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Effect of Flat Plate Collector on Performance of Simple Solar Still - A Review

Prachi K. Ithape[1], S. B. Barve [2] and A. R. Nadgire[3]

[1]PG student, [2]Professor, [3]Assistant Professor, Department of Mechanical Engineering, MAEER's MITCOE, Kothrud, Pune, Maharashtra, India

Abstract

Water is one the most important sources of survival for living creatures on earth. But the amount of water available for drinking is only 1% of total water bodies available on earth. Solar still is one such technique of water purification by the use of naturally available sunlight or solar energy. Though this method has various advantages, its major issue is low productivity. The simple solar still gives yield of only 2.5 to 5 liters per m^2 area per day when maximum amount of solar radiations are received. Hence integrating solar still with external devices such flat plate collectors, solar ponds, focusing mirrors, concentrating collectors etc. can help to improve the distillate output. In this review paper, detailed review of solar still integration with flat plate collector is discussed with the aim to increase its productivity or fresh water yield.

Keywords: Solar energy, solar still, flat plate collector, distillate output, productivity.

1. Introduction

It is a well-known fact that water covers two-third of the surface of earth, of which about 95% of resources is in the form of oceans and seas that consists of high concentration salts. This highly contaminated salty water is not suitable for human consumption. Out of the remaining 5% water available on earth's surface, more than 3% is frozen & iced at Polar Regions. About 1.5 – 2% of water resources only are available for humans in the form of rivers, lakes, ponds etc.

Solar desalination is one of the best method that can help to purify impure and salty water, but on a small scale. Solar still is one such technique that can be used to purify impure water by naturally available solar energy. Solar still has many advantages such as: no skilled manpower required, easy to build, ease of maintenance, replaces use of fossil fuels, pollution free operation and reduces waste. Besides all these advantages, the major disadvantage of a solar still is its low productivity due to its inability to capture all solar radiations. Hence this technique is suitable only where productivity is not an important issue. Figure 1 shows the schematic of a simple solar still.

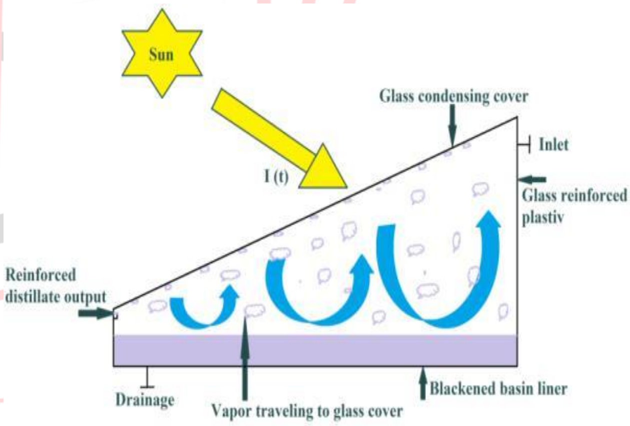

Fig. 1 Schematic of a conventional solar still

Solar still working is no different to nature's hydrological cycle. It is basically an air-tight unit whose bottom wall and side walls are painted black so as to increase the absorptivity of solar radiations. Sunlight or solar radiations that fall on the inclined glass or condensing cover, pass through it and start heating the water in the basin. This heated water is then evaporated and the vapors rise upwards towards the condensing cover, leaving behind salts and impurities. Water vapor condensation on the inner side of cover takes place due to flowing wind velocity. Thus, the vapors condense and pure water in the form of water droplets and start rolling down the condensing cover due to gravity.

