



Experimental Analysis of Pyramidal Solar Still with Sponge as Absorber

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ABSTRACT

The availability of drinking water is one of the most important requirements of the world. Desalination process through solar energy is a very useful process for converting impure water into drinking water. In the present article a pyramidal solar still (PSS) has been designed and fabricated and its performance has been compared with a fabricated conventional solar still (CSS). Sponge as absorber is being used for enhancing the quantity of distillate. The absorber increases the surface area for evaporation and this, in turn, increases the distillate obtained. A comparison of performance was done. The results show that the maximum temperature of water in the basin of PSS was 47°C at 2:30 P.M. and the maximum temperature of basin water of CSS was 43°C at 2:30 P.M. Maximum temperature of PSS upper glass was 46°C, PSS inner glass temperature was 54°C and CSS glass temperature was 42°C. The maximum hourly productivity of PSS is 314.47% higher than CSS basin. Accumulated productivity of Pyramidal solar still (PSS) is 419.42% higher than the conventional solar still (CSS). Maximum accumulated distillate of PSS and CSS are 1480 ml and 278 ml, respectively, at 4:30 P.M. The optimum water input flow was 250 ml/hr.

Keywords –Pyramid solar still, absorbers, desalination, brackish water, saline water

I. INTRODUCTION

Solar energy is a most important cause of heat which can be utilized in desalination, cooking, heating and

cooling processes etc. Solar energy can be employed through thermal and photo voltaic conversion system. Water available on the earth as sea water and drinking water are 96.54% and 2.53%, respectively [1], and only 0.36% of the drinking water is directly available for people [2]. With the increase in population and development of industry, freshwater supply has become a serious issue globally. A solar still is small device which converts saline or impure water into the portable or drinking water using solar radiation. In the solar still, water is vaporized through solar radiation directly coming from the sun. These vapors are condensed beneath the glass cover solar still and get collected through channel. This collected water is portable. The use of solar still is a cheap and easy method for getting drinking water. Low installation cost, free water production at the point of use and no requirement of skilled labour for maintenance are some of the benefits of solar stills. Also, low efficiency and problems associated with the deposit of salt, scale and corrosion are some of the demerits. Their rate of production depends on solar radiation. When there is no sunshine, the production is almost nil. The aim of present research is to develop a highly capable solar distillation system which is easy to construct and applicable to small unit.

II. LITERATURE REVIEW

Many researchers have reviewed the previous works. For example, Murugavel et al. [3] outlined the progresses in the work done on single basin passive

types still to improve its productivity. The optimum orientation and inclination to receive maximum radiation and lower the condensation loss, different materials used in the basin to improve the performance were discussed. Rubber was found to be the best basin material which improves absorption, storage and evaporation effects. The effect of varying the depth of the basin water was also studied.

Suneesh et al. [4] reported a "V" type solar still for water desalination with a Cotton Gauze Top Cover Cooling (CGTCC) with and without air flow over the glass cover. Water flowing over bare glass cover is not even over the width of the glass cover. A new method of water distribution is presented using a CGTCC for increased distillate output. The freshwater production performance of this new still is observed in Tamilnadu, India climatic conditions. The water production rate with no CGTCC (water flowing over bare glass) was 3300 ml/(m²-day). However, with CGTCC production increased to 4300 ml/(m²-day), and with CGTCC and air flow, it further increased to 4600 ml/(m²-day). Experimental parameters such as glass temperature, inner air temperature, ambient air temperature, solar radiation and distillate output were recorded during sunny days. The CGTCC without air flow is more cost-effective than the basic still and should be promoted for rural areas in the world.

Elango et al. [5] presented a novel way to improve the yield of the solar still by using glass as basin material. Single and double basin double slope solar still of same basin area were manufactured using glass. The water depths were altered from 1 to 5 cm and experiments were carried out under insulated as well as uninsulated conditions. During the heating period, the yield of single basin was more than the double basin while during the cooling period, it was more for double basin. At the minimum water depth of 1 cm, the yield of the still was more. Insulated stills gave more production as compared to uninsulated stills. At the water depth of 1 cm, double basin insulated and uninsulated stills gave 17.38% and 8.12% higher production, respectively, than the single basin still.

