weighed on digital weighing balance. The nocturnal distillates, collected from 5:00 PM to 9:00 AM were measured next day in the morning.

4. RESULT AND DISCUSSIONS

The experiments were performed on both modified and conventional still simulataneously for several days during the month of April, 2019. The best experimental results were found on 11th April, 2019 when basin water depth was 4 cm, width of wick was 1 inch and 75 % area of basin was covered with wick. The experimental results to find that the effect of wicks on the performance of solar intensity and the results are discussed in this section. The variation of solar intensity, ambient temperature and wind velocity are shown in Figure3. The solar intensity starts increasing as the day progress and then start decreasing. The maximum solar intensity on horizontal surface of solar still was 993.32 W/m^2 at 11:50 AM. The ambient temperature of solar still start increases as the time increase but certain point of time and after that it starts decreasing slowly. The maximum ambient temperature is to be found 38.4□C at time 01:30 PM. The wind velocity fluctuates throughout the day does not vary too much. The detailed results of 11th April 2019 is explained in the following subsections.

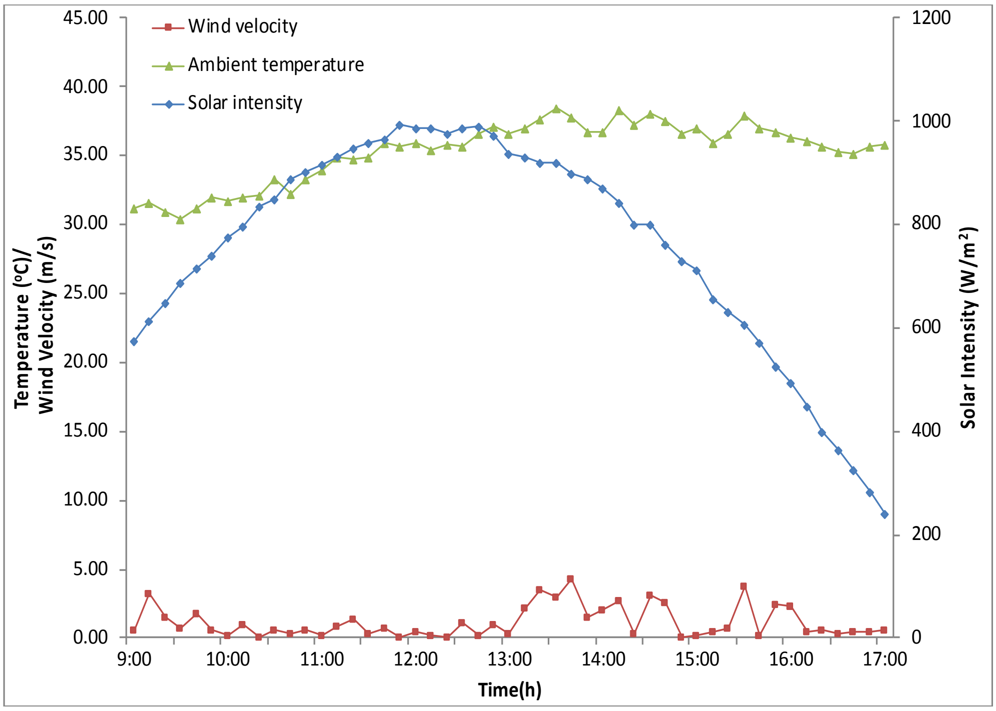

Figure 3: Variation of Weather Parameters on 11th April 2019.

4.1 Component Temperature of Conventional and Modified Still

The variation of component temperature such as glass, basin water and basin air of conventional solar still is shown in Figure 4. The basin air temperature increased with the time and then become stagnant after 3:00 PM. Basin air temperature is higher among the other components because vapours also absorb direct solar radiation. The temperature of basin water remains below the glass temperature up to 02:00 PM and then start rising. It is due to absorption solar radiation in the glass and more thermal inertia in the basin water during early part of the day which leads to take some time to raise the temperature of water. The temperature of glass rises till 1:30 PM then starts decreasing as the solar intensity decreased.

