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Augmenting the productivity of solar still using jute cloth knitted with sand heat energy storage

A.E. Kabeel[a,*], S.A. El-Agouz[a], Ravishankar Sathyamurthy[a,b,c,**], T. Arunkumar[d]

[a] Mechanical Power Engineering Department, Faculty of Engineering, Tanta University, Egypt
[b] Department of Mechanical Engineering, S.A. Engineering College, Chennai 600077, India
[c] Centre for Excellence in Energy and Nano Technology, S.A. Engineering College, Chennai 600077, India
[d] Institute for Energy Studies, Anna University, Chennai 600025, India

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ABSTRACT

The best methods in improving the fresh water yield from the solar still is incorporating sensible heat energy storage materials. This paper presents the improvement in fresh water and thermal from the conventional basin solar still using sensible heat energy storage knitted with jute cloth wrapped over the entire surface of the material under different water mass. Experimental investigations were carried out in the single slope solar still with and without jute cloth knitted with the material and for validation of results the solar still without any material is tested for the same experimental condition. Results show that the yield of fresh water is completely depends on the parameters such as mass of sensible energy material and depth of water kept in the basin. The yield of fresh water under least water mass (mw = 20 kg) from the solar still with and without jute cloth knitted with sensible heat storage material were found as 5.9 and 5 kg/m^2, respectively.

1. Introduction

The serious problem faced by the world in this century is to provide adequate supplies of fresh water. To meet the current global scenario on water scarcity, the saline water is converted into fresh potable water for drinking purpose. In order to convert this saline water to useable water various methods are adopted. These methods include, multi stage flash distillation, Multi effect evaporation, reverse osmosis, thin film distillation, electro dialysis. These methods are used high energy intensive and operations costs. Therefore, the solar energy is represented as a promising method to overcome the major operation cost required in each cases of above methods. Solar desalination method is the simplest technique among other methods and is suited to use in the small-scale units. Due to the increase in population, economic growth and global warming leads to the worldwide imbalance in supplying fresh drinking water. It is well known that nearly three-fourth of the earth is covered with water [1–17].

Harris Samuel et al. [11] improved the thermal performance and yield of solar still using encapsulated salt heat energy storing material. Results showed that by increasing the surface area of water in the basin with salt as heat storing material the productivity of fresh water enhanced up to 133% than conventional basin type slope solar still. Also, study revealed that during night time with the use of salt and sand as heat storing medium achieved a maximum yield of 0.3 kg/m^2 and 0.5 kg/m^2 respectively.

Naim and Abd El Kawi [18] used mixture of phase change material to improve the performance a continuous single-stage solar still. Results showed that the use of an energy storage material led to a larger productivity. The increase depended on the temperature of the inlet saline water, concentration, and flow rate. Phadatare and Verma [19] studied the thermal performance of still made of plastic under various water depths. The results showed that the best minimum water depth of d_w = 0.02 m. The yield was decreased by 12% and a temperature was decreased by 3% with increased in depth water. The average of basin water temperature was about 50 °C. Yadav and Tiwari [20] theoretically and experimentally studied a double slope solar still. The results showed that the effect of shadow from the sidewalls was reduced by a 45% compared to the single slope solar still. The productivity of still was increased from 1.7 kg/m^2 to 2.4 kg/m^2. It was reported that the temperature of water initially filled in the first basin (lower basin) acts as a driving force for evaporation in the successive basin of the still. On successive periods, the drop in yield is 28% due to its mass. The performance of solar still was higher during off shine period due to the higher rate of heat released by saline water to regain its thermal equilibrium.

Sodha et al. [21] experimentally studied the thermal performance of

* Corresponding author.
** Correspondence to: R. Sathyamurthy, Department of Mechanical Engineering, S.A. Engineering College, Chennai 600077, India.
E-mail addresses: kabeel6@f-eng.tanta.edu.eg (A.E. Kabeel), drravishankar@saec.ac.in, raviannauniv23@gmail.com (R. Sathyamurthy).

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single slope multi wick solar still using GI sheet and fibre reinforced plastics (FRP) as basin material. Results showed that the maximum hourly and cumulative yield of 0.45 and 2.45 kg/m^2 respectively were achieved during sunny day. Srivastava and Agrawal [22] studied the effect of porous fins in the basin of conventional basin type still with black wick material. Results on water temperature showed that there was a reduction of about 25% over water temperature and lower as compared to conventional basin type still, whereas, the improvement in yield during summer and winter were found as 30 and 45% respectively. There was also an increase in fresh water yield of about 22.2% when the depth of water decreased from 0.04 to 0.03 m. Srivastava and Agrawal [23] experimentally analyzed the effect of water depth in a conventional single slope solar still with low inertia absorber and external boosting mirrors. Eventually, the floating absorber medium is covered with jute cloth material for effective evaporation. Results showed that the effect of water depth decreased the yield of fresh water by 10%. Similarly, the driving force for effective condensation depends on the gradient temperature difference between water and glass. It was found that there was an increase of about 70% in water-glass temperature difference as compared to conventional solar still. Several modifications such as incorporating fins, sponges, pebbles, sand material inside the conventional solar still was incorporated by Velmurugan et al. [24, 25]. The incorporation of fins in the basin improved the fresh water to about 40.2% than conventional solar still whereas, the use of sponge inside solar still improved the yield of freshwater by 45%. Velmurugan et al. [26] also used industrial effluent from the textile industry and studied the fin type still with effluent settling tank and solar pond. When analyzing their study, it was found that the yield with industrial effluent as feed reduced and it was higher to about 53%than conventional solar still with integration of finned absorber and settling tank. Omara et al. [27] studied a modified absorber plate solar still with finned and corrugated structure and analyzed the thermal performance with varied water mass kept in the solar still as a comparative study. Results showed that the yield of fresh water increased to about 5 and 25% for finned and corrugated absorber than flat basin solar still. Also, from the experimental study it was found that the fresh water obtained and distribution of water temperature from the solar still depends on the fins numbers, fin efficiency and characteristic length-breadth ratio.

