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A Review on different Domestic Designs of Solar Stills

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Abstract

The availability of safe, fresh and clean potable water is the major problem faced by most of the countries in the world. Many water purification technologies are developed out of which solar distillation or desalination is being most economical and sustainable technology under development. The solar stills provide a great relief to the remote areas where advanced purification technologies such as reverse osmosis, UV, electro dialysis cannot be used due to cost constraints. In last few decades there are number of solar still designs developed. This article reviews different solar still designs used at domestic level relative to each other. The solar stills are not commercialised or standardized due to their limited yields. However with the current research and improvements they can be successfully commercialised for future domestic applications.

Keywords: *Domestic Designs of Solar Stills etc.*

1. Introduction

The basic requirement of all living organisms is a drinking water. Currently the availability of clean water resources is the major issue for humans. Only 1% potable water complying the standards is available out of 71% water covering earth's surface. Reverse osmosis, Ozone, UV, electro dialysis, activated carbon filtration and vapour compression are used to provide clean portable water. However, the costly technologies are affordable for people living in the remote areas. The remote areas can get supply of water at very low cost by using solar still as the alternate renewable energy technology. The maintenance of solar still is very low and easy to fabricate on small scale.

For desalination of brackish water into potable water the heat obtained from solar radiation is used. Pure water can be developed using different designs of solar stills. Lower yields (approx. 2-3 l/m^2 per day) and low thermal efficiency (max. 30%) restricts their wide use in domestic life. Hence to increase the yield of this system has become todays need. Many researchers have proposed different methodology to enhance the productivity and thermal efficiency of solar still. This paper reviews different designs of solar still used at domestic level.

2. Classification of Solar Still

Many research work has been carried out on designs of solar still by various researchers throughout the world.

Table1 Materials used for fabrication of solar still

Materials	Uses
Plexiglass, toughened glass and polythene	Glass cover
Fibre reinforced plastic, wood, G.I sheet	Basin
Glass wool and ceramic wool	Insulation
Aluminium cladding	Supporting structure
Sand, photo catalyst, sponge, wax Heat storage	Heat storage

Solar still includes Single basin single slope, Single basin double-slope, Hybrid solar still, and Hemispherical, Triangular and Pyramid type solar still. Commonly used material for fabrication of solar still are listed in Table1.

3. Review of Solar Still based on design

3.1 Single basin single slope solar still

Single basin single slope solar still was developed by Sahoo at centre of energy IIT Guwahati, with base area of 0.73m×0.73m, is fabricated from 4mm FRP the 8mm thick, make an angle of 10º with the horizontal edge of container using rubber gasket fig.2.

The phase change material luric acid was used by Swetha and Venugopal as heat storage material increased distillate output 36%.Also galvanised iron sheet used as heat reservoir, increased distillate output 13% Fig.3.

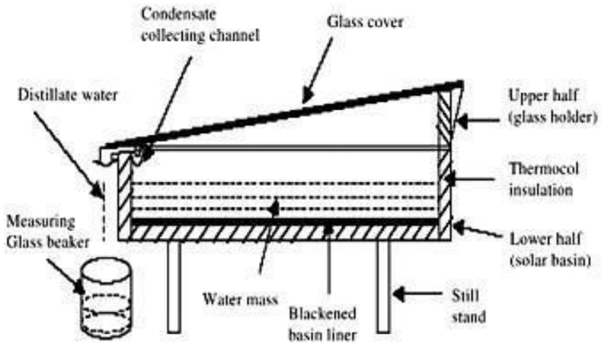

Fig.2 Schematic diagram of Sahoo et al.solar still

Fig.3 Swetha and Venugopal's solar still and Lauric acidis

The single basin single slope solar still was fabricated Phadatare and Verma. The plexiglass (3mm thick) is used for manufacturing of bottom and all sides of still. To reduce leakage of vapour to the surrounding the solar still was sealed. The unit consist of an acrylic box which as four sides and base. The overall dimensions of solar still are: length= 176cm, width=85cm, lower side height=32cm, higher side height=60cm, basin liner area (A_s)=1.446m^2 and the cover area(A_c)=1.44m^2 Fig.4.and Fig.5.