Sandeep et al. [6] increased the yield of a basin type single slope active solar still with a new condensation technique. A still design having an extra condensing cover has been utilized and its performance is studied. Due to this condensing surface, higher efficiency was obtained as compared to conventional single slope still. It was experimentally concluded that the water depth, shading on condensing surface and material of extra

condensing surface have remarkable role on the yield. The productivity of the new solar still was found to be 3.015 kg/m²/day which was about 25% more than that of a conventional solar still. The study evaluates the optimum design condition for this still for better performance. Extra increase in water yield up to 14.5% was noticed with further improvements in the design.

Srivastava et al. [7] analyzed the performance of a modified basin type solar still, incorporating multiple low thermal inertia porous absorbers, floating adjacent to each other on the basin water with the help of thermocol insulation by conducting experiments at Rewa, MP, India. The porous absorbers were made up of ordinary blackened jute cloth. The distillate output was obtained by the modified still was about 68% more, whereas 35% more on cloudy days. On applying the twin reflector booster with the modified still an increase in the yield by 79% was obtained over the modified still without booster. As the basin water depth does not have any noticeable effect on the performance, the modified still can be usefully used in stills with deeper water levels. Results revealed that the thermal model have reasonable agreement with the experimental values. Further, the influence of wind transfer coefficient, base heat loss coefficient and the floating insulation heat transfer coefficient were theoretically analyzed.

Agouz [8] modified a stepped solar still using continuous water circulation using a storage tank for sea and salt water. Total dissolved solids (TDS) of seawater and salt water before desalination were 57,100 and 2370 mg/l, respectively. The influence of storage tank and cotton black absorber on the freshwater yield of modified still was investigated. The yield of the modified still was found to be higher than that for conventional still by 43% and 48% for sea and salt water with black absorber respectively, while 53% and 47% of sea and salt water, respectively with cotton absorber. The daily efficiency of modified stepped still was observed to be more than that of conventional still by 20%. The maximum efficiency of modified stepped still is observed at a feed water flow rate of 1 LPM for sea water and 3 LPM for salt water. TDS of seawater and salt water after desalination were 41, and 27 mg/l, respectively

Sathyamurthy [9] increased the contact time of water in the basin by utilizing a semicircular absorber solar still with baffles which enhanced the distillate productivity. The performance of still was analyzed in terms of effect of the number baffles and the water flow rate. A fair

agreement between the experimental and theoretical results was observed. The daily distillate of modified still was more than that for conventional still by 16.66%. The outlet water temperature of this still was high enough and can be integrated with multi-state of solar still to increase the productivity. Thus, this still can be satisfactorily utilized for other continuous solar desalination systems. The payback period still is lesser compared to other solar still.

Ahsan et al. [10] devised a low cost system which can be used in rural and coastal areas for getting fresh water with the help solar energy. A triangular solar still (TrSS) was designed and fabricated with low cost, lightweight, local available materials and its performance was evaluated. Some essential correlations were developed, e.g. between the daily yield and the initial water depth, the daily production and daily solar radiation, and the daily production and the average ambient temperature. The influence of water depth in the basin on the water productivity was observed by varying the water depths (1.5, 2.5 and 5 cm) in the climatic conditions of Malaysia, and an inverse proportional relationship was found between them. The daily water productivity was nearly proportional to the daily solar radiation. Some important water quality parameters were tested to assess the distillate quality and were compared with the drinking water standards.

Taamneh et al. [11] studied the influence of forced convection on the performance of pyramid-shaped solar still under outdoors of Tafila City. It was inferred that the use of fan and photovoltaic solar panels is cost-effective and viable in increasing the evaporation rate and hence the fresh water yield. The daily yield of freshwater was increased up to 25% as compared to free convection solar still.

Kabeel [12] used a concave wick surface for enhancing the evaporation in a pyramidal shaped still. It was observed that daily average distillate productivity was 4.1 l/m² and a maximum instantaneous system efficiency was 45% with average daily efficiency of 30%. The maximum hourly yield was 0.5 l/h. m² after solar noon. Cost of 1 l of distillate was 0.065 \$.

