EXPERIMENTAL STUDY ON IMPACT OF TEXTILE MATERIAL SPREAD OVER A FLAT PLATE ABSORBER ON THE PRODUCTIVITY OF MODIFIED SINGLE-BASIN SOLAR STILL

by

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The solar still is an environmental friendly method of producing distilled water from brackish water to overcome drought. In remote areas, conventional solar still system is used to produce potable water. However, such solar still is not widely used because of its relatively lower water flow rate at outlet. The objective of this work is to improve the outlet flow rate of distilled water that can be produced from a conventional solar still. An investigation has been carried out by incorporating a Formica sheet as an inclined absorber surface into a conventional solar still spread with a textile material. This modified solar still is supplied with brackish water as input in active mode. The flow rate of water into the system is controlled to just wet the textile material spread on the inclined absorber surface. In order to calculate the exact effect of the inclined absorber surface spread with textile material, the modified still is compared with the conventional still. The experimental results indicate that the system temperature has increased significantly which increases outlet flow rate by 80%.

Key words: *solar still, inclined absorber surface, distilled water, solar distillation, active mode*

Introduction

Clean water is the key to progress of mankind towards a prosperous future. In urban area water treatment plants are cost efficient to provide purified water as per requirement. However, in rural areas and remote places water treatment plants are not feasible as population is very less rendering it costly to meet the water demand. In such places solar distillation is an effective way to satisfy the water demand. The solar distillation process evaporates water from any water source available and condenses the vapor as pure water. It requires less initial investment for fabrication and can work with any type of brackish water. The cost of distilled water produced by a passive solar still is as low as \$0.014 per kg for a 30 year life time system [1]. Despite, its huge potential solar still is not popular amongst the people due to its lower output per square meter aperture area [2]. Hence, researchers all over the world are working on methods by which the output of a solar still can be increased. The use of solar desalination devices has so far been restricted to small scale systems in rural areas [3]. The solar distillation is feasible when the demand is limited to few cubic meters. The output of a solar still can be increased

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by decreasing the heat losses [4], increasing the temperature difference between evaporating and condensing surfaces [5], making use of the latent heat of condensation [6] and maximize the heat sink capacity [7]. These considerations, however, increase the cost of the system. They require more materials, vacuum pumps, external flat plate collectors integrated with a solar still [8]. This work focuses on improving the productivity of the solar still. Various factors play important role in the productivity of a solar still. One such factor is the thickness of water in the basin of a solar still. A thin layer of water on basin ensures a better evaporation rate [9]. Hence a modification is done on a simple basin type of solar still to maintain a thin layer of water. This modified system is tested alongside with a standard simple basin type solar still. The results obtained from experimentations are compared in terms of productivity to recommend a cost effective system amongst both the systems.

The device used for solar distillation is called solar still. The sun ray enters the glass cover of the device and evaporates the source water. The vapor generated is condensed beneath the glass cover and channelized to the container in which distilled water is stored for consumption. The solar still is a simple device which can be made at source of use even by a semi-skilled laborer at an economic cost easily. There are several models of solar stills available like pit, cone and dome solar stills amongst which basin solar still is the most common type of solar still that is being used widely [10]. The primary aim of this work is to develop a cost effective solar still with increased productivity. A simple asymmetrical greenhouse type solar still of a solar still was selected as it has 20% more output in comparison to symmetrical solar still [11]. Modifications were incorporated in this asymmetric greenhouse solar still and tested for performance by comparing it with other conventional solar still which has not undergone any modification.

Experimental set-up

The experimental set-up shows one of the simplest types of solar still readily available in the renewable energy market. It is an asymmetric greenhouse type solar still with an effective aperture area of 1 m^2. The frame and body is made of fiber reinforced plastic with transparent glass cover. The assembly is made leak proof with rubber gasket and screws. Two solar stills of the same type are utilized in this work. One of the still is, used as a standard for comparison without any modification and the second one is subjected to modifications. A thin layer of water in the absorber basin will promote the evaporation process [12]. To ensure a thin layer of water a flat plate of mica was incorporated in the second solar still. This plate acts as an absorber surface. The thin layer of water was maintained by using active flow of water from an external tank reservoir. The outputs of the two systems were compared to see the effectiveness of this modification. Several modifications were incorporated into the modified solar still step by step and both the systems were tested for performance. The flat absorber surface plate parallel to a glass can increase the absorptivity of solar radiations in the system. More energy absorbed will enhance the output of the system [13]. The selection of material for a flat plate is crucial. The Formica sheet is selected for absorber plate as it is light in weight and further withstand temperature up to 80-90 °C. When water is made to flow from the reservoir over the plate it doesn't spread the water effectively. Textile materials were used for uniform spreading of water over this flat plate.

