A REVIEW ON SOLAR STILL AUGMENTED WITH WICK MATERIALS

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ABSTRACT

The pure water is basic need for human being. Unsafe drinking water can causes various diseases, so it is necessary to convert ordinary water to distilled water. The solar desalination is the simple distillation technique which uses solar energy for distillation purpose. The conventional solar still have a very less productivity. Nowadays the solar stills are available with different designs and different configurations to enhance the productivity. The wick type solar still is also a development of conventional solar still. The present paper reviews the various advancements in solar stills with wick and also considers the effect of various parameters and various configurations on productivity.

Keyword: - *solar still, desalination, wick*

1. INTRODUCTION

Water is vital for human beings. It is in plenty, but the quantity is not infinite. Human beings are reliant on rivers, ponds and wells to get pure water, but these resources are not always clean. The fresh water gets polluted by industrial wastes. The total quantity of global water is about 1.4 billion km3. From that around 97.5% is Seawater and the residual 2.5% is clean water i.e. available in the form of exterior water, frozen water in poles and ground water. So, only around 0.014% is accessible to human beings and other living creatures [1].

Unsafe drinking water can cause more diseases like diarrhea, which can become a primary cause of death of millions of people including number of children. From the estimation, it is clear that in developing countries, the spoiled water, water shortage and inadequate hygiene causes 85–90% of diarrheal diseases [2]. Because of not having connected to water distribution systems, people generally rely on potentially contaminated water sources like lakes, rivers and waterways that are filled with debris and dirt.

There are various distillation or desalination techniques developed to distil the saline or brackish water. Among them Vapor Compression (VC), Multi Effect Distillation (MED), and Multi Stage Flash (MSF) are included in thermal technologies, whereas Reverse Osmosis (RO), Nano filtration (NF), Microfiltration (MF) and Ultrafiltration (UF) are included in membrane technologies [3] (Fig.1). RO, MED and MSF are practically used in mega cities. In these techniques, the water is passes across two different membranes, and through an electric field. These techniques are based on thermal energy so if the fossil fuels are used for requirement of thermal energy, it can give negative impact on environment.

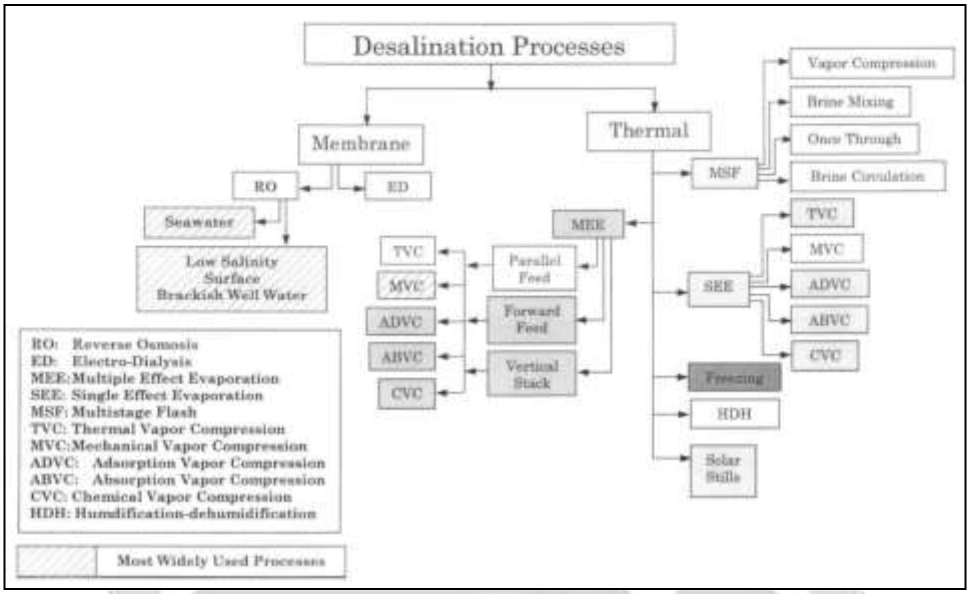

Fig. 1: Broad Classification of Desalination Processes [3]

The solar desalination technique is the good alternative to conventional desalination technique because it uses only solar energy as an input to the system. So, the system becomes environment friendly. In isolated and dry areas, the drinking water scarcity is a main issue. If those areas have higher solar radiation than solar desalination becomes most suitable technique for distillation of water. But the main problem with this technique is that it has high initial cost and also the solar energy is intermittent in nature. Because of these constraints the existing capability of solar desalination systems is only about 0.01% of the existing large-scale usual desalination plants worldwide [4]. The solar desalination uses solar still as a main component for distillation of saline water.