Al-Tahaineh et. al (2005) coupled FPC with solar still and studied its effect on the productivity. They found that distillate output increased by about 36% on coupling FPC with solar still. Badran et. al (2007) combined a FPC with a solar still to improve it efficiency. They carried out experimental investigations on the solar still by considering three important parameters that affect it productivity, namely: solar radiation intensity, orientation and water depth. They concluded that coupling FPC with solar still increases the distillate yield by 36 % i.e. and output of 3.5kg/day of pure water can be obtained. Zeinab, Abdel and Ashraf (2007) coupled the desalination system with a heat exchanger and parabolic collector and studied their effects theoretically and experimentally. G.N. Tiwari et. al (2009) studied the response of water depth of conventional solar still combined with flat plate collector. Their results showed that as the water depth increases, water mass increases which reduces the distillate output. Tiwari and Dwivedi (2010) studied the effect of double basin solar still using a FPC under natural circulation mode. Omara and Eltawil (2013) improved the productivity of conventional solar still (CSS) by integrating it with a FPC, perforated tubes, spraying units, solar air collector and an external condenser. The newly developed solar still (DSS) was compared with CSS in active and passive modes and it was found that DSS gave 51-148% more productivity in comparison with CSS, depending upon the mode of improvement. Hitesh Panchal and P. K. Shah (2013) studied the effect of vacuum tubes and FPC coupled with solar still. According to their study, the annual yield of integrating FPC with solar still is less as compared to the annual productivity of coupling vacuum tubes with solar still. Velmurugan and Prakash (2015) studied the outcomes of various factors like water depth, heat storage capacity, area of absorption, etc. with the aim to improve the productivity of the still by the use of FPC, reflectors, mirrors etc.

2. Performance Parameters of Solar Still

Solar still productivity is mainly dependent on solar radiation intensity, ambient temperature, velocity of wind, insulation, depth of water, temperature of cover plate, difference of temperatures between water and glass, absorber plate material, condensing cover thickness, angle and orientation. The solar radiation intensity, wind velocity, ambient temperature and dust and cloud condition are metrological parameters, hence are not under our control. The remaining factors can be changed to improve the distillate output of the solar still as they are under design control.

Another method to enhance solar still output is by integrating it with devices such as flat plate collectors, solar pond, parabolic trough collectors, focussing mirrors etc. and can be called as active solar still. This allows an extra amount of thermal energy to the solar still basin by an external mode which helps to increase the evaporation rate, which in turn improves the productivity of the solar still. This is different from passive solar still wherein the basin water receives heat only from the solar radiations that are absorbed by condensing glass cover.

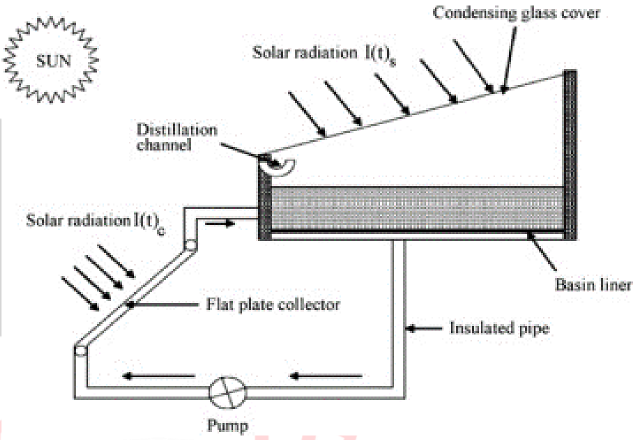

Fig. 2 Simple solar still coupled with flat plate collector

3. Productivity Enhancement of Conventional Solar Still Integrated with Flat Plate Collector (FPC)

Rajaseenivasan, Nelson and Srithar (2014) conducted an experimental investigation to study the performance of conventional solar still and solar still integrated with FPC. The FPCB (flat plate collector basin) still is integrated with an arrangement of horizontal FPC's forming 6 compartments of size 0.108m x 1m each in the basin. The space between two consecutive basins are made of fins having a size of 0.07m x 1m and serves as a basis of extended surface which helps to increase the basin temperature and solar collector temperature where the water gets heated before entering the basin. As there are compartments present in the basin, the water mass contained in basin reduces, thereby increasing the rate of evaporation. In this study, experiments were conducted by the use different energy storing materials in both basins. Figures 3 and 4 show the sectional view and top view respectively of the CSS and FPCB still of the experimental setup.

