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Comparative study on double slope solar still using different absorber basin tray materials

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Abstract — *Increase in population and depletion of water resources by livelihood and exploitation for industrial and other process requirements necessitates purification and recycling of contaminated water as a conservative measure apart from desalination. Solar still is a simple device used for converting water from such sources into pure one. The performance and distillate production of a solar still is influenced significantly by various parameters like intensity of solar radiation, temperature difference between surface water and glass cover plate, collector area, water depth, glass thickness and insulation. In this research, various absorber basin trays made up of Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic (GFRP) have been used in the double slope solar still. This experimental analysis has been carried out to harness the maximum solar energy inorder to yield higher distillate output. Solar still with Copper basin tray exhibited a better performance than the others. The results of solar still with GFRP basin tray is comparable to that of the others and thus shall be employed by modifying and improving the design of solar still by taking into account its life and ease of maintenance.*

Keywords*-solar still; absorber basin; performance; distillate production; efficiency.*

I. INTRODUCTION

Water is an elixir of life. Hence, no livelihood would exist on the Earth without water. A.E. Kabeel et al [1] has discussed that the clean water is one of the major challenge faced by many part of the world, especially in the past forty years. Also, industrialization and rapid increase of population lead to greater demand for fresh water. Kuldeep H. Nayi et al [2] conferred that one of the simplest and eco-friendly technology is solar desalination. And this desalinating process is done to obtain pure water from the brackish water by segregating the salt using the solar energy. Hence, solar desalination is one of the viable option to purify the brackish water from any sources by using solar stills.

Since abundant solar energy is available, solar still is a simple and eco-friendly device as it uses renewable energy for purification of water [3]. Evaporation and condensation are the two major processes involved in the operation of a solar still. A simple solar still consists of a basin tray, glass cover plate, collection channels, insulation to prevent heat losses through bottom and a housing to accommodate all the above as a support structure. Pure distillate obtained from nearly any sources by using the solar still can be utilized for numerous purposes ranging from domestic to industrial process requirements and also in areas where no other sources of energy for such a purification is available. The basic classification of simple passive solar stills are single slope and double slope solar stills. The existing conventional solar still is perceived to be inefficient for domestic as well as small scale industrial use primarily due to its less rate of purification by taking the occupational area into consideration apart from the other limitations. Efforts have been taken by many researchers to improve the conventional design in order to increase the rate of distillate collection [4]. The rate of distillate production of the solar still is affected by various parameters like solar intensity, wind velocity, water-glass temperature difference, depth of water, temperature of feed water, area of the absorber plate, thickness and inclination of glass cover plate of which the metrological parameters like solar intensity, wind velocity are non-controllable [5].

The most influential parameters are solar radiation intensity, collector area, basin water depth and the temperature difference between glass cover plate and water. Solar radiation intensity being a metrological and non-controllable parameter the other factors like area of absorption, minimum depth of water, water-glass cover temperature difference and inlet water temperature can be controlled and managed effectively in order to increase the distillate production [6]. Further, to augment the distillate production, use of heat storage, phase change materials, vacuum technology and other methods such as employing reflectors, condensers have been proposed by researchers [7].

Researchers have attempted experiments by employing various absorber basin tray materials. One way to harness the solar energy in order to maximise the performance of the solar still is to choose an appropriate material for absorber basin tray. The absorber basin material should effectively absorb and transfer heat while withstanding high temperatures.

Omara et al. [8] have done an experimental investigation on solar still in Egypt in the month of May and July 2014 and estimated an efficiency of 33% for conventional solar still with galvanized iron basin tray of 1 m^2 in which water depth was 1 cm. Mohammed Shadi [9] had stated that due to the higher thermal conductivity of 390 W/m.K, solar still with Copper basin tray has been chosen for the experimental study.

Panchal et al. [10] have reported a distillate collection of about 3.7 litres and 2.3 litres by using Aluminium and Galvanized Iron plates in solar still respectively. The experiment was conducted in Mehsana, Gujarat in the month of July 2011 with a water depth of 4 cm.

Hitesh N. Panchal and P. K. Shah [4] have done a comparative analysis by using solar stills having Copper, Aluminium plates against the conventional passive solar still. They have reported an increase in distillate output of about 20% for solar still with Copper plate and 10% for solar still with Aluminium plate when compared with passive solar still for a water depth of 3 cm.

Hitesh N. Panchal [11] has also done an experimental analysis by employing three different absorber plate materials namely Galvanised Iron, Copper and Mild Steel. He has inferred that solar still with Copper plate has more distillate production than the other two absorber basin plate materials.

