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Review on the important methods used to enhance the productivity of the solar still

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Abstract— In this paper, a review is made on the various methods improving the productivity of the solar still systems. The studies on the methods improving productivity such as using solar collector, internal and exterinal reflectors, nanoparticles, and phase change materials are discussed here. The methods used in the past years to improve the performance of the different designs of active and passive solar stills werere viewed in this paper.The review showed that the use of internal and external reflectors and improves the productivity of the solar stills. Initial heating of the feed water to the still basin by solar collector shows a considerable improvement in the performance.The studies showed that solar stills with phase change materials and heat storage medium phase change materials can plays a vital role in increasing the productivity through produce water distillate during night hours and thereby, enhance the total productivity. Also, adding different nanoparticles mateial in basin water of still is the main parameter that affects the productivity of the still, Also, different designs in the solar still systems such as weir type stills, multi effect distillation, thermoelectric cooling, inclined type stills, etc. enhanced the productivity.

Index Terms— solar, solar still, distillation, solar still systems.

1 Introduction

In recent years solar energy has been strongly promoted as a viable energy source. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Also, the fuel cell is also used as alternative energy sources, the efficiency of fuel cells is higher than the internal combustion engine and the only byproducts are water and heat, fuel cells are considered as prominent power sources for the future [1-3]. Hence way that the domestic sector can lessen its impact on the environment is by the using of solar collectors [4-7], solar still [8-9], fuel cell, solar panal, ect. It is commonly known that desalination by using solar energy is a practicable solution to produce potable water especially in remote areas which suffer from scarcity in potable water because the infrastructure is weak and the area is not connected to main water supply network. On the other hand, a small distillation system can be a practicable and economical solution for demand for potable water hoth at present and in the future provided enough water sources and sunlight are available in these remote regions. Thus in order to enhance the productivity of solar distillers of water, researchers all over the world have carried out work to define the factors which play a major role in solar distiller productivity and efficiency and to find means to improve their productivity. Thus in order to enhance the productivity of solar distillers of water, researchers all over the world have carried out work to define the factors which play a major role in solar distiller productivity and efficiency and to find means to improve their productivity.
In this paper, the studies on performance of the solar stills are reviewed. The methods such as using internal and external reflectors area of absorption, minimum water depth, water–glass temperature difference, hot inlet water temperature, heat storage, phase change materials, vacuum technology and other different designs in the solar still systems such as weir type stills, multi effect distillation, thermoelectric cooling, inclined type stills, ect. are focussed.

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2 Solar still with an integrated solar collector

An experimental investigation on a solar still integrated with a flat plate collector (FPCB) (Fig.1) was studied by Rajaseenivasan et al. [10]. It was found that, the FPCB still gives about 60% higher distillate than the conventional still for the same operational conditions. Also, the result shows that the cost of distilled water for the FPCB still is lower than that for the conventional still.

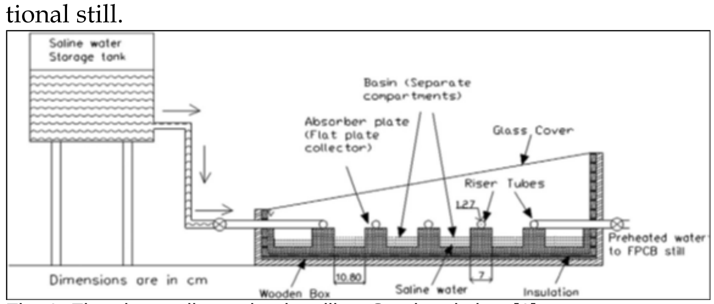

Fig. 1. Flat plate collector basin still — Sectional view [1]

Panchal [11] Studied experimentally the effect of adding a vacuum tube collector to solar still with double -basin on productivity. The result shows that the productivity of this system was 56% higher than that of the conventional double basin still.
Tiwari [12] analyzed the effect of double basin still with flat plate collector to supply hot water in lower basin. It was found that using of flat plate collector gives 50% higher productivity than the conventional double basin still. Also higher produc-

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tivity observed when the collector was disconnected from the still during off-sunshine hours to avoid heat losses through the collector.

