THE EFFECT OF VARIOUS TYPES OF WICK MATERIALS ON THE PERFORMANCE ENHANCEMENT OF DIFFERENT TYPES OF SOLAR STILLS: A REVIEW

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Abstract: **Despite of having huge amount of water on earth, the shortage of clean drinking water is very severe because of its salinity. Various methods to convert saline water in to distill water, using conventional energy sources are already there in to existence. Typically Electricity is being utilized to convert saline water in to fresh potable, which is indirectly responsible for environmental pollution and are expensive as well. Therefore, a device is needed, which can work economically and environment friendly. Solar Stills are therefore the best solution to resolve both the problems. But, the productivity of solar still is very low hence the researchers are working hardly to enhance the performance of the solar stills using various augmentations. Out of many alternatives, one of the ways to enhance the still efficiency is by using the wick of different materials. This research paper highlights the effect of performance improvement of the various types of solar stills using different wick materials like cotton cloth, charcoal cloth, wool, water coral fleece, jute, coir mate, wood pulp, paper wick, polystyrene sponge etc.**

I. INTRODUCTION

Though we are living in the 21st century, the strive for the availability of clean and potable drinking water is still a biggest need and challenge for each and every country across the globe and so with the India. Rapid development, growth of economy and population rise leads to the shortage of the pure drinkable water. Despite of the fact that earth is having more than two third of water on its surface, the sources of pure drinking water are very much limited and are also depleting at an alarming rate. More than 97% of water on earth is saline water, rest 2.6% is fresh water and less than 1% water is within the reach of human being [1]. Looking to this fact and need, the sincere efforts are required to be made to convert saline water in to pure drinkable water. There are many desalination methods like reverse osmosis, electro dialysis, vapour compression, multistage flash distillation, multiple effect distillation and solar distillation etc to convert salty water in to drinkable water. Majority of the methods mentioned above needs electricity for desalination process, which is costlier and indirectly responsible for the pollution of the environment. Therefore, it is very much essential to use any renewable source of energy for distillation to avail the fresh water at cheaper rate with no environmental pollution. Therefore, solar distillation can be judiciously chosen as most effective and economic device that can be utilized for desalination process.

The prescribed maximum limit of TDS (Total Dissolved Solids) by WHO (World Health Organization) is 600 ppm and is allowable up to 1000 ppm in some special cases. The water available on the earth surface has the TDS up to 10000 ppm and that of the sea water has TDS range of 35000 ppm to 40000 ppm [1]. The laboratory test result shows that the water available from the solar still is free from impurities like Nitrates, Chloride, irons and dissolved solids [2]. Therefore the solar stills are widely utilized for the desalination purpose.

The distill water output from the conventional solar stills are generally ranging from 1 to 2 liter/m^2.day. However, this amount of distillate outlet is considered to be low, and hence the various types of solar stills with different augmentations are necessary to raise the yield of the distillate output. The performance of the solar stills can be raised by using fins, wick, gravels, PCM (Phase change Material), Nanofluid etc. The aim of this study is to identify the best suitable material to be used as wick to enhance the productivity of the respective solar still.

II. LITERATURE REVIEW OF THE WICK MATERIAL

Minasian et al. (1995) [3] had performed the experiment as shown in fig.1 on the conventional solar still, tilted wick type solar still and wick basin type solar still. The size of conventional basin was 1.5 x 0.67 m. The material used was galvanized iron sheet of 22 gauge painted with black colour. The basin was covered by 4mm thick transparent glass. The wick type basin still there are two parts:

The tilted wick-type solar still and wick basin type solar still. The blackened jute cloth was used as wick material. The evaporating area of tilted wick still was 1.4 x 0.72 m and wick basin solar still was 0.8 x 0.5 m. From the experimental test, the result obtained shows that the efficiency of wick basin type still is highest compared to other two types of basin. The maximum distillate output obtained in conventional basin, tilted wick type basin and wick basin type still was 5.103 liter/m^2.day, 5.970 liter/m^2.day and 8.477 liter/m^2.day respectively. The productivity of wick basin type still is increased by 85% and 43% over conventional basin type and wick type stills respectively.

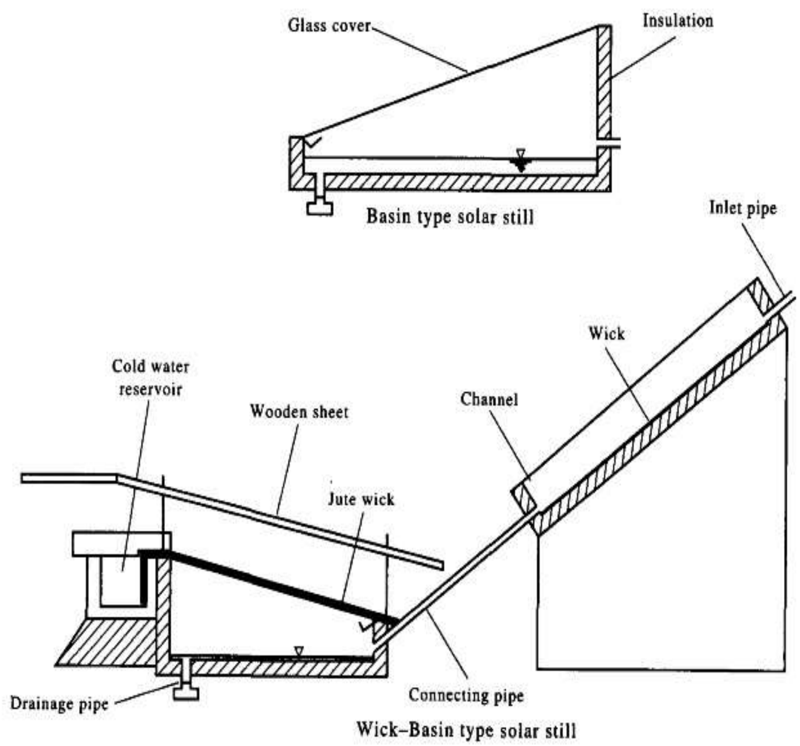

Fig. 1 Experimental stills of Minasian et al. [3]

