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IMPROVING THE PERFORMANCE OF SOLAR DESALINATION SYSTEM BY USING LATENT HEAT STORAGE

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ABSTRACT

Solar desalination is one of the most sustainable and attractive method employed to meet the supply of drinking water for remote areas at very reasonable cost. Heat loss is one of the major parameter affecting the productivity of the solar still. The objective of this study is to enhance the thermal performance and productivity of single basin solar still with integrated phase change material. The important parameters affecting the performance of the still are analysed theoretically. Effect of water depth in galvanised iron, aluminium and copper basin still and effect of mass of PCM in solar still were investigated. It was found that the productivity of still decreases with increase in water depth. The highest daily productivity of 1.39 kg/m^{2}wasobtainedwhen the depth of water was maintained at 10 mm. The use of stearic acid and paraffin wax as PCM beneath the basin liner improved the daily productivity of still by 164% and 180% respectively compared to still without PCM.

***Keywords:* Freshwater production, Productivity, Solar desalination, Solar energy.**

I. INTRODUCTION

There is an urgent need of clean, pure and safe drinking water in many countries. Often, water sources are brackish and containing harmful bacteria and therefore cannot be used for drinking. Fresh water supply by trucks and laying long pipelines carrying potable water from far off region is usually not economically feasible. In addition, due to pollution of the rivers and lakes by industrial wastes and large amount of sewages results in contamination of water quality. Also in coastal areas and deserts potable water for drinking is the main problem. So, there is a need for desalination of brackish water to meet the requirement economically. One of the options used to obtain potable water from saline water is to use solar distillation process. Solar still represent a good option and a simple technique compared to the other desalination techniques. Elango et al. [1] found that provision of wick or porous or energy storing material in the basin increases the distillate output. The depth of basin water is an important factor affecting fresh water productivity of the still. Solar desalination process can be significantly enhanced using the active mode operations. Therefore, many attempts have been made to improve the solar still by coupling the stills to parabolic trough, solar ponds and solar thermal collectors [2-4] Another method that can be used to enhance the productivity of still is by using thermal energy storage systems (sensible and latent heat storage). The latent heat storage system has a significant advantage over sensible heat system, including high energy capacity and almost constant temperature for charging and discharging.

Arunkumar et al. [5] investigated the effect of phase change material on the productivity of the concentrator-coupled hemispherical basin still. The aim of the present work is to study the enhancement of the distilled water

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productivity of the single basin solar still with phase change material integrated storage. The effect of mass of PCM on the performance of still with PCM is theoretically investigated and the study results are compared with conventional still, to evaluate the enhancement in the distillate water production when using phase change material storage.

II. METHODOLOGY

The theoretical investigation was carried out to assess the performance of the solar still for the following cases, the effect of (i) water depth,(ii)different basin liners(iii) still with PCM(iv)still without PCM. Amathematical model was developed by writing the energy balance equation of water ,mass, glass and basin liner, to predict theoretical temperature of glass, basin water, basin line rand the yield of distilled water, using the convective and evaporative heat transfer coefficients values which are calculated by using known initial values of various temperatures. The mat lab program was used for the mathematical model to predict the theoretical temperature of water, glass, basinlineranddistilled out put. The mathematical model has been developed for the following cases effect of water depth, effect of different basin liners and effect of phase change material. In the mathematical model all the climatic, design and operational parameters affecting the performance of solar stills appear explicitlyinenergybalanceequations.Theanalyticalexpressionshavebeenderivedforhourlywaterglassandbasinlinert emperaturesasafunctionof design and climatic parameters. These expressions are based on energy balance equations for each component of solar stills. A computer program has been developed to predict the hourly performance of the solar stills. The values of internal and external heat transfer coefficients obtained using known initial values of various temperatures of the solar still. This model predicts the theoretical values of water temperature, glass temperature, glass temperature, basin liner temperature, basin liner temperature and productivity of solar still at every hour.

