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Thermal Performance of Single Slope Solar Still with Cover Cooling

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Abstract: This paper investigates experimentally the thermal performance of conventional solar water still with cover cooling. The still is modified connected with water reservoir of a garden fountain (spray pond). As in garden fountain water from the reservoir is pumped and delivered back to the fountain head where it is sprayed into the air through nozzles, as a result of heat and mass transfer, the water is continuously cooled. To utilize stored cooled water in the fountain of reservoir for cooling the glass cover of solar still. With flow of cooled water the temperature of glass cover is reduced; this enhances the distillate output. The performance analysis is carried out by developing mathematical model of the proposed method and result obtained is verified by experimental setup. Moreover the distillate output increases slightly with increase in mass flow rate and tends to saturate around 0.075 kg/s. The effect of depth of water in the basin of still is also evaluated. Numerical computations have been carried out for Jodhpur climatic conditions. Experimental results and comparison with other researchers show that, the daily distillate output 43.4% increment in productivity.

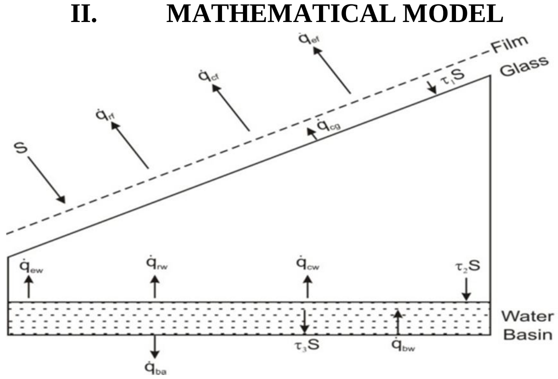
Keywords: Single slope solar still, Fountain reservoir, Mass flow rate, Distillate output

I. INTRODUCTION

Portable water is a human birthright as much a birthright as clean air. However, much of the world's population does not have access to safe drinking water. Hence, new and reasonable way of saving has to be found, using and recycling the water that we have. As people can survive for days, week or month's without food, but cannot live for more than a week without water. The body uses water for digestion, absorption, circulation, transporting nutrients, building tissues, carrying away waste and maintaining body temperature. The average adult consumption about 10 cups of water daily. Adults should drink six to eight cup liquid per day. About 50% of water comes from underground water tables, i.e. ground water and the other 50% from surface water, i.e. rivers, lakes and reservoirs. About 70% of the water is consumed for the agriculture purpose for cultivation of crops .The world council believes that by 2020 we shall need 17% more water than is available if we are to feed the world. Today, one person in five across the world has no access to safe drinking water. Every day more than 30,000 children die before reaching their fifth birthday, killed either by hunger or by water borne diseases.

Among other methods to disinfect the polluted water, the most prominent and simplest method is the solar distillation. Comparatively this requires simple technology and low maintenance due to which it can be used anywhere with less number of problems. Solar distillation is an easy, small scale cost effective technique for providing safe water at home or in small communities. In solar distillation, water is evaporated, thus separating water vapor from dissolved matter. The vapors get condensate as pure water.

II. MATHEMATICAL MODEL



The following assumptions have been made while writing the energy balance equations

1) The heat capacity of the glass cover, flowing water and insulating material is negligible.
2) There is no vapor leakage in the still.
3) The inclination of the glass cover is taken to be minimum possible (10^0-15^0)
4) Efficiency of fountain system (spray pond) is taken as 0.7.
5) Thickness of water film is assumed to be very small (0.1mm).

Energy balance equation for water flowing, glass cover, basin water and basin liner can be written as

A. Water Flowing

$$\dot{m}_f c_w \frac{dT_f}{dx} dx = h'_2(T_g - T_f)bdx - h_2(T_f - T_a)bdx - \dot{q}_{ef}$$ -- (1) here,

b is breadth of still cover normal to the direction of flow, $\dot{m}_f$ and c_w are mass flow rate of water flowing over glass cover and specific heat of water, h_2 is the sum of radiative and convective heat transfer coefficient between film and air and h'_2 is convective heat transfer coefficient between glass cover and water film.

$$h_2 = h_{cfa} + h_{rfa}$$

$$h_{cfa} = 2.8 + 3v_a,$$

$$h_{rfa} = \varepsilon_w \sigma \left[\frac{(T_f + 273)^4 - (T_a + 267)^4}{(T_f - T_a)} \right]$$

v is the velocity of air in (m/s).