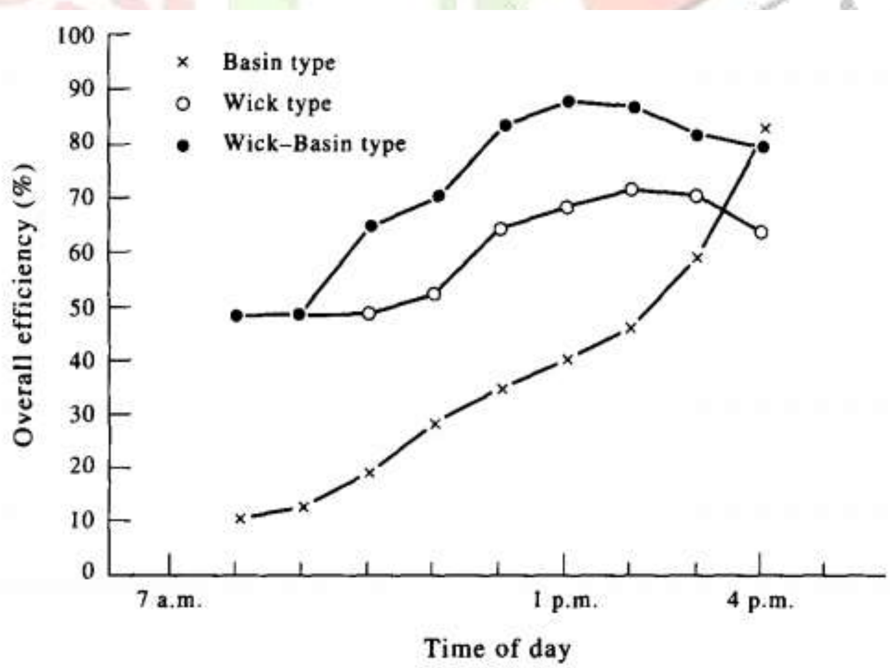

Fig. 2 Efficiency of stills [3]

Kabeel (2009) [4] has experimented on pyramid shape solar still with concave wick to enhance evaporation rate. The basin dimensions are 1.2 m x 1.2 m. The basin was insulated by glass wool of 5 cm thickness and is covered from surrounding with 2 mm thick steel sheet. The solar still was surrounded by glass cover of 3 mm thickness with tilt angle of 45°as shown in fig. 3. Experimental result shows the average distillate water output as 4 liter/m^2.day, which was higher than normal. The increase in distillate output is due to increase in evaporative area due to capillary effect of the wick.

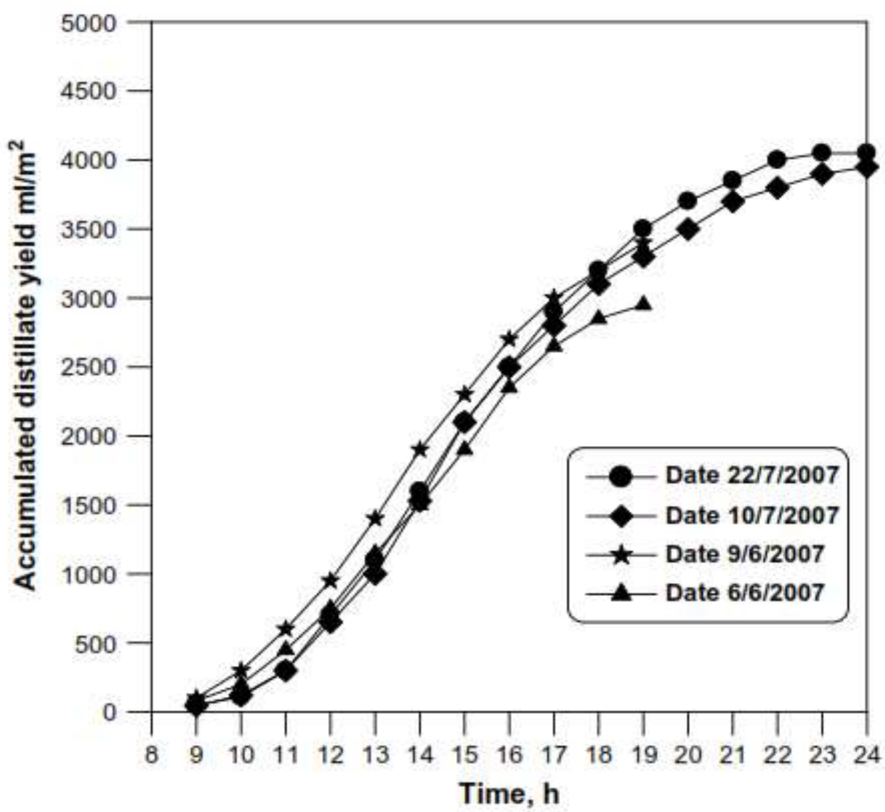

Fig. 3 Variation of the accumulated distillate water during the day for different days [4]

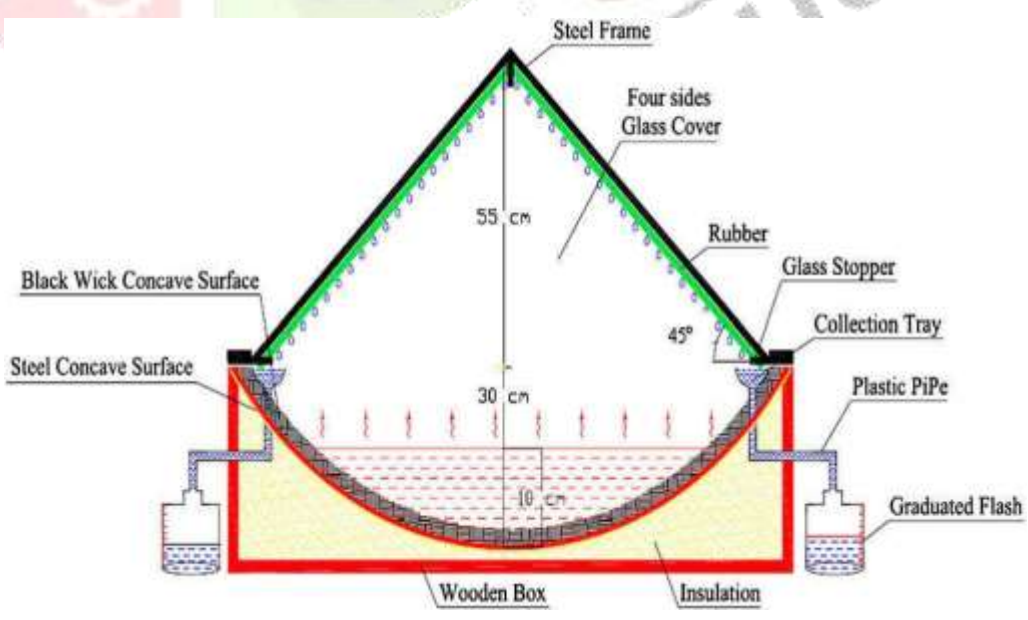

Fig. 4 Schematic diagram of concave wick solar still [4]

