A DETAILED TECHNICAL REVIEW ON SQUARE PYRAMID SOLAR STILL

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ABSTRACT

Availability of pure drinking water in sufficient quantity with permissible quality is a primary requirement of all human being as well as animals and also for agriculture and industrial uses. Solar desalination is non-conventional method of extracting salt and other impurities from saline water to get pure drinkable water which utilizes the freely available solar energy for this conversion. Solar still is device used to achieve this conversion. But the major limitation of solar still is its lower productivity and because of that continuous technical improvements and researches are carried out by various researchers. Pyramid solar still is one of these improvements for conventional old design of solar still to increase the productivity. This technical review gives the detailed ideas about different configurations and advancement in pyramid solar still. This paper also describes the various modification and fabrication strategies for pyramid solar still.

Keywords: *Solar Energy, Renewable Energy, Desalination, Solar Still, Pyramid Solar still, Various Designs.*

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1. INTRODUCTION

Clean drinking water is crucial for human being and all other animals. Fresh and pure water is also requirement of agriculture and industrial applications. The earth contains about 1.4 billion km^3 of water in which 97.5% is salty. From the remaining fresh water, only 0.5% is available and accessible to support all life on earth [1]. The demand of pure water increases day by day rapidly as exponential increment in world population and industrialization but deforestation, pollution and irregularities in rainfall create scarcity of clean drinking water. The availability of clean water for our future generation is today's major concern for researchers. As all know that, sea water is available in plenty amount so if one can convert this saline water in to pure drinkable by any means then it will become one major step towards the solution. Desalination is important process to convert saline or/and impure water in to clean drinkable. There are various Desalination processes available. The broad classification of desalination process is shown in Fig.1.

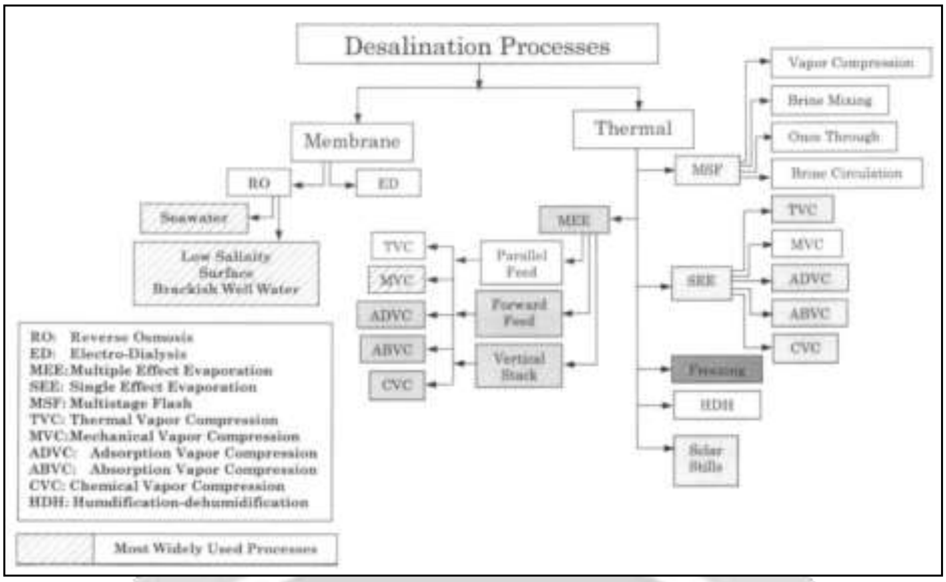


Fig.1: Broad Classification of Desalination Processes [1]

1.1. Solar Desalination and its working Principle

Solar desalination is process in which solar energy is used to remove salts and other impurities from sea water to get pure drinking water. Solar desalination works on principle same as that of raining. A closed vessel, called solar still is used to perform this solar desalination process. The basic structure of conventional solar still is as shown in Fig.2. Conventional solar still is one in which saline water is filled in single basin and this basin is covered by single inclined glass cover. Copper, Aluminium, Galvanized Sheet or Mild Steel plate is used as absorber plate material in basin and upper surface of this absorber plate is painted by black matt paint to increase the absorption of solar radiation. This basin is insulated by wood, thermocole or glass wool from sides and bottom to reduce heat transfer losses from basin and water to atmosphere. Top of basin is covered by highly transparent glass or plastic so that generated water vapor cannot escape from the system.