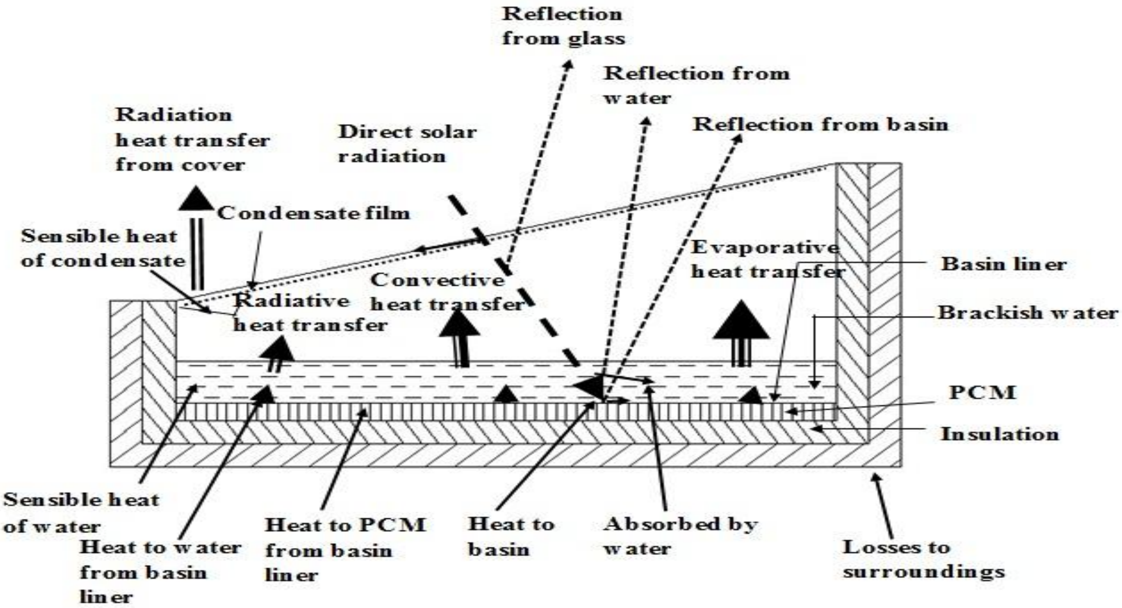

Fig. 1. Singlebasin solarstill with PCM - Energy flow diagram

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III. MATHEMATICAL MODELS

3.1 Internal heat transfer

Radiative loss coefficient (h_{rw})

$$h_{rw} = \varepsilon_{eff}\sigma\left[(T_w)^2 + (T_g)^2\right](T_w + T_g) \quad (1)$$

Convective loss coefficient (h_{cw})

$$h_{cw} = 0.884\left[T_w - T_g + \frac{(P_w - P_g)(T_w)}{268.9 \times 10^3 - P_w}\right]^{1/3} \quad (2)$$

Where, P_w and P_g are saturated vapour pressure

Evaporative loss coefficient (h_{ew})

$$h_{ew} = 16.273 \times 10^{-3} \times h_{cw} \times \frac{P_w - P_g}{T_w - T_g} \quad (3)$$

3.2 External heat transfer

Top loss coefficient

$$h_{rg} = \frac{\varepsilon_g \sigma\left[(T_w + 273)^4 - (T_g + 273)^4\right]}{(T_g - T_a)} \quad (4)$$

Expression for h_{cg}

$$h_{cg} = 2.8 + 3\,V \quad (5)$$

where, V - wind velocity in m/s

Bottom loss coefficient (U_b)

$$U_b = \frac{k_{in}}{L_{in}}$$

Where, L_{in} - thickness of insulation

k_{in} - thermal conductivity of insulation

3.3 Evaluation of distillate output

Hourly productivity of still

$$P_h = \frac{q_{ew}}{L_w} \cdot 3600 = \frac{h_{ew}(T_w - T_g) \cdot 3600}{L_w} \quad (6)$$

Daily productivity of still

$$P_d = \sum_{24\,hrs} P_h \quad (7)$$

3.4 Efficiency of still

$$\eta_d = \frac{P_d L_{w,av}}{(A_p \sum I)\,\Delta t} \times 100\ (\%) \quad (8)$$

where, $L_{w,av}$ - daily average latent heat of vaporization of water.