Arjunan et al. (2011) [5] had conducted a test on solar still using sponge liner at the inner side of the basin wall as shown in experiment setup in fig. 5. The effective basin area comes out to be 1000mm x 500mm ($0.5m^2$) made up of galvanized iron (G.I.) sheet of 1.4mm thickness. The glass cover provided for condensation is prepared from 4mm thick glass and is mounted on the side wall of the solar still keeping rubber gasket below it. The result of the experiment shows the decrease in heat loss from the side walls due to sponge liners. The effect of liner thickness was also studied to check the improvement in the distill water production. The result of variation in sponge liner thickness on distill water output is shown in fig. 6. From the result it has been concluded that the maximum distill water output was available to be 1.535 kg/day when 5mm thickness of sponge liner was used, which is 35.2% higher than the conventional still without sponge. The fig. 7 shows the graph of efficiency versus sponge thickness, which represents the effect sponge thickness in distillate output from the still.

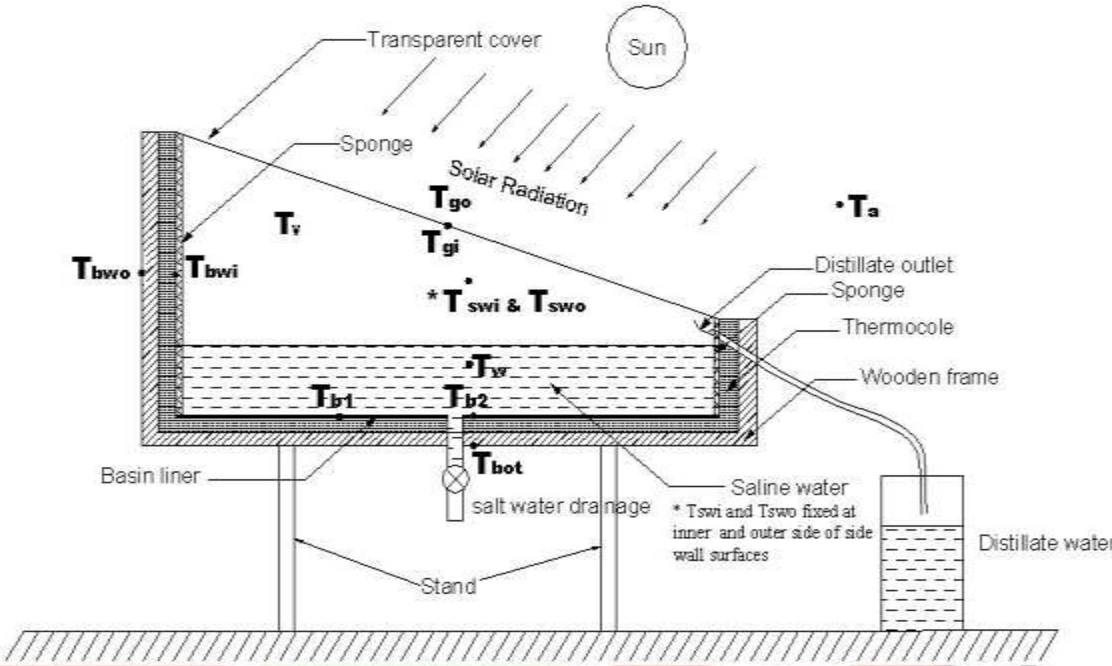

Fig. 5 Schematic diagram of the single slope solar still with sponge liner at inner wall surfaces [5]

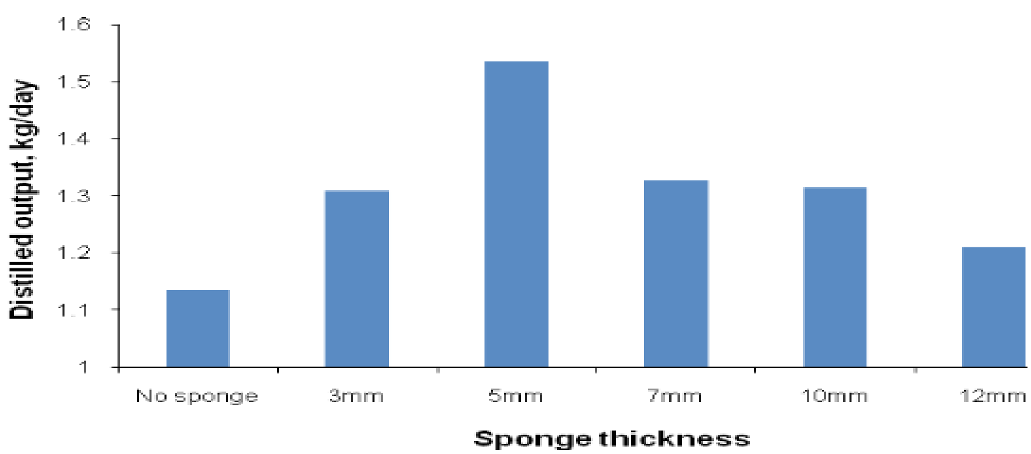

Fig. 6 Variation of daily yield with respect to all sponge liner thicknesses [5]