1.1 Solar Still

The solar still works on the same principle as nature makes rain. In the process of rain, the sea water evaporates with the help of solar radiation. The evaporated water vapour goes upward in atmosphere, where it precipitates and the rainfall occurs. The simplest type of solar still is described in Fig. 2. The basic components of it are absorber plate, glass cover, water collecting trough, water inlet valve, and blow off valve. In solar still, the water enters through inlet valve. The water gets heat energy from solar radiation falling on solar still. Gradually water gets heated and starts evaporating, the evaporated water moves to the glass cover. Because of temperature gradient among glass cover and the evaporated water vapour, the water vapour condenses on the inclined glass cover. Because of inclined position of glass cover, the condensed water flow through cover and get collected in the collecting trough. From where, the water can be used directly by human being. To increase the efficiency of solar still the absorber surface is painted black, as black surface absorbs more amount of solar radiation. The heat energy in the solar still gradually increases as the time passes in the day because of greenhouse gas effect taking place in solar still.

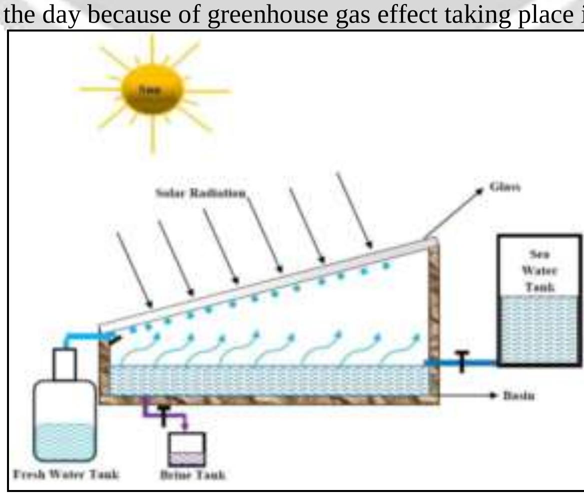

Fig. 2: Working Principle of Solar Still [5]

The solar still can broadly be ordered in two groups viz. Active and Passive solar still (Fig. 3).

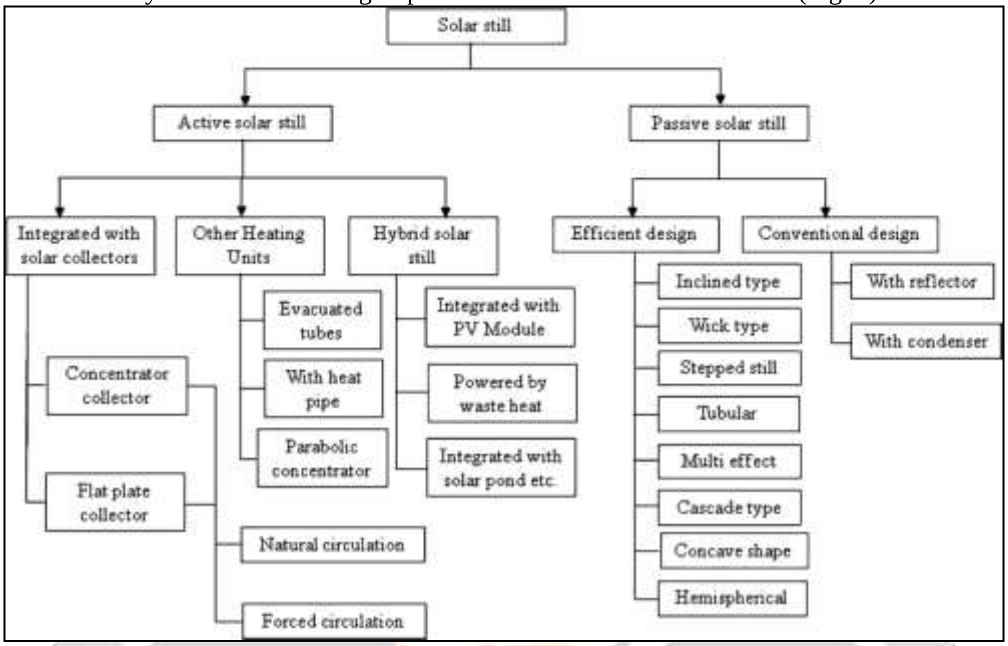

Fig. 3: Classification of Solar Still [6]

2. WICK TYPE SOLAR STILL

In this type of solar still, solar radiation reaches the wick surface through the glass cover, where it gets absorbed. From that certain amount is employed for heating the water passing across wick through capillary action and major quantity of heat remains in the still, and energy transfer done through the wick surface to glass cover and atmospheric air. In the solar still heat transfer are governed by two modes, i.e. external and internal. In external mode radiation and convection takes place, which are not dependent to each other and takes place outer side of the solar still. Whereas internal mode involves convection, radiation and evaporation, that is accompanied inside the solar still. Water gets heated and evaporated into vapours when it gets passed through the wick surface. The saturated water vapour condenses releases latent heat of vaporization at the glass cover inner surface. The condensed water particles drop down and get accumulated in the collecting channel.

With the use of wick materials the productivity increases in the solar still because of following reasons.

1. The wick materials have greater heat storing properties than water only.
2. In the wick material the water moves slowly through pores in the upward direction from absorbing pad.
3. The evaporating area of the brine increases with use of wick material.
4. It reduces the thermal capacity of solar still and subsequently gives rapid response to solar radiation. So, greater evaporator temperatures are attained, which, produces higher yield.