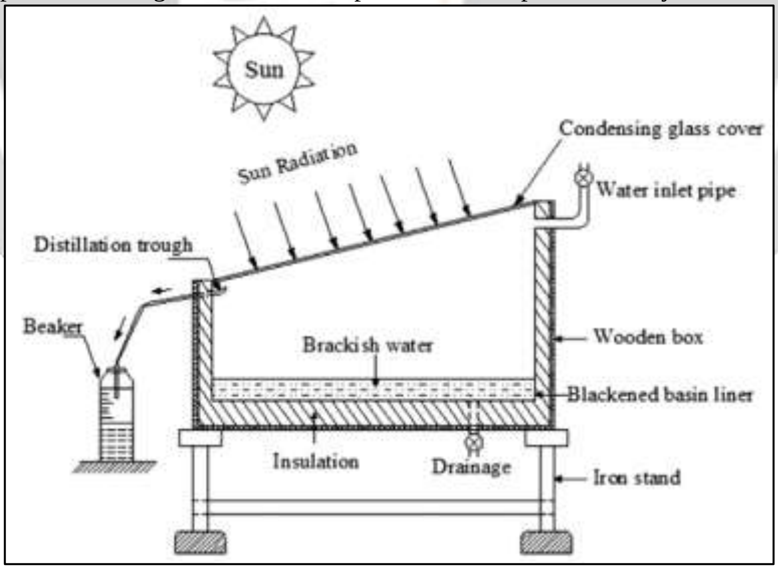


Fig.2: Schematic of Conventional Solar Still [2]

As solar radiation penetrates through the cover and absorbed by basin, basin temperature increases. This heat conducted to saline water and only water gets evaporated. This water vapor flows up and come in contact with cover which is at lower temperature so the vapor condensed on inner surface of cover and this pure condensed water collected in distillation trough. Water inlet port is provided to feed the make-up saline water in basin and drainage port is provided at the bottom of basin to remove the salts remaining in basin.

Continuous technological advancement and innovation in this field leads towards various configurations and designs of solar still. Various designs of solar still is as shown in Fig.3

This paper presents an overall review of the various developments in Pyramid solar stills with their relative advantages over conventional solar still.