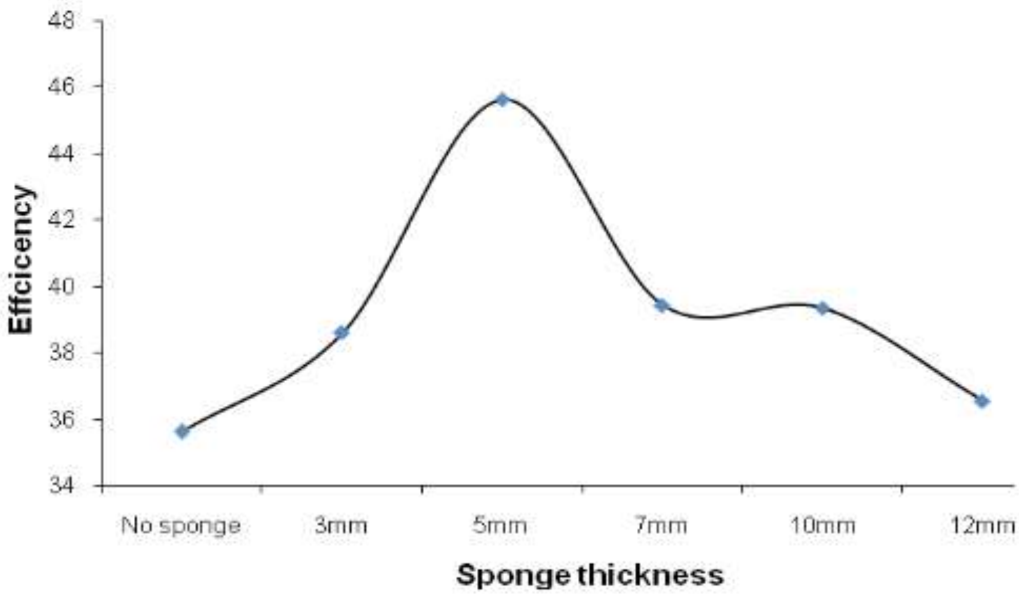

Fig. 7 Variation of overall efficiency for different sponge liner thicknesses [5]

Mahdi et al. (2011) [6] had worked upon tilted solar still with tilted wick attached to the basin. The charcoal cloth is having absorptiveness of about 98% and hence it was used as wick material. Fig. 8 shows the arrangement of the experimental setup. The test result shows that, as the salt concentration increases the efficiency decreases from 37.7% to 28% and 53.4% to 33.7% for indoor and outdoor condition respectively. However, the efficiency of 53.4% is comparatively good due to use of charcoal cloth as wick material.

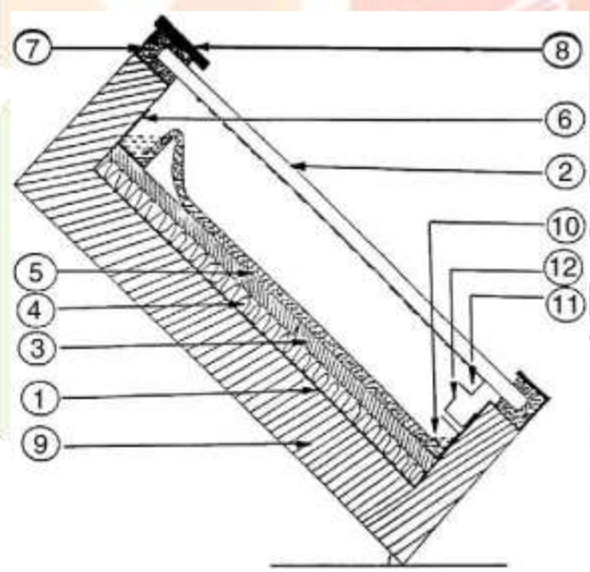

Fig. 8 Cross sectional view of the solar still (1) Galvanised steel tray, (2) glass cover, (3) support board, (4) polystyrene, (5) charcoal cloth, (6) aluminium channel, (7) rubber gasket, (8) steel strip, (9) Styrofoam, (10) brine gutter, (11) distillate gutter, and (12) distillate outlet channel [6]

Murugavel et al. (2011) [7] have performed the experiment on double slop single basin solar still with rectangular aluminum fin and different wick material like light jute clothe, coir mate, sponge, light black cotton cloth, waste cotton pieces etc as shown in fig. 10. The test experimental setup is as shown in fig. 9. The dimension of the inner side of basin was 2.08m x 0.84m x 0.075m and was manufactured from mild steel material. The basin was lined with concrete to reduce heat loss and insulated with glass wool on the side walls. The top of the still was covered with the glass of 4 mm thickness. The level of water inside the basin was maintained at 5mm height equivalent to 7.5 kg. The experimental result shows that performance of the black cotton cloth wick material is best among all the wick material as shown in fig. 11. However, using black cotton cloth with aluminum fin gives slightly more productivity and gives the maximum distillate output as shown in fig. 12. Moreover, bar chart shown in fig. 13 shows the comparative distillate output of solar still using different wick material.

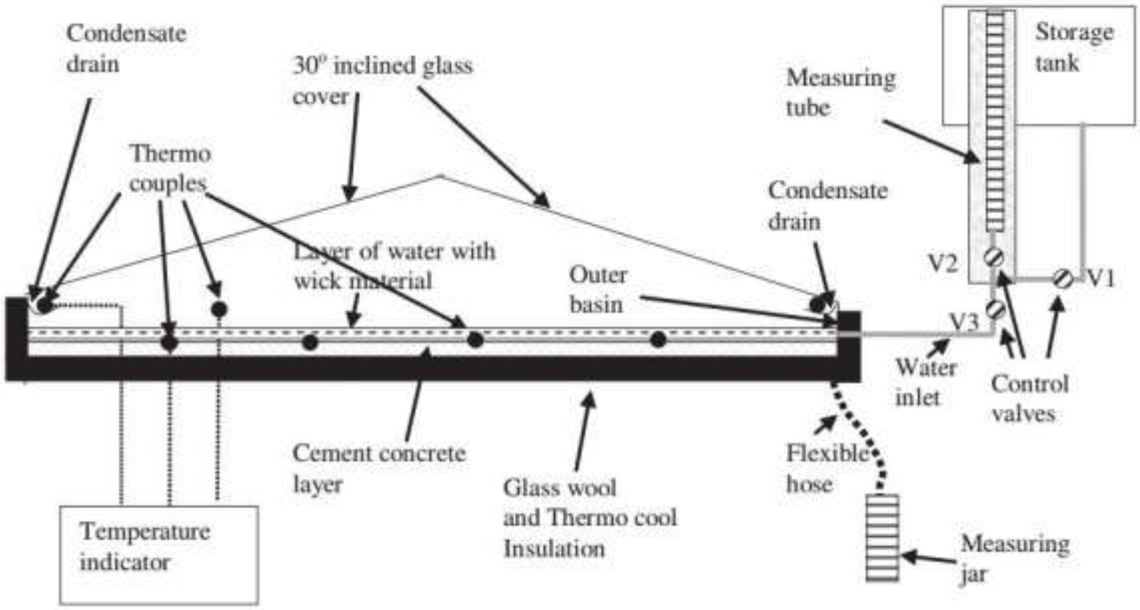

Fig. 9 Single basin double slope solar still [7]