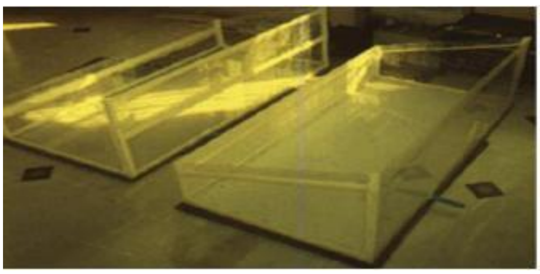

Fig.4 Still boxes made from Plexiglas

Fig.5 Plastic solar still in wooden box

Dev and Tiwari proposed different inclination angles of the condensing cover (15º, 30º, 45º) in their research of single slope passive solar still to maximize they evaluate optimum water depth(0.04m) inside the basin. For the best performance of single slope solar still, the optimum inclination angle was obtained 45º. Figure shows different solar still used in experiment Fig.6.

Fig.6 Different solar still used by Dev and Tiwari

El- sebaii used stearic acid as phase change material to increase thermal performance of single slope solar still. The daily efficiency and productivity increased up to 85.3% and 9.005 kg/m^2 /day respectively Fig.7.

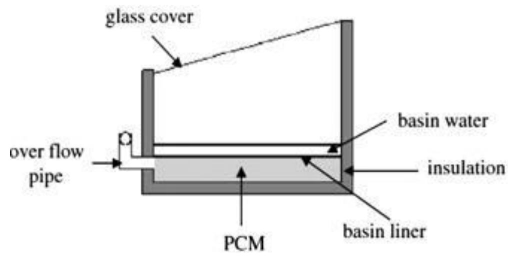

Fig.7 El-Sebaii's single slope solar still

Badran studied of single slope solar still having constant head tank and feeding tank with 32º tilted glass cover. To increase the absorptivity, he used two different basin liners made up of iron sheet (1.4 mm thickness) of 90×110 cm with maximum height of 5 cm and measures the effect of wind solar radiation over productivity of distillate output. He discovers that use of asphalt gives an increment of 29% in productivity. Productivity is also increased by 22% if the only use of asphalt is replaced by the sprinkler combination with asphalt. It was concluded that solar still is affected by ambient conditions (i.e. wind and temperature) Fig.8.

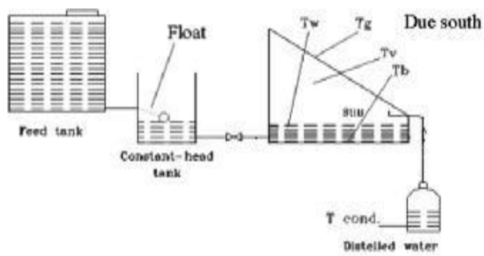

Fig.8 Badran's solar still

Abdallah represent modified design of single slope solar still. The modifications in design are as follows :(a) fixing interior reflecting mirrors, (b) flat basin is replace by step wise water basin, and (c) sun tracking system is introduce in coupling of step wise solar still because it gives highest thermal performance with an average of 380%. Up to 30% thermal performance is improved due to use of internal mirrors. Up to 180% performance was enhanced by using of step wise basin. Fig.9a and b.

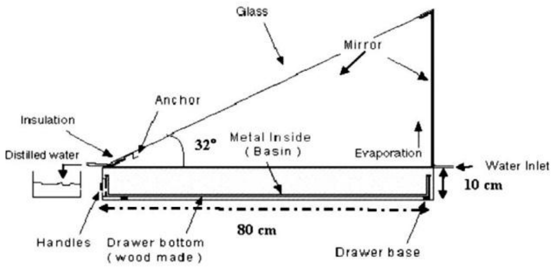

Fig. 9(a) Abdallah's solar still

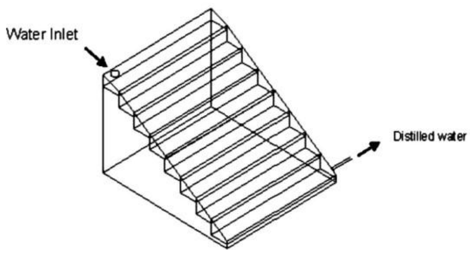

Fig. 9(b) Abdallah's solar still

Ali Samee fabricated simple single solar still. With basin area 0.54m^2, fabrication is done by using galvanized iron sheet having thickness of 18 gauge for basin area of 0.54m^2 the daily distillate output of 1.7 l/day was obtained with average efficiency 30.65% Fig.10.

