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Design, Fabrication, and Performance Evaluation of Double Slope Active Solar Still under Forced Circulation Mode

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Abstract

Water is fundamental to human life on earth for survival and good health. Access to safe water is a major challenge in many communities in developing countries. As world population and social-economic growth, societies are challenged to provide fresh water to meet those needs for all of their people. Growing demands of freshwater resources are creating an urgent need to develop self sustained system to meet the demand of fresh water. Among the available purification technologies, solar desalination process proves to be a suitable solution for resolving this existing crisis. This renewable energy technology operates on a basic principle of solar water distillation. The sun's energy heat increases the rate of evaporation. As the water evaporates, water vapor rises and condenses on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. In this study, a basin type double slope active solar still under forced circulation mode was designed and fabricated, and a performance evaluation were carried out for different water depths viz 0.03 m, 0.04 m and 0.05 m. The distillate output is maximum 4.82 kg for water depth 0.03 m and minimum 4.36 kg for water depth 0.05 m. The maximum instantaneous thermal efficiency is 46.96 at water depth of 0.04 m.

Keywords: *Active solar still, Water depth, Instantaneous thermal efficiency*

1. Introduction

The need for safe, clean drinking water is increasing rapidly. Rapid economic growth and climate change have resulted in increasing pressure on quality and quantity of water resources-especially in tropical and developing countries. There is often enough water available, but it is salty, brackish and need technique to make it safe to drink. Emerging desalination technology using renewable energy is viewed as a feasible alternative to supply water as it can be cost effective but also has potential to transform the lives of people living in small communities in remote areas and islands.

Many research works on design, fabrication methods, and performance evaluation of solar distillation have been carried out by various researchers throughout the world since ancient times. Zaki et al. studied an active system of conventional single-slope solar still integrated with a flat plate collector under thermo siphon mode of operation and found that the maximum increase in the yield was up to 33% when the water in the still was preheated in the collector [1]. Mink et al. proposed an air-blown solar still with heat recycling to produce fresh water. They reported a threefold increase in yield using the heat recovery [2]. Kwatra simulated the quantitive relationship between the evaporation area and distillate yield [3]. Khalifa et al. constructed several single and double slope solar stills. They studied the effect of feed water preheating on performance of solar still. The results showed improvements in the output and efficiency of the solar stills [4]. Shruti et al. developed the convective mass transfer relation for double condensing chamber solar still. In relation $Nu = C(GrPr)^n$, the values of C and n were determined using regression analysis for different temperature ranges and found that the values of C and n proposed by Dunkle are valid only for lower temperature ranges, however for higher temperature ranges the values of C and n change [5]. Rubio et al. evaluated the distillate yield for a double-slope laboratory still under controlled conditions for basin water and collector temperatures within typical operating ranges and propose a new empirical model for estimating mass flow rates in single slope solar stills [6]. Nafey et al. developed an equation to predict the daily productivity of a single-sloped solar still. The developed equation relates the dependent and independent variables which control the daily productivity [7]. Tripathi and Tiwari have developed the thermal models to