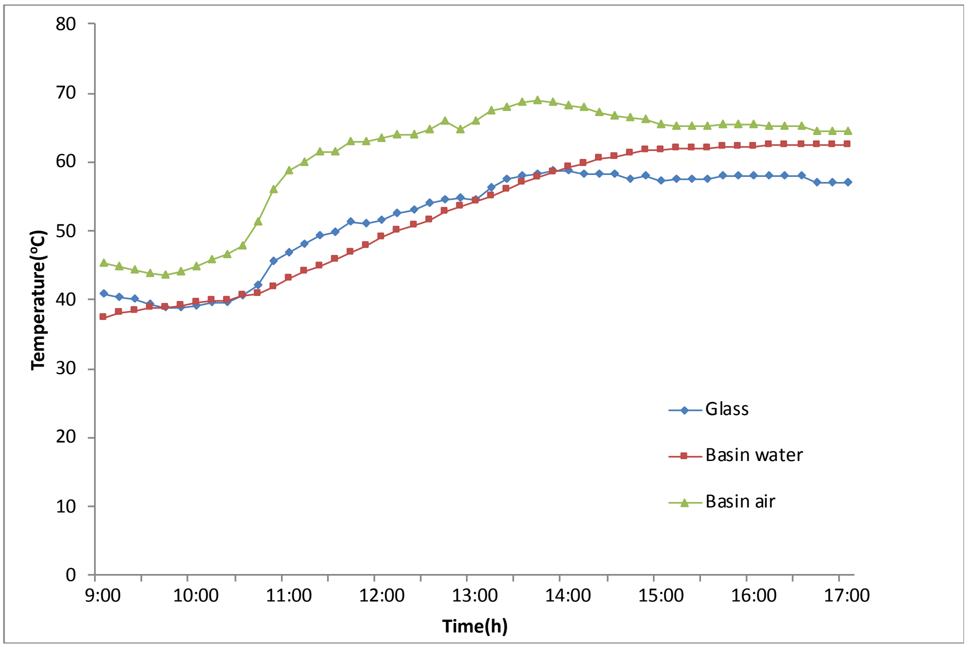

Figure 4: Component Temperature of Conventional Still.

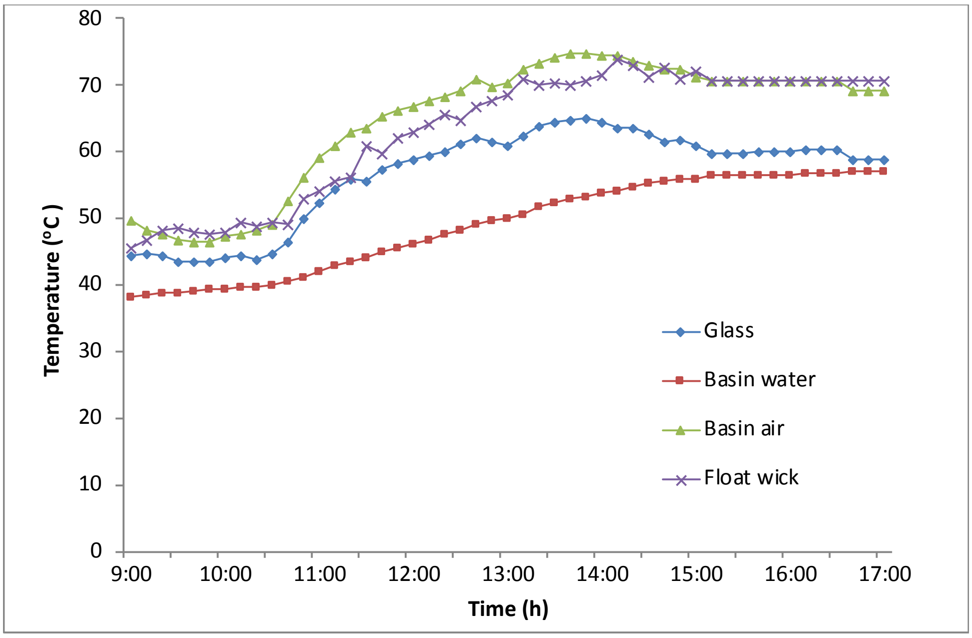

Figure 5: Component Temperature of Modified Still.

The experimental result shows the various component temperature of modified still are shown in Figure 5. The glass temperature starts increase slowly in the morning time and it achieve its maximum temperature 65.08 □C at 01:50 PM and then start decreasing gradually with time up to 17:00 PM. The basin water temperature start increasing at very slow rate with the time during early part of the day and then become stagnant after 3:00 PM. The temperature of float wick stays above the basin water temperature due to low thermal inretia of water on wick surface which leads to increase in evaporation rate of water in basin of modified still.

4.2 Comparison of Components Temperature of Conventional and Modified Still

The comparison of different components temperature of modified and conventional still represented in Figure 6. It has been observed that the basin water of modified still falls below the basin water temperature of conventional still throughout the day due to area of basin water was covered with float wicks. But, the temperature of float wicks of modified still stays above the temperature of basin water of both stills during the day which leads to increase in productivity of modified still. The float wicks helps to increase the rate of evaporation due to low thermal inertia and direct sunlight falls on it leads to increase in evaporation. Since the level of basin water changes as the day progress, the float wicks helps make continous contact with the basin water.