Mohammed Shadi S. Abujazar et al. [12] have done experiment on inclined stepped solar still using Copper trays. The distillate production of 4383 ml / m^2 / day and also a maximum efficiency of 58% was reported. Further, they have stated that the Copper has higher thermal capacity when compared with Steel and Aluminium.

Thus, from the inferences of various researchers it is observed that solar still with metallic basin trays, especially solar still with Copper basin tray has exhibited a better performance and higher distillate production.

In this research article, the experimental results and inferences on employing different absorber basin trays made up of both metallic and non-metallic materials namely, Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic have been discussed. The purpose of the research is to analyse, compare the performance and distillate production of solar stills with metallic and non-metallic basin trays, besides establishing the technical feasibility and economic viability of the same. Glass Fibre Reinforced Plastic has been chosen as a non-metallic material due to its ease of maintenance and long life besides being anticorrosive. The experimental setup, performance analysis, rate of distillate collection and subsequent inferences are discussed below.

II. EXPERIMENTAL SETUP AND INSTRUMENTATION

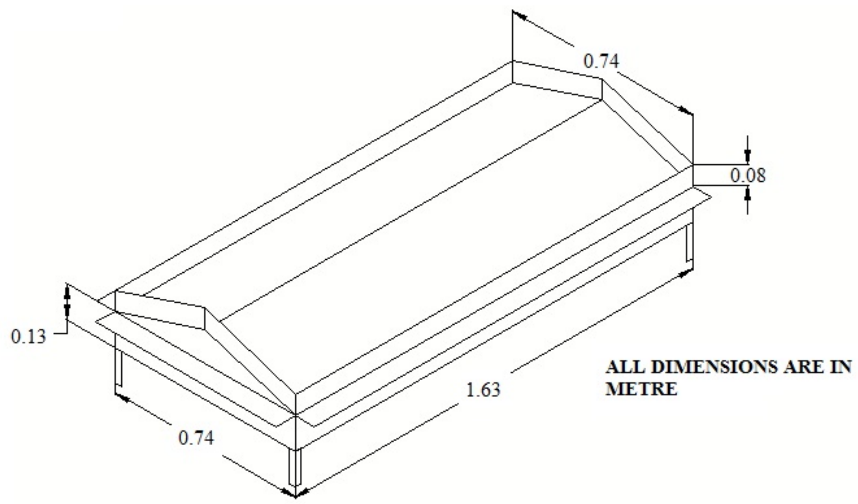

Figure 1. Double slope solar still

A double slope solar still as shown in figure 1 was designed and fabricated by adopting standard procedures. The solar still contains two major segments, namely Evaporating Unit and Condensing Cover in the bottom and top respectively, which will be locked together for maintaining the solar still, air and vapour tight during the regular operations. The evaporating unit consists of a housing that accommodates absorber basin tray, Insulation, supports collection channels and also acts as a protection cover. Condensing cover plate is a single unit that contains glass cover plate with a provision for collection of rain water on the top and internal reflectors.

Absorber basin trays made up of Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic were used as collectors with an area of about 1 m^2. Absorber plates were painted by using matte black paint for absorbing maximum radiation heat. In order to prevent the heat loss, the bottom and sides of the basin were insulated for a thickness of about 0.05 m by using polyurethane foam with a thermal conductivity of 0.02 W/m.K. All the above has been accommodated in a protection housing that also supports two collection channels made up of Stainless Steel with a dimension of 1.6 m x 0.025 m x 0.025 m for collecting the condensed water from the glass cover plate. At the top of the double slope solar still, clear glass of 83% transmissivity and 3 mm thickness is kept inclined at an angle of 20° to the horizontal on either side. The area of the glass cover plate is 1.28 m^2 and it has a stopper on either side of the slope in the bottom and provision for rain water collection in the top.

Solar power meter is used for measuring the solar radiation intensity in W/m^2. Calibrated Resistance Temperature Detectors (RTD) were connected to a data logger for continuous monitoring and measurement of temperatures of absorber plate, glass cover plate, surface water in degree Celsius. Other meteorological parameters such as ambient temperature in degree Celsius, Wind velocity in m/sec and relative humidity in % were continuously monitored and measured using a professional mini weather station. The hourly distillate output was measured by using a measuring jar in litres.

