Performance Evaluation Of A Novel Wick Type Four Slope Solar Still Coupled With A Parabolic Reflector

Arun Kurien Reji, G. Kumaresan, Archit S Menon, Ajaykrishnan Mukundhan, Harikrishna A P, Jitesh J Parappadi

Abstract*: *A Solar still helps convert brackish water to potable water by utilizing solar energy. The impure water is collected in a collecting tank and is fed into the solar still via a conical reflector, from where it gets heated up. This water, at an elevated temperature, gets evaporated easily and gets condensed on the face of the solar still from where it is collected. Here, the conical reflector is kept at an optimal angle and is covered with reflecting foil to enhance the performance of still. This experiment is a proof which suggests the overall efficiency of the solar still can be increased drastically by incorporating easy methodologies in an economical fashion

Index Terms*: *Distillation, Desalination, Solar energy, Solar still

I. INTRODUCTION

Only a mere 0.5 percent of our population has access to clean and potable water. Water has thus become a scarce commodity in many of our major cities and its time we think of economic and efficient solutions. Since conventional methodologies like reverse osmosis and artificial rain simulator all end up using quantities of electricity, they are not sustainable options. It comes to a point where efficient and reliable methods need to be considered and Solar stills might be the answer that we are looking for. Solar stills offer the advantage that it relies only on solar energy and no other forms of energy whatsoever. [1]

A still consist of a basin in which hard water is filled and the still is covered by a glass surface. Upon receiving energy from sun, the water gets heated up and, this in turn evaporates and condenses over the glass surface. The condensate (water free from dissolved particles) can be collected separately This method had proved in numerous studies that it is reliable and efficient for optimal usage in rural areas and in places that have acute scarcity of water either due to geographical reasons or in case of natural disasters like floods or earthquake. The water produced would be free of all contaminants as the minerals and germs would be eliminated by the heat from the sun and also as it gets deposited eventually on to the base of the solar still.

Various researchers had conducted numerous experimentation on the wick material and had stressed its importance because of its distinct and diverse property of capillary action [2] [3]. Some of the popular wick material used are Terry cloth, Polyester cloth materials, Linen, Fur material, Jute etc.

Pyramidal solar still differs greatly from its conventional counterparts like basin and double basin in terms of efficiency because all of its increased surface area as more number of faces are facing the direction of sun and thus in turn receives more sunlight which makes it thus capable of producing more water [4]

A performance comparison of multiple basin solar still, both experimental and theoretical, was carried out by M.A. Hamdan et al., [5]. A pyramidal shape was given to the top cover. Three models were fabricated using G.I sheets namely, single, double and triple basins. The readings of intensity of solar radiation, velocity of the wind, different temperatures like ambient, glass surface, basin and water temperatures; and output from still were monitored every hour. The results pointed to the fact that the output from triple basin was the better by 24% and 5.8% as compared to single and double basin stills repectively. Also, the results suggested that a maximum efficiency of 44% was obtained from triple basin as compared to 42% and 32% of double and single basins respectively.

An analytical study conducted by H.E.S. Fath et al., compared the performance of a single slope solar still with a pyramidal still. Parameters which suggest the performance such as still output and efficiency were simulated. The results suggest that the solar radiation absorbed was $% higher for pyramidal still. On the other hand, the results also suggest that the average value of daily output was comparatively similar for both configurations. Thus it was concluded that the pyramidal configuration could be an effective alternate for slope configuration.

Peter Wassouf e.t al. [7], in their study, threw light upon the strategies to make cost effective and portable still. Their work culminated into the design of a square pyramidal still and a triangular prism solar still. The square pyramidal still had an area of base of 0.2 m^2 and the triangular prism still had 0.6 m^2. The test runs were

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conducted over a period of 7 days. The results suggested that the square pyramid topped the triangular prism pyramid's efficiency by 49.9% to 35.8%. In a similar study Yazan Taamneh [8] et. al., investigated the effect of forced convection on the performance of a square pyramid. A fan, which was used to induce convection, was operating on solar power. The results suggested a 25% increase in output distillate from the still in comparison with free convection.