I - intensity of solar radiation

Δt - time interval

A computer program has been developed in Mat lab for solving the analytical expressions for various temperatures of solar still to predict water temperature, glass temperature and basin liner temperature. This model takes the internal and external heat transfer coefficients which are obtained using known initial values of various temperature of solar still and carry out the computation of all performance parameters. The hourly various temperatures T_g,T_W and T_P was determined using explicit runge-kutta method.

IV. RESULTSANDDISCUSSIONS

4.1 Effect of different Basin Liners

4.1.1 Productivity of solar still

The hourly productivity P_h of GI, Aluminium and copper basin still with different depth of basinwater are shown in Figures.

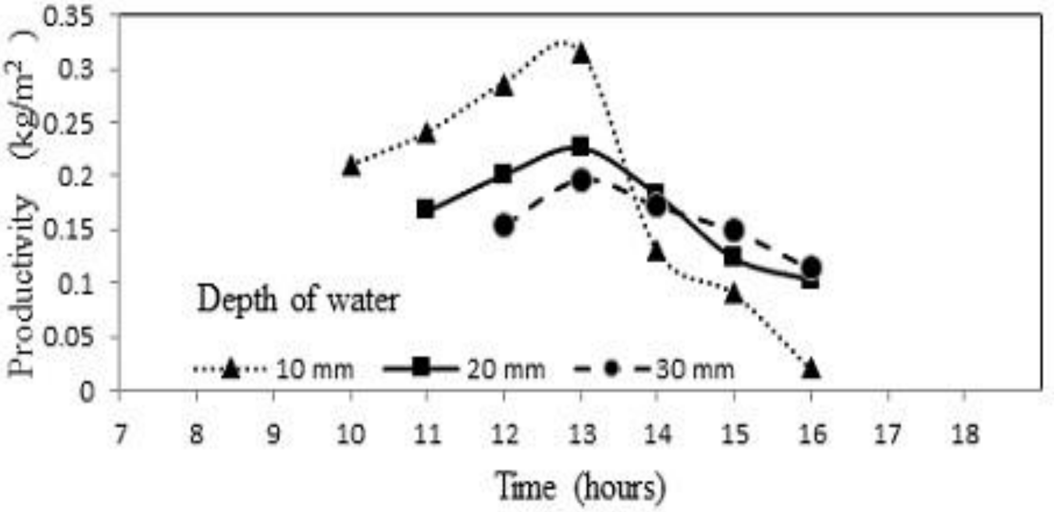

Fig. 2. Hourly productivity of GI basin still with different water depth

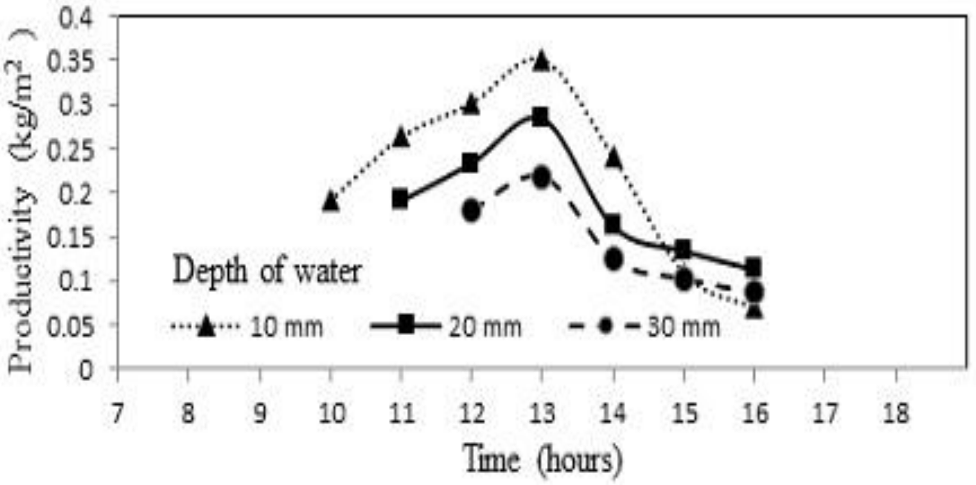

Fig. 3. Hourly productivity of aluminium basin still with different water depth

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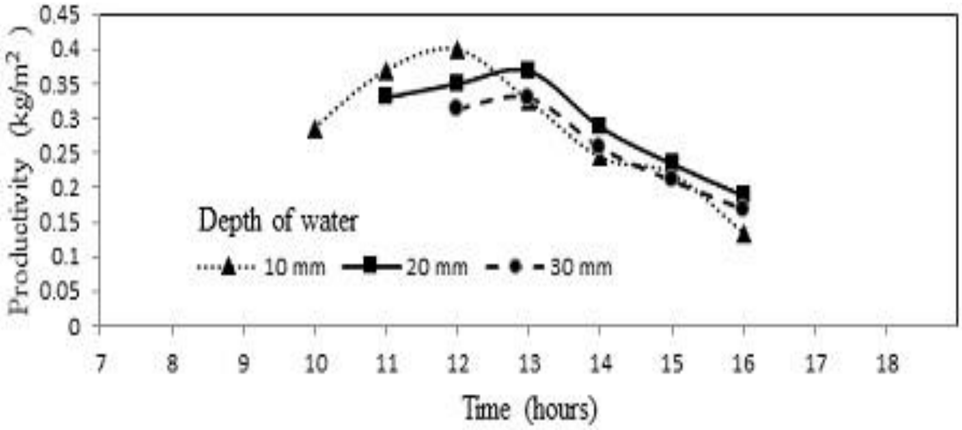

Fig. 4. Hourly productivity of copper basin still with different water depth

The effect of water depth on the hourly yield of GI, Aluminium and copper solar stills are show nin Figures. From the observation, when 10mmdepthofwater,themaximum yield perh our for GI, Aluminium and Copper basin still areabout 0.30kg, 0.342 kg and 0.36 kg respectively.For20mmdepth,the maximum hourly yield for GI, Aluminium and Copper basin still are around0.216 kg, 0.28 kg and 0.39 kg respectively.The maximum accumulated yield per day of GI, Aluminium and Copper solar still with 10 mm depth of water are 1.412 kg, 1.749 kg, and 2.105 kg respectively. The daily productivity is increased by 23.86 % using aluminium basin instead of GI basin still. The daily productivity is increased by 49 % using copper basin instead of GI basin and the daily productivity is increased by 20.35 % using copper basin instead of aluminium basin.

4.1.2 Effect of Phase change material

The hourly productivity of still with different mass of PCM is shown in figures. From the observation, the morning period, hourly productivity of still decreases slightly with increasing with increasing mass of PCM due to the heat capacity of PCM. The slight decrease in P_h during period means a considerable amount of heat is gained by the PCM instead of wasting it to surroundings. The shift of peak positions of hourly productivity verses time curves with increasing mass of PCM is probably due to the increased time taken by the PCM to reach its melting temperature. It is also obvious from the results of above figures that after sunset, hourly productivity of still increases significantly with increasing mass of PCM because the amount of heat stored within the PCM increases with increasing mass of PCM.