III. EXPERIMENTAL PROCEDURE

Figure 2. Fabricated double slope solar still

The fabricated double slope solar still is shown in figure 2. The experiments were conducted during the month of January 2018 at the open terrace of Krishnasamy College of Engineering and Technology, Cuddalore (latitude 11° 75') Tamil Nadu, India. The glass cover plate slopes of the experimental setup were maintained in north-south and south-north orientation throughout the experimental work. A Water depth of 5 mm is maintained throughout the experiment for all the absorber basin trays by using a solenoid valve controlled by a level control circuit. The metrological parameters including solar radiation intensity, wind velocity were continuously monitored recorded at 30 minutes interval. By using a measuring jar the distillate output was recorded once in an hour besides overnight production. The observations were recorded between 9.00 a.m. and 6.00 p.m.

IV. RESULTS AND DISCUSSIONS

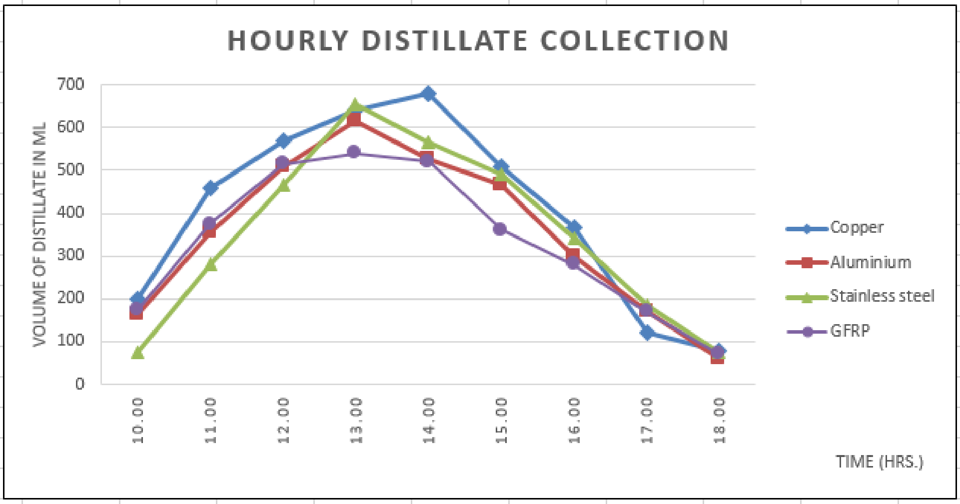

Figure 3. Comparison of hourly distillate collection

The experiments were conducted on double slope solar still with four different absorber basin trays made up of Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic. Parameters like solar insolation, absorber plate temperature, glass cover plate temperature, surface water temperature, ambient temperature, wind velocity and hourly distillate collection were recorded at regular intervals. The average solar insolation during the period of study was about 557.95 W/m^2. The results of the double slope solar still with different absorber basin trays are discussed below.

Figure 3. shows the comparison of hourly distillate collection of the double slope solar still with different absorber basin trays. In general, the hourly distillate production increased as the intensity of solar radiation increases and the maximum production was at around 1 p.m to 2 p.m. The total distillate production for solar still with Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic trays are 3800 ml, 3340 ml, 3265 ml and 3005 ml respectively. Higher yield was realised in solar still with Copper tray and the overnight production was also significant.

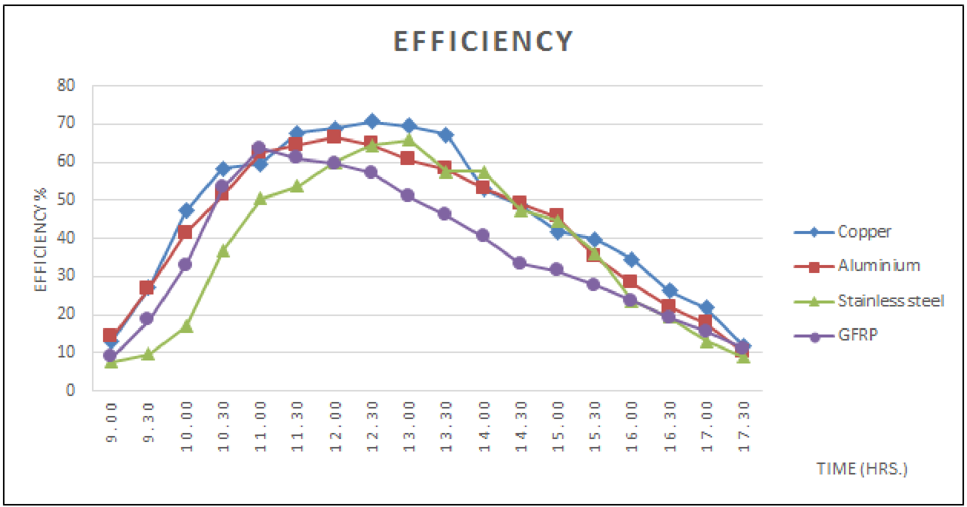

Figure 4. Comparison of efficiency with time

Figure 4. shows the comparison of efficiency of the four different absorber trays. The maximum efficiency attained by the solar still with Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic trays were estimated to be 70.65 %, 66.39 %, 65.87 % and 63.61 % respectively. The daily average efficiency was about 45.92 %, 42.83 %, 37.42 % and 36.32% for solar still with Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic trays respectively. From the above results, it is inferred that the performance of solar still with Copper basin tray is better when compared with the rest of the trays. Also, the efficiency of the solar still with Glass Fibre Reinforced Plastic tray is comparable to that of the solar still with Stainless Steel basin tray. The efficiency of solar still with Glass Fibre Reinforced Plastic tray was lesser in the afternoon because of its less heat storage capacity unlike metallic surfaces.

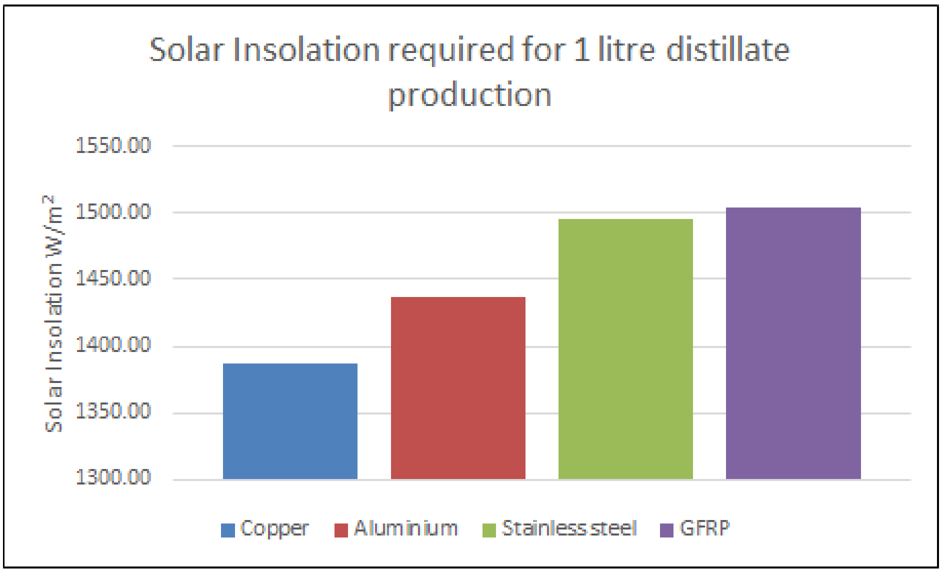

Figure 5. Comparison of solar insolation required for 1 litre distillate production

V. PAYBACK PERIOD

The payback period has been estimated for solar still with Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic absorber basin trays. The total cost of the solar still with Copper, Aluminium, Stainless Steel and Glass

Fibre Reinforced Plastic trays are INR 12720, INR 6920, INR 8620 and INR 8420 respectively. The payback periods estimated are 478 days, 290 days, 347 days and 339 days for solar still with Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic trays respectively. The payback period of solar still with Copper basin tray is more, whereas the same that of the solar still with Aluminium tray is least amongst the choices. Meanwhile, the payback period of solar still with Stainless Steel and Glass Fibre Reinforced Plastic basin trays are comparable to each other. Thus, any further design improvement attempted in solar still by using Glass Fibre Reinforced plastic as basin tray material by taking its life and ease of maintenance into account which may improve its performance on par with solar still with metallic basin trays.

VI. CONCLUSION

A double slope solar still was designed and fabricated in which the experiments were conducted by employing four different absorber basin trays namely Copper, Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic. A water depth of 5 mm is maintained throughout the study. From the observations, it is inferred that solar still with Copper basin tray yields higher distillate production of 3800 ml with a maximum efficiency of 70.65% and daily average efficiency of 45.92% when compared to the solar still with other three absorber basin trays chosen for the study. The solar insolation required per litre of distillate production is estimated to be 1387.66 W/m^2 for solar still with Copper basin tray. Hence, the performance and distillate production of double slope solar still with Copper as absorber basin tray material is better when compared to the solar still with Aluminium, Stainless Steel and Glass Fibre Reinforced Plastic basin tray materials. However, its payback period is more. Further design improvement of the solar still with Glass Fibre Reinforced Plastic absorber tray would make it as an alternate choice due to its anticorrosion characteristics, life and ease of maintenance when compared to metallic surfaces.

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