Fig.10 Ali Samee's single slope solar still

3.2. Single basin double slope solar still

Tabrizi and Sharak proposed a single basin double slope solar still. Due to low cost and large availability as a heat reservoir, the basin was loaded with sand (p=2.5g/cm^2). Sand has 704j/kg/ºc average measured specific heat capacity. In the experiment, the 3000cm^2/m^2 distilled output yield was obtained and observed 75% increment in productivity using sand as a heat reservoir Fig.11.

Fig.11 Tabrizi's double slope solar still

Kalidasa Murugavel proposed a single basin double slope solar still, tested with a layer of water and various sensible heat storage materials like cement concrete pieces, quartzite rock, washed stones, red brick pieces and iron scrap. For increasing the yield, they focussed on the study to find the best heat storage material and found that the most effective basin material is 3/4in. sized quartzite rock Fig.12.

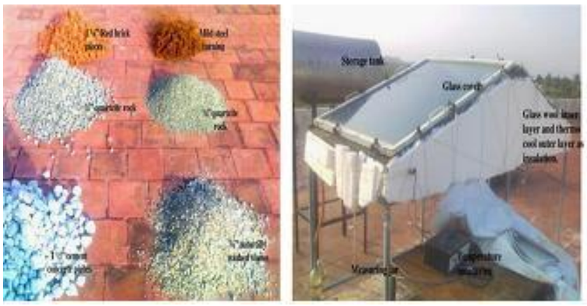

Fig.12 Different storage material and sill used By Kalidasa Murugavel

Kalidasa Murugavel made a single basin double solar still. To reduce heat loss through bottom, outer basin was lined with concrete. By using surface heating effect i.e. jute cloths and aluminium fins of size 65mm×45mm covered with the black cotton were used Fig 13.

Fig.13 Kalidasa's still with aluminium fin covered with black cloth in the basin

Zeroual used two identical solar still prototypes, one was used as reference unit and other was investigated. To enhance the heat transfer rate inside basin, the investigated still is having aluminium tray. To prevent the heat leakage silicon sealent is used. When cooling its north glass cover by flowing water over glass cover, the average daily was improved by about 11.82% Fig.14.

Fig.14 Zeroual's solar stills

Rajamanickam and Ragupathy proposed two experimental setup single slope and double slope of same area and at same and fixed orientation they tested with different water depth. With water depth 0.01 m and DS solar still with north-south orientation the maximum distillate output of 3.07 $l/m^2/day$ was obtained Fig. 15(a) and(b).

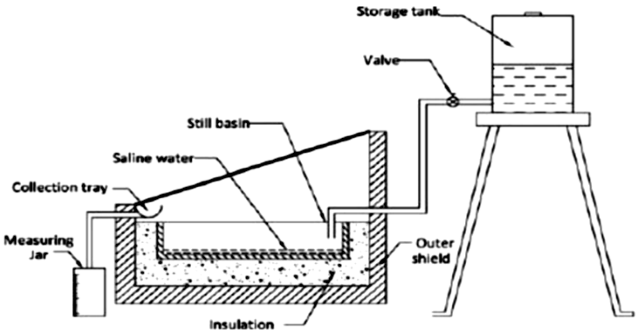

Fig.15 (a) Rajamanickam's single slope

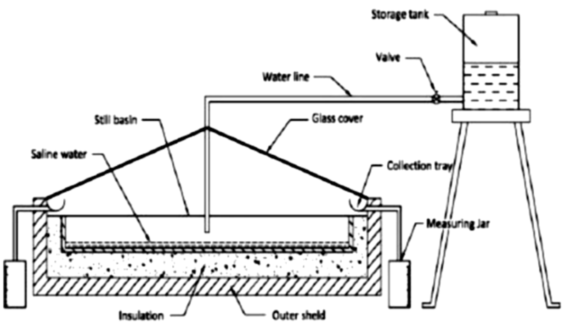

Fig.15 (b) Rajamanickam's double slope

Aburideh fabricated a double slope solar still. The basin of the still is made of materials with glass fibres and a layer of resin. It represents the lower part painted in black of surface area 1.39m^2 in order to capture the maximum solar energy. The absorber is covered with sea water of 3cm in depth characterised by salinity of 37.7g/l. The insulation of 40mm thick glass woollen layers is done to side and lower walls. It is estimated that maximum atmospheric temperature was 32º. The production of distilled water was 5and 5.38 l/day respectively Fig.16.