$\dot{q}_{ef}$ in equation (1) is the rate of evaporative heat transfer per unit area from the film to air and is given by,

$$\dot{q}_{ef} = 0.013 h_{cfa}(P_f - \gamma P_a),$$ --- (2)

P_f and P_a are the saturated vapor pressures of air at water film temperature and the saturated vapor pressure of air, given by,

$$P_f = \exp\{25.317 - 5144/(T_f + 273)\}$$

$$P_a = \exp\{25.317 - 5144/(T_a + 273)\},$$

and γ is the relative humidity of air.

Average film temperature will be given by,

$$\overline{T_f} = \frac{1}{x}\int_0^x T_f dx$$ --- (3)

x is width of glass cover (1m).

B. Glass Cover

1) With Film

$$h_1(T_w - T_g) + \tau_1 S = h'_2(T_g - T_f)$$ --- (4) (4)

here h_1 is the sum of radiative, convective and evaporative heat transfer coefficient between the water in the basin and the glass cover, h_{rw}, h_{cw} and h_{ew} are the radiative, convective and evaporative heat transfer coefficients respectively and are given by,

$$h_{rw} = \varepsilon_{eff}\sigma\left[(T_w + 273)^2 + (T_g + 273)^2\right](T_w + T_g + 546),$$

$$h_{cw} = 0.884\left[(T_w - T_g) + \frac{(P_w - P_g)(T_w + 273)}{(268.9x10^3 - P_w)}\right]^{1/3}$$

$$h_{ew} = 16.273x10^{-3} h_{cw} \frac{(P_w - P_g)}{(T_w - T_g)};$$

and τ_1 in Eq.(3) is the fraction of incident solar energy absorbed by the glass cover.

2) Without Water Film

The energy balance of the cover is

$$h_1(T_w - T_g) + \tau'_1 S = h_{1g}(T_g - T_a) \quad \text{--- (5)}$$

Where h_{1g} is the sum of radiative and convective heat transfer coefficients between the glass cover and the ambient,

$$h_{1g} = h_{rg} + h_{cg},$$

h_{rg} and h_{cg} radiative and convective heat transfer coefficients and are given by,

$$h_{rg} = \varepsilon_w \sigma\left[\frac{(T_g + 273)^4 - (T_a + 261)^4}{(T_g - T_a)}\right]$$

and $h_{cg} = 2.8 + 3v_a$

and τ'_1 in equation (4) is the fraction of solar energy absorbed by glass cover without flow of water over it.

C. Water Mass

$$h_3(T_b - T_w) + \tau_2 S = M_w c_w \frac{dT_w}{dt} + h_1(T_w - T_g) \quad \text{(6)} \quad \text{--- (6)}$$

here T_b is the temperature of basin liner, T_g is the temperature of glass cover . τ_2 is the fraction of solar energy absorbed by water mass,; τ_2 is replaced by τ'_2 when the glass cover is without a water film. h_3 is the heat transfer coefficient between basin liner and water. M_w is the mass of water in basin.

D. Basin Liner

$$\tau_3 S = h_3(T_b - T_w) + h_b(T_b - T_a) \quad \text{--- (7)} \quad \text{(7)}$$

where τ_3 is the solar energy absorbed by basin liner and τ_3 is replaced by τ'_3 when the glass cover is without a water film. h_b is the heat transfer coefficient between basin and air, is given by,

$$h_b = [\frac{1}{h_3} + \frac{L_i}{K_i} + \frac{1}{h_4}]^{-1}$$

L_i and K_i are thickness of basin liner and thermal conductivity of basin material (FRP), h_4 is the convective heat transfer coefficient between base and ambient, and it is given by [16],

$$h_4 = 5.7 + 3.8v_a$$

v_a is the average wind velocity.

E. Efficiency of Fountain System

Efficiency of fountain system is given by,

$$\eta_f = \frac{T_a - T_e}{T_a - T_{wb}} \quad \text{--- (9)}$$

Here T_a and T_e are the inlet temperature of water in water fountain (ambient temperature) and exit water temperature from fountain reservoir, which will be equal to inlet temperature of water into the glass cover of solar still. T_{wb} is wet bulb temperature of ambient, from Eq. (7) exit water temperature from fountain reservoir or inlet temperature of water into the glass cover is given by,

$$T_e = T_{fi} = T_a - \eta_f (T_a - T_{wb}) \quad \text{--- (10)}$$

T_{fi} is inlet temperature of water into the glass cover or initial water temperature at x=0.