Dashtban and Tabrizi [28] analyzed the effect of PCM on the bottom of weir cascaded solar still. Their study revealed that the use of PCM reduce the yield from solar still during sunshine hours as compared to solar still without PCM. The heating of PCM required to completely convert into liquid reduce the temperature of basin during sunshine hours whereas, the water and basin temperature was higher during offshine hours as the thermal energy stored is discharged.

Arunkumar and Kabeel [29] studied a parabolic concentrator tubular solar still with phase change material on the circumference of absorber basin material. The fresh water with the addition of PCM with concentrator improved the fresh water yield by 8.86%. El-Sebaii et al. [30] studied a basin type single slope solar still with sensible heat storing material and studied the effect of water mass and wind speed. Kabeel and Abdelgaied [31] used different PCM material in a single slope solar still. Results revealed that the thickness of PCM has no effect of fresh water yield. Also, results revealed that the use of organic PCM improved the thermal performance by 92% and has got lower negative impact over the environment.

Kabeel et al. [32] investigated a solar still experimentally using PCM under Egyptian climatic condition. From their experimental study it was found that the cost of produced potable water reduced and there was a significant improvement in fresh water yield from solar still with PCM.

Sarhaddi et al. [33] carried out an exergy and energy analysis on weir cascaded solar still. Energy analysis revealed that increase in ambient temperature reduces the thermal efficiency of both cases and the thermal efficiency is higher in the case of solar still with PCM. Similarly, the irreversibility of absorber plate is higher in the case of bright sunny condition rather than semi cloudy condition.

Dumka and Mishra [34] and M.S. Sodha et al. [35] compared the energy and exergy efficiencies of modified solar still using sand bed earth. From their experimental and theoretical study it was found that the internal efficiency and exergy efficiency is higher for the modified solar still as comparing it with conventional still. The experimental and theoretical model (Kumar and Tiwari [36]) were in good agreement of about 11.9 and 12.31% for modified and conventional still respectively.

In this study, the use of sensible heat energy storage and jute cloth wrapped around the sensible heat storage material is experimentally investigated on improving the thermal performance of single slope solar still. Similarly, the effect of water mass (depth) is experimentally investigated on the effective capillary rise of water in the wick material as the wick material absorb the water for effective capillary rise and further to evaporate from the circumference of the surface. Furthermore, the effect of water mass on overall thermal efficiency of the modified solar still is analyzed.

2. Experimental setup, procedure and uncertainty

The experimental setup consists of a basin with side height of 0.3 m on one side and 0.4 m on other side with an inclination angle of 13° to keep the glass in an inclined position. Water is continuously fed into the basin through the inlet provided on the sidewall of the basin, and drain valves are provided the bottom of the basin to take the contaminated water and for cleaning purpose. For the present study the cover material is made of glass with a thickness of 3 mm. The experiments for the present study using single slope solar still is made in such a way that the glass cover is inclined and facing North-South direction so as to receive the maximum solar intensity falling on the inclined surface. The water droplets formed on the inner cover surface glass glides to the distillate collector kept at the end of the glass. Due to the increase in the temperature of water inside the basin and partial pressure developed vapor is formed in between the water and glass surface and thus condenses. The area of the basin is fabricated with 1 m × 0.5 m and area of the glass is almost the same as the basin. The experimental photograph of the modified solar still is shown in Fig. 1 and the schematic diagram of the experimental test rig is shown in Fig. 2. The jute wick material is wrapped around the sand heat energy storage material. Due to the continuous heat dissipated from the sand box energy heat storage, water absorbed in the jute cloth will be evaporated. Due to continuous capillary effect and absorption of water in the jute cloth, evaporation would be rapid. Experiments are carried out in the open terrace of Department of Mechanical Engineering, S.A. Engineering College, Chennai. Measurements of various environmental parameters such as solar radiation, wind speed, ambient temperature, and accumulated fresh water yield were measured using Solar power meter (TES1333R),

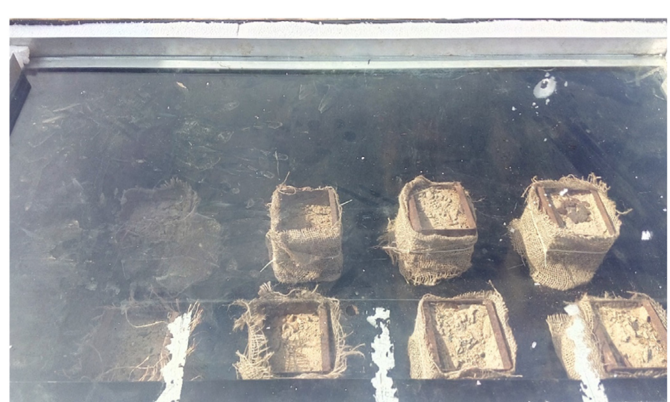

Fig. 1. Experimental photograph of modified solar still with jute cloth knitted to sensible heat storing material.