Fig. 10 Different wick materials used in solar still [7]

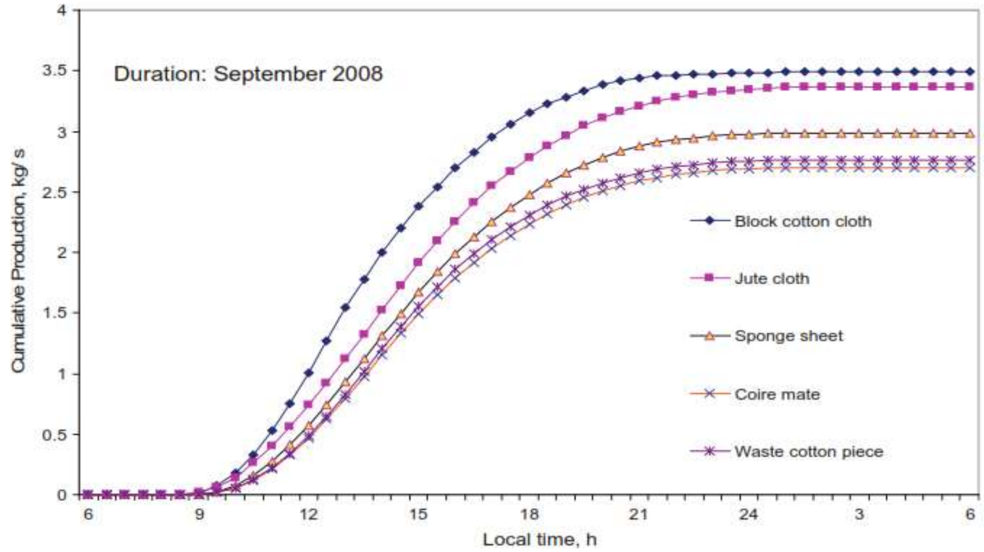

Fig. 11 Variation of cumulative production for different wick material [7]

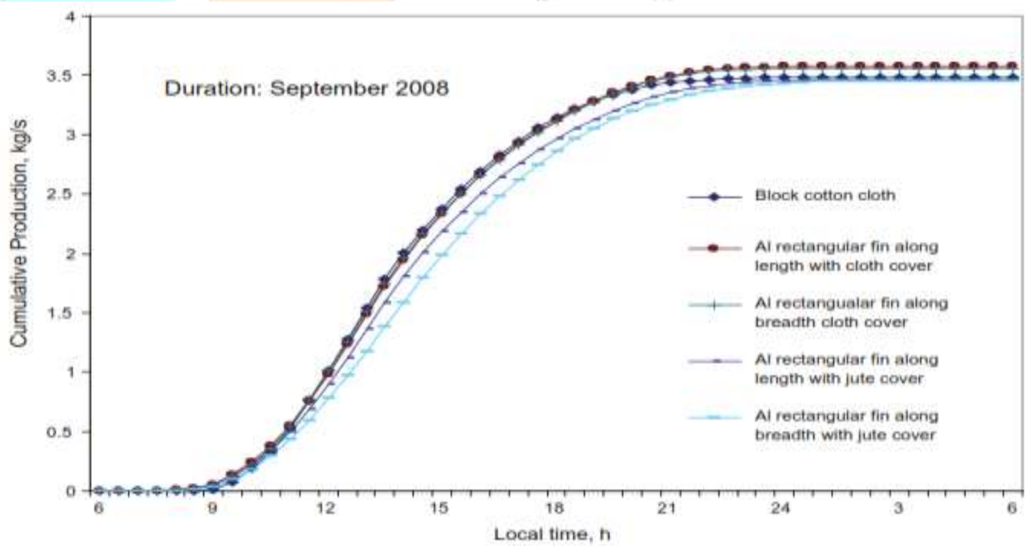

Fig. 12 Variation of cumulative production for wick with fin [7]

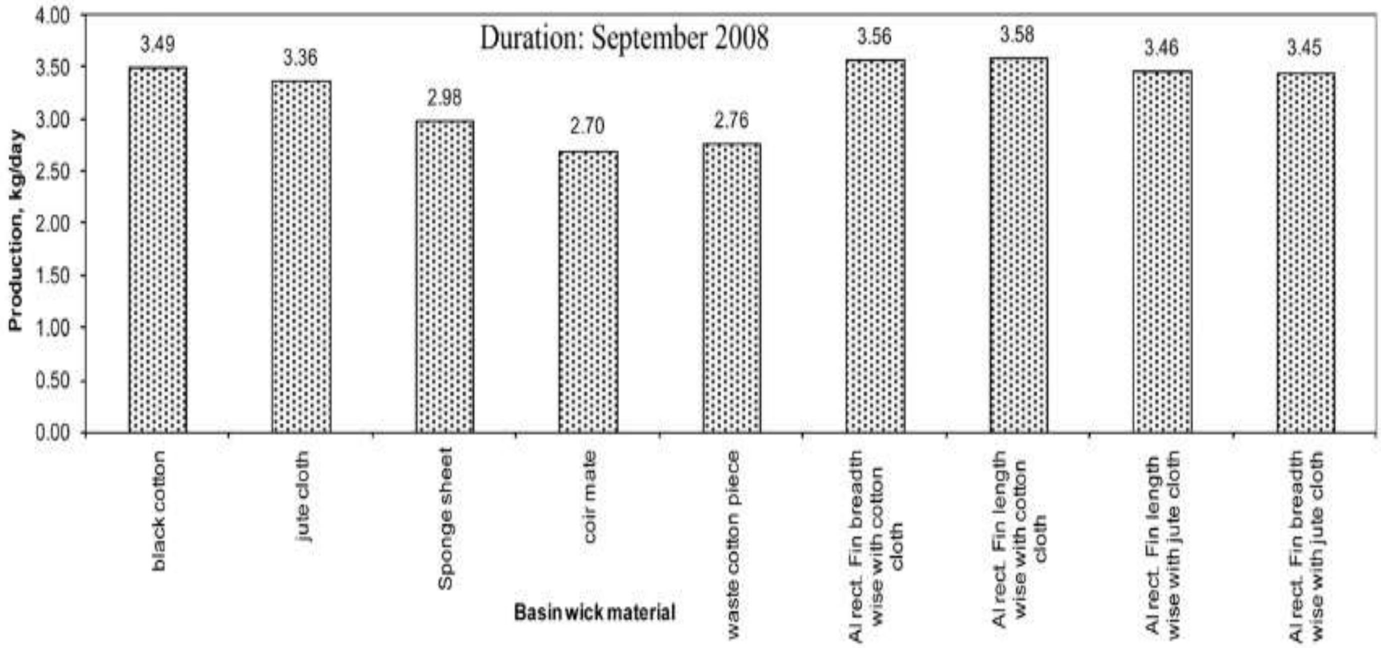

Fig. 13 Variation of total distillate production for various basin materials [7]