Eqs.(1-8) can be solved to determine the values average film temperature, average glass temperature, temperature of water in basin. Eq.(1) can solved to determine exit film temperature at *x=l*, by substituting initial film temperature at x=0 as T_{fi}(Eq.10), and Eq. (6) can be solved to determine temperature of water in basin by substituting time step of 1hour, by solving above equations,

F. Hourly Yield Of Solar Still Is Given By

$$\dot{m}_e = \frac{h_{ew}(T_w - \overline{T_g})}{L} x3600 \quad (11)$$

Daily, monthly and annual yield is given by,

$$M_d = \sum_1^{24} \dot{m}_e \, , \quad M_a = \sum_1^{24} M_m \, , \quad M_a = \sum_1^{24} M_m \qquad M_m = M_d n \quad (13)$$

G. Fraction Of Solar Energy Absorbed By Glass Cover, Water And Basin Of Still

For normal incidence of light, the reflection coefficient at the interface of two media is given by,

$$R = \frac{(\mu_1 - \mu_2)^2}{(\mu_1 + \mu_2)^2},$$

where μ_1 and μ_2 are refractive indices of the two media.

Fraction of solar energy absorbed by the glass cover is,

$$\tau_1 = \alpha_g (1 - R_{aw})(1 - R_{wg}) \text{ with water film} \quad (15)$$

where R_{aw}, R_{wg} and R_{ag} are the reflection coefficient of air-water, water-glass and air-glass interfaces respectively and α_g is the absorption coefficient of glass cover and is given by

$$\alpha_g = 1 - \exp(-\beta_g l_g)$$

l_g is the thickness of the glass cover and β_g is the attenuation factor of glass.

Fraction of solar energy absorbed by water in the basin is,

$$\tau_2 = P\alpha_w + P(1 - \alpha_w)(1 - \alpha_b). \quad (16)$$

$P = (1-\alpha_g)(1-R_{aw})(1-R_{wg})(1-R_{gw})(1-R_{wa})(1-R_{aw})$ here R_{gw}, R_{wa}, R_{aw} are the reflection coefficients of glass-water, water-air, and air-water interface respectively; α_w and α_b are the absorption coefficients of water and basin.

Fraction of solar energy absorbed by the basin is,

$$\tau_3 = P(1 - \alpha_w)\alpha_b.$$

(1

III. VALIDATION OF MATHEMATICAL MODEL

A. Experimental Validation of Mathematical Model

Mathematical model of single slope solar still developed is experimentally validated for climate of Raipur (Chhattisgarh) by observing hourly distillate output with the flow of water over the glass cover of still