Working of the modified solar still

The solar irradiation enters the system through the glass surface. This is absorbed by the flat plate absorber surface integrated into the system. This flat plate is parallel to the glass surface and is spread with a black cloth to maximize absorption of solar radiation and to uniformly spread the water. The saline water is supplied from an external reservoir through a control valve and an aluminum pipe with a number of small holes of 3 mm diameter. When the control valve is opened water is supplied to the system, it flows through these holes and spread uniformly on the absorber surface. The absorber surface gets the solar radiation and heats up. The water spread on the surface evaporates due to the sensible heat and moves up towards the glass surface due to lower density. The temperature of the glass is low as it is having low absorptivity and maximum transmissivity. Hence the vapor condenses beneath the glass surface and is collected as pure water from the system.

Experimental methodology

The main objective of the present work is to improve the distillate output by incorporating simple modifications in a conventional still and test for its performance. In order to quantify the improvement in performance the modified still is tested alongside a conventional still under the same conditions. The experiments were conducted in actual outdoor conditions in the month of May 2019.

Standardization of the solar stills

The basic idea of taking two conventional stills and modifying one of them is that it will be easy to ascertain the increase in productivity due to the modification incorporated under the same operating conditions. To ensure that the performance of both stills without any modification is same, they were initially subjected to standardization test. The outputs of both the stills were measured and compared in for a 24 hour cycle. The results are shown in figs. 1 and 2. The bar chart shows that there is a minor variation of about 6% initially. However, it is only about 2% at 16.00 hours when there was maximum output. Thus one of the still can be used as a standard for comparison while the other still can be modified for improvement in productivity.

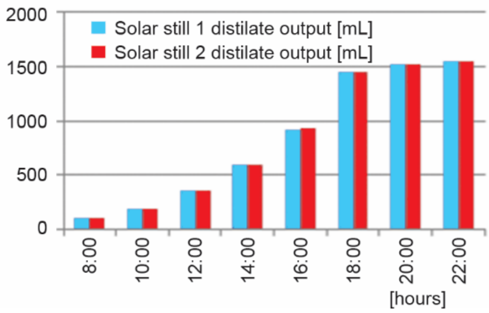

Figure 1. Standardization of solar stills

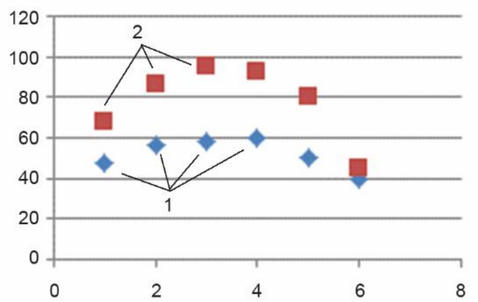

Figure 2. Testing with bare absorber plate; *1 – basin temperature of conventional solar still [°C], 2 – absorber plate temperature of modified solar still [°C]*

Testing with bare absorber plate

The formica sheet used as an absorber plate was initially incorporated beneath the glass surface and used without any of the water spreading textiles. In the conventional still 15 L of water was filled in the basin and for modified still 15 L of water was poured into the reservoir which supplies water to the inclined absorber plate. The maximum temperature reached were 95.5 °C in the flat absorber plate and 67 °C in the basin trough of the conventional still. The temperature has increased by 42.5% in the modified still. However, only 25% increase in productivity has been achieved in the modified still with just bare absorber plate [12]. During the experimentation, it was observed that there was uneven spreading of water on the inclined absorber surface. This in turn had affected the evaporation of water as the entire heat of the absorber plate could not be transferred to water. Hence, proper spreading of water over the entire absorber plate is necessary to achieve a better productivity.

Testing of absorber plate spread with plain jute textile

Jute cloth is spread over the absorber plate for uniform distribution of water. The flow of water was adjusted in such a way that it will maintain the wetness of the textile spread over the absorber plate. This will enhance the evaporation rate of water and hence in turn will increase the productivity. Initially a cheap and widely available Jute cloth recovered from a gunny bag was used. The maximum temperature of the flat plate absorber plate, spread with jute cloth is found to 81.2 °C and 67.5 °C in the basin trough of conventional still, fig. 3. The maximum temperature achieved in this case is less than the bare absorber plate. This is due to the proper transfer of heat to the water layer uniformly spread over the absorber surface. The net increase of the cumulative distillate output for a 24 hours cycle is found to be around 125%, fig. 4. The uniform thin layer of water maintained over the absorber surface ensured better evaporation of water molecules and condensation underneath the glass surface. Further if the jute textile spread is blackened by suitable dye, solar radiation absorption can be increased.