2.1 Review on wick type solar still

The **Mahdi *et al.* [7]** (1994) have done experiment on solar desalination of water by a V-trough solar concentrator with wick in 1990. A V-trough solar concentrator (of apex angle of 30°) has been joined with a flat wick solar still to enhance the outdoor operation of wick solar still. The glass cover contains the concentrator on the outer surface. Because of use of concentrator the average temperature in still increases. So, less amount of heat is required to evaporate water in still. From experiment result it is clear that the productivity increases with concentrator.

In 1995, **Minasian *et al.* [8]** had developed solar still containing tilted wick type and conventional type solar still connected together. The conventional type solar still was made up of a metallic basin of 22 gauge black painted Galvanized iron having dimension of 1.5 x 0.67 m. The basin consists of 4 mm glass cover inclined at 15° angle to the horizontal. The 5 cm thick single layer of polystyrene, and 1 cm dense saw dust was used as the insulator. The metallic basin contains the insulation under the 2 cm thick wooden frame. The float valve was provided in the still to keep a steady water level of 5 cm. The valve was attached to a saline water storage tank located at a height of 1.5 m over ground level. In wick basin type still there are two parts, one had inclined basin having wick material place at the bottom and another had a simple basin covered with jute wick on the top surface. The inclined basin had an evaporating area of 1 m^2 covered with 4 mm glass cover. The blackened jute cloth used as a wick. The same float valve arrangement was done for constant water level in basin. The wick-type still was fixed at an angle of 45° in the winter and at 25° in the summer to get highest solar radiation. Another part was a small simple basin-type had area of 0.8 x 0.5 m^2. To prevent this combined still beyond the reach of beam solar radiation, a wooden sheet, 50 cm away, was put over the jute cloth cover (Fig. 4).

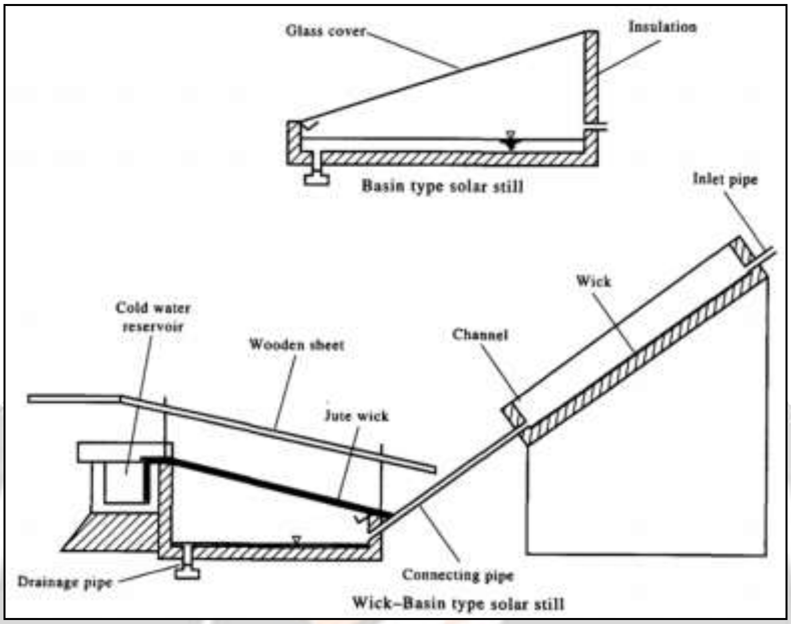

Fig. 4: Experimental stills of Minasian *et al.* [8]

From experimental results, they conclude that the productivity of wick basin type still is greater compared to the conventional wick type and wick type still (Fig. 5). Efficiency of wick basin type still is also high. The productivity of wick basin type still is increased by 85% and 43% over conventional type and wick type still respectively.

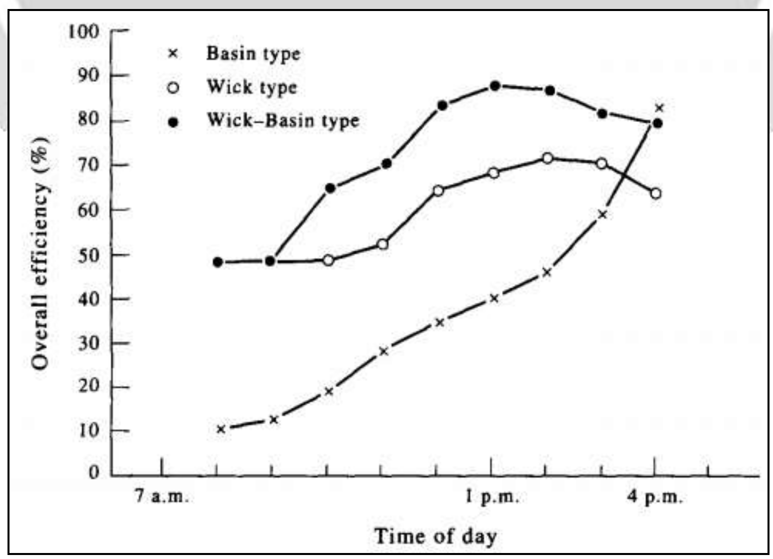

Fig. 5: Efficiency of stills [8]