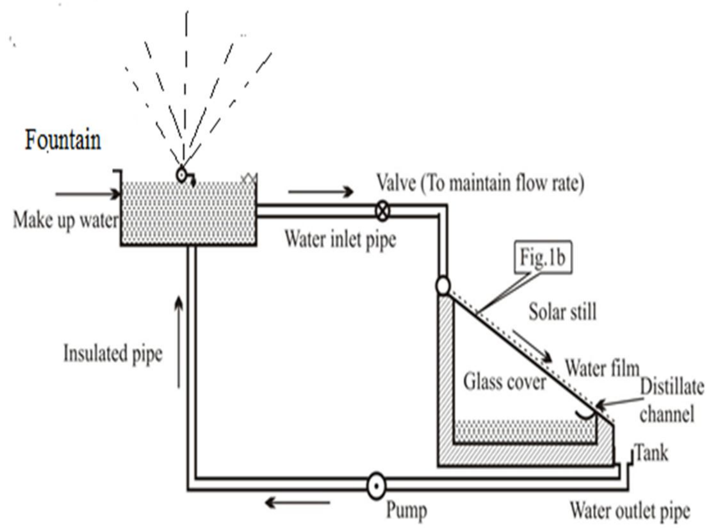


Fig: Schematic representation of a solar still coupled to a fountain reservoir

B. Description of Solar Still

The photograph of the experimental set-up of the single slope solar still is shown in the figure below. Solar still is made up from the mild steel plate of thickness (5mm), a slot is provided in the front face of the solar still is to fix a glass cover on the top of the solar still. Glass of thickness (4mm) and area $1m^2$ is fixed in the top of the solar still. Temperature sensor (RTD) is connected on the top of the glass cover to determine the temperature of the glass cover. Above the glass cover on the top a PVC pipe with holes at uniform distance is fixed as shown in the figure to allow water flow uniformly over the glass cover. In the bottom a gutter (Half cut pipe) is fixed to collect the water flowing over the glass cover. To allow the water flow over the glass cover and back to the fountain an inlet pipe and exit pipe is connected. The solar still is connected to the reservoir of the garden fountain as shown in the figure.

The experiment was performed in the climate of Raipur (Chhattisgarh). To measure the temperature of the basin water RTD temperature sensors are connected in the bottom of the solar still. To avoid the heat loss to surroundings the solar still is insulated from sides and bottom by thermocole sheet of thickness 5cm. The humidity of the air is measured by a hygrometer with accuracy of 5%. The Pyranometer is used to measure solar radiation

C. Experimental Instruments

The following instruments are used while performing the experiment:

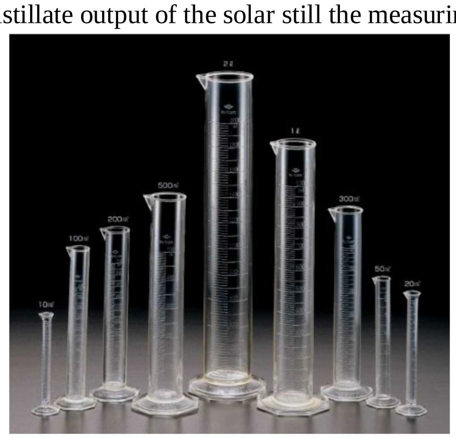
1) *Hygrometer/ Pschrometer:* Hygrometer (Maxtech) was used to measure the relative humidity of inlet and exit air. The least count of hygrometer 1% with accuracy ±5% and range was between 10% to 90%

2) *Temperature sensor (RTD):* Thermocouples (Temptech) Copper–Constantan calibrated thermocouples were used to measure the temperatures at various points with least count 0.1^{o}C and accuracy ±0.5% .

3) *Pyranometer (Kipps & Zenon):* A silicon SP lite pyranometer to measure the intensity of solar radiation falling on glass cover with sensitivity 60 to 100 $V\ W\ m2$ and maximum irradiance 2000W/m^2 [Fig.]

4) *Anemometer (Vane Type):* Anemometer (HT-628) was used to measure the velocity of air. It had a least count of 0.1m/s with accuracy ±3%±0.1 and range between 0m/s to 45m/s. [Fig.].

5) *Measuring Cylinders:* To measure the distillate output of the solar still the measuring cylinders made of glass (borosil) are used



D. Experimental Observations

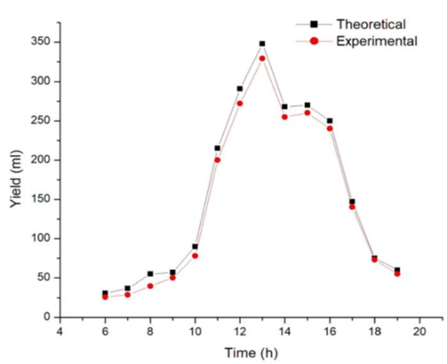
Experiment was performed in month of May 2019, in Raipur (Chattisgarh), basin of single slope solar still is filled with impure water depth (2cm), The experimental solar still is coupled to the reservoir of the garden fountain and the following observations are taken

1) Hourly yield (ml) produced by solar still
2) Ambient temperature, glass cover temperature and temperature of water in basin of solar still.
3) Hourly solar intensity (insolation) falling over glass surface.
4) Velocity of air

Average temperature of glass cover, temperature of water in basin and theoretical yield is computed by the proposed mathematical model in chapter 2 by using Eqn. (11). Theoretical values are compared with observed (experimental) values and shown in table and figure below, mass flow rate of the water flowing over the cover is computed before starting observations. The time taken to fill the volume of the known vessel is measured to determine the mass flow rate. The mass flow rate of the water flowing is determined equal to 0.0062kg/s. The depth of the water in the basin of the solar still is taken as 2cm. To determine the temperature of the water inlet to the glass considered as 0.8 (80%).