Fig.16 Aburideh's double slope solar still

3.3 Hybrid Solar Still

Singh developed and fabricated a photovoltaic thermal double slope active solar still. The system consists of three components namely double slope solar still, photovoltaic integrated FPC's and DC water pump. FRP of low thermal conductivity and 0.005 m of wall thickness is used to fabricate single basin double slope solar still having 2 m ×1 m of basin area. At the bottom of the one of the collector a photovoltaic module of 36 cells has been integrated. In forced mode of operation 40 W DC water pump is used to circulate water inside basin. The module of size 0.55×1.25 m^2 is designed.
Fig 17

Fig.17 Singh's hybrid single basin DS solar still integrated with PV collectors

Dev and Tiwari at the Solar Energy park, IIT, Delhi. The set up consists of 1×1 m^2 basin area of single slope solar still with 30^0 inclination connected with two flat plate collectors. The FPC's are connected in series having total effective area 4 m^2 with the help of an insulated galvanised iron pipe of 1.25 cm of diameter. It is integrated with photovoltaic module with its lower temparature zone to run DC motor of rating 60 W, 2800 rpm. Fig.18

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Fig.18 Dev and Tiwari's hybrid solar still.

Omara used wicks solar still with evacuated solar water heater to increase the productivity and made a hybrid desalination system. The productivity of water is increased by almost 114% than a conventional still for double layer sqare wick solar still at 30^0 base slope angle. The average efficiency calculated by daily performance was obtained as 71.5%. When hot brackish water was fed during night time, the distillate productivity was increased by 215% for DLSW. Fig19

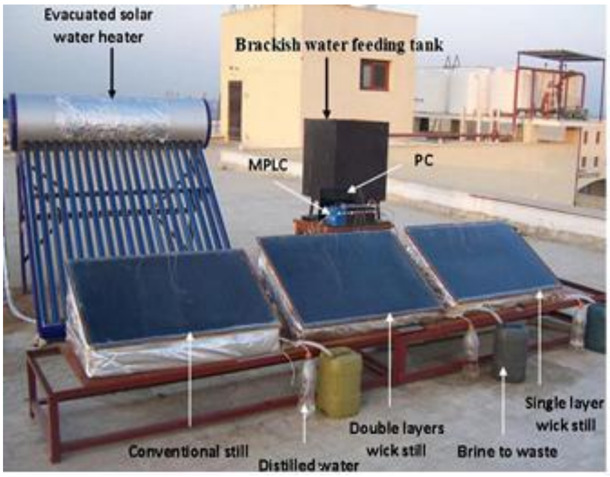

Fig.19 Omara's Hybrid System

Hidouri designed and fabricated two different experimental models of solar still: simple solar still and hybrid solar still with heat pump system and without heat pump system. In order to increase the quantity of distilled water output, heat pump is used. Using the heat pump hourly production increased from 300 ml/m^2/hour to 1700 ml/m^2/hour i.e. increase from 2 l/m^2 to 12 l/m^2 in daily production due to application of heat pump. Fig19 a & b.

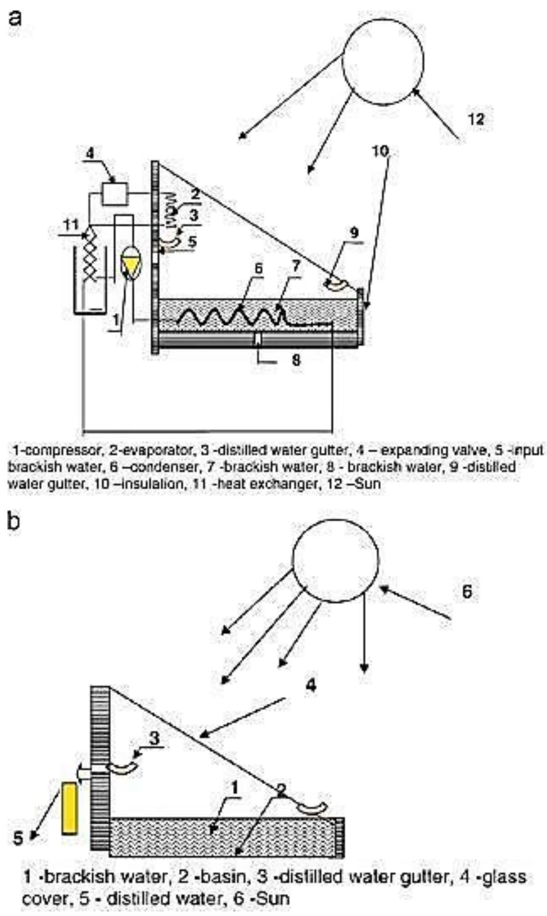

Fig.20 (a) Single slope solar still with heat pump, (b) Single slope solar still without heat pump