Yadav [13] and Yadav and Jha[14] analyzed the double basin still with and without forced and natural circulation solar water heater (Fig. 2). They concluded as performance of the system with forced circulation was slightly better than and natural circulation. It is also suggested to use thermosiphon mode in the places where electricity is not available

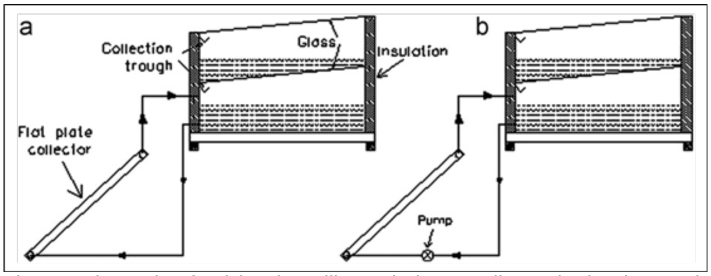


Fig. 2. Schematic of a (a) solar still coupled to a collector in the thermosiphon mode and (b) Solar still coupled to a collector in the forced circulation mode [13].

Dwivedi et al. [15] validated thermal modeling of adouble slope still integrated with flat plate collector in such away that the hot water from collector plate entersin to the basin under natural circulation. The double slope active solar still under natural modes gives 51% higher yield in comparison to the double slope passive solar still. The thermal efficiency of double slope active solar still is lower than the thermal efficiency of double slope passive solar still. However, the efficiency of double slope active solar still is higher than the efficiency of double slope passive solar still.

3 SOLAR SILL WITH AN INTEGRATED REFLECTOR.

Anaka and Nakatake [16] studied the performance of a tilted wick solar still with an inclined flat plate external reflector (Fig. 3). Their results indicated that the productivity of a still with an inclined reflector would be around 15% or 27% over that with a vertical reflector when the reflector's length is a half of or the same as the still's length.

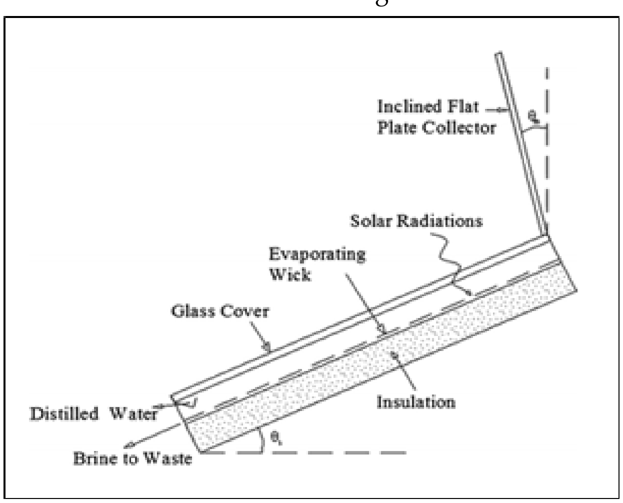
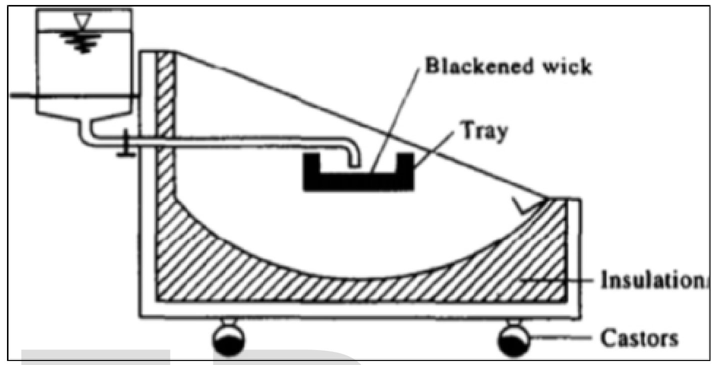


Fig. 3. Top external reflector with TWSS [16].