The effect of forced convection heat transfer in a square pyramid with a single basin was investigated both experimentally and analytically by Ali Kianifar et. al. [9]. To bring about the effect of forced convection, a small fan was installed inside the still. This resulted in a turbulent flow of evaporated water vapour. The effect of parameters like water depth, thickness of insulation, Renolds number and wind velocity were also experimentally studied. The results showed that a depth of 6 cm in the basin gave the best output in terms of distillate produced. The Reynolds number and wind velocity directly affected the output distillate proportionately. Also, it was observed that when thickness of insulation is increased, heat losses was decreased which resulted in an increase in productivity.

II. PROBLEM DEFINITION

Solar still is a commonly used desalination device. The available solar energy is not efficiently used by normal solar still. So to overcome the problems faced in the conventionally used solar stills, a novel solar still is constructed by incorporating small variation in glass cover in such a way that the solar energy incident on the solar still is completely absorbed by the water throughout the day time. This is done by modifying the design by introducing four slope arrangement of glass instead of single slope arrangement used commonly in conventional stills. Also usage of wick materials will improve efficiency of the setup by increasing the thermal conductivity of the water and thus the productivity of the solar still is increased. The performance of any still is measured in the yield of fresh water produced. The researchers have analyzed the performance in terms of the yield obtained when a parabolic reflector is used along with the still, which provides water at an elevated temperature to it, thereby increasing its operational efficiency.

III. EXPERIMENTAL SETUP

The experimental test set up consists of a four slope wick type solar still. The tank which holds the brackish water is made to supply water through the effect of gravity to the parabolic reflectors. The water flow from the tank to the reflector is regulated with the help of a valve. The water flows through four continuous Copper tubes of length 50cm each, which are bend along the ends in a serpentine fashion. The parabolic reflector is coated with Aluminum foils which enhances the reflectivity of incident solar rays. The parabolic reflectors help focus the sun rays onto the four copper pipes passing through it carrying water.

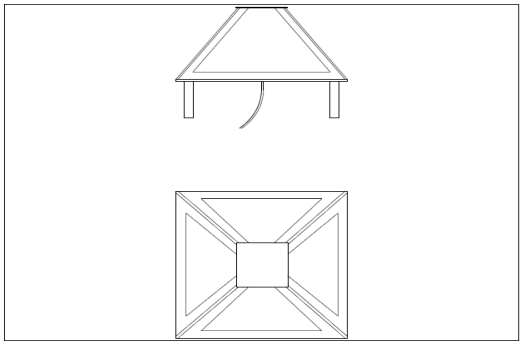

Figure 1. Configuration of four slope solar still with wick

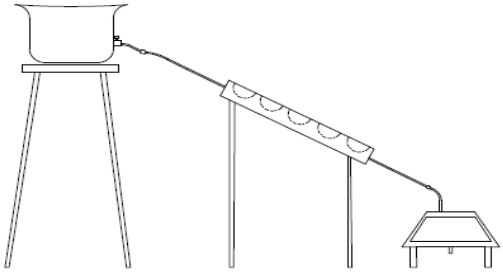

Figure 2. Line diagram of the experimental setup

The water, as it flows through the copper tubes, gets heated up and this water is fed to the four slope solar still. The tilting angle of the parabolic reflector can be varied using a nut and bolt arrangement on the setup. The inclination angle was fixed at 30^0 for the research work.

K-type temperature sensors are placed at strategic locations to measure the water temperature, which is displayed on the display unit.

Table I. Porosity of Wick materials used.

Wick Material	Porosity ø in %
Polyester	18.2
Terry Cloth	23.33
Jute Cloth	16
Cotton	30

The structure of the still is made up of Cast Iron in a novel pyramidal fashion. The still can hold up to 35L of water. Wick materials transfer the water to the pyramidal faces. From the evidence suggested by previously done research works and basics experiments conducted to know the capillary capability, the researchers have chosen cotton, jute and polyester as wick materials because of its ability to gather a huge quantity of water to the upper corners and thus helping in the operative process. Glass plates are placed along the faces of the pyramid. The incident rays, after reflection and absorption through the glass are transmitted through to the wick material placed on the face of the pyramid. This water is further evaporated and gets condensed upon touching the glass plate on top of the still. This condensed water is then collected from the collecting ducts, placed along each face of the solar still. The collected water will be free of contaminants and can be deemed fit for drinking.

Figure 3. Pictorial View of Four Slope Solar still and parabolic reflector

IV. RESULTS AND DISUCSSION

The value for solar radiation during the days of the experiment were found using a solar power meter (range 0–8000 W/m2). A measuring jar of 5L capacity was used for distillate collecting with 50mL interval. Thus this particular setup helps calculate the hourly yield of the still.

Porosity is the underlying parameter on the selection of wick materials. It is basically the measure of pores present in a unit space of the cloth material. The porosity is directly related to the capillary action, which pulls and helps in the transport of water molecules against gravity. Porosity (Ø) is calculated in % by the relation suggested by Mahdi, J. T., B. E. Smith, and A. O. Sharif [10].

$$Ø = V_{por} / V_{bul} \quad (1)$$

Where, V_{por} is the pore volume (m^3) and V_{bul} is the bulk volume (m^3)

$$V_{por} = W_w / \rho_w \quad (2)$$

Where,

$$W_w = W_{sat} - W_{dry} \quad (3)$$

W_{sat} is the saturated weight (kg), W_{dry} is the dry weight (kg) and W_w is the weight of water in pore space (kg)

$$V_{bul} = l \times b \times t \quad (4)$$

Where l, b and t are length, breadth and thickness of the wick material respectively.

The porosity of the wick materials are calculated using the above mentioned relationship and are furnished in Table I. The experiment was repeated using four different wick materials; Polyester, Jute, Terry cloth material and Cotton respectively. As suggested by the theoretical calculations, better characteristics of porosity are showcased by Cotton as it gave the best results in terms of productivity and efficiency also.

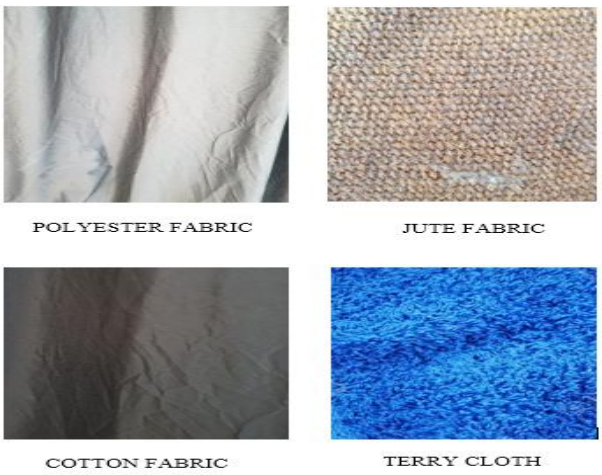

Figure 4. Various wick materials used in the still.

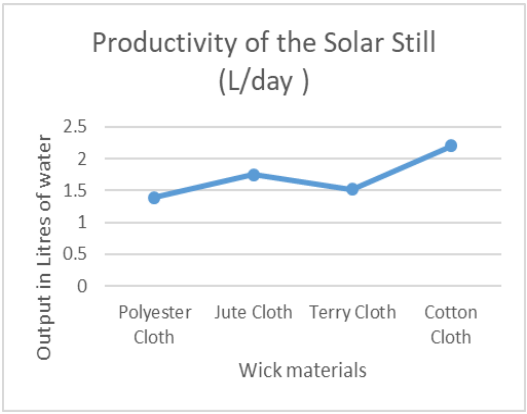

Figure 5. Productivity of the still for various wick material

Table II. Analysis of the Solar Still

Types of wick materials	Productivity of the Solar Still (L/day)
Polyester Cloth	1.39
Jute Cloth	1.75
Terry Cloth	1.52
Cotton Cloth	2.20

V. CONCLUSION

The work focuses and experimentally investigates the performance of four slope solar still with wick integrated with a parabolic collector. The work was carried under outdoor conditions of Coimbatore City in the month of February 2019.

Among the different wick materials used, Cotton gave better performance in terms of capillary action and yield of fresh water. The efficiency of the slope was calculated in terms of quantity of fresh water condensed and collected. The collected water can be used directly for the purpose of drinking as the source for contamination was removed during the process. Per day production of pure water amounts to 2200 ml while using cotton fabric as wick material.

High productivity can be attained if it is ensured that the glass surface is free from any leaks and is cleaned regularly. It was further observed that, the hardness of the water before the distillation using still was 5016 ppm and the hardness after distillation was 76 ppm. This proves that the water is potable. Thus it can be concluded that the still which uses cotton as wick material and which is coupled with a parabolic reflector gives a good yield.

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