3.4 Pyramidal Solar Still

Taamneh designed pyramidal solar still having basin area of 0.95m^2 and a glass cover of pyramidal shape has been designed and constructed. The experimental results illustrated the use of fan work along with photovoltaic solar panels making it cost effective and viable to enhance the evaporation rate and hence the output purified water. The production of distilled water for natural and forced convection was found to be 2.485 and 2.99 l/day respectively. Fig 21 a and b.

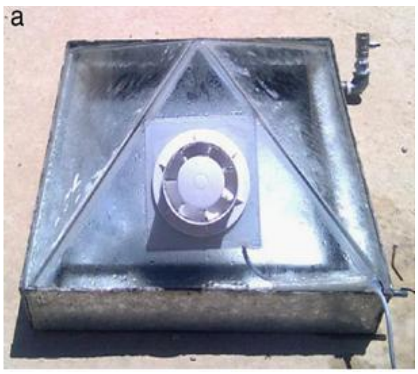

Fig.21 (a) Yazan's pyramidal solar still with fan condensation

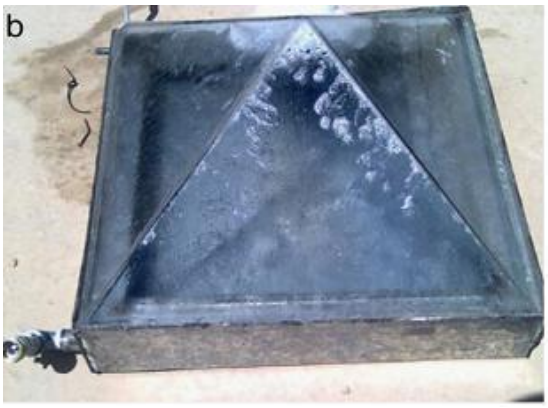

Fig21 (b) Yazan's pyramidal solar still without fan condensation

Fig.22 Ravishankar's pyramidal solar distiller

Kabeel fabricated a pyramidal solar still. A concave shaped wick surface was used for evaporation and four different sides of pyramid shaped still were used for condensation. Due to the capillary effect a concave shaped wick surface increases the evaporation area. Daily productivity of 4.1 l/m^2 in day time, maximum instantaneous efficiency of 45% of system and 30% of average daily efficiency was obtained. Fig 23.

Fig.23 Kabeel's pyramidal solar still

3.5 Hemispherical Solar Still

Arunkumar developed himispherical type of solar still having diameter 0.95 m and height 0.10 m. It is constructed from transparent acrylic sheet of 3 mm thickness with solar transmittance of about 88%. The outer box of the still was made up of wood of thickness of 4 mm having dimension 1.10 m×1.10 m×0.25 m. The bottom of the basin was was filled upto height of 0.15 m with the sawdust. The glass wool was used as a insulator to all sides. Fig 24 a and b.