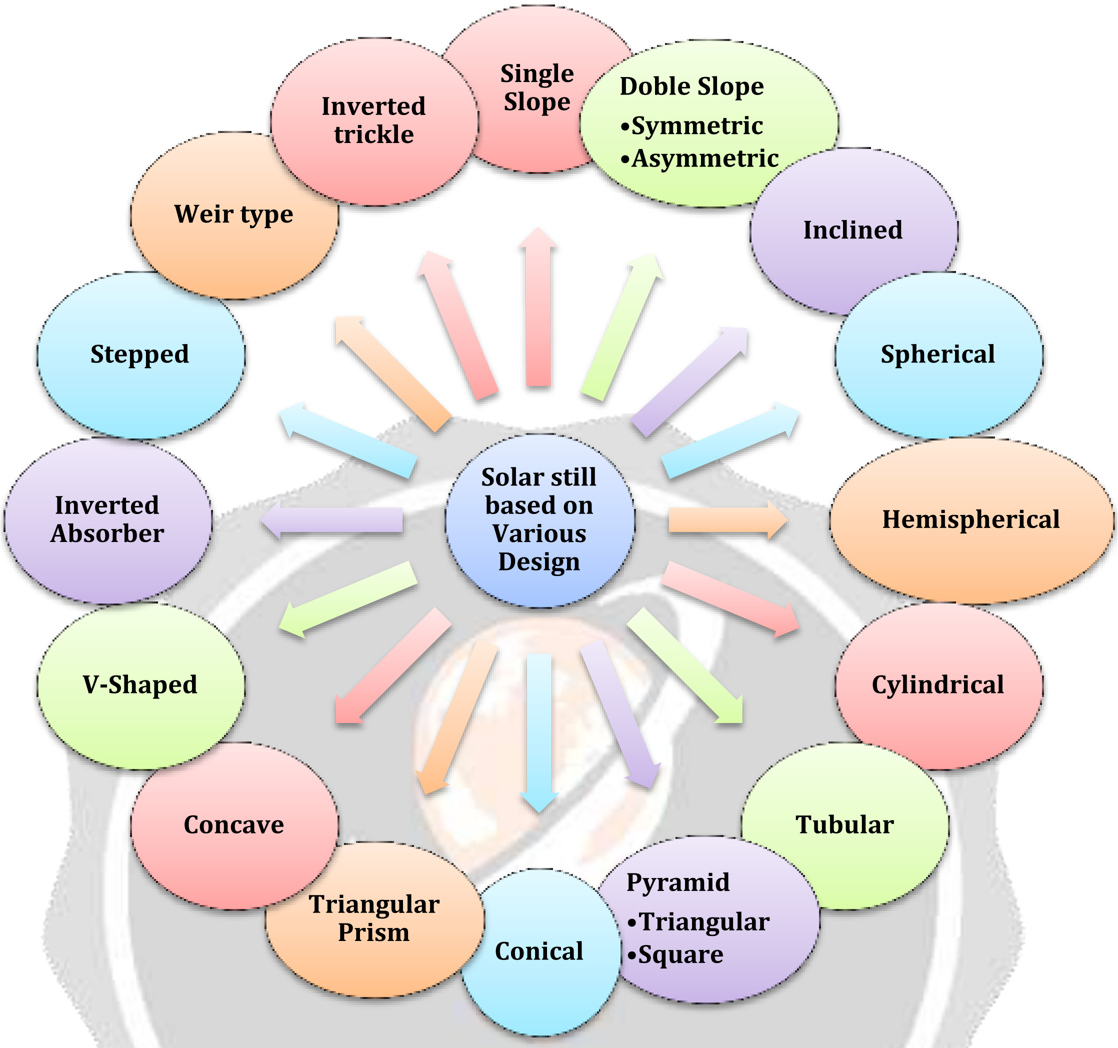


Fig.3: Various Solar still based on their geometry

2. PYRAMID SOLAR STILL

Pyramid solar still is one in which top cover is in shape of pyramid. There were mainly two shapes in this category: Triangular Pyramid Solar Still and Square Pyramid Solar Still. The main difference between these two types is shape of basin. In Triangular Pyramid solar still, basin is of Triangle shape whereas square shaped basin used in Square Pyramid Solar Still.

Advantages of Pyramid Solar Still over conventional single slope solar still:

- In conventional single slope solar still, solar still must be located so that its inclined surface faces directly sun i.e. facing towards south for northern hemisphere and facing towards north for southern hemisphere and also continuously to be moved as sun travel for gaining maximum solar radiation throughout the day whereas in pyramid Solar still, this is not required.
- In pyramid solar still, shading of side wall on water surface is less than that in case of conventional solar still.
- For same basin area, cover area is higher for pyramid shape so this will increase the condensation as condensing area in pyramid shape is higher than that of single slope.
- In pyramid solar still, any one side of cover directly gain the direct and higher solar radiation than other side. So other side remains at lower temperature than this one side which enhances the part of condensation that occurs on these sides due to higher temperature difference between water surface and cover.