Hansen et al. (2015) [8] had experimented on inclined type solar still with different newer materials of wick like wood pulp paper wick, wicking water coral fleece fabric and polystyrene sponge etc. The dimension of still was 1 x 0.75 x 0.157 m and was made by mild steel. The basin was again provided with the absorber plate of aluminum material with 1 mm thickness. The basin was covered by glass of 4 mm thickness. The basin was insulated by thermocole material of 4 mm thickness. The tilt angle of the basin glass cover was fixed at 30o facing due south. The water gets collected in to measuring jar through condensate collection channels attached to basin. The complete experimental setup is shown in fig. 14. In this experiment the newer wick materials were chosen based on the wick material characteristics like absorption, capillary rise, porosity, water repellence and heat transfer coefficient suitable for the solar desalination application. On comparing the results after experiment, it was found that the water coral fleece material with porosity (69.67%), absorbency (2 s), capillary rise (10 mm/h) and heat transfer coefficient (34.21 W/m^{2}°C) is the most suitable wicking material for higher productivity of solar still. While stills with other different wick materials like wood pulp paper and polystyrene sponge has comparatively lower productivity. Maximum distillate achieved in the still with water coral fleece as wick material was achieved to be 4.28 liter/day.

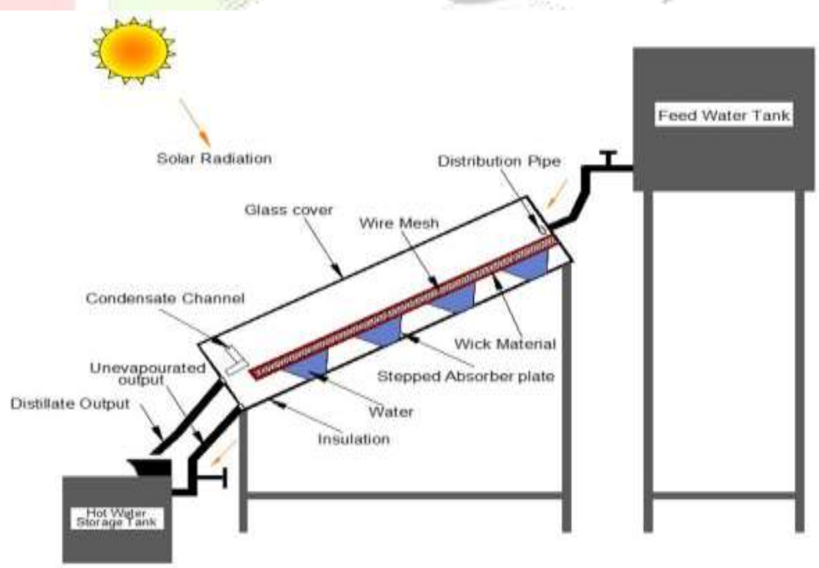

Fig. 14 Schematic drawing of inclined type solar still [8]

Alaian et al. (2016) [9] had performed the experiment on conventional solar still and pin-finned wick solar still at Egypt. The solar still was manufactured from galvanized steel sheet of 1 mm thickness. The basin dimensions are 0.8 m x 1.25 m. The basin glass cover thickness was 4 mm and inclined at 17º to horizontal surface. The still was insulated by glass wool of 5 cm thickness. Out of two still one still is being augmented with 294 pin-finned wicks with 9 cm height, 1 cm diameter and was immersed in 3 cm water depth. The fig. 15 shows the schematic arrangement of experiment setup. The experimental result from the fig.16 and fig.17 shows the distillate output of conventional still varies from 2.95 liters/m^2.day to 4.195 liters/m^2.day and that of pin-finned wick still varies from 3.29 liters/m^2.day to 4.8725 liters/m^2.day. That shows the increase in productivity by 23% using pin-finned wick solar still compared to conventional still. The maximum efficiency is observed to be 44.74% and 55.06% for conventional still and pin-finned wick still respectively.