Dev et al. [13] investigated an inverted absorber solar still (IASS) and a single slope solar still (SS) by varying water depths (dw) at Muscat, Oman. A thermal model was also developed for the IASS and validated with experimental results. A fair agreement was found for the daytime operation of the IASS. A higher water temperature was achieved in IASS as compared to the

SS. The daily yield obtained from the IASS were 6.302, 5.576 and 4.299 kg/m²-day at water depths 0.01, 0.02 and 0.03 m, respectively. At same respective water depths, the daily yield of SS is 2.152, 1.931, and 0.826 kg/m²-day, respectively which were lesser that of the IASS. The optimum water depth for the IASS was 0.03 m above which the addition of reflector under the basin does not influence its performance much more in comparison to that of the SS for sea water. For IASS, the annualized costs of distilled water were Rs. 0.74, 0.66 and 0.62 per kg-m² for the lifetime of 15, 20 and 25 years, respectively.

Sathyamurthy et al. [14] presented the theoretical analysis of the effect of mass flow, feed water temperature, internal heat transfer coefficient and the absorber plate temperature on freshwater production of a modified inclined solar still. The results show that, at a minimum mass flow rate, production was increased by 57.14% and the maximum average water temperature for the flow rates of 0.0833, 0.1666, 0.3222 and 0.4166 kg/min are found to be 62, 45, 40 and 38°C respectively. The mean temperature of hot water collected in the lower storage was 47.9°C. There was an increase in production by 65% with a flow rate of 0.0833 kg/min and the inlet temperature 60°C respectively. With the use of baffle plates in the basin absorbs heat which heat up the flowing water for attaining higher brine temperature. This model, called as RHN (Ravi-Harris-Nagarajan) model, can be used for step and weir cascade solar still.

Kabeel et al. [15] investigated two solar stills a conventional single slope solar still and a modified stepped solar still. For augmentation of the yield a wick on the vertical sides is added to the stepped still. A fair agreement between the experimental and theoretical results is observed. The productivity of the stepped solar still is found to be dependent on the tray depth and width. The maximum productivity of stepped solar still is achieved at a tray depth 5 mm and tray width 120 mm, which is about 57.3% higher than that of the conventional solar still. The daily efficiency and cost of 1 l of distillate for stepped and conventional solar stills were 53%–0.039\$ and 33.5%–0.049 \$, respectively.

Eldali [16] studied an active vibratory harmonic solar still. In the bottom of basin flexible packed stretched media was installed to improve the performance. The flexible packed media is made of helical coiled copper wires, which are good for transferring and acts as heat absorbing thermal system. The productivity of helical wires is found to be 3.4l/m² day, with an efficiency of

35%, and productivity vibration is increased upto $5.81/m^2$ day.

Esfahani [17] used a solar collector, a wall covered with black wool, and water sprinkling system to increase evaporation rate and a thermoelectric cooling device to enhance water condensation. The setup was tested under the climate condition of Semnan, Iran. The results show that ambient temperature and solar radiation have direct effect on still performance but water productivity decreases when the wind speed increases. By comparing the results of summer and winter, it is found that efficiency in summer is higher than winter. The results also show that the cost per liter of still is comparable with other types of solar stills.

Feilizadeh [18] developed a model for a single-slope solar still has been which, for the first time, takes into account the effect of all walls of the still on the amount of incident solar radiation on the water surface and each wall. The walls are projected on the cover to calculate the amount of beam radiation received by any components inside the still. The predictions of the model are compared with the experimental data and a good agreement between the theoretical results and the experimental data was found. It was found that the effect of the back and side walls is not inconsiderable and they must be taken into consideration to improve the accuracy of the thermal radiation analysis of single-slope solar still performance.

Mahdi [19] designed tilted wick-type solar still and analysed its performance. Charcoal cloth was used as an absorber/evaporator material and for saline water transport. The solar still is incorporated with constant head device. Indoor and outdoor experimental tests were carried out to analyse the performance of the still. The representative daily efficiency of the still was about 53% on clear days in summer. It has been concluded that, the charcoal cloth is a good material to be used as an absorber/evaporator and also as a water transport medium. Increase of the input water mass flow rate leads to a reduction in the efficiency of the wick-type solar still. The still efficiency decreased linearly with increase of salinity of the input saline water.

Monowe et al. [20] designed a portable thermal-electrical solar still with an external reflecting booster and an outside condenser. The system minimizes the loss of latent heat of condensation to the environment. The latent heat is accumulated in a condenser and can be used to preheat saline water for household purposes

or to use the still during night times. The maximum efficiency of still was 77% if the preheated saline water is used for household purposes, and it was 85%, if preheated saline water is used to operate the still during night times and to recharge the still by the next batch of preheated water.

Omara et al. [21] modified a stepped solar still through internal reflectors. The effect of installing a reflecting mirror on the vertical sides on the steps of stepped solar still on the distillate productivity was investigated. The productivity of the modified stepped solar still with and without internal reflectors is higher than that of conventional solar still approximately by 75% and 57%, respectively. Also the daily efficiency for modified stepped solar still with and without internal reflectors and conventional solar still is approximately 56%, 53% and 34%, respectively.

Tanaka [22] designed, fabricated and investigated a vertical multiple-effect diffusion solar still, consisting a series of closely spaced vertical and parallel partitions in contact with saline-soaked wicks, coupled with a flat plate reflector at Fukuoka, Japan. The overall daily productivity of the modified solar still with 6- effect and 5 mm diffusion gaps was about 13.3 kg/m^2 day at maximum when the global solar radiation on a horizontal surface was 13.4 to 15.7 MJ/m² day and radiation on the glass cover was 20.2 to 22.9 MJ/m² day. The productivity of the still was be greater than or equivalent to other types of multiple-effect diffusion still.

Rajaseenivasan et al. [23] introduced an additional basin in the double slope solar still. Two solar stills viz. single basin double slope and double basin double slope with the same basin area were fabricated and tested at Kovilpatti, Tamil Nadu, in India. For both stills, water yield decreases with increase of water depth. The production rate gets higher when mild steel pieces are used as storing material in the basin, in both the stills. The water yield in double basin still was 85% more than that of single basin still.

III. MATERIALS AND METHODS

Two solar still are designed and fabricated viz. simple solar still and pyramidal- shaped solar still (PSS). The PSS was fabricated by G.I. sheet 0.5 mm thick, having basin area of 0.64 m^2 . And basin height 10cm. A small triangular glass plate (TGP) was integrated on the inner side of still with a 9cm distance away from one of the glass wall. This plate was black painted that increase the absorption of solar radiation. The sheet of

toughened glass was 5mm thickness. The base of solar still and inner glass surface are blackened with paint for good absorptivity of solar radiation. Wood was used as insulator on the bottom. At the starting of experiment, water is filled in basin and small amount of water is continuously supplied and spread on the TGP. Sponge is used as an absorber. The direct and diffused solar radiations are transmitted through the glass cover and absorbed on basin water, which heat up the water and evaporates it, the vapour is then condenses on the glass cover. The distillate water flows down and collected through the bottom collecting channel and some amount of hot vapor was collected from the inner glass surface. The distillate from inner glass and basin of PSS is measured every hour by collecting cylinder and is compared with conventional solar still CSS. To flow of water is maintained by using 1 liter bottle of plastic

integrated with IP set. In this experiment some important parameters were measured viz. solar radiation (W/m^2) with the help of Pyranometer, humidity RH (%) with the help of hygrometer, atmospheric wind velocity (m/s) with the help of anemometer, and temperature at different points: PSS glass cover temperature, MSS inside temperature, CSS basin temperature, CSS glass cover temperature, inside nozzle temperature and atmospheric temperature. These are measured every hour. Experiments were performed from 10:30 AM to 4:30 PM in the premises of Radharaman Group of Institutes' campus.