Janarthanan *et al.*[9] (2006) had developed the model of solar still having tilted and floating wick solar still with the water passing above the glass cover. The experimental model is as in Fig. 6. The black jute as a wick was placed along with the 15° inclined portion and the residual part of the wick been made in corrugated shape and it floats over the water reservoir of still. The floated part was fitted with a 2 cm thick polystyrene sheet. The constant water level in the basin has been sustained i.e. remains 0.5 cm below the inclined portion. The corrugated floating wick surface faces upside due the glass cover and corresponds with the upper water level in basin. The tilted wick remains soaked due to the higher level of water in the basin. The evaporated water vapour condenses on glass cover having water cooling of cover. Because of glass cover cooling the cover temperature decreases and it increase the condensation and condensate output.

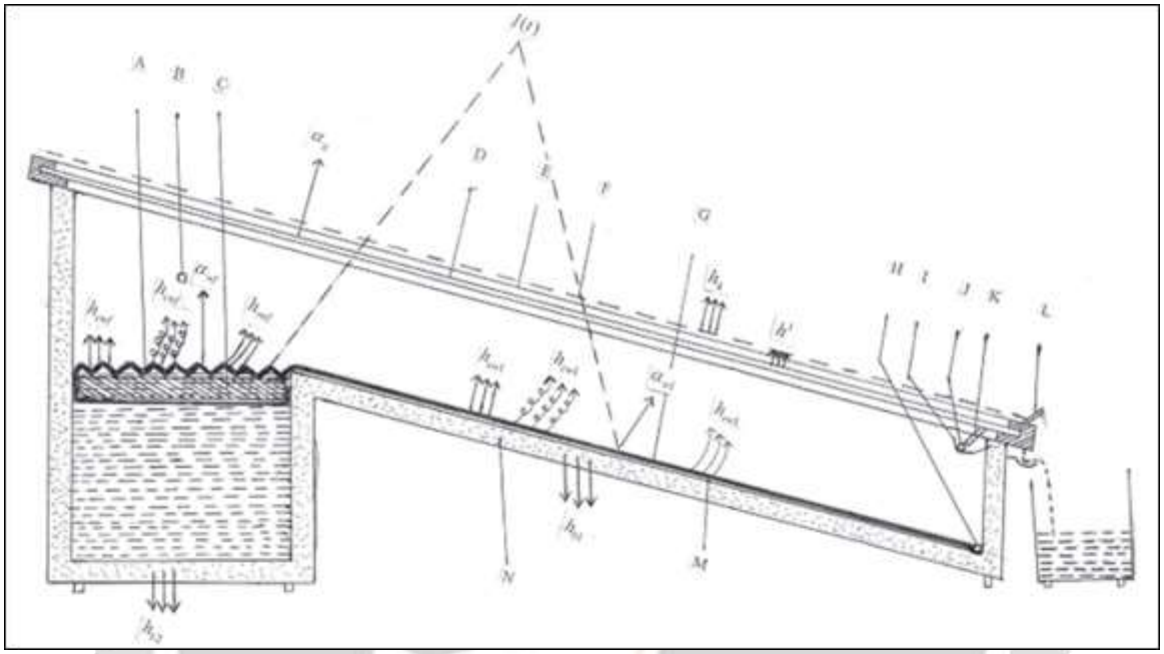

Fig. 6: Sectional view of the still of Janarthanan *et al.* [9]

Kabeel [10] (2009) has used the solar still with concave shape evaporative wick surface with pyramid shaped top cover. In this study the basin of still having square opening of 1200 mm x 1200 mm. The insulator used for bottom and sides was 5 cm thick glass wool surrounded by a 2 mm thick steel sheet. The 5 cm thick wick surface covers the basin. It was painted black to get greater solar radiation. Glass cover is used was made up of ordinary glass of 3 mm thickness and tilted at 45° angle to the flat surface (Fig.7). The experimental result shows that the average distillate productivity is about 4.0 l/m^2. Here the concave area of wick has greater evaporative area because of capillary effect. So, the distillate output increases.

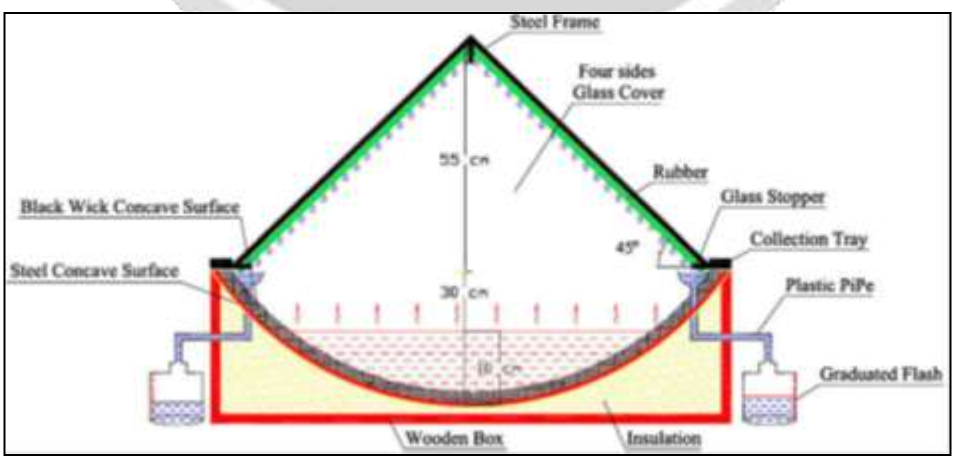

Fig. 7: Diagram of concave wick solar still [10]