Table 3.1 Theoretical and experimental yield from single slope still for Raipur climate

Time (h)	Ambient Temp. (^oC)	Thermal radiation (W/m^2)	Th. yield (m_{th}) (ml)	Ex. Yield (m_{ex}) (ml)	% Deviation
6.00	11	0	31	26	16
7.00	12	21	37	29	21
8.00	17	229	55	40	27
9.00	19	486	57	50	12
10.00	22	705	90	78	13
11.00	28	865	215	200	7
12.00	29	930	291	272	6
13.00	31	976	348	329	5
14.00	36	898	268	255	5
15.00	34	775	270	260	4
16.00	33	584	250	240	4
17.00	31	321	147	140	5
18.00	28	41	75	73	3
19.00	22	20	60	55	8



Graph b/w Theoretical & Experimental values

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E. Determination of the Coefficient of Correlation (r)

The relationship between the theoretical values and experimental values is presented by a coefficient called as coefficient of correlation (r). The coefficient of correlation can be evaluated with the help of following expression as given by,

$$r=\frac{N\sum X_{pre}X_{exp}-(\sum X_{pre})(\sum X_{exp})}{\sqrt{N\sum X_{exp}{}^{2}-(\sum X_{exp})^{2}}\sqrt{N\sum X_{pre}{}^{2}-(\sum X_{pre})^{2}}}$$

Here N is the number of observations. The experimental and theoretical values are said to be in a strong correlation, if the value of r is close to 1.

The value of the correlation coefficient (r) is computed by above formula by putting the theoretical and experimental observations given in the table 3.1. it is seen that the coefficient of correlation r is 0.987 which is very close to 1. It means that the experimental values are reasonably close to the theoretical values. The percentage deviation between the experimental and the theoretical values is between 3% to 27%.

IV. NUMERICAL COMPUTATIONS

Numerical computations have been done to study the effect of the parameters like the mass flow rate of the water flowing over the glass cover of the solar still and the depth of the water in the basin of the solar still. Meteorological date for a day has to be considered to compute the distillate output. In the present work for numerical computations the data of hot climate of Jodhpur has been considered for the numerical computations it is referred by Tiwari []. The other parameters considered for the numerical computations are given in table 4.1. For numerical computations initial temperatures of water and glass were assumed to be nearly equal to,

1) Ambient and
2) Nearly equal to the wet bulb temperature of ambient air.

Heat transfer coefficients and other temperature dependent constants were computed by use of initially guessed values, by considering time step of one hour and length of still (1 m). Exit film temperature and average film temperature, average glass temperature with and water temperature is computed from the proposed model. For computing daily yield process was repeated till the daily cycle repeated itself. Efficiency of the fountain system is considered as 0.8.

A. Effect Of The Mass Flow Rate Of Water Flowing Over Cover

To investigate the effect of mass flow rate of water flowing over condensing cover on distillate output of solar still. Daily yield of solar still with flow of water is computed at different mass flow rates for hot and dry climate of Jodhpur with water flowing at wet bulb temperature (from fountain tank). Depth of water in basin is considered as 2cm, mass flow rates considered are 0.010kg/s, 0.025kg/s,0.050kg/s, 0.075kg/s and 0.085kg/s**.** Monthly average of wind velocity is considered while computation, variation of daily yield at different mass flow rates for a typical day in summer for Jodhpur is numerically computed by keeping depth of water in solar still constant (2cm) and graphically shown in Fig. 4.3.

Table 4.1 Still parameters used for numerical computations.

$(MC)_w = 83800\,J/K.m^2$	$d_w = 0.02m$
$A_g = A_b = 1m^2$	$\alpha_g = 0.05$ [70]
$h_w = 135W/m^2K$ [39]	
$h'_2 = 135W/m^2K$ [39]	
$\alpha_w(0.02m) = 0.32$ [70]	
$\varepsilon_{eff} = 0.82$[70]	$,\varepsilon_w = 0.95$[70]
$\sigma_s = 5.67x10^{-8}W/m^2K^4$	$,e_{g1} = 0.94$[70]

Day-1(Summer/May)			
Time	T_a (°C)	γ	S (W/m^2)
01	29.2	32	0
02	28.4	32	0
03	27.9	34	0
04	27.4	34	0
05	27.3	34	0
06	27.6	33	166
07	28.3	33	378
08	29.6	30	586
09	31.4	28	763
10	33.6	25	901
11	36.0	22	985
12	38.3	18	1016
13	40.0	17	985
14	41.2	17	901
15	41.6	17	763
16	41.2	17	586
17	40.2	18	378
18	38.6	18	166
19	36.7	20	0
20	34.9	23	0
21	33.3	24	0
22	31.9	27	0
23	30.7	28	0
24	29.9	30	0

Table 4.2 Meteorological data of Jodhpur (India).