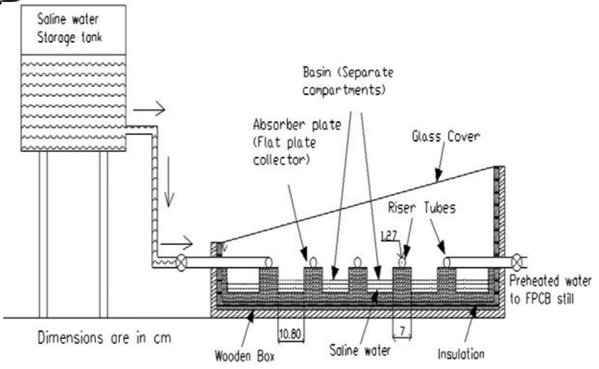

Fig. 3 Sectional view of Flat plate collector basin still

Both the CSS and FPC were constructed of same effective basin area i.e. 1m² and having a thickness of 0.025m. Transparent glass (thickness 4 mm) is used on both the stills as a condensing cover and is tilted at an angle of 10° to horizontal. Saw dust is used as an insulating material between the basin and plywood to avoid any loss of heat to the surrounding. A storage tank of 50 liters capacity was used to provide salty water to both solar stills.

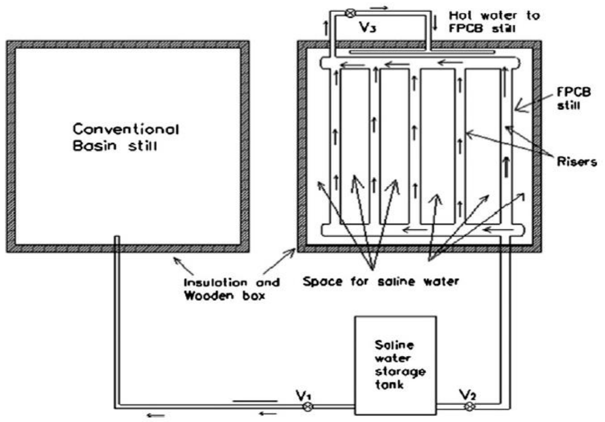

Fig. 4 Conventional & FPCB solar still – Top View

The CSS and FPCB still were tested under same climatic conditions but with various modifications in the basin such as black gravels and jute cloth in order to enhance the rate of evaporation of water and heat capacity of the solar stills. It was found that FPCB still had higher evaporation rate as compared to CSS. This was due to the effect of extended surfaces and supply of preheated water which helped in increasing the distillate output of FPCB still by about 60% more than the CSS for same climatic and design conditions. The maximum yield for CSS was 3.62 kg/m² per day, whereas the productivity of FPCB still was 5.82 kg/m² per day. Fig 5 and 6 show the variation of distillate output for various modifications in CSS and FPCB still respectively.

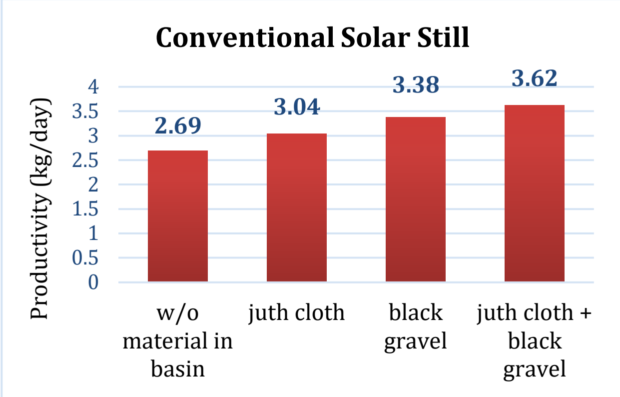

Fig. 5 Variation of distillate output with modifications in conventional solar still