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establish the energy balance equations of passive and active solar still with different concepts and in different operating modes and validated the theoretical results with the experimental results [8]. Abu-Hijleh et al. studied the effects of sponge cube and showed that the daily production of solar still can be greatly enhanced [9]. Radhwan studied the transient performance of a stepped solar still with built-in latent heat thermal energy storage and conclude that efficiency and fresh water production rate increased [10]. El-Sebaii studied the thermal performance of a triple-basin solar still based on an analytical solution of the energy-balance equations. It was found that productivity of the lower basin is higher than the productivities of the middle and upper basins during the daytime [11]. Sow et al. have carried out the exergy analysis to define the thermodynamic efficiency correctly, expressing the degree of perfection. They reported the exergetic efficiencies in the range of 19-26% for triple effect system, 17-20% for double effect system, and less than 4% for single effect system [12]. Shukla and Sorayan develop a thermal model for multi-wick single and double slope distillation system with different assumptions and predicted the result in fair agreement with experimental results using modified internal heat transfer coefficients [13]. Phadatare et al. studied the influence of water depth on internal heat and mass transfer in a plastic solar still and found that maximum distillate output of 2.1 L/m^2/day, at water depth of 0.02m in still basin, could be achieved [14]. Sakthivel and Shanmugasundaram have shown that the efficiency of single slope solar still using the black granite gravel reaches up to 52% maximum which is 8% higher than the conventional single slope solar still [15]. A. Ahsan and T. Fukuhara proposed a new mass and heat transfer model of a tubular solar still incorporating various mass and heat transfer coefficient taking account of the humid air properties inside the still [16]. O. Badran studied the performance of active single slope solar still using different operational parameters theoretically and compared with the experimental data for validation purposes, to find out best factors enhancing still productivity [17]. Rajamanickam and Ragupathy study the effects of orientation and depth of water in the basin of the still on the productivity of a double slope solar still and compare the same with that of a single slope solar still [18]. Ghenai and Janajreh studied comparison between renewable, fossil fuel and nuclear power systems and shows that efficiency of solar power is only 10% to 18% compared to 30-50 % for conventional and nuclear power systems; and the capacity factor for solar power is as low as 10% compared to 80% for conventional power system [19]. H. Fath et al. explore the current desalination technologies and their respective energy demands in Gulf Cooperation Council (GCC) countries with different alternatives to reduce energy consumption and analyzes the present and the future prospective of water production rates and trends as well as the corresponding energy consumptions [20].

In this study double slope active solar still under forced circulation mode was designed and fabricated, and distillate output and instantaneous thermal efficiency were calculated different water depths viz 0.03 m, 0.04 m and 0.05 m.

2. Design and fabrication of solar still

The distillation system consists of four main parts as shown in schematic diagram fig.1.

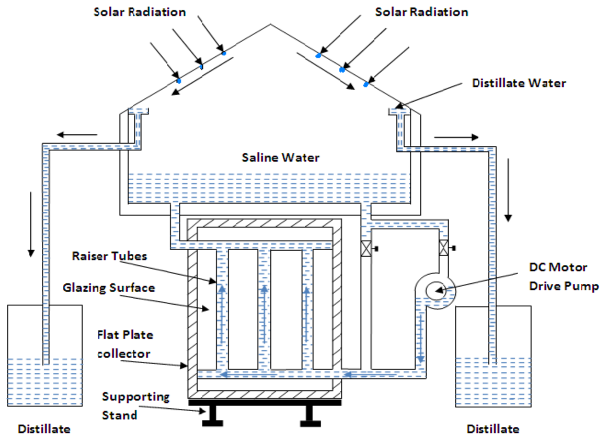

Fig.1. Schematic diagram of double slope active Solar still

(i) The solar still is simple equipment without any moving parts. The body of solar still basin is made up of a fibre reinforced plastic (FRP) to stand-up to the harsh conditions produced by water and sunlight. The advantages of FRP over traditional reinforcing materials such as glass fibre, carbon fibre etc are their specific strength properties, easy availability, light weight, ease of separation, enhanced energy recovery, high toughness, non-corrosive nature, low density, low cost, good thermal properties, reduced tool wear, reduced dermal and respiratory irritation, less abrasion to processing equipment, renewability and biodegradability. The basin area of the solar still is kept as 2 m^2. The heights of the solar still at lower and higher sides are 0.20 m and 0.66 m respectively. The thickness of FRP body is kept as 0.006 m. The bottom surface of the solar still is painted black to have high absorptivity of solar radiation. The top of the basin is covered with glass of thickness 0.004 m, inclined at 25^0 and oriented due East and West (E-W) direction respectively to receive the maximum possible solar radiation. A hole is provided at the bottom surface of the basin to drain water and impurities for cleaning of solar still. Holes are also drilled in the body of solar still to fix the thermocouple to monitor temperature of water, inner condensing cover and vapor. A separate hole is also provided for replenishing raw water in the basin. The whole system is made vapor tight using silicone rubber sealant, as it remains elastic for long time.

(ii) Flat-plate collector is a metal box with a glass cover (called glazing) on top and a black-colored absorber plate on the bottom. The sides and bottom of the collector are insulated to minimize heat loss. The casing of collector plate surrounds the various components and keeps it free from dust and external environments. The rubber gaskets are used to attach the glass cover with the walls of the casing. The flat plate collector used in double slope active solar still is of copper tube- aluminum absorber type. The Aluminum sheet is painted black to work as an absorber plate. Window glass of 0.004 m thickness is used as glazing over the collector body. Ten risers used in the collector plate are made of copper and are brazed to the two headers of diameter 0.0127 m each. The spacing between consecutive copper tubes is 0.12 m. The copper tubes are in contact with the Aluminum absorber plates.