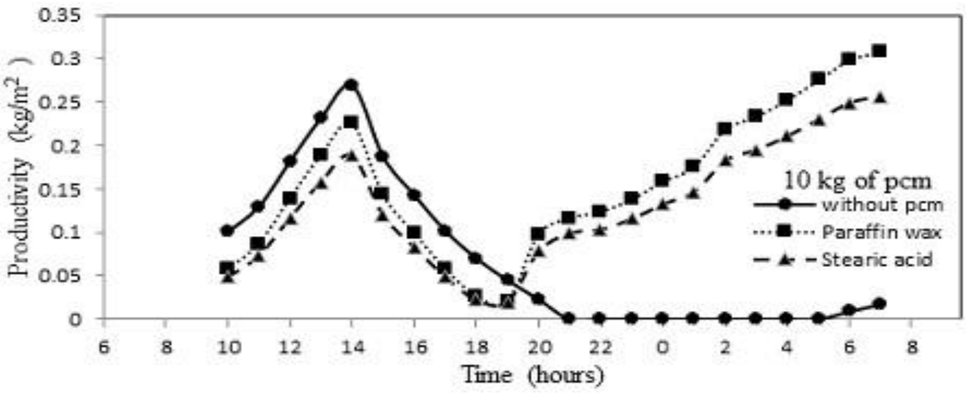

Fig. 5. Hourly variations of distilled output for withpcm 10 kg of stearic acid and paraffin wax

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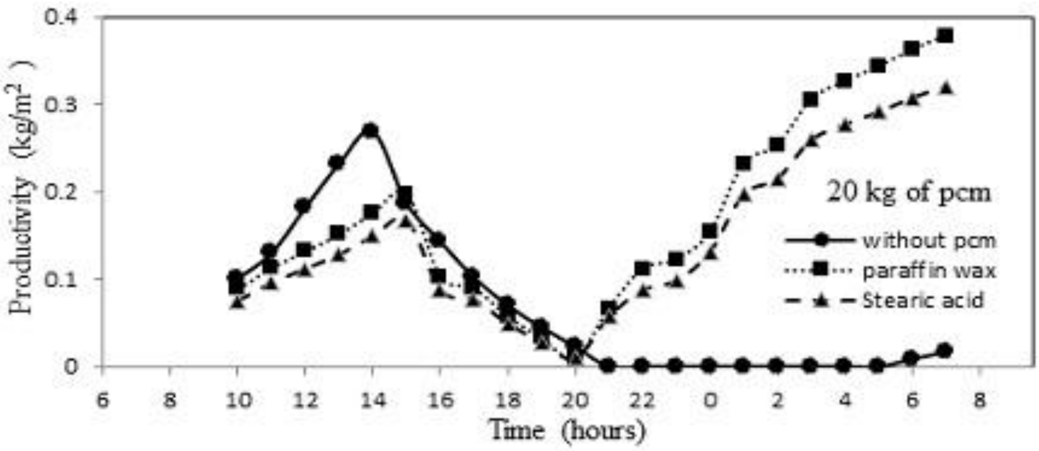

Fig.6. Hourly variations of distilled output for with pcm 20 kg of stearic acid and paraffin wax

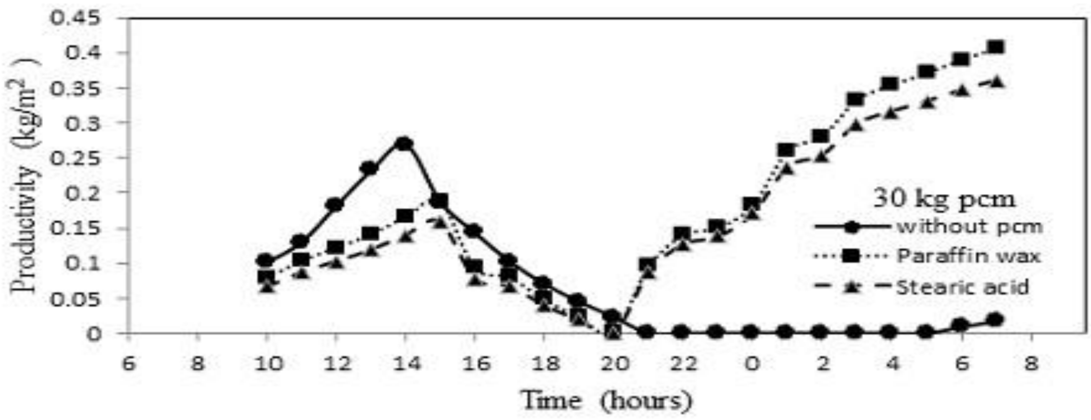

Fig. 7. Hourly variations of distilled output for with pcm 30 kg of stearic acid and paraffin wax