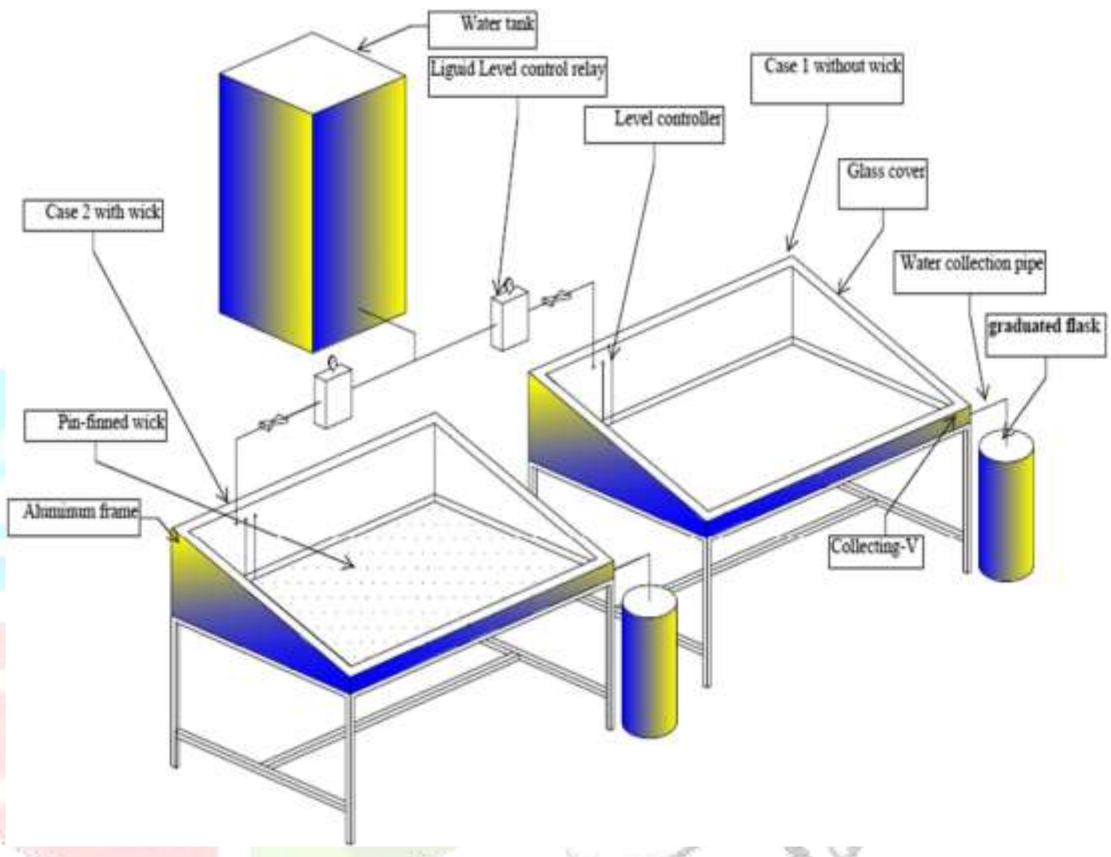

Fig. 15 Schematic diagram of test experiment unit [9]

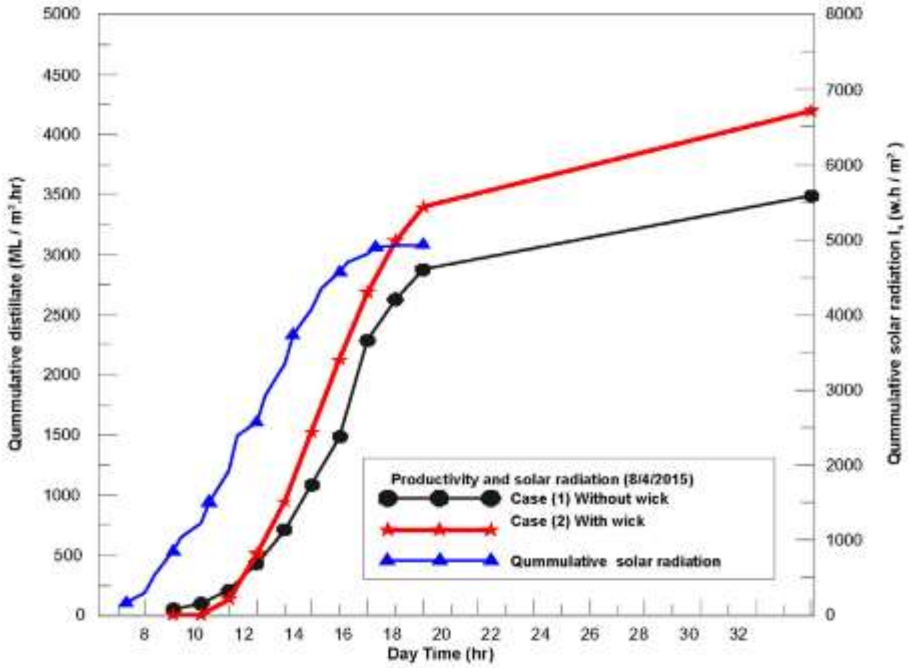

Fig. 16 Cumulative distillate output for day 1[9]

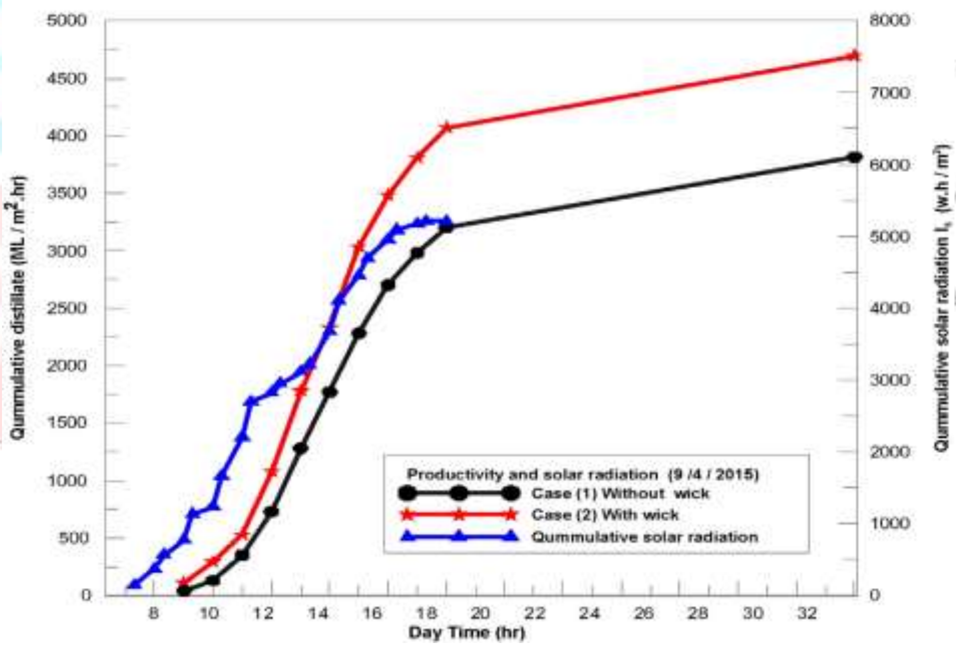

Fig. 17 Cumulative distillate output for day 2[9]

Pal et al. (2017) [10] had performed the experiment on double slope multi-wick solar still at Allahabad, India. The dimensions of the basin were 2 m x 1 m made up of fiber reinforced plastic of 5 mm thickness. The basin was painted with black colour. The glass cover inclination was kept at an angle of 15°. The side walls of the basin were made up of acrylic material of 3 mm thickness on south, east and west side while 5 mm thick sheet on north side. The wick materials used were jute and black cotton cloth. The maximum distillate output produced at 2cm water depth using black cotton wick and jute wick were 4.50 liter/m^2.day and 3.52 liter/m^2.day respectively. The result shows 9.04% rise in the productivity of distilled water, when black cotton wick was used as compared to jute wick. Also, the overall thermal efficiency of the still with black cotton wick was 23.03% in comparison to jute wick 20.94%. The fig.18 and fig.19 below shows the schematic arrangement of the experimental setup with jute wick and black cotton wick respectively.