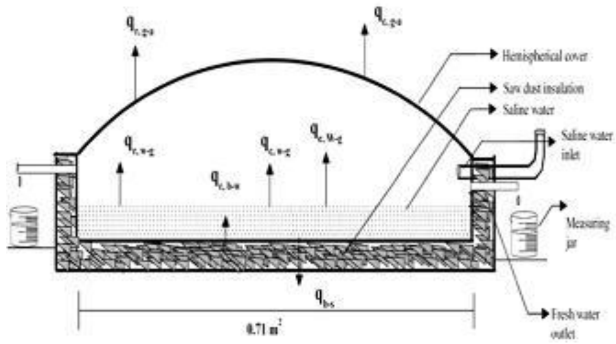

Fig.24 Schematic view of Arunkumar's hemispherical solar still

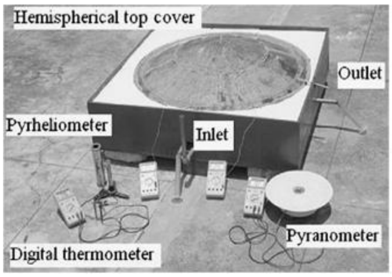

Fig.24 Photographic view of Arunkumar's hemispherical solar still

Ismail designed a domestic type transportable hemispherical solar still. The still consists of mainly the circular tray (basin) and absorber plate with the saline water, hemispherical cover, the conical distillate collector, the plastic container for distillate output and the portable support structure (trolley). The basin holds the absorber plate of aluminium having surface area of 0.5 m^2 and 4 mm of thickness. A hole of approximate diameter 25.4 mm was drilled into tray for providing accessibility of saline water to basin. Fig 25.

Fig.25 Hemispherical solar still of Ismail

3.6 Miscellaneous designs of solar still

Ahsan designed simple triangular solar still. This still was made using waste materials such as polythene for cover, frame of PVC pipe, trough using Perspex, nylon for rope and for sealing the solar still a transparent scotch. The daily distillate output for 1.5 and 2.5 cm of depth obtained is 1.6 and 1.55 kg/m^2/day respectively. Fig26.

Fig.26 Ahsan's miscellaneous design of solar still

Esfahani tried different portable and domestic solar distillation system designs. A PV panels, 12 V power source was used for driving fan, pump and thermoelectric cooler. In every experiment, evaporating basin having 4 l capacity was filled with raw water. Right and bottom side of evaporating basin have been fabricated using black coloured plexiglass and also covered with black wool for absorbing maximum solar radiation. The performance for 7 sunny hours is evaluated in winter season and the 1700 cm^3/m^2 productivity was observed. Fig 27 a and b.

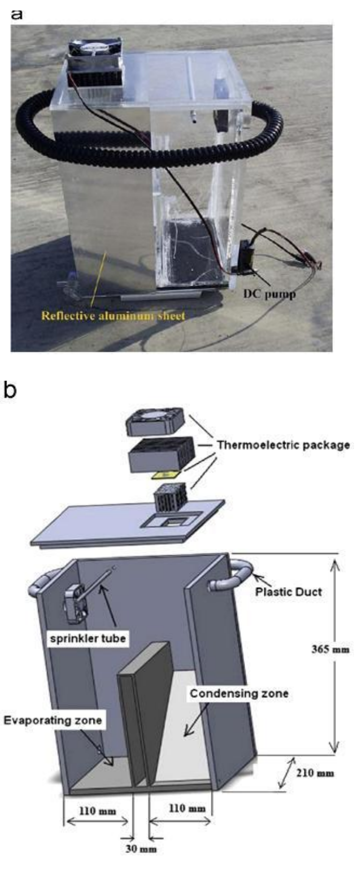

Fig.27 (a)&(b)- Esfahni's miscellaneous solar still design

4. Discussion and future scope

This paper analyses the different designs of solar stills at domestic level. Many further improvements are needed in current solar still designs. The glass cover temperature inside basin should be kept as low as possible compared to basin water temperature in order to increase the condensation on the glass cover surface. In order to optimize the performance and to improve the productivity, a systematic approach of design is necessary. The yield of the solar still can be increased by the small scale hybridization of the solar still design. The thermal efficiency can be increased by using photo catalysts like granular activated carbon, CuO, MnO_2, PbO_2, cow dung cakes etc.

Conclusion

Variety of solar still designs from conventional to hybrid concepts were reviewed in this paper. This review will enhance the understanding of previously designed solar stills. This paper will provide a way to conceptualize the optimum designs with better performance. The following section summarizes the key design aspects of solar still:

- The factors such as location, type, quality of saline water availability of required materials economics etc. affect the selection of specific type of solar still.
- The performance of solar still gets affected by design parameters like basin area, orientation of still, depth of water, temperature of inlet water, water-glass temperature difference.
- The metrological parameters like availability of solar radiation, wind velocity and surrounding temperature play an important role in performance of solar still.
- The hybrid solar still system with evacuated solar water heater gives the maximum output so far around 12.48 l/m^2/day.
- The range of maximum thermal efficiency obtained for different designs varies from 17.4-45%.
- Solar desalination system is not available for commercial or domestic in spite of lot of advancements.
- Economical solar stills with higher distillate output, more efficient and optimized domestic designs must be developed for solving the problems of water scarcity in future.

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