In 2011, **Arjunan *et al.* [11]** had done experiment on solar still having sponge liners on an internal wall of still. The experiment was done with different thickness of sponge liners. The experimental setup is shown in Fig. 8. The effective area of basin of both still was about 1 m × 0.5 m and it was made from 1.4 mm thick galvanized iron sheet. The condensing cover of glass was 4 mm thick, and set to upper surface of the vertical side wall of the still by rubber gasket. The experiment results shows that the temperature of water decreased in still also the loss of heat is decreased because the heat lost in conventional still through walls are negligible in the case with sponge liners, as sponge absorbs heat which can lost through walls. From various sizes of sponge liners, the still shows maximum productivity and efficiency at liner thickness of 5 mm which is described in Fig. 9.

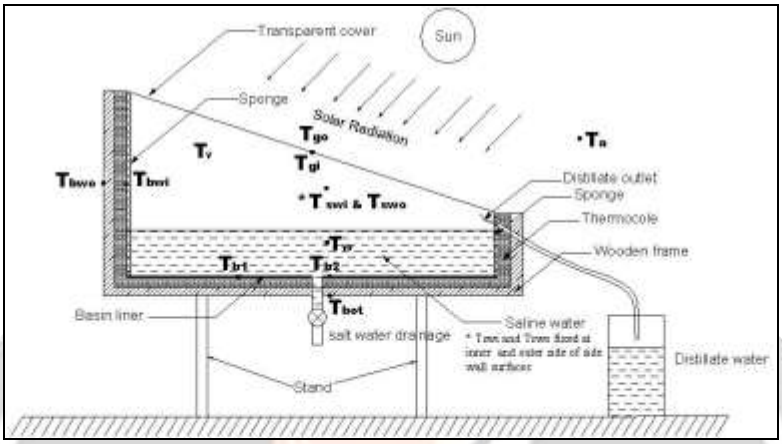

Fig. 8: Layout of the single slope still had sponge liner at inside wall surfaces [11]

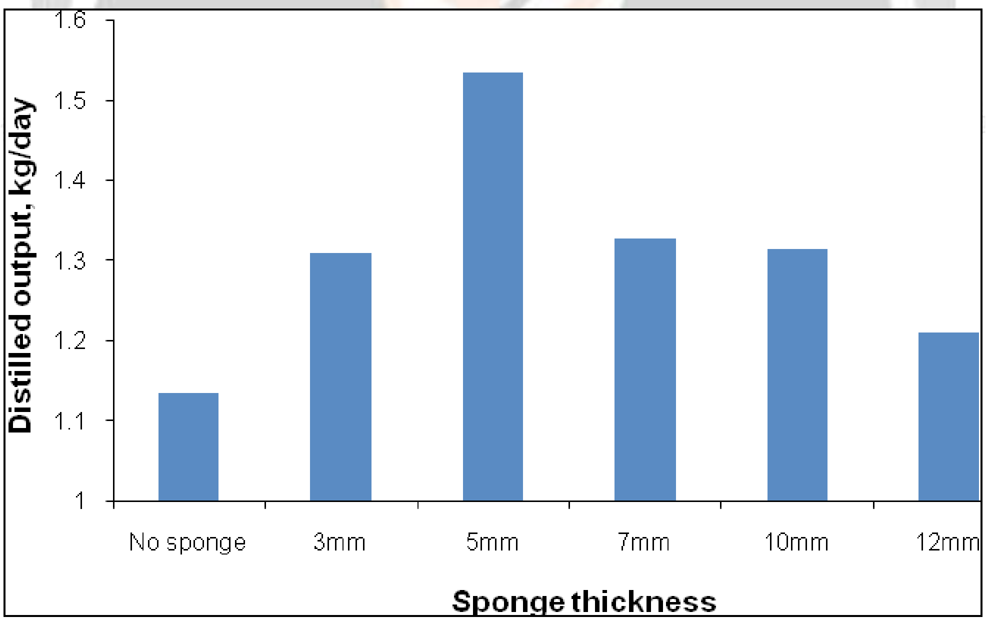

Fig. 9: Deviation in daily productivity with respect to various thickness of sponge liner [11]

Mahdi *et al.* [12] (2011) had developed a model of inclined wick type solar still. The charcoal cloth was used as wick material or absorber surface. The experimental model is shown in Fig. 10. Here, the experiment was done with different salt concentration with indoor and outdoor condition. From experimental results, they concluded that as salinity increases, the efficiency of the still in both indoor and outdoor condition decreases. But the effect of salinity is less in the case of outdoor condition compared to indoor condition.