2.1. Review on Pyramid Solar Still

Many researchers **[2-10]** have reviewed various design of solar still in which they have addressed a limited discussion and/or arrangements on any one particular design because their main aim was comparative reviews among different designs available for solar still. So here, authors proceeding with the aim of reviewing thoroughly different technological advancements and works conducted in pyramid solar still.

Fath *et al.* (2003) [11] conducted analytical study on solar still having pyramid shaped top cover. Thermal and economic comparisons between two solar still configurations: the pyramid and the single slop have been carried out and the daily total yield by each still basin was recorded. In their model, top cover of single slope solar still was inclined at 24° (same as the local latitude of Aswan City, south of Egypt) whereas for pyramid shaped top cover, it was 51°50' (same as the inclination of Great Pyramid of Giza) as shown in Fig.4.

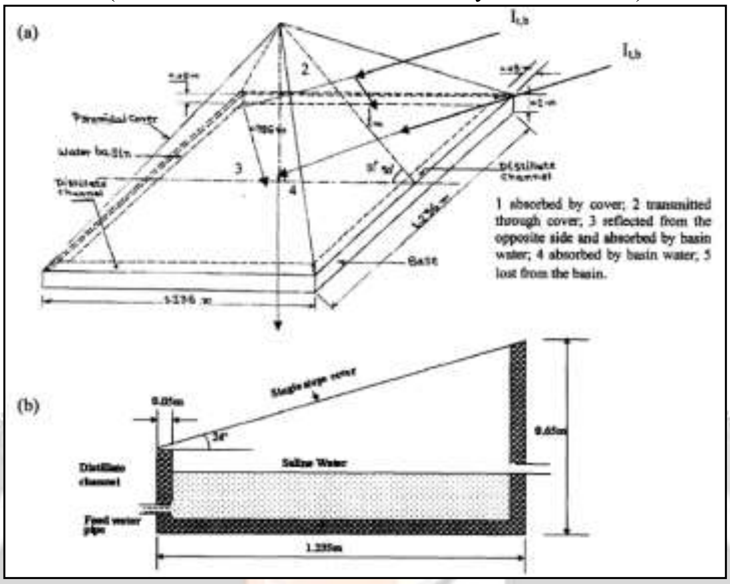


Fig.4: (a) Pyramid solar still (b) Single slop solar still [11]

From the results, they have concluded that the daily average yearly incident radiation and absorbed radiation for the pyramid-shaped still are 4% higher than that of the single-slope still and the annual average daily productivity is very close for both pyramid and single slope stills and is around 2.6 l/m^2-d but the daily total efficiency in case of pyramid solar still is little bit lower than single slop and it is because of tilt of top cover for pyramid shaped is double than single slop (i.e. local latitude angle) resulting high top cover area so high radiation losses from the cover than that of single slop solar still.

Kabeel (2009) [12] used a concave shaped basin covered with wick in solar still having pyramid shaped top cover to increase the daily productivity of simple pyramid solar still in his experimental investigation.

Location	:	Tanta University, Egypt
Basin	:	Concave, 1.2m × 1.2m , 2 mm galvanized steel
Insulation	:	5cm Glass wool + 2mm steel
Wick	:	5cm black painted Jute
Top Cover	:	3mm Ordinary Glass at 45°

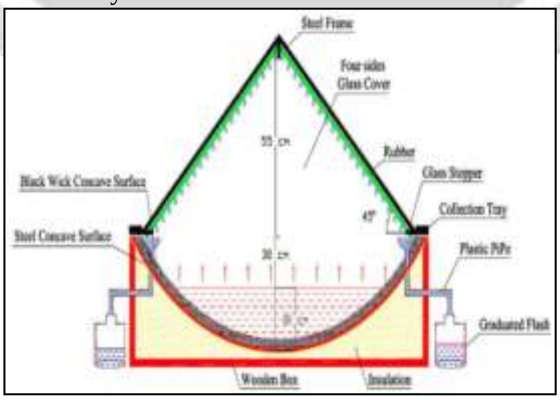


Fig.5: Pyramid shaped concave wick solar still [12]

The experiment was performed hourly basis during June, July 2007 during 09:00am to 09:00pm. Accumulated water output was 4.1 l/m^2-day with 45 % instantaneous efficiency and30 % average daily efficiency. Wick surface increases the evaporation area due to the capillary effect results in higher performance of this system.

Randeep Singh *et al.* (2011) [13] has developed novel and low cost portable square pyramid solar still and long triangular prism solar still and performed experimental and economic comparison between them and found that efficiency of Pyramid solar still was 49.9% whereas for long triangular prism solar still it's 35.8% .

Fig.6: Long Triangular Prism Solar Still and Square Pyramid Solar Still [13]

O Mahian *et al.* (2011) [14, 15] has performed one innovative way to increase the productivity of square pyramid solar still. They used a small DC fan to create turbulence inside the solar still by circulating water vapor as shown in Fig.7. They has performed comparative experimental investigation between active and passive square pyramid solar still and also developed mathematical modeling for that. From their experimentation, they have concluded that this small DC fan increases daily productivity by 15-20% and the cost of fresh water per liter for an active system is 8-9% lower.

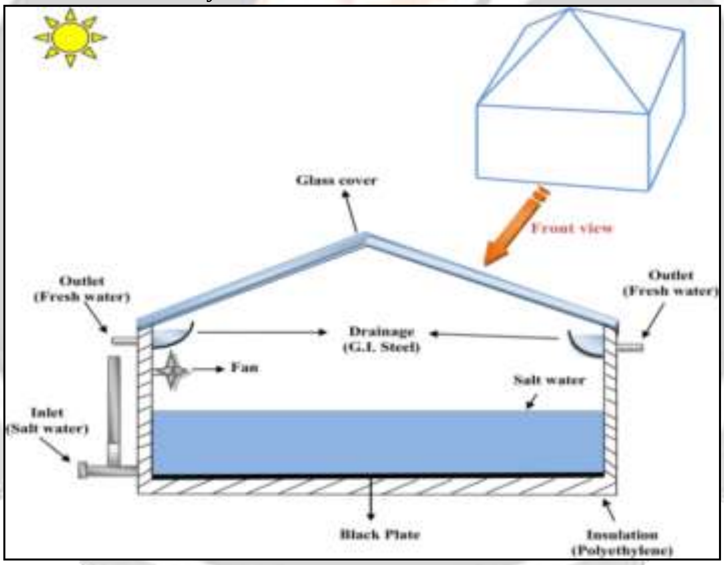


Fig.7: Active solar still (with small DC Fan) [14, 15]

A similar attempt was made by **Yazan Taamneh *et al.* (2012) [16]** but they had changed the location of fan. They have put fan on one side of pyramid shaped top glass cover as in Fig.8 and recorded daily output was 2.99 l per day (25% higher than solar still with free convection) for forced convective heat transfer in solar still with fan.

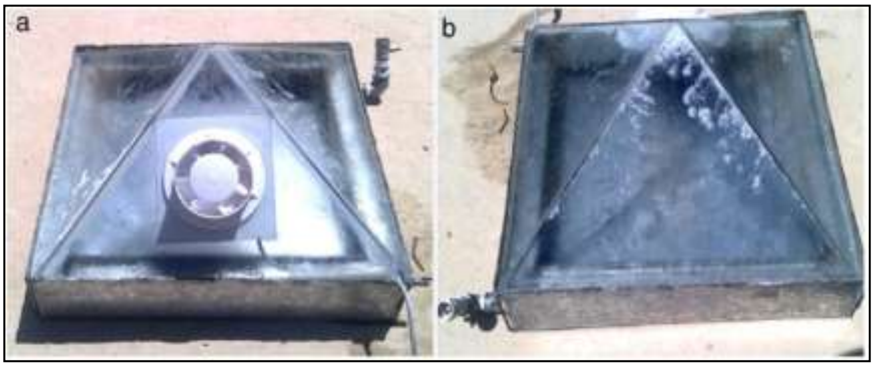


Fig.8: Square Pyramid solar Still (a) with fan (b) without fan [16]