(iii) The DC water pump of size 40W is used to circulate the water in forced mode of operation. The pump is driven directly by the DC power. The pump operates only during sunshine hour, to avoid reverse heat flow from water during off sunshine hours.

(iv) The condensed water is collected in a galvanized iron channel fixed at the lower end side of both the glass covers. The distillate collected is continuously drained through flexible pipe and stored in a jar placed outside on both side.

2.1. Measuring Instruments

2.1.1 Measurement of temperature

Copper (100% Cu)-constantan (55% Cu + 45% Ni) thermocouple were used to measure water, water vapor and condensing cover temperature. Thermocouples used in the experiment are properly calibrated with the help of zeal thermometer (standard thermometer). The ambient air temperature is recorded with the help of a calibrated mercury thermometer having a least count of 1°C.

2.1.2 Measurement of distillate yield

The condensed water is collected in a galvanized iron channel fixed at the lower end side of both the glass covers. The distillate collected is continuously drained through flexible pipe and stored in a jar placed outside on both side. The collected distillate yield has been measured using graduated cylinder with least count of 1 ml.

2.1.3 Measurement of solar radiation

The sun emits an electromagnetic radiation with different wavelengths and with a peak centered in the visible spectrum. This radiation is arrive to the earth ground must go through the earth atmosphere, where suffer absorptions, refractions, reflections and emissions that work in selective way. Every element in the atmosphere in fact reacts in different way to the various electromagnetic radiation wave lengths that is every component absorbs and emits the radiation to a different wave length (absorbing the radiation it heats in accordance with the reached temperature and emits a different one). This fact provokes that the solar radiation to the ground level has a spectrum much different from the extra atmospheric level.

The solar intensity was measured with the help of a calibrated solarimeter, having least count of 2 mW/ cm2 (20 W/m2). Solarimeter contains a thermopile, which measures the temperature difference between a calibrated blackened surface and the temperature of the body of the instrument, which for this purpose is approximately constant. A plastic dome protects the sensing surface, and has suitable optical transmission properties to allow radiation in the 300nm to 3micron range to pass un-attenuated.

3. Experimental Set-up

The photograph of double slope active solar still under study have been shown in fig.2. In active solar still, the flat plate collector is integrated with double slope active solar still in such a way that the hot water from collector plate enters into the basin of solar still under forced circulation mode. The inlet and outlet connections to the collector plate are taken from the bottom of the basin as shown in Figure 1a. A gate valve has been provided in the inlet pipe to control the circulation of water through the collector plate. The collector plate absorbs the solar energy and transfers that energy to water flowing through tubes. The double slope solar still placed in east-west direction and collector plate was inclined at 30^o facing south to receive the maximum possible solar radiation as shown in fig.2.

Fig.2. Photograph of double slope active solar still set up

4. Experimental Procedure

Outdoor and Indoor tests of the solar distillation system were carried out with various variables. Those steps have been classified according to their time relative to the data collection i. e. before, during and after data collection.

4.1 Before data collection

- A proper adhesive was applied on all side, at all joints of distillate carrying channels to ensure leak proof collection of distillate.
- Sponge rubber gasket and silicon wax were used between the contact surface of condensing cover and basin to avoid any chances of vapor leakage.
- The lower edges of the still were set horizontally using the spirit level.
- The inclination angle of the flat plate collector was set with the aid of the inclinometer.
- The required flow rate of the feed water was adjusted by measuring the over-flow rate and the distillation rate, with the aid of a stop watch and measuring cylinder.

4.2 During data collection

The following were the parameters measured every hour for a period of 24 hours during each experiments conducted.

- Outer glass cover temperature
- Inner glass cover temperature
- Water vapor temperature
- Water temperature in the basin
- Ambient air temperature
- Solar intensity on glass cover
- Solar intensity on collector plate
- Weight of distillate yield

4.3 After data collection

Analysis has been carried out as discussed in the subsequent section.