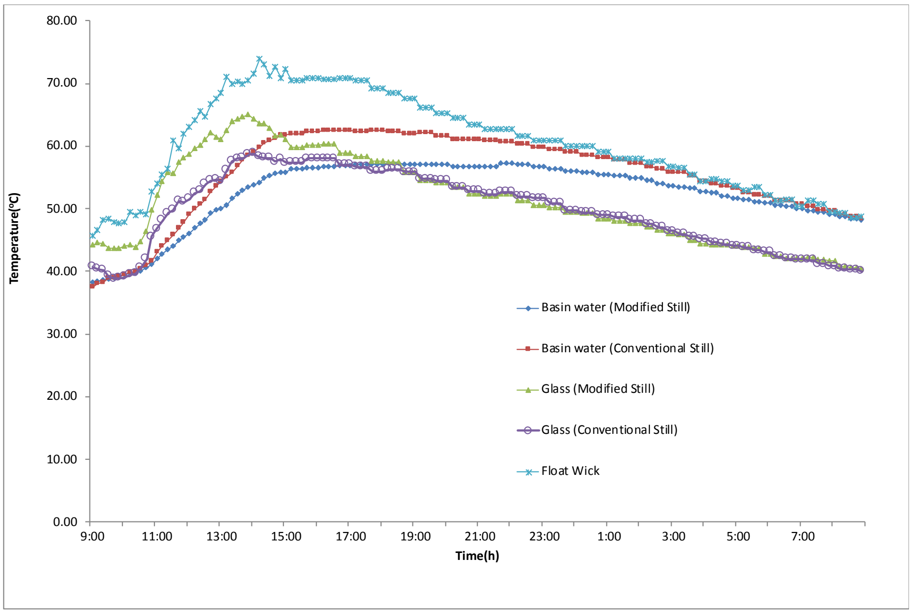

Figure 6: Comparision of Components Modified and Conventional Still.

4.3 Comparison of Distillate and Cumulative Efficiency of Conventional and Modified Still

Figure7 shows the variation of distillate formed in modified and conventional still. During the early morning, the quantity of distillates formed was less due to low solar intensity. As the solar intensity increased the amount distillate produced in both still increased till 2 pm. The amount of distillate production start decreasing in both stills from 2 to 5 pm, due to decrease in solar intensity. The amount of distillate produced in modified still was more than that of conventional still throughout the day. But the night distillate formed of both the stills were almost same. The float wick temperature of modified still stays above the basin water temperature of conventional still leads to rise of productivity of modified still by 39.06 % during day and 0.97 % during night. The difference in night productivity of both stills is not much because during night time float wicks cover the basin area which hinders the rate of evaporation. The overall gain in productivity of modified still was 24.19% over the conventional still.

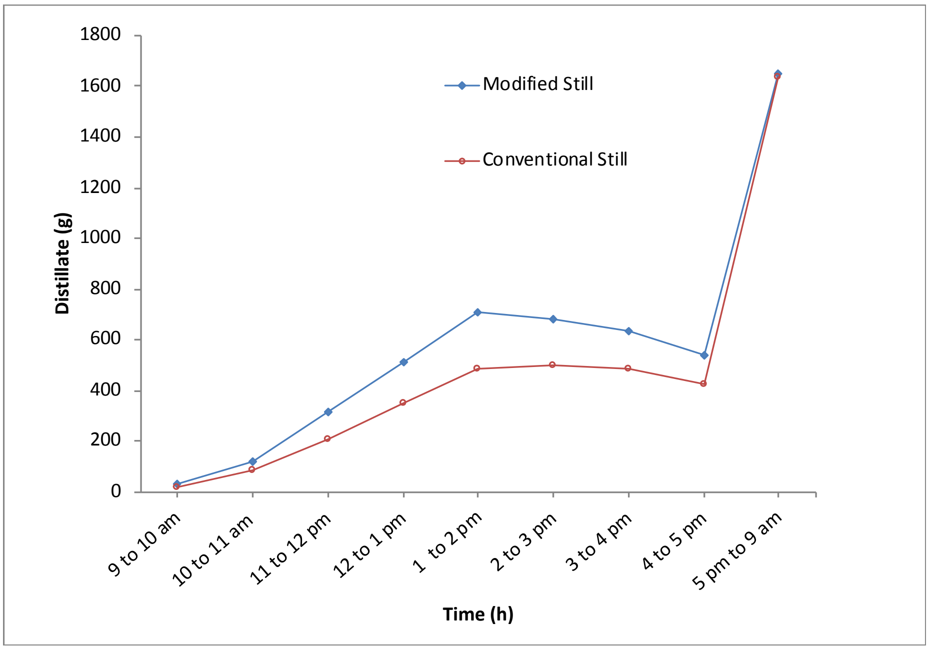

Figure 7: Comparison of Distillate for Conventional and Modified Still on 11th April, 2019.

CONCLUSIONS

The following conclusions can be drawn from the experimental study of modified and conventional still:

- The day productivity of modified still was 24.19 % higher than the conventional still when solar intensity and ambient temperature was 22.32 MJ/m^2 and 35.29 °C respectively.
- The use of floating wicks in the basin enhance the evaporation rate of basin water leads to increase the productivity of modified still.
- The overall distillate of modified and conventional still was recorded as 4.33 kg/m^2 and 3.48 kg/m^2 respectively.

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