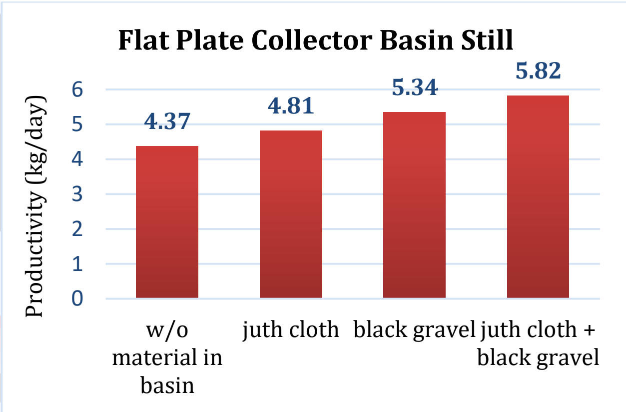

Fig. 6 Variation of distillate output with modifications in FPCB solar still

Morad, Kamal, et. al (2015) examined the performance of double slope solar still by using FPC and glass as cooling cover. In their study, active and passive (CSS) solar stills were used to produce clean and fresh water. Experimental investigations were done on both the stills to measure internal as well as external glass cover temperature and water on hourly basis.

The passive solar still unit is made up of rectangular box, a black tray of basin area of 1.9 m². The cover is tilted at an angle of 25° oriented towards east-west. In this, the solar still basin receives direct solar radiations which is only energy source to increase temperature of water. Fig. 7 shows the passive double slope solar still used in the experimental investigations.

Fig. 7 Passive double slope solar still

The active still receives an extra amount of energy to enhance the evaporation rate by an exterior system which helps to increase the productivity. The FPC is fabricated in rectangular shape with dimensions 180 cm x 75 cm and consists of an absorber plate of GI sheet of thickness 3mm. The absorber plate and flat plate collector glass cover have an inclination of 30° facing south to absorb maximum amount of solar radiations. Saline water from storage tank flows to the FPC and gets heated up by the solar radiations. This pre-heated water is then guided to the solar still which helps to rise evaporation of still.

Fig. 8 Active solar still (solar still with FPC)

Experimental investigations to measure the productivity of active and passive solar still was done on hourly basis from 9:00 hours to 17:00 hours. It was observed that maximum hourly distillate output was obtained at 14:00 hours considering all the experimental conditions. Experiments were conducted by varying brine depth from 1 cm to 3 cm with glass cover thickness of 3mm which resulted into decrease in productivity of the passive solar still system from 1.15 liter/m^2 per hour to 1.07 liter/m^2 per hour, whereas in case of active system the productivity was observed to be reduced from 1.59 liter/m^2 per hour 10 1.4 liter/m^2 per hour. The effect of glass cover thickness was also considered by varying its thickness from 3 mm to 5 mm. It was noticed that with increment in glass thickness, the productivity decreased from 1.33 to 1.07 liter/m^2 per hour for passive still and for active solar still, these values noted were 1.63 to 1.36 liter/m^2 per hour.

According to their conclusions, the highest productivity for passive solar still obtained was 6.38 litre/m^2 per day for a brine depth of 1 cm and glass cover thickness of 3 mm. For active solar still, the highest productivity obtained was 8.52 litre/m^2 per day for same conditions. This is because lower the depth of water, lower is the water mass, higher is the evaporation thus giving higher distillate output. Also, keeping minimum thickness of glass will allow maximum radiations to transmit through it.

4. Conclusion

From the above discussions on the review of using flat plate collector with solar stills, following are the conclusions that can be made-

The productivity of solar still is dependent on parameters like wind velocity, ambient temperature, solar radiation intensity etc. and are called climatic parameters and on design parameters such as water depth, inclination of condensing cover, insulation, energy storage materials, use of flat plate solar collectors, solar pond, reflectors etc. Jute cloth and black gravels act as heat storage media which enhances the evaporation rate and heat storage capacity of water. Water depth and glass cover have direct impact on solar still output. Lower the water depth, higher the evaporation rate, thus yielding high productivity. Also, lower the glass thickness, more are the radiations transmitting to basin which results in higher distillate output. Incorporating flat plate collector with solar still can help to enhance the evaporation rate because pre-heating of water can be done using FPC as an exterior system. Thus the performance of solar still with flat plate collector is higher as compared to a simple solar still.

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