4.4 Procedure

Experiments were conducted at the Galgotias College of Engineering & Technology Greater Noida, UP, India (latitude 28.4962° N, longitude 77.5360° E, altitude 200 m from mean sea level) throughout a year starting from July 2011 to June 2012 and carried out from 9 a.m. and lasted for 24 hr. During experimentation, properly calibrated thermocouples were fixed at the inner and outer surfaces of condensing covers and inside the water to measure the condensing cover and water temperature. One thermocouple is hung between water and condensing cover to measure vapor temperature. The basin is then filled with required quantity of water, one day before the start of experiment to attain steady state condition. The condensing covers are cleaned properly before the start of experiment. Experiments were conducted at the water depth of 0.03 m, 0.04 m and 0.05 m. During experiment when water depth was varied from 0.03 m to 0.04m and 0.05 m, the solar stills were left idle for one day to achieve steady state condition before the start of next day experiment. Experiments at each water depth are started at 9:00 a.m. in the morning and continued for 24 hours.

5. Experimental Observations

The temperatures of water, glass cover and water vapor were recorded with the help of calibrated copper constantan thermocouples in combination with a digital temperature indicator. The ambient temperature is measured by calibrated mercury thermometer. The distillate from the still was measured using measuring jar. The blackish was supplied to the flat plate collector using tap valve. The solar radiation on inclined plane facing east and west were measured using a solarimeter. Table 1 shows the accuracies and error for various instruments used.

Table 1. Accuracies, range and error for various measuring instruments

No.	Instrument	Accuracy	Range	% Error
1	Thermometer	±1^{0}C	0–100^0 C	0.25
2	Thermocouple	±0.1^0 C	0–100^0 C	0.5
3	Solarimeter	±20 W/m^2	0–2500 W/m^2	0.5
4	Measuring jar	±1 ml	0–1000 ml	1

The experiments were carried out to study the effect of water depths (0.03, 0.04 and 0.05 m) on the performance of double slope active solar stills. The experimental observations for water depth 0.03 m, 0.04 m and 0.05 m for a typical day have been given in Table 2, Table 3 and Table 4, respectively.

Table 2. Measured Parameters for 0.03 m Water Depth in a Double Slope Active Solar Still of 25^0 Inclination of Condensing Cover on a Day of August 10, 2011.

					Double Slope (East side)				Double slope (Westside)			
Time	T_a	T_w	T_v	I_c	T_{coE}	T_{ciE}	I_{tE}	m_{wE}	T_{coW}	T_{ciW}	I_{tW}	m_{wW}
9 AM	31	35.7	39	320	40.3	31.7	360	0.023	38.8	31.3	240	0.014
10 AM	31	37.8	35.4	420	45	32.6	440	0.011	42.9	31.6	360	0.015
11 AM	32	41.3	34.5	480	54.2	33.8	560	0.101	51.6	33.9	460	0.112
12 Noon	32	44.6	33.4	580	60.5	33.8	600	0.142	59.7	35.1	640	0.237
1 PM	33	49.8	37.3	720	62.8	34.2	640	0.238	63.4	36.2	700	0.303
2 PM	33	55.2	40.7	660	66.1	35.7	660	0.332	66.9	37.5	680	0.352
3 PM	34	63.4	52.3	460	62.3	36	300	0.354	63.5	38.3	420	0.325
4 PM	33	60.7	52.6	300	60.5	38.9	180	0.274	62.9	39.2	280	0.308
5 PM	32	54.7	47.6	140	60.2	40.8	80	0.258	63.5	42.6	180	0.217
6 PM	31	50.5	44	0	50.2	37.4	0	0.143	54.6	41.5	0	0.144
7 PM	30	44.6	38.4	0	40.6	33	0	0.118	41.8	38.3	0	0.098
8 PM	30	41.4	35.9	0	36.6	32	0	0.081	37.4	37.2	0	0.064
9 PM	30	38.6	35.4	0	35.4	32	0	0.059	36.2	34.6	0	0.058
10 PM	29	35.8	34.2	0	33.9	31	0	0.053	34.5	33.6	0	0.039
11 PM	29	33.8	32.6	0	33	30.7	0	0.045	33.6	32.5	0	0.025
12 PM	28	32.7	31.5	0	32.5	31	0	0.038	32.9	31.8	0	0.018
1 AM	28	32.3	30.9	0	32.1	30.9	0	0.03	32.5	31.3	0	0.016
2 AM	28	31.7	30.5	0	31.5	30.7	0	0.026	31.1	30.8	0	0.014
3 AM	27	31	29.9	0	30.6	30.2	0	0.022	30.3	30.6	0	0.014
4 AM	27	31	30.5	0	29.1	29.6	0	0.02	28.9	29.9	0	0.013
5 AM	27	30	30.4	0	28.6	29.1	0	0.014	28.4	29.4	0	0.013
6 AM	26	30	30.5	0	27.8	28.6	0	0.013	27.1	28.8	0	0.009
7 AM	29	33.2	34.4	100	29.3	30.5	100	0	28.2	29.5	60	0
8 AM	30	34.6	36.7	200	34.3	30.8	220	0.011	33	29.3	180	0.009
Total								2.406				2.417