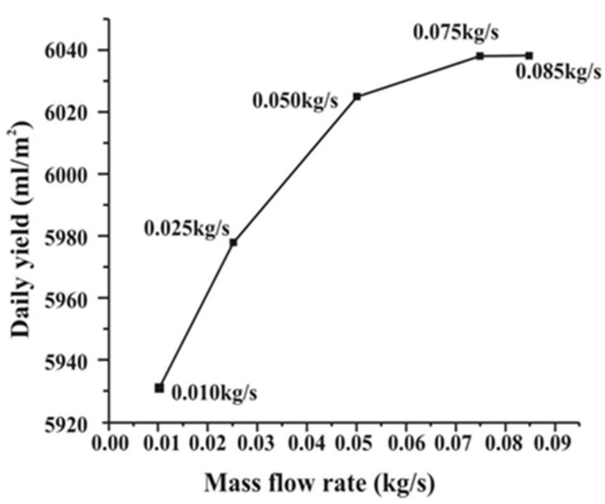

Fig. 4.1: Effect of mass flow rate on performance of still

It is seen that with flow of water from fountain there is very little increase in yield with increase in mass flow rate. As rate of evaporation of flowing water is very less (almost negligible) there is a slight increase in temperature of water flowing over cover, which is more at a low mass flow rate and thus decreases the temperature difference between water in basin and average temperature of glass cover, yield increases only by 1.8% from mass flow rate of 0.010kg/s to 0.075kg/s; it tends to saturate at mass flow rate of 0.075kg/s.

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B. Effect Of Depth Of Water In The Basin Of Still

To study the effect of depth of water in the basin of still, the daily yield is computed for a day in summer with 0.02m, 0.05m, 0.1m water depth in basin is computed and shown in Table 4.7, mass flow rate is taken as 0.075kg/s (flowing water from fountain) and 0.001kg/s . Monthly average of wind velocity is considered for computation is taken as 4.2 m/s. Other relevant parameters for computations are same as given in the table

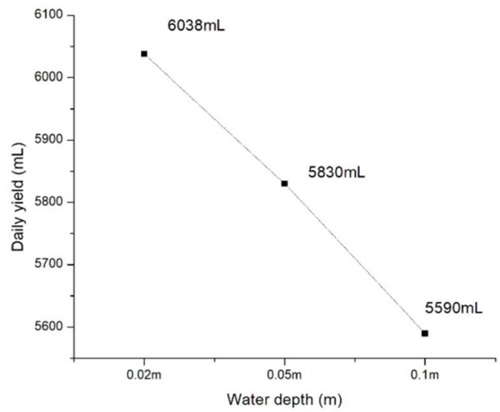

Fig. 4.2 Effect of depth of water in the basin on performance of still

It is seen that the yield increases at lower water depths in comparison to higher depth of water in still. As the heat capacity of water in the basin is small for lower depth, the rise in temperature of water in basin is more which increases production rate of still.

The daily yield at a depth of 2cm (0.02m) is 6038mL and at depth of 5cm (0.05m) it is 5830mL and at 10cm(0.1m) depth the daily yield is lowest 5590mL. It is clearly seen that the daily yield increase to about 8% when the depth in the basin of still decreases to 2cm from 10cm.

V. CONCLUSIONS

A. A mathematical model of the solar still with the provision of cooled water flowing over the glass cover has been developed .The proposed model has been validated by conducting a experiment in a day of May month in Raipur Chhattisgarh (latitude 21.250000 and longitude 81.629997). It is seen that the experimental values are reasonably close to the theoretical value, the value of correlation coefficient " r " is 0.987 and it is close to 1 (the degree of freedom considered here is 14).