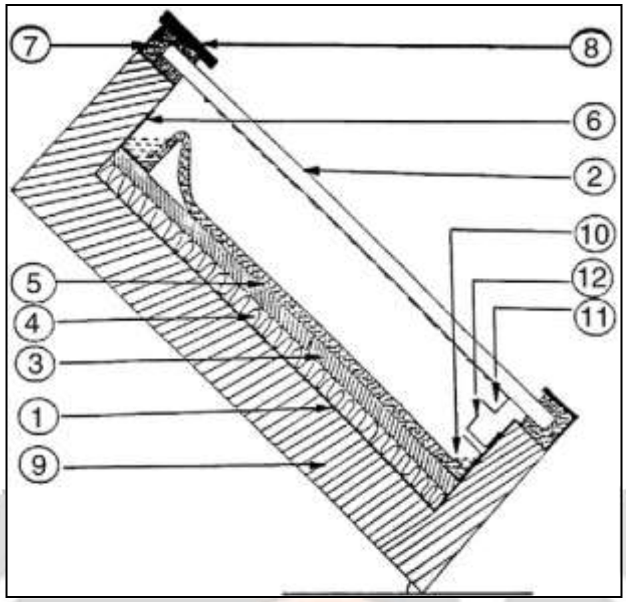

Fig. 10: Cross sectional of the solar still of Mahdi *et al*. [12]

Murugavel *et al.* [13] (2011) had done the experiment on double slope single basin solar still having various wick materials and minimum water mass. The experimental model was described in Fig. 11. It shows that the basin type double slope solar still made of mild steel of 2300 mm x 1000 mm. The concrete was used as basin liner to lower the heat loss. The size of the inside basin was 2080 mm x 840 mm x 75 mm. The glass wool was used to fill side gap of basin and to make it air tight. The thermo cool and glass wool layers were used as insulator to insulate outer surfaces of the still. The angle of inclination of 4 mm thick glass cover is at 30° inclination for maximum production. In this study, a double slope single basin solar still was constructed. And it was tested with a 5 mm water depth at definite solar radiation. Constant water level was kept in the still. Various wicks like black cotton cloth, waste cotton pieces, sponge sheet, coir mate and light jute cloth were used in the solar still. Also the experiments were done with rectangular aluminium fin organised in breadth and length wise directions in the basin having wick materials.

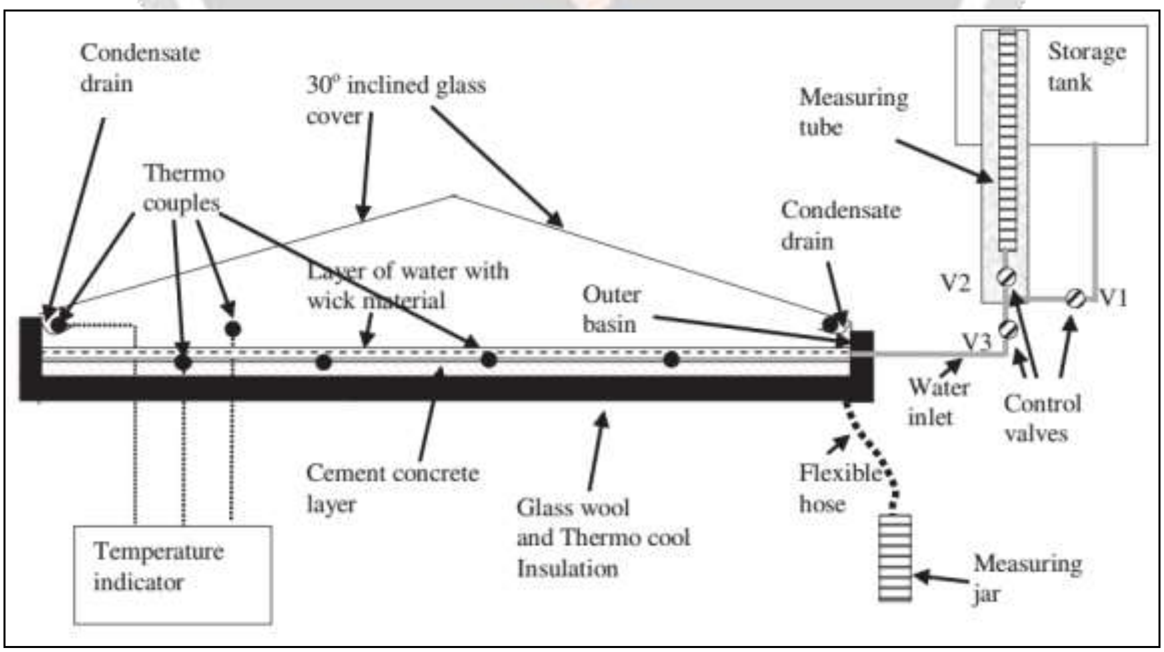

Fig. 11: Double slope single basin solar still [13]

From experimental result it is clear that, the black cotton cloth gives the maximum productivity of distillate. With several aluminium fin configurations, the fins covered by cotton cloth and organised in lengthwise direction was efficient and gave greater productivity than black cotton cloth.

In 2015, **Hansen *et al.*[14]** had done performance testing on inclined solar still have various wick materials and wire mesh. The dimensions of the still basin were 1 × 0.75 × 0.157 m and it was made up of mild steel. The flat absorber plate was of 3 mm thick mild steel, the rectangular stepped absorber plate was of 2 mm thick aluminium, the weir absorber material was of 1 mm thick aluminium. It also contains 4 mm thick glass cover, distribution pipe, condensate channel and thermocol isolated water tanks. The inclination angle of the basin was 30° facing due south. The distribution pipe has 20 drilled holes at equal intervals for distribution of feed water in basin. The water creates a layer over the absorber plate passing through the wick. The photograph of the experimental model is shown in Fig. 12.

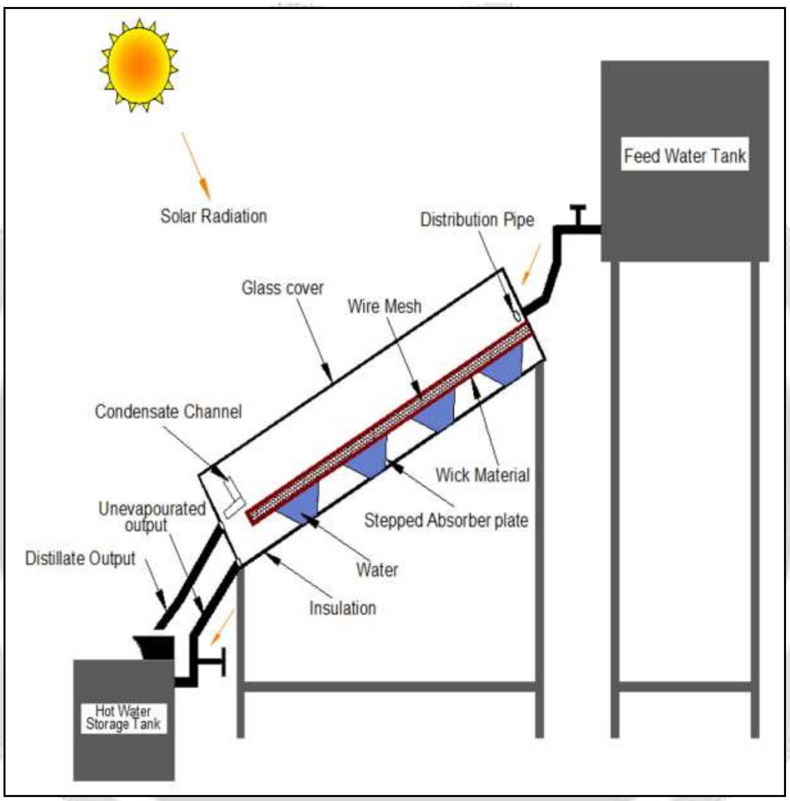

Fig. 12: Layout of inclined basin solar still [14]

In the experiment different wick materials (water coral fleece, wood pulp paper and polystyrene sponge) were used on various absorber plates (wire mesh, rectangular stepped and flat absorber). From experimental results, it is concluded that water coral fleece was the great wick material. The results indicate that the total yield was increased, when stepped wire mesh absorber with water coral fleece was used.

In 2015, **Omara *et al.* [15]** had done experiment on effect of vacuum and nanofluids on the yield of corrugated wick solar still. They have done comparative study between conventional still and modified hybrid still. The 1.5 mm thick iron sheets were used for basin in the conventional still. The basin area was 0.5 m^2. The black colour is used to enhance the absorptivity of the solar still. The 5 cm thick fiberglass was used as insulator. The basin has 3 mm thick glass sheet inclined at 30° horizontally as top cover. The modified still was identical as conventional still excepting that it has corrugated absorber plate. The base of absorber has a 50 mm vee height. The angle of bend between consecutive tops or bottoms is 80°, and the pitch is designed to be 100 mm. The experimental model is as shown in Fig. 13.