Table 3. Measured Parameters for 0.04 m Water Depth in a Double Slope Active Solar Still of 25^0 Inclination of Condensing Cover on a Day of August 17, 2011.

					Double Slope (East side)				Double slope (Westside)			
Time	T_a	T_w	T_v	I_c	T_{coE}	T_{ciE}	I_{tE}	m_{wE}	T_{coW}	T_{ciW}	I_{tW}	m_{wW}
9 AM	28	33.5	37.7	380	41.7	32.3	360	0.019	40.1	30.6	260	0.015
10 AM	29	38.8	41.2	500	46.8	33.4	480	0.008	44.5	31.3	400	0.009
11 AM	29	43.4	38.9	560	55.1	35.4	580	0.05	52.3	32.2	520	0.046
12 Noon	30	48.6	38.8	620	61.4	36.8	660	0.087	60.2	33.7	640	0.129
1 PM	30	52.4	40.8	680	65.4	37.8	600	0.176	64.9	37.9	660	0.241
2 PM	32	55.3	41.5	520	68.4	38.7	500	0.274	69.3	38.2	620	0.297
3 PM	33	58.2	46.7	360	63.9	41.5	320	0.333	65.2	40.2	420	0.316
4 PM	33	55.3	44.8	220	57.8	44.3	200	0.295	60.1	45.8	260	0.257
5 PM	32	49.1	39.7	80	51.9	40.6	80	0.236	55.3	42.4	160	0.219
6 PM	32	45.8	37.2	0	47	36.4	0	0.193	51.2	38.4	0	0.197
7 PM	32	43.2	35.6	0	38.3	32.7	0	0.153	40.4	34.3	0	0.141
8 PM	31	38.3	31.9	0	33.6	28.9	0	0.098	34.7	32.5	0	0.078
9 PM	31	35.2	30.9	0	30	26.6	0	0.084	30.9	31.2	0	0.072
10 PM	30	34.2	30.5	0	28.8	26.6	0	0.068	29.6	31.2	0	0.056
11 PM	28	33.3	30.4	0	27.5	26	0	0.058	28.2	30.3	0	0.044
12 PM	27	31.4	28.9	0	27.1	26	0	0.035	27.6	29.2	0	0.028
1 AM	27	29.4	27.1	0	26.6	25.8	0	0.026	27.1	28.3	0	0.02
2 AM	27	28.5	26.4	0	26.4	25.8	0	0.021	25.6	26.8	0	0.014
3 AM	26	27.2	25.3	0	25.6	25.4	0	0.022	25	25.6	0	0.01
4 AM	25	26.3	24.6	0	24.6	25	0	0.019	24	24.8	0	0.01
5 AM	25	25.7	25.6	0	24.1	24.7	0	0.013	23.3	24.8	0	0.009
6 AM	24	25	26.2	0	21.4	23.5	0	0.01	20.3	24.8	0	0.009
7 AM	27	30.7	31.8	120	29.2	30.6	80	0	28	29.3	40	0
8 AM	28	32.8	35.1	180	33.4	31.2	160	0.009	31.6	30.2	140	0.009
Total								2.287				2.226

Table 4. Measured Parameters for 0.05 m Water Depth in a Double Slope Active Solar Still of 25^0 Inclination of Condensing Cover on a Day of August 22, 2011.