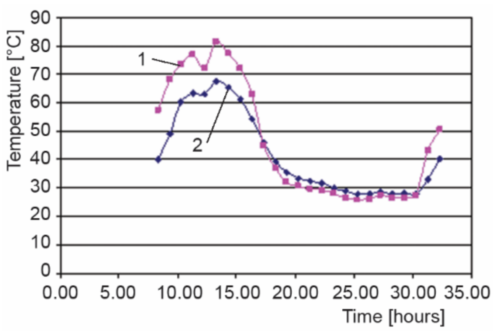

Figure 3. Temperature plot for absorber plate with jute; *1 – absorber plate (jute) temperature in modified solar still [°C], 2 – basin water temperature in conventional solar still [°C]*

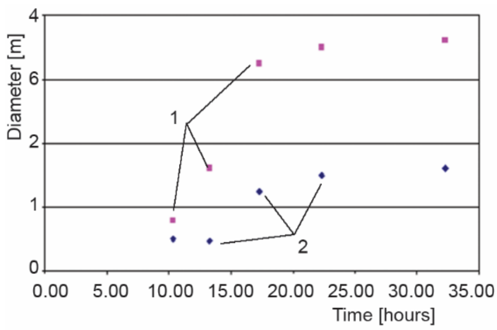

Figure 4. Distillate output plot for absorber plate with plain jute textile; *1 – distillate modified solar still [mL], 2 – distillate conventional solar still [°C]*

Testing of absorber plate spread with blackened jute textile

The jute in the previous test was of natural brown color and hence the maximum temperature reached was limited to 81.2 °C. The jute was then blackened using black cardboard paint and the testing was repeated. The maximum temperatures reached were 90.6 °C in the flat absorber plate with jute as water spreading textile and 69.8 °C in the basin trough of conventional still as shown in fig. 5. A maximum percentage increase of distillate output of 132.3% was obtained with net percentage increase of distillate output of 124.9%, as can be seen from fig. 6. With the increase in temperature the performance efficiency must have increased. But we note that the percentage increase of distillate output has not increased with increase in operating temperatures. This may be overcame by optimizing the cavity volume between the absorber plate and glass.

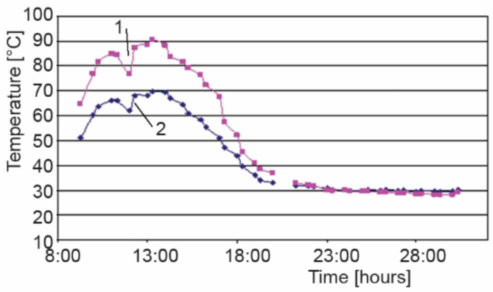

Figure 5. Temperature plot for absorber plate with blackened jute; *1 – absorber plate temperature (black jute) modified solar still [°C], 2 – basin temperature conventional solar still [°C]*

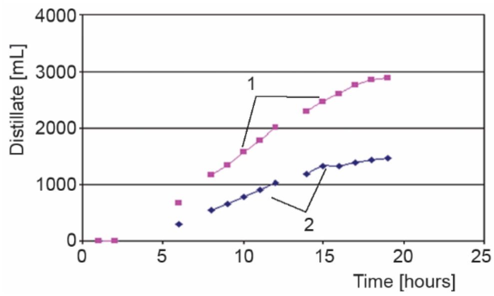

Figure 6. Distillate output for absorber plate with blackened jute; *1 – distillate modified solar still, 2 – distillate conventional solar still*

Conclusion

In this work, to augment evaporation of the inlet water, a flat plate absorber was integrated over the basin of the still. The flat plate absorber was placed in such a way that it is parallel to the glass cover of the solar still so as to maximize the absorption of solar radiations. By this modification, the maximum temperature of the absorber plate achieved was 95 °C whereas in conventional still it was only 67 °C. In order to improve wetting area of the plain absorber, textiles such as jute and blackened jute textile were used over absorber. This has improved the system performance. Experimental results of modified still in comparison to a conventional still shows that distillate output increased by 125% with flat plate absorber spread with jute and by 132% with flat plate absorber spread with blackened jute cloth when compared to conventional still under the same operating conditions.

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