Huda Algaim ***et al*** **(2013) [17]** have conducted comparative study between pyramidal solar still and single basin single slop solar still under different atmospheric circumstances of Basra city, Iraq. Both solar still has been built of transparent glass (4mm thick) and $0.25m^2$ aluminum basin. In their experiments, the efficiency of the single basin solar still was 55% and 66.5 % for the pyramidal solar still. It was noted that solar still with pyramid shaped top cover always gives the higher productivity that the conventional one.

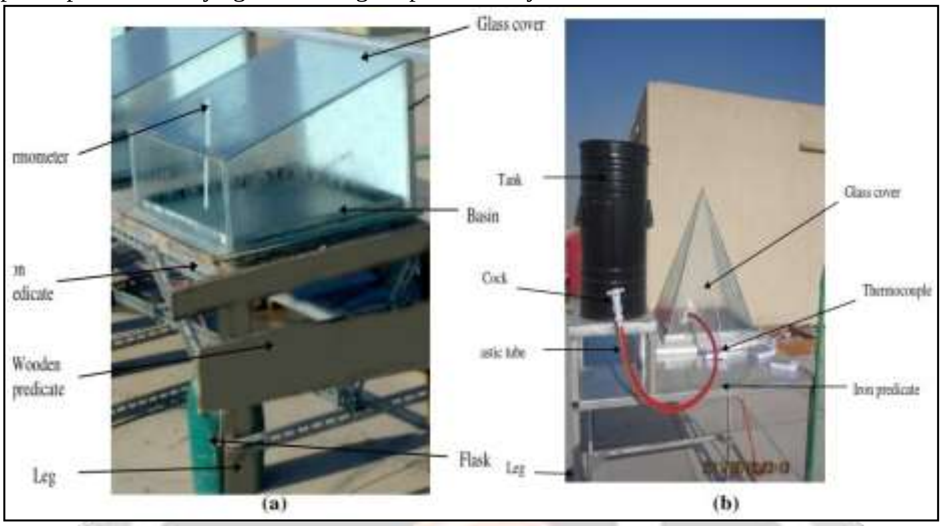


Fig.9: (a) Single basin single slop solar still (b) single basin pyramid solar still [17]

S Kalaivani ***et al.*** **(2013) [18]** has made an attempt to find out various heat transfer coefficient and thermophysical properties for square pyramid solar still. In the results, evaporative heat transfer coefficient rises with rise in water temperature.

Fig.10: Single Basin Pyramid Solar Still [18]

Senthil Rajan ***et al.*** **(2015) [19]** investigated square pyramidal solar still augmented with biomass heat sources at different water depth with thermal storage material and glass cover cooling by water sprinkling and recorded 84% increment in productivity with sensible heat storage material, 69% increment in productivity with latent heat storage materials in ballet form and 24% increment due to manual glass cover cooling.