					Double Slope (East side)				Double slope (Westside)			
Time	T_a	T_w	T_v	I_c	T_{coE}	T_{ciE}	I_{tE}	m_{wE}	T_{coW}	T_{ciW}	I_{tW}	m_{wW}
9 AM	30	35.6	40.2	260	41.2	30.8	400	0.014	39.8	29.5	340	0.018
10 AM	30	37.1	40.6	360	45.7	31.2	480	0.01	43.5	30.2	420	0.013
11 AM	31	39.8	37	540	53.2	31.6	540	0.045	50.1	30.8	580	0.038
12 Noon	32	44.2	38.4	620	56.9	31.5	600	0.075	55.5	31	640	0.087
1 PM	33	48.6	40	680	58.9	30.3	640	0.127	58.3	33.4	700	0.122
2 PM	34	52.8	43.3	700	60.7	34.3	680	0.229	61.1	36.2	740	0.208
3 PM	35	60.4	48.7	560	63.5	43.1	460	0.302	64.3	47.6	440	0.326
4 PM	34	63.1	52.5	380	65.9	50.3	240	0.245	67.5	54.6	320	0.272
5 PM	33	57.3	47.1	180	60.2	46.8	100	0.212	63	50.8	160	0.221
6 PM	33	50.1	40.9	0	52	40.4	0	0.202	55.9	43.6	0	0.215
7 PM	32	45.3	36.7	0	43.6	37.2	0	0.176	46.2	40.8	0	0.209
8 PM	32	41.5	33.3	0	39.6	35.3	0	0.12	41	37.9	0	0.132
9 PM	32	38.7	32.3	0	38	34.8	0	0.093	38.9	36.1	0	0.085
10 PM	31	35.7	30.9	0	36.5	34.2	0	0.069	37.3	34.6	0	0.047
11 PM	30	33.2	28.6	0	33.7	32.4	0	0.058	34.5	32.7	0	0.034
12 PM	30	32.1	27.8	0	32.9	31.8	0	0.045	33.5	31.9	0	0.028
1 AM	30	31.4	27.7	0	31.3	30.7	0	0.042	31.9	31.2	0	0.027
2 AM	29	30.8	28	0	30.7	30.3	0	0.034	29.9	30.6	0	0.024
3 AM	29	30.2	28	0	29.4	29.2	0	0.025	28.7	29.7	0	0.021
4 AM	29	29.4	27.5	0	28.3	28.6	0	0.022	27.5	27.3	0	0.016
5 AM	28	30.8	29.1	0	27.4	28.3	0	0.016	26.3	27.3	0	0.014
6 AM	28	29.6	29.1	0	26.5	27.9	0	0.013	25.1	27.5	0	0.013
7 AM	29	30.6	33	40	27.8	29.4	40	0	25.7	28.3	20	0
8 AM	30	34.1	37.4	140	34.9	30.8	220	0.01	32.5	29.2	200	0.014
Total								2.184				2.184

6. Mathematical Modeling

(a) Instantaneous thermal efficiency of active solar still

The hourly yield can be obtained by adding yield obtained from east and west side as

$$m_W = \sum (m_{wE} + m_{wW}) \quad (1)$$

The values of m_w for different water depth during sunshine hours (9AM-5 PM) are given in Table 5.

The instantaneous thermal efficiency is defined as

$$\eta_{th} = \frac{m_w \times L}{\left(A_s \times \sum I_t \times 3600\right) + \left(A_C \times \sum I_C \times 3600\right)} \quad (2)$$

Where L is given by this equation

$L=2.4935*10^6*[1-(9.4779*10^{-4}T_w+1.3132*10^{-7}*T^2_w-4.7974*10^{-9}*T^3_w]$

The instantaneous thermal efficiency is calculated by eq. 2 during sunshine hours (9 AM-5 PM) are shown in Table 5.

7. Result and Discussions

The experiments were conducted in the month of August 2011, to investigate the effect of water depth in the basin on distillate output and instantaneous thermal efficiency. Hourly measurements were made for ambient temperature, basin water temperature, glass cover temperature, distillate output and solar intensity from 9 AM for 24 hours and shown in table 2.4 to 2.6. For different water depths viz. 0.03 m, 0.04 m, and 0.05 m during clear sunshine hours (9 am-5 pm), distillate output and instantaneous thermