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Comparative Analysis of Glass Fiber Sheet and Crepe Paper for a Wick Type Floating Solar Still

Hashim Hasnain Hadi[1a], Imran Khan[1b], Ghulam Sarwar[1c], Muhammad Mushtaque[1d], Salman Masroor[1e]

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ABSTRACT

Water is a prerequisite for the existence of life on earth. Rapid growth in the global population and industrialization have created a dearth of freshwater resources. Escalating water scarcity suggests that the use of passive solar stills is the most suitable and viable option in the arid and semi-arid areas around the world. In this study, the yield of wick type floating solar still is experimentally investigated for different wick materials. Capillary rise and absorbency of two different absorbers are considered as performance parameters for analysis of the research. Based on results, crepe paper with absorbency (1.8s) and capillary rise (112mm/h) proved a better absorber for higher productivity of the still. The efficiency of still with crepe paper was observed to be 16.68% higher than that of glass fiber sheet when applied in still during the investigation. The maximum internal temperature and the productivity of still were 9.1°C and 0.8 L/day respectively higher when crepe paper was used instead of a glass fiber sheet as a wicking material.

Keywords: Floating Solar Still, Wick, Crepe Paper, Glass Fiber Sheet, Passive Solar Still

1. INTRODUCTION

Potable water supply has become an arising problem for the people around the world. Some regions around the world are affected more while the others are less. Although water has covered 71% of the earth's surface, only 1% of which is available for the safe drinking purposes. Enormous availability of seawater provides an opportunity to distill it for fulfilling the potable water demand. Sun energy is a secure and free source and thus can be harnessed as one of the most favorable alternate energy option for the distillation. The usage of solar energy makes the process environment friendly and help in reducing the global warming. Solar distillation is a process in which the contaminated water is evaporated by the solar thermal energy and then these vapors are condensed back to give potable water. This process is simple, easy and economical [1]. Numerous Researchers have worked for the development of energy efficient technologies for the desalination process using solar energy.

The solar stills were in use prior to the 16th century in arid and semi-arid areas as an alternative source for getting fresh water. These are categorized into active and passive depending upon source of energy used for the purpose [2]. A lot of work have been done for improving the output of these stills from that time via design alternations. Various type of passive, active, single effect and multiple effect solar stills are assessed in [3]. Sarkar *et al.* [4] performed an extensive literature review and discussed the optimum design parameters of passive solar stills for the prevailing climatic and operational conditions. Different techniques used for improving the efficacy of the inclined solar still have been argued in [5]. Heat absorbing materials also affect the performance of the

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[1] Department of Mechanical Engineering, Balochistan University of Engineering and Technology, Khuzdar, Pakistan. Email: [a]hashimhasnainhadi@gmail.com (Corresponding Author), [b]imrankhanblch@gmail.com, [c]Sarwarnawaz678@gmail.com, [d]mushtaquerajput@buetk.edu.pk, [e]salman.masroor@buetk.edu.pk

stills. Such as black dye, black ink, black rubber mat and black paint alleviate the output up to 100% [6,7]. Experimental investigation for observing the effects of preheating the feed water via solar heater and condensing vapors using external and internal condensers was done in [8]. Flat plate collector is used for pre-heating the feed water and the yield of solar still has been analyzed in view of its effect in [9]. Several factors that affect the yield of the stills were reviewed and the productivity was found to be the mainly dependent on water depth by [10]. The studies reveals that the usage of reflectors, condensers, vacuum inside still and phase change materials improve the output. Active solar stills having various collector areas are fabricated and experimentally investigated. Active solar still production was reported to be increased by enlarging solar collector area and decreasing the brine depth in [11].

Simple and effective technique for the thermal behavior depiction about various passive solar stills established and assessed by [12]. Performance of solar stills with reference to depth of the water container and thickness of cover of glass for the cooling conditions by flash method as well as without cooling the glass cover are studied in [13]. Influence of wind velocity on production rate of a solitary basin passive solar still has been investigated in the environment of Jeddah (lat. 21.7°, long. 39.2°E) and validated by computer simulation in [14]. The study shows that the fins affixed to basin lining of still increased the heat transfer rate of water container and the output increases considerably [15]. Concave dish is used to enhance the efficiency of the still and confirmed the increase in the productivity up to 54% in [16]. Vacuum tubes are also used in the solar still to enhance the distillate amount by [17].