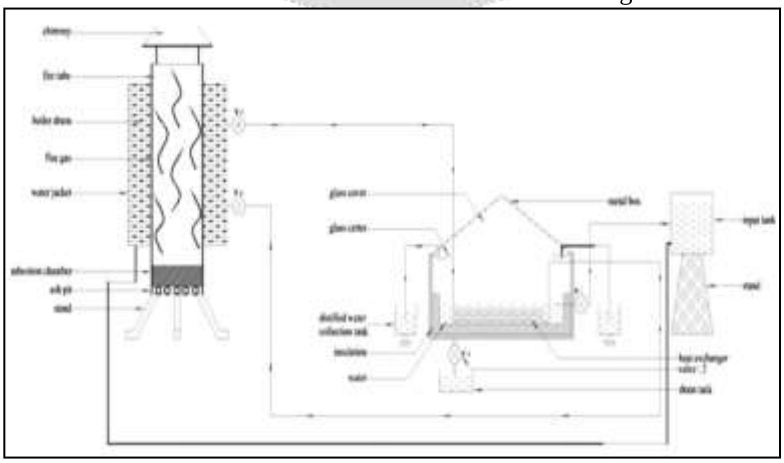
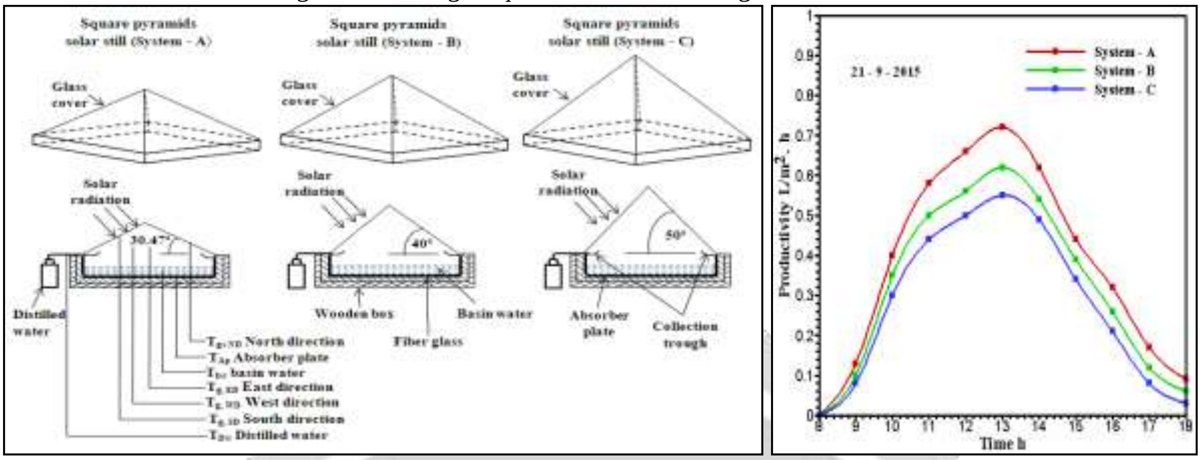


Fig.11: Pyramid solar still in association with biomass heat source [19]

AE Kabeel *et al.* (2016) [20] have experimentally studied the effects of glass cover angle on the performance of a square pyramid solar still under ambient conditions of Tanta City-Egypt (φ=30.47°N) and concluded that the accumulated distillate water productivity decrease with increase and decrease the glass cover angle from the Latitude angle and maximum accumulated distillate water productivity from the square pyramid solar stills occurs when the glass cover angle equal to the Latitude angle.



(a) (b)

Fig.12: (a) A schematic diagram of the three square pyramids solar stills (b) Hourly productivity for three different square pyramids solar stills configuration [20]

3. CONCLUSION AND FUTURE SCOPE

Solar still proves best option to meet the growing need of water utilizing renewable, unlimited, pollution free and free of cost solar energy. So many researches have been carried out in this field for continuous innovative and efficient revolution. Pyramid solar still is one of them. This design of solar still has greater advantages over conventional one. This type of solar still totally eliminates the requirement of tracking mechanism and reduces the shading effect of side wall. This design is also suitable for applying various techniques for improving performance and productivity. Various parameters including water depth, glass cover temperature, ambient air velocity, inlet saline water temperature, movement of water vapor inside the solar still and materials of various components (Basin, Insulation and Transparent cover) has significant effect on the performance so they all must be optimized for the maximum performance. Force convection, wick materials and cooling glass cover increase the yield of pyramid solar still. There is wide scope available in the area of design optimization for further works. Proper heat losses analysis and 2nd law efficiency analysis should be carried out for proper and strong comparison. Much of the research has to be focused on the simulation of water vapor inside the solar still using some computational software to study the effect of such geometry of cover.

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