From the figures, the accumulated yield with 10 kg of stearic acid, 10 kg of paraffin wax and without PCM are 3.26 kg, 3.801 kg and 1.512 kg respectively. Hence, the daily productivity of still is increased by 115% using 10 kg stearic acid and the P_h is increased by 150 % increased by using with 10 kg of paraffin wax. The accumulated yield with 20 kg of stearic acid, paraffin wax and without PCM is 3.54 kg, 3.97 kg and 1.512 kg respectively. Hence, the daily productivity of still is increased by 134% using 20 kg stearic acid and the P_h is increased by 162 % increased by using with 20 kg of paraffin wax. The accumulated yield with 30 kg of stearic acid, 30 kg of paraffin wax and without PCM are 3.73 kg, 4.21 kg and 1.512 kg respectively. Hence, the daily productivity of still is increased by 164% using 30 kg stearic acid and the P_h is increased by 180% increased by using with 30 kg of paraffin wax.

V. CONCLUISON

From theoretical investigation on performance of single basin solar still with PCM, following conclusions were made.The accumulated yield of still highly dependentonthermal conductivity of basin liner. When we use high thermalconductivity basin liners, the accumulated yield of still increases. The maximum accumulated yield per day of GI, Aluminium and Copper solar still with 20 mm depth of water are 1.163 kg, 1.608 kg, and 2.136

kg respectively. In morning, hourly productivity of still decreases slightly with increasing with increasing mass of PCM due to the heat capacity of PCM .After sunset, hourly productivity of still increases significantly with increasing mass of PCM because the amount of heat stored within the PCM increases with increasing mass of PCM. The highest accumulated yield with 30 kg of stearic acid, 30 kg of paraffin wax and without PCM is kg, 3.73 kg, and 4.21 kg respectively. Hence, the daily productivity of still is increased by 164 % using 30 kg stearic acid and the P_h is increased by 180% increased by using with 30 kg of paraffin wax.

VI. ACKNOWLEDGMENT

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REFERENCES

[1] T. Elango , K. KalidasaMurugavel (2015) 'The effect of the water depth on the productivity for single and double basin double slope glass solar stills' Vol. 359, pp. 82-91.

[2] Amumul Ahsan, Arunkumar. T and Sanjay Kumar (2012) 'An experimental study on hemispherical solar still', Desalination, Vol.286, pp. 342-348.

[3].Tiwari. A.K and Tiwari. G.N (2006) 'Effect of water depths on heat and mass transfer in a passive solar still in summer climatic condition', Desalination, Vol.195, pp.78-94.

[4].Naga SaradaSomanchi, Sri LalithaSwathiSagi, Thotakura and Ajay Parik (2015) 'Modelling and analysis of single slope solar still at different water depth', Aquatic Prodedia, Vol. 4, pp. 1477-1482.

[5]. Arunkumar. T, Amimul Ahsan and Jayaprakash (2013) 'The augmentation of distillate yield using concentrator coupled solar still with phase change material', Desalination, Vol. 314, pp. 189-192.

[6]. Bhardwaj. R, Mudde. R.F and Kortenaar. M.V (2013) 'Influence of condensation surface on solar desalination', Desalination, Vol. 326, pp. 37-45.

[7]. Elango. T, KalidasaMurugavel. K and Rajaseenivasan(2013) 'Comparative study of double basin and single basin solar stills', Desalination, Vol. 309, pp. 27-31.

[8]. El-Sebaii. A.A, Aboul-Enein. S, Ramadan M.R.I and El-Bialy. E (2009). 'Year- round performance of a modified single basin solar still with mica plate as a suspended absorber', Renewable Energy, Vol. 25, Issue 1, pp. 35-39.

[9]. GanapathySundaram. E, Sivakumar. V (2013) 'Improvement techniques of solar still efficiency', Renewable and Sustainable Energy Reviews, Vol. 28, pp. 246-264.

[10]. Hitesh. N and Panchal (2013), ' Enhancement of distillate output of double basin solar still with vacuum tubes', Engineering Sciences, Vol.29, pp. 123-128.