Fig. 1. Experimental Setup



Fig. 2. Instruments used to during Experiment

IV. RESULTS AND DISCUSSION

It was observed that the maximum temperature of PSS outer glass was 46°C and PSS inner glass was 54°C and the glass temperature of CSS was 42°C as shown in figure 3. In PSS, the basin temperature was 47°C and in CSS it was 43°C and the absorber temperature was 61°C. The temperature variation of PSS basin and CSS basin are shown in figure 4. The maximum hourly productivity of 315 ml and 76 ml is recorded for PSS

and CSS, respectively at 2:30 PM. Thus, the maximum hourly productivity of PSS is 314.47 % higher than CSS basin (figure 5). The maximum accumulated productivity is observed to be 1444 ml and 278 ml for PSS and CSS till the end of the experiment (at 4:30 PM) i.e. for 6 hours as shown in figure 6. This accumulated productivity of PSS is 419.42 % higher than CSS. All the results indicated that the productivity of the pyramidal solar still with sponge as absorbers is 4.2 times higher than conventional.

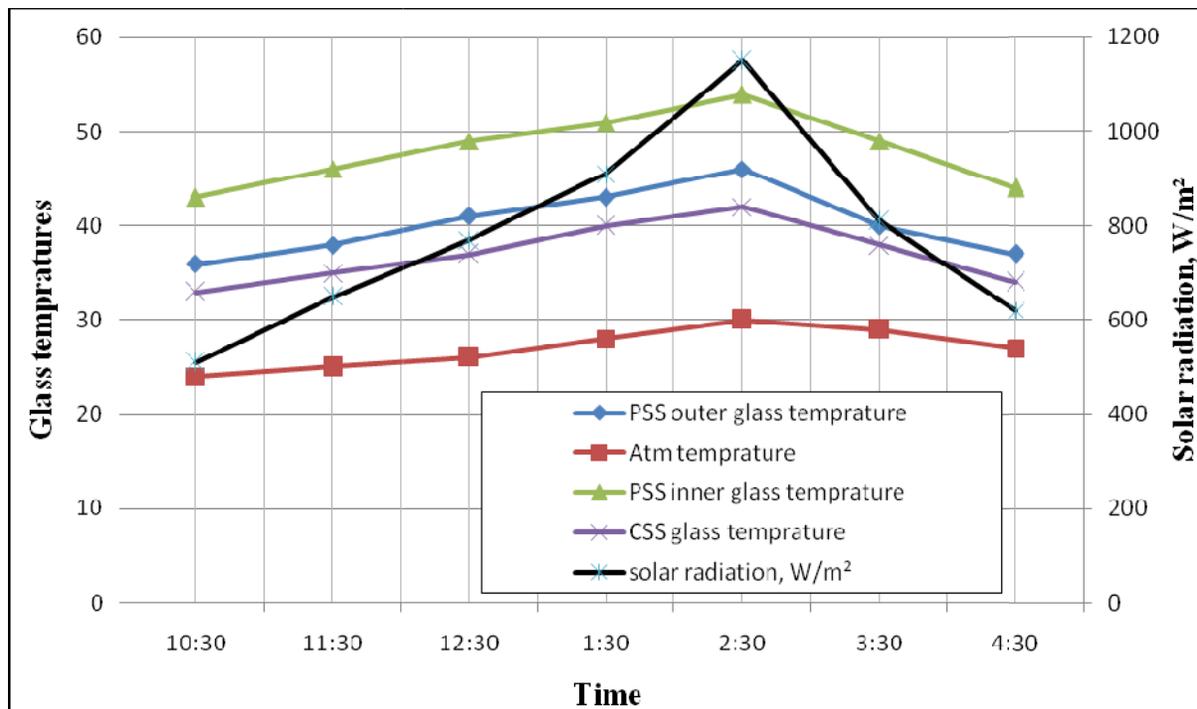


Fig. 3. Temperature variations of PSS upper glass, PSS inner glass, CSS glass and atmospheric temperature with time