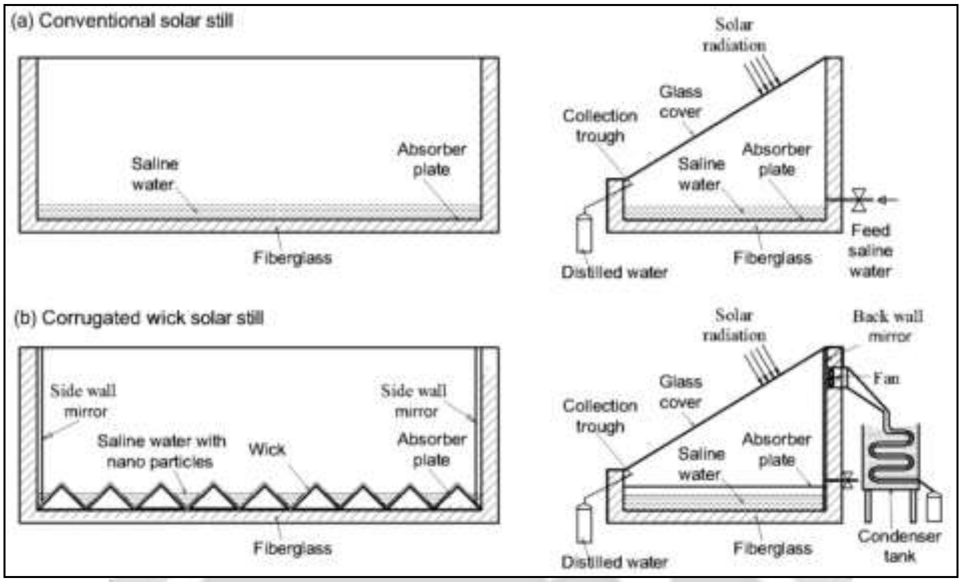

Fig. 13: Cross-sectional view of solar stills [15]

The experimental results shows that the yield of modified still is greater than conventional still, because in modified still the evaporation takes place quickly with the help of wick and also the cooling is provided with help of fan, so, the condensation takes place quickly.

Alaian *et al.* [16] (2016) had done experiment to investigate the working of solar still with pin-finned wick. The setup consists of two units. From them one consists of a pin-finned type wick. The 1 mm thick galvanized steel sheet was used as an absorber in the basin. The dimensions of the basin are 0.8 m and 1.25 m. The 4 mm thick glass sheet was used as a cover of basin and it was inclined at an angle of 17° to horizontal. The other unit has only simple absorber plate. Rubber and Silicon are used for to fill all gaps and to prevent leakage. The 5 cm thick glass wool was used as a side and bottom loss insulator. The insulation layer was supported by aluminium frame. The basin and the wick material were painted with black colour to get best absorption (Fig. 14). The pin-finned wicks of 9 cm height and 1 cm diameter have 3 cm dipped in the water to get capillary action.

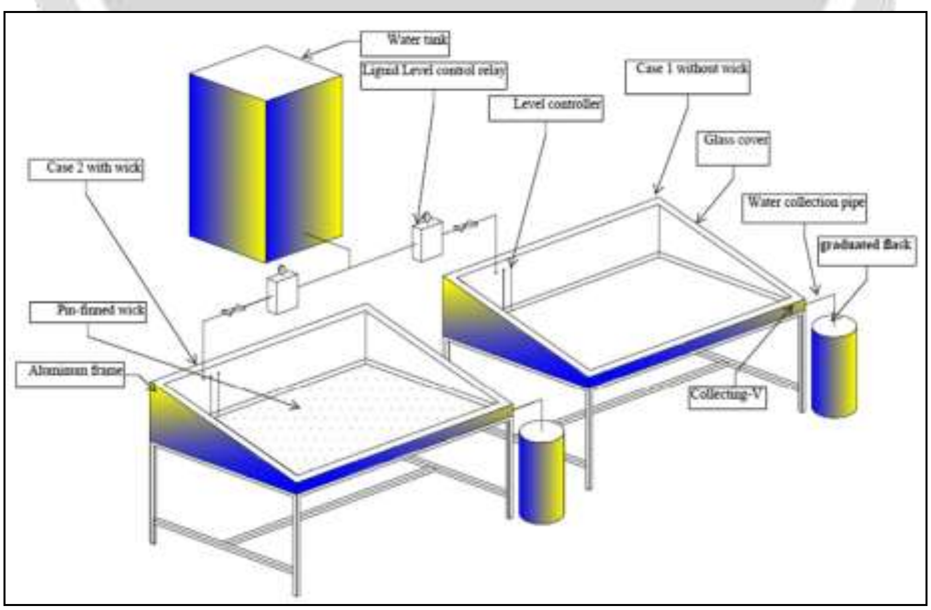

Fig. 14: Diagram of the experimental model of Alaian *et al.* [16]

From experimental results it is clear that the productivity and efficiency of pin-finned wick still is greater than conventional one. It increases about more than 23%.

3. CONCLUSIONS

The solar thermal desalination system is simplest system to get distilled water by the use renewable energy. Many researchers have worked on different designs of solar stills for different climatic conditions. The solar still with wick is also an advanced system which gives greater output compared to conventional one. Therefore solar stills having wick materials are considered as a good and cost-effective option for the production of pure water. From the above literature it is clear that the charcoal cloth gives greater productivity. Also from research of Murugavel et al. [13] it is clear that the light black cotton cloth as a wick material can give greater productivity compared to other wick materials like jute cloth, coir mate and sponge sheet on single basin double slope solar still. The Hansen et al. [14] have also done experiment with various wick materials and various absorber plate on inclined solar still and conclude that the stepped wire mesh absorber plate with water coral fleece can give maximum output compared to other wick materials. So, there is large scope for research to find the optimum design parameters for new designs to get higher distillate output.

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