Fig. 18 Photograph of solar still with jute wick [10]

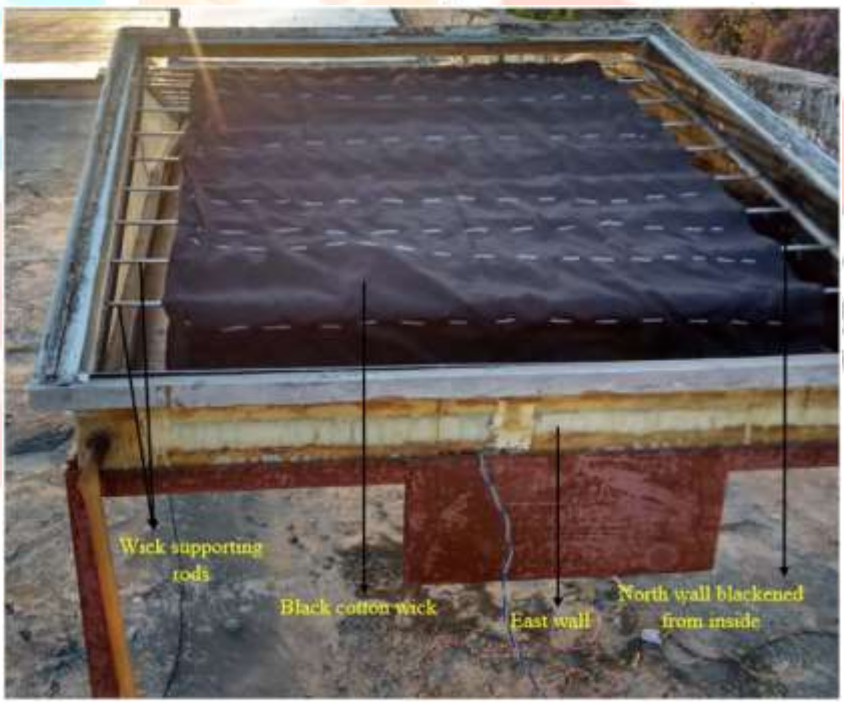

Fig. 19 Photograph of solar still with black cotton wick [10]

Agrawal et al. (2018) [11] had performed the experiment on two same size single slope single basin solar still with and without the use of blackened jute material to carry out comparative study of the productivity of solar still in terms of distillate output. The experiment was carried out at Rewa Engineering College, Rewa, Madhya Pradesh, (Latitude: 24°33' 20.81" N, Longitude: 81°18' 49.1" E). The still basin was fabricated from galvanized iron sheet of 1 mm thickness with basin dimensions 0.85 m x 0.6 m x 0.2 m. The basin was painted with black colour. The basin is insulated outside by polystyrene sheet of 5 mm thickness and protected with plywood sheet of 9 mm thickness from outside. The glass cover inclination was kept at 24^{o}. The distillate output of solar still with jute wick was 62% higher than the conventional solar still. The fig.20 below shows the photograph of both the types of solar stills. The fig. 21 below shows the cumulative distillate output on hourly basis in kg/m^2.day for conventional and modified still.

Fig.20 Photograph of modified and conventional single basin single slope solar still [11]

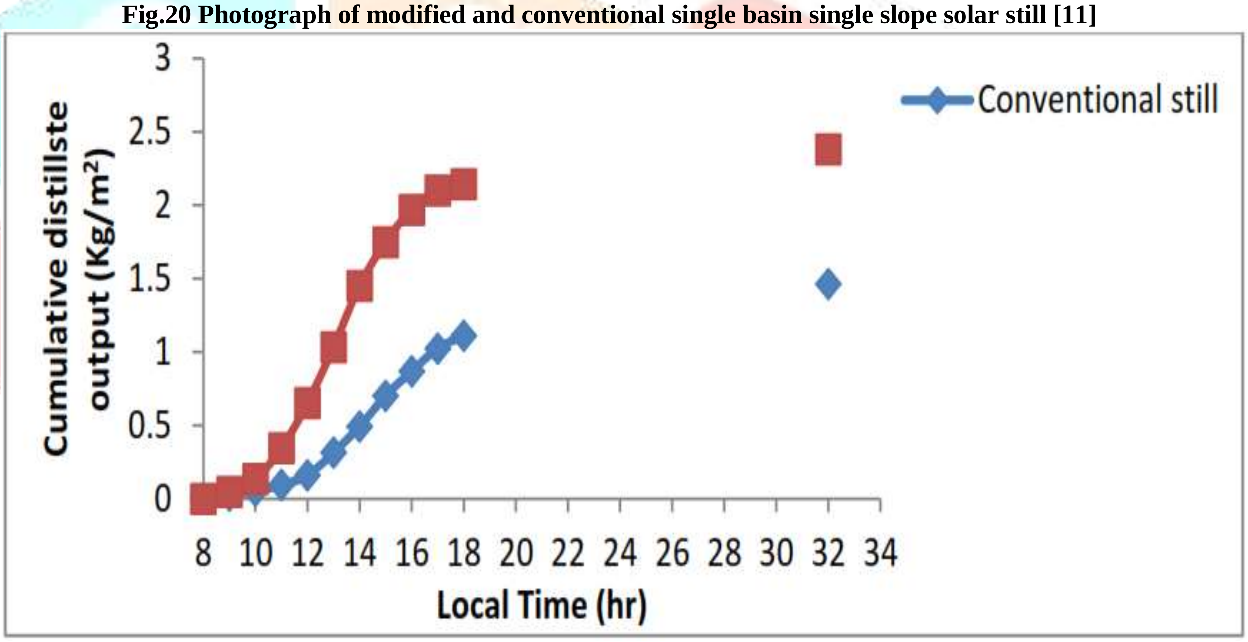

Fig. 21 Comparison of experimental values of cumulative distillate output for 24 hours (8 A.M. to 8 A.M.) for conventional and modified solar still [11]

III. Conclusion

The wick of different material in the different solar still is very much useful to enhance the performance of the solar still in terms of the productivity of distillate output. The widely used material used as the wick materials are jute and cotton cloth. However, some other materials like water coral fleece, wool, charcoal cloth, sponge etc. are being also utilized to improve the distillate output of the solar stills. Generally all the wick materials are less expensive and easily available in the market. Hence, the distillate output of the solar stills increases without making any considerable expenses and therefore leads to higher productivity.

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