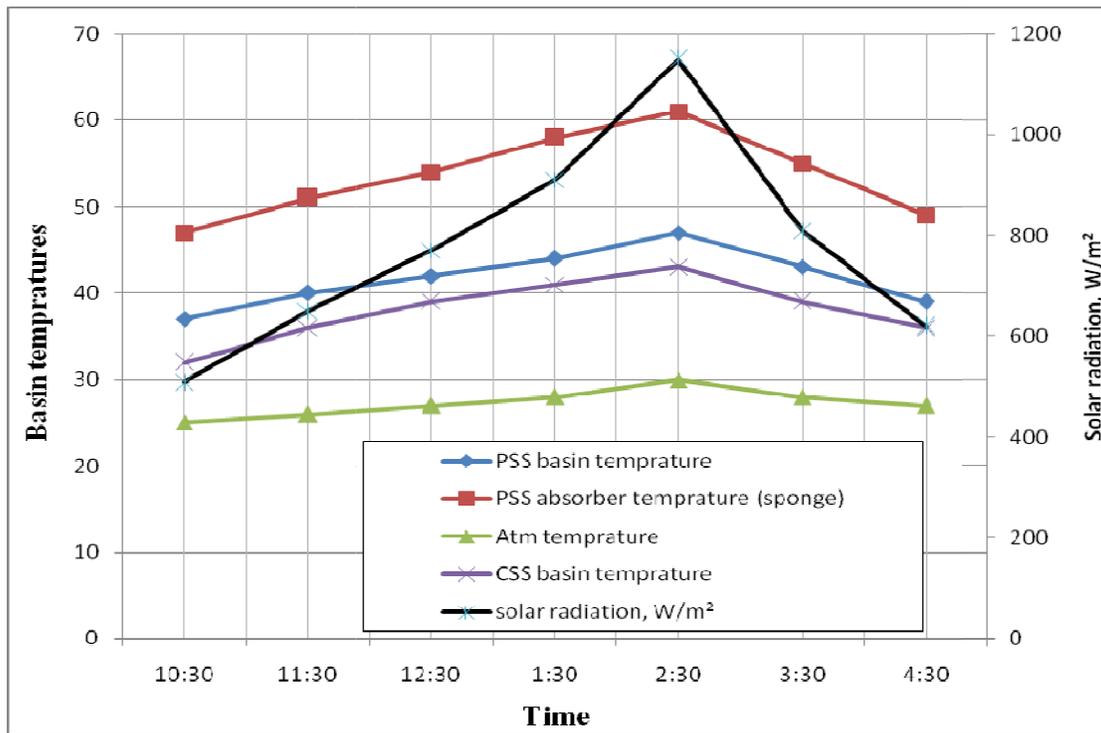


Fig. 4. Variation of temperature of PSS basin, CSS basin and absorber with time

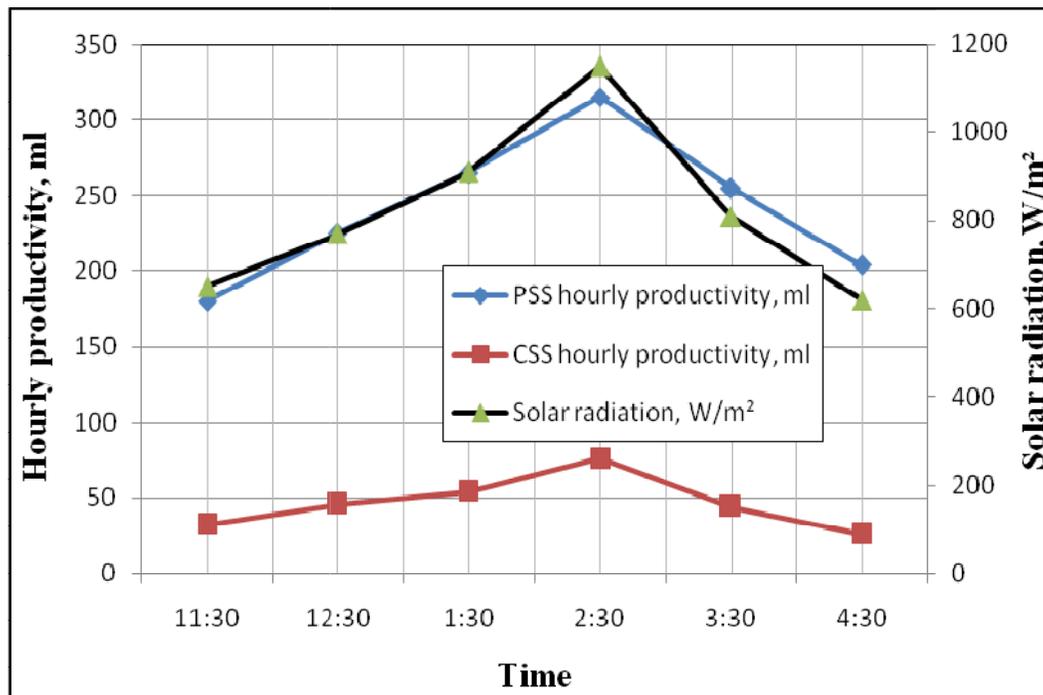


Fig. 5. Variation of hourly productivity of PSS and CSS with time

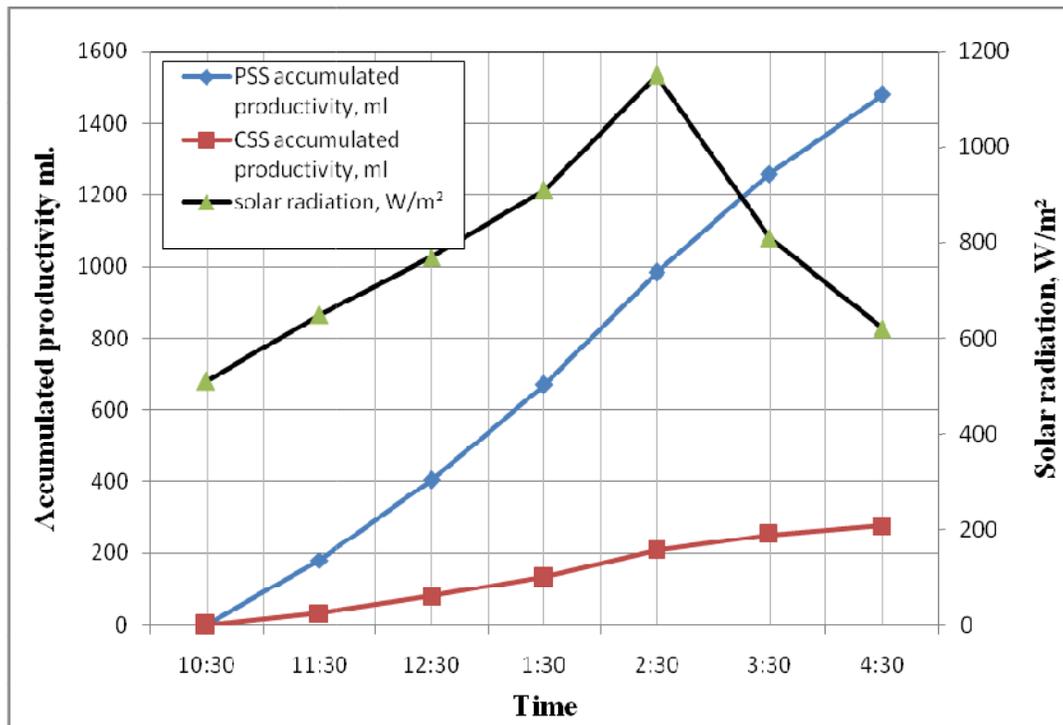


Fig. 6. Accumulative productivity of PSS and CSS

V. CONCLUSION

The need of pure water is one of the most important aspect of human life. Solar still is one of the most promising devices which can be used to convert brackish water into the potable water. It is a simple and low cost device and without the requirement of any skilled person. In the present article pyramidal solar still with sponge as absorber and inner glass plate is designed and tested; its performance is compared with the conventional solar still. After the analysis, the following conclusions are drawn.

1. The maximum temperature of PSS basin was 47°C and that of basin water of CSS was 43°C.
2. The maximum hourly productivity of 315 ml and 76 ml is recorded for PSS and CSS, respectively at 2:30 PM.
3. The maximum hourly productivity of PSS is 314.47% higher than CSS basin.
4. The maximum accumulated productivity is observed to be 1480 ml and 278 ml for PSS and CSS till the end of the experiment at 4:30 PM i.e. for 6 hours.
5. The accumulated productivity of PSS is 419.42% higher than CSS. Thus, the productivity of the pyramidal solar still with sponge absorber is 4.2 times higher than conventional.

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