B. To study the effect of parameters like mass flow rate and depth of water in solar still numerical computations have been made . It is seen that the yield increases with increase in the mass flow considering. The increase in yield is about 1.8% when the mass flow rate is increased from 0.010 kg/s to 0.075kg/s moreover the yield tends to saturate at a mass flow rate of 0.075kg/s. Performance of solar still is good when the lower depth of water is considered.

C. The obvious reason is at low depth the thermal capacity is low and the rise in temperature will be more it is seen that the daily yield increases to about 8%.when the depth of water in basin of still decreases 2cm from 10cm

REFERENCES

[1] Frick G, Sommerfield J V., Solar still of inclined evaporating cloth., Solar energy 14, 427, (1973).
[2] M S Sodha, G.N Tiwari, R C Tyagi., Simple multiple wick solar still: analysis and performance, Solar energy 26, 127, (1981).
[3] G.N Tiwari, S.B Sharma M S Sodha. Performance of double condensing multiple wick solar still.Energy conversion management 24, 193-199, (1984).
[4] Sanjeev Kumar, G.N Tiwari, H.N Singh., Annual performance of active distillation system., Desalination 127, 79-88, (2000).
[5] Rajesh Tripathi and G.N Tiwari., Thermal modeling of passive and active solar stills for different depth of water by using the concept of solar fraction., Solar Energy 80, 955-957, (2006).
[6] G.N Tiwari, S.K Shukla, J.P Singh., Computer modeling of passive/ active solar stills by using inner glass temperature., Desalination 154, 171-185, (2003).
[7] M.S. Sodha, A. Kumar, G.N. Tiwari, G.C. Pandey., Effects of dye on the performance of a solar still., Applied Energy 7, 147-162, (1980).
[8] A.K. Tiwari, G.N. Tiwari., Effect of condensing cover's slope on internal heat and mass transfer in distillation: an indoor situation., Desalination 180, 73-88, (2005).
[9] A.K. Tiwari, G.N. Tiwari., Effect of water depths on heat and mass transfer in a passive solar stills in summer condition., Desalination 195, 78-94, (2006).
[10] Salah Abdallah, Mazen M. Abu-Khader, Omar Badran., Effect of various absorbing materials on the thermal performance of solar., Desalination 242, 128-137, (2009).

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue XII, Dec 2019- Available at www.ijraset.com

[11] H.N. Singh, G.N Tiwari., Monthly performance of passive and active solar stills for different Indian climatic conditions., Desalination 168, 145-150, (2004).
[12] G.N. Tiwari, V.S.V. Bapeshwara Rao., Transient performance of a single basin solar still with water folwing over the glass cover., Desalination 49, 231-241, (1984).
[13] Bassam A.K Abu-Hijleh., Enhanced solar still performance using water film cooling of the glass cover., Desalination 107, 235-244 (1996).
[14] G.N. Tiwari, Maduri, H.P. Garg., Effect of water flow over the glass cover of a single basin solar still with an intermittent flow of waste hot water in the basin., Energy Convers. and Management, 25-3, 315-322, (1985).
[15] S.A. Lawrence, S.P. Gupta, G.N. Tiwari., Effect of heat capacity on the performance of solar still with water flow over the glass cover., Energy Convers. and Manag. 30, 277-285, (1990).
[16] Bassam A.K Abu-Hijleh, and Hasan A. Mousa., Water film cooling over the glass cover of solar still including evaporation effects., Energy 22-1, 43-47, (1997)
[17] Ahmed and Alfayalakawi., Productivity enhancement of conventional solar still using water sprinkler and cooling fan., Journal of advanced science and engg. Research 2-3, 168-177, (2012).
[18] Badran O.O., Experimental study of the enhancement parameters of single slope solar still productivity., Desalination 1-3, 136-143, (2009).
[19] R. Mukherjee, GN Tiwari., Economics of various designs of conventional solar stills .Energy conversion and management 26, 155-167, (1986).
[20] Delynnis , Dellynis, ., Economics of solar stills ., Desalination 52, 167-176, (1985)
[21] Tleimat BW, Howe ED. Nocturnal production of solar distillers. Solar Energy 10, 61–6., (1996)
[22] Madani AA, Zaki GM. Yield of stills with porous basins. Applied Energy52:273, , (1995)
[23] G.N Tiwari., Solar Energy Fundamentals, Design Modeling and Applications, Narosa publishing house, New Delhi, (2002).
[24] Meteorological data center , Raipur (Chhattisgarh).