Tanaka (2009b) evaluated the effect of internal and external reflectors on the productivity of basin type solar still. He concluded that using still with reflectors increased the productivity by 70.-100%

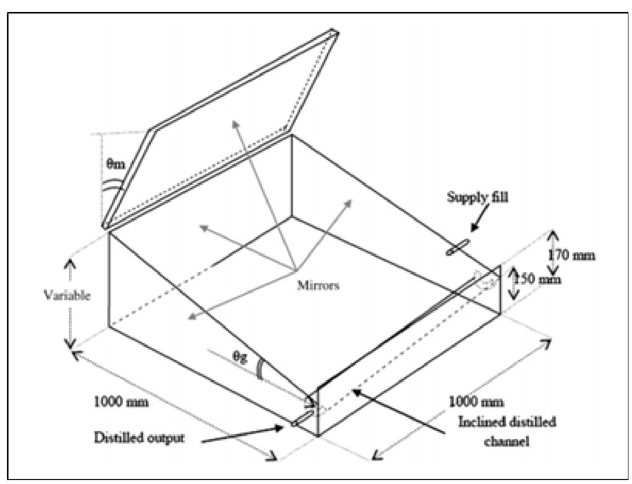
Minasian et al. [17] experimentally investigated a new solar desalination system. The modified desalination system consists of a metallic cylindrical parabolic reflector. The reflector was designed to concentrate incident solar radiation on the black outside surface of a tray located on the focal line of the reflector. The tray was lined with blackened wick, representing the evaporative surface of the modified still (Fig. 4). The experimental results also show that the productivity of this system was 25-35% higher than that of the conventional basin type still.

Fig. 4. A basin solar still with cylindrical parabolic reflector [17].



Abdul Jabbar et al. [18] experimentally investigated the productivity of a basin type solar still with internal and external reflector (fig 5). The inclination angle of reflector was varied by 0˚, 10˚, 20˚, and 30˚. The still cover angle was varied by 20˚, 30˚ and 40˚. The results showed that the glass cover angle do not affect on the productivity of the still with no reflectors. The most productive solar still in winter is a stillwith a cover angle of 20˚ and an internal and external reflector inclined at 20˚ and its productivity will be around 2.45 times that of simple still with no reflectors.

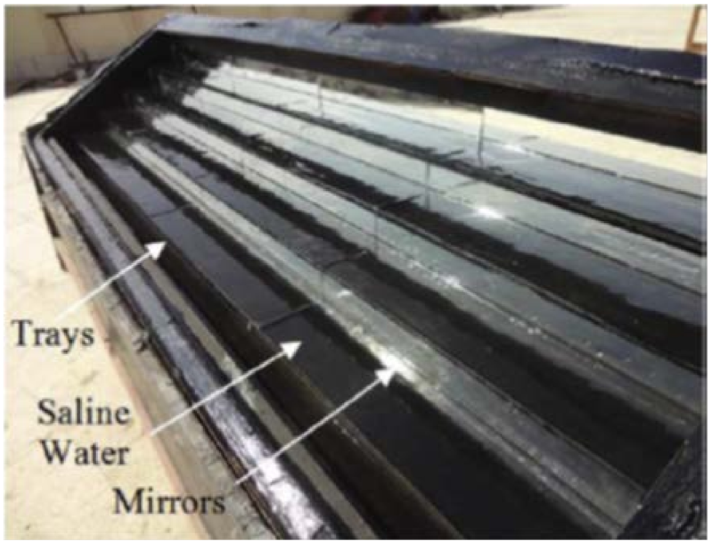
Fig. 5. A conventional solar still with IERs [18].



The performance parameters of the Stepped Solar Still (CtSS)

(F.g 6) and Conventional Solar Still (CSS) with and without IRs were investigated experimentally by Omara et al. [19]. They illustrated that the productivity of stepped solar still with and without internal reflectors were improved by about 75% and 57%, respectively over conventional solar still.

Fig. 6. Stepped still with IRs [19].



4 Solar still with an Phase Change Materials

'Many researchers investigated the methods to enhance the productivity of the solar still. Energy Storage Material (ESM) is one of the particles used by many researchers in their experimental [20-21]. Experimental evaluation of a single basin solar still Energy Storage Material (ESM) was done by Naim et al. [22]. The energy storage material is placed in tray in the basin.

A specially formulated mixture consisting of an emulsion of paraffin wax, paraffin oil and water to which aluminum turnings are added to improve heat transfer is used effectively to store heat in the daytime,and then give off its heat at night time. The productivity was enhanced by 26%, 47% and 300% respectively when the mixture of paraffin wax, paraffin oil and water with added Al turnings were used.

Ho [23] investigated experimentally the active thermophysical properties of PCM prepared by his team, including latent heat of fusion, density, dynamic viscosity, and thermal conductivity. The experimental tests showed that there is a relative increase in the dynamic viscosity of the paraffin containing alumina particles.

Mettawee [24] carried out an experimental study to investigate the influence of aluminium particles on melting and solidification processes of paraffin used in a solar collector. The results revealed that the time required for charging and discharging operations could be reduced substantially by adding the aluminium particles. Hence, the mean daily efficiency of the solar collector with composite PCM was much higher than that of with pure paraffin.

Diaconu et al. [25] conducted an experimental work to determine the heat transfer and enthalpy change characteristics of the new PCM. The study assessed the suitability of used PCM for integration into a low-temperature heat storage (cold storage) system for solar air conditioning applications. The results showed that the phase change intervals displayed higher values of natural heat transfer coefficient compared to water. It can rise to five times depending on temperature conditions. The optimum temperature range for heat storage overlapped on a temperature interval with high values of the natural convection heat transfer coefficient.

Miqdam et al [26] investigated experimentally the performance of phase change material storage for use with a conventional solar still with an integrated concentrating solar collector (fig 55). Results showed that the solar still working time increased to 3 h when Paraffin wax added without solar collector. Also, the solar collector efficiency increased by about 50% and the system heating efficiency increased by about 41%. Moreover, the system productivity increased by about 180%.

5 Solar still with Nano Particles

Gnanadasan et al. [27] have fabricated a single slope solar still. They performed experiments by adding carbon nanotubes in copper basin. They concluded that using nanoparticles increased the productivity by
50%.

Sindal et al. [28-29] has uses Zinc Oxide (ZnO) and Copper oxides (CuO) nanoparticles as photo catalyst and concluded that productivity as well as quality of the raw water increases to remarkable extent.

Panitapu et al. [30] investigated experimentally the effect of adding Titanium Oxide (Titania, TiO_2) Nanoparticles in basin water of still and studied the variations of water temperature, vapour temperature, glass inside and outside temperature during sunshine. They concluded that using nanoparticles increased the productivity by 40%.

Kabeel et al. [31] studied experimentally the effect of adding Aluminum Oxide (Al2O3) on productivity of solar still. They observed that adding Al2O3 increases the productivity by 76%.

Guptaa et al. [32] studied experimentally the effects of adding nanoparticles Copper oxides (CuO) in single slope solar still with white painted side walls. They concluded that using CuO nanoparticles increased the distilled productivity by is 22.4% higher than conventional still at water depth of 5cm while 30% higher at water depth of 10cm

6 solar still with Various Designs

T. Arunkumar et al. [33] experimentally investigated the productivity of a solar still with seven solar still designs such as spherical solar still (see fig 7), pyramid solar still (see fig 8), hemispherical solar still(see fig 9), double basin glass solar still, concentrator coupled single slope solar still, tubular solar still and tubular solar. The results showed that the tubular solar still coupled pyramid solar still shows the maximum amount of productivity due to the concentrator effect. The productivity of the solar still entirely depends on the climatic parameters as well as increasing the water temperature. This

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leads to raise the evaporative and convective heat transfer coefficients in the solar still. The concentrator effect plays a vital role to increase the water temperature up to 95◦C compared to the other types of designs. So evaporative heat transfer is more for tubular solar still, and it is showing the maximum amount of yield.

Fig. 7: Pictorial view of Spherical Solar Still [33]

Fig. 8: Pictorial view of pyramid solar still [33].

Fig. 9: Pictorial view of hemispherical solar still [33].

Wissam et al. [34-35] carried out an experimental study to improve the productivity of the conventional solar still. This done by modifying conventional still in a way that the distilled basin is larger than distillation basin, thus providing an increase in the condensation surface and speeding up the condensation process. Moreover, increase in the dimensions of the distilled base helps coupling reflective panels to the distilled base to reflect incident solar radiation to the distillation basin (see fig 10). Experimental results showed that the modified still gives about 18%-24% higher distillate than the conventional still for the same basin condition.

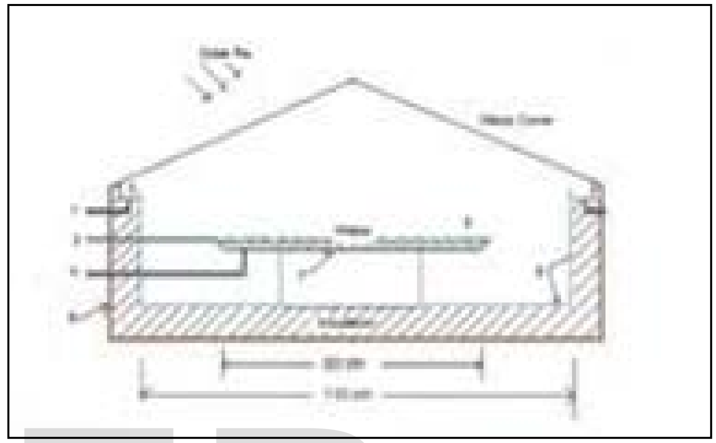

Fig. 10: Schematic diagram of the double-basin glass solar still [34]

An experimental study of Inverted Absorber Solar Still (IASS) was carriedout by Devetal. [36]. The schematic diagram of inverted absorber solar still is shown in Fig. 11. An inverted absorber solar still with acurved reflector under the basin of solar still was used to heat the basin from its bottom surface also.The result shows that the maximum optimized water depth can be taken as 0.03 m for the IASS at which the addition of reflector under the basin does not affect its performance considerably in comparison to that of the single slope solar still.

Fig. 11: Invertedabsorber solar still [36].

4 Conclusion

In this paper, a review is made on the various methods improving the productivity of the solar still systems. The studies on the methods improving productivity such as using solar collector, internal and exterinal reflectors, nanoparticles, and phase change materials are discussed here. The methods used in the past years to improve the performance of the different designs of active and passive solar stills werere viewed in this paper. The essential points are high lighted below.

- Using of of internal and external reflectors increases the yield more than 50% the conventional solae still
- Initial heating of the feed water to the still basin by solar collector shows a considerable improvement in the performance.
- The solar stills with phase change materials and heat storage medium phase change materials can plays a vital role in increasing the productivity through produce water distillate during night hours and thereby, enhance the total productivity.
- Adding different nanoparticles mateial in basin water of still is the main parameter that affects the productivity of the still.
- Different designs in the solar still systems such as spherical solar still, pyramid solar still, hemispherical solar still, double basin glass solar still, concentrator coupled single slope solar still, tubular solar still and tubular solar enhanced the productivity.

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