Numerical expressions are utilized for modelling the behavior of solar stills. Characteristic equation is presented for a passive type still by using experimental results [18]. Various factors for example water depth, glass cover tilt angle, etc. govern the efficiency equation. Simulation of the solar still involve the various relations that depend on the meteorological and operational parameters. Solar still with various alterations such as augmenting preheaters and condensers at local climatic conditions of Jordan, was demonstrated analytically and experimentally investigated by [8]. Salinity, water depth and cover inclination effects on the solar distillation process using solar stills and their productivities are discussed in [19]. The study presented that enhancement in salinity decreases the output of solar still. Thermal as well as economic comparisons between the pyramidal and the single slope was done using the mathematical model in [20]. Analysis confirmed superiority of the single slope solar still. Researchers are also interested in investigating the multiple effects to increase the productivity of the existing solar stills. The output of a still augmented with a greenhouse has been investigated at Mediterranean climatic conditions in south-eastern part of Spain in [21]. Multi-effect solar stills are observed to be more thermally efficient than single effect solar stills by [22]. But being costly and cumbersome, multiple effect solar stills are not popular.

Even though some Nanosheet assembled [23] and paper based composite membranes [24] are being investigated but the use of these latest techniques require exceptional arrangements. Different wick materials like jute 30% [25], sponge cubes 18% [26], cotton cloth [27, 29] coral fleece fabric and weir mesh [28] black velvet fabric [29] are also used for improving the evaporation rate but the thermal efficiency remained limited (20-40%).

Accordingly, the current work has focused on the comparative study of the two wick materials i.e. glass fiber sheet and crepe paper for enhancing the productivity of the wick type floating solar still. From this study, it is clear that the water layer thickness is in inverse proportion with the rate of evaporation. The objective has been attained by using the aforementioned technique for reducing the water layer thickness to increase the performance of the still.

2. WICK MATERIAL CHARACTERIZATION

It is studied that water absorbency and capillary rise are significant characteristics of an effective wick material [28]. The various wick materials were tested for their characters at Fluid Mechanics Lab, Balochistan University of Engineering & Technology

(BUET) Khuzdar, Pakistan. Following procedures were practiced as:

2.1 Absorbency of Water

Measure of time rate at which the wick material takes up the water and transform it into other phase is termed as absorbency of water. Depending on the type of material, water absorbency vary from one material to the other. For example, the water absorbency in fabric is dependent on the yarn being used for weaving. Water absorbency tests of various materials can be performed by determining the time taken by the wick material to absorb the placed water droplet completely as shown in Fig. 1(a-b).

Wick material is positioned onto the top of a flask in order to make its some portion bared from rear side. Water is taken into pipette and a quantified water droplet is placed on the fabric sample 10 mm above. Water absorption into the material is then observed visually and time is measured using stop watch unless the water droplet is entirely absorbed.

2.2 Capillary Rise

Capillary rise occurs due to upward movement of water via the spaces available in the structure of a porous material owing to the adhesive and cohesive forces as well as surface pull created by upward force. For example, paper and fabric. Standard vertical wicking test can be performed to measure the capillary rise of a wick material. From current experimentation, it is observed that crepe paper (112 mm/h) has high capillary rise while glass fiber sheet has comparatively less capillarity Table 1 illustration of the various wick characteristics attained from experiments as shown in Fig. 1(a-b).

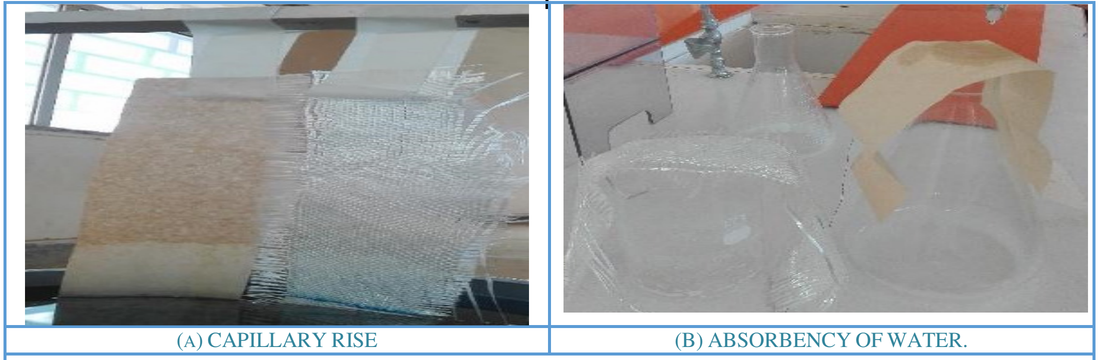
Table1: Wick Materials Characteristics

Type of Wick	Wicking Characters	
	Water absorbency (Seconds)	Capilary Rise (mm/h)
Glass Fiber Sheet	3	95
Crepe Paper	2	112

3. EXPERIMENTAL SETUP

3.1 Solar Still

Schematic of the floating type passive solar still with wick materials used in the current study is presented in Fig 2. Fig 3(a-b) are the photographs of the setup with glass fiber sheet and crepe paper respectively. The experimental arrangement consists of wick type floating still having tilt angle for cover as 27° in accordance with latitude of Khuzdar (27°44′ N). The acrylic glass with a thickness of 5mm was used for housing and cover. Acrylic glass joints were sealed by Silicon Sealant to circumvent the leakage of water vapors. The height of the rear wall was kept as 0.51m while that of the lower as 0.04m to evade the drop of condensed vapors in the still. The wick materials were coated with carbon black for maximum heat absorption before wrapping onto the expanded polystyrene foam pads and inserting inside holes in the base of the still.



(A) CAPILLARY RISE | (B) ABSORBENCY OF WATER.

FIG. 1. INVESTIGATION TECHNIQUE

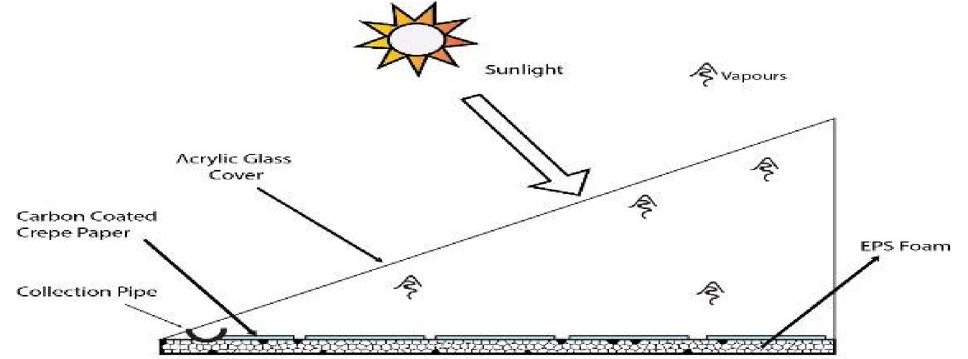
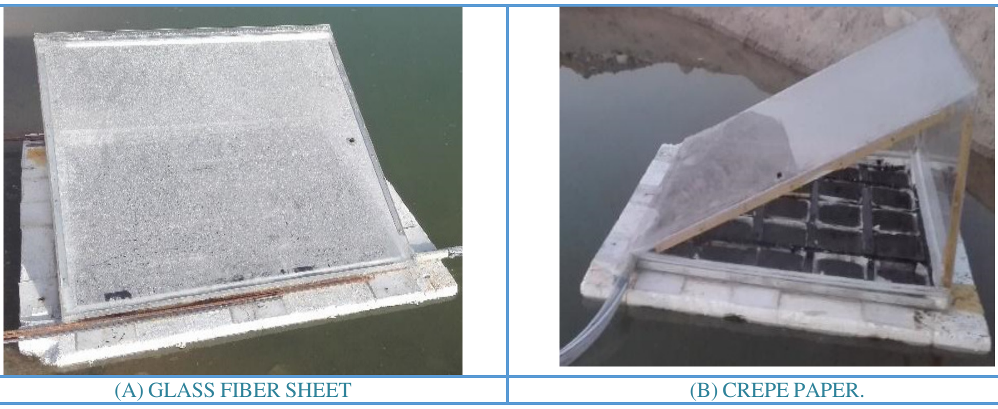


FIG. 2. SCHEMATIC OF A WICK TYPE FLOATING SOLAR STILL



(A) GLASS FIBER SHEET

(B) CREPE PAPER.

FIG. 3. WICK TYPE FLOATING STILL

Wetting of wick surface area was achieved by dangling of extended wick edges in the pond water through capillary action. Area of the acrylic and expanded polystyrene base was made as 1×1m with evaporating area of $0.5625m^2$ which absorbed the incoming solar radiations and facilitated the evaporation. Half cut four PVC pipes of internal diameter 0.04m were fixed to all sides of the still for the collection of condensate which were further channeled to the collection bottle by flexible rubber pipe. This collection bottle floated along with the still on the source water and also served as a condenser.

3.2 Procedure

The solar still was fabricated and tested at Baluchistan University of Engineering & Technology, Khuzdar (Lat: 27°44′ N, Long: 66°38′E), Pakistan. The experiments were carried out separately for each of the wick material, fiber glass sheet and crepe paper; experiments for the glass fiber sheet were conducted from 4-10 June and 6-12 August 2017, whereas for crepe paper from 11-17 June and 13-19 August. Starting from 6:30 am, all the experiments were conducted on 24 hours basis. Solar still was put on the water surface of the pond located at the university campus so that the extended edges of the wick material dangle into the water and bring the water on the surface of the still by capillary action. It took 15 minutes to completely wet the entire surface of the wick material. During process, evaporated water from the carbon coated wick material was trapped by the acrylic covering, condensed and collected dropwise through half cut PVC pipes in plastic bottle floating beside the still. The wick material then absorbed the additional water to replace it.

The hourly values of pond water temperature, inner still temperature, outer glass cover temperature, distillate temperature and yield were measured for the performance evaluation of the solar still. An infrared temperature measurement gun of least count as 0.1°C, calibrated by a zeal thermometer was used to measure the various temperatures. Ambient temperature was recorded by HM Digital COM-100 Temperature Meter. A transparent graduated beaker with a least count of 1 ml was used for measuring the distillate. Distillate coming out of the still was collected in plastic bottle, hourly, between 7.00 am. to 6.30 pm. The night distillate, collected from 6.30 pm to 7.00 am. next day morning, had also been measured. The daily yield of the still has been calculated by summation of measured distillate values during day and night distillate. Fig 4(a-b) re the photographs of the rear side of the prototype with glass fiber sheet and crepe paper after tests, respectively.

4. RESULTS AND DISCUSSION

The Solar radiation, being the primary energy source, is most significant factor that dictates the passive solar still performance. Consequently, the thermal response of the still is increased due to high solar radiation intensity. Withal, the variation in extreme values of temperature noted during the months of June and August for inside glass, cover outer, distillate and pond water using glass fiber sheet as a wick material is shown in Figs. 5-6. The maximum inside glass temperature reached up to 59°C in June at 1.30 pm with glass fiber sheet as a wick.

(A) GLASS FIBER SHEET

(B) CREPE PAPER

FIG. 4. REAR VIEW OF STILL AFTER TESTING

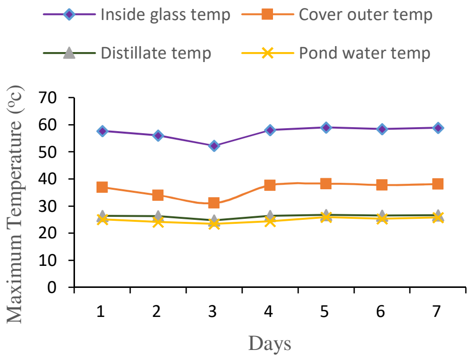


FIG. 5. VARIATION OF DIFFERENT TEMPERATURES 4-10 JUNE FOR GFS

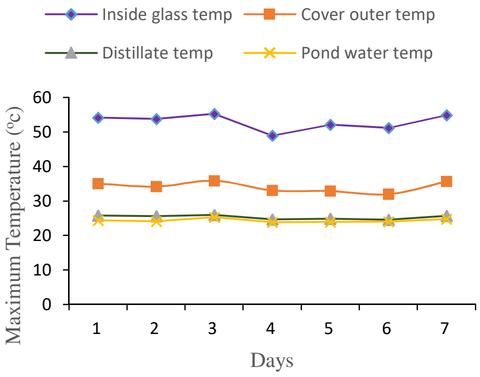


FIG. 6. VARIATION OF DIFFERENT TEMPERATURES 6-12 AUGUST FOR GFS

Figs. 7-8 indicates the trends of maximum values of inside glass, cover outer, distillate and pond water temperatures for the still with crepe paper recorded during the months of June and August. While using the crepe paper as a wick material, it was interestedly noted that the maximum inner glass temperature reached up to 68.1°C at 1:30 pm due to its better thermal response. This optimum inside glass temperature ultimately increased the evaporation rate and in turn, the productivity.

Even though the evaporation takes place at all temperatures but the elevated temperature accelerate this process resulting in increased output. Daily yield of the still determined for glass fiber sheet and the crepe paper during experiments conducted in June and August 2017 is illustrated in Figs. 9-10. It can be clearly observed that the output of the still was improved with crepe paper as compared to the glass fiber sheet at all. The maximum output of the still noted for glass fiber sheet and crepe paper was 2.87 L and 3.63 L respectively. This difference in the productivity clearly indicates the better water absorbency and thermal response of the crepe paper.

For evaluation of the performance, we have calculated the efficiency of the still which is depicted by the Equation (1):

$$\eta = \frac{Q \times L}{G \times A} \times 100 \qquad (1)$$

where η is the efficiency of the still [30], G is daily global horizontal solar radiation (MJ/m^2/d), A is effective area of solar still (m^2), L is Latent heat of vaporization of water (MJ/kg) and Q is average daily output of the still (kg/m^2/d).

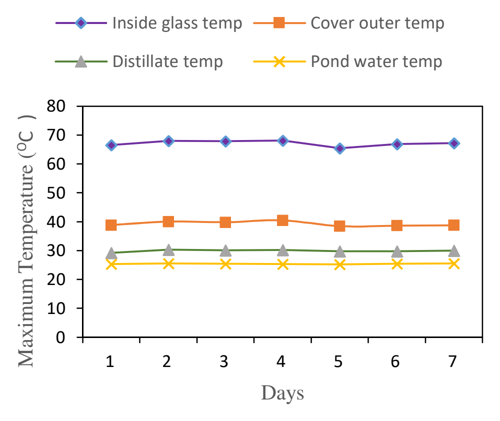


FIG. 7. VARIATION OF DIFFERENT TEMP 11-17 JUNE FOR CREPE PAPER

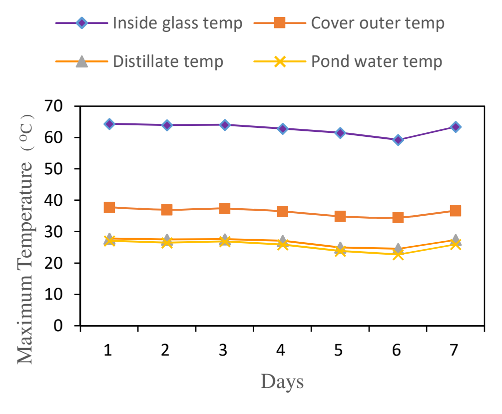


FIG. 8. VARIATION OF DIFFERENT TEMP 13-19 AUGUST FOR CREPE PAPER

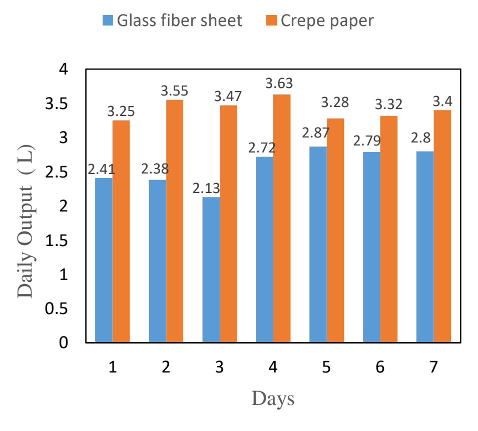


FIG. 9. DAILY OUTPUT OF GFS AND CREPE PAPER FOR MONTH OF JUNE

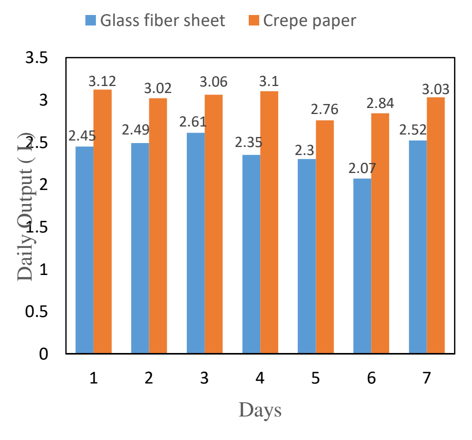


FIG. 10. DAILY OUTPUT OF GFS AND CREPE PAPER FOR MONTH OF AUGUST

The variation in daily efficiencies of the still during the months of June and August calculated for the glass fiber sheet and crepe paper is shown in Figs.11-12. The maximum efficiency of the solar still calculated was 61% for glass fiber sheet and 76.11% for the crepe paper in the month of June whereas the minimum efficacies computed using glass fiber sheet and the crepe paper were 53.47 and 43.40% for the months of June and August respectively. The higher average daily efficiency of 67% for wick type floating solar using crepe paper dominates over the glass fiber sheet.

5. CONCLUSIONS

The experimental analysis, for investigating the effect of the wick material on the performance of solar sill, is reported and compared. In this work, two different wick materials i.e. glass fiber sheet and crepe paper are analyzed. From the experiments, it is observed that the crepe paper has better water (due to high capillary effect) and solar radiations absorbency which lead to better performance of the wick type floating solar still. Being cheap, durable and locally available, crepe paper can be utilized for the wick type floating solar still. The results illustrate that the efficiency of the still was increased by 16.68%, when crepe paper was used instead of glass fiber sheet.

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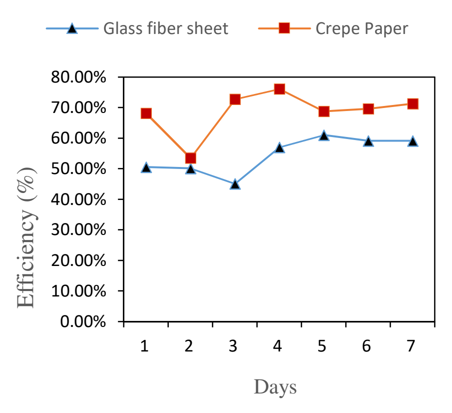

FIG. 11. EFFICIENCIES OF THE STILL WITH GFS AND CREPE PAPER FOR JUNE

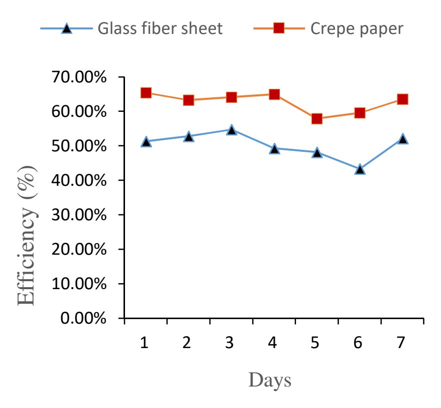

FIG. 12. EFFICIENCIES OF THE STILL WITH GFS AND CREPE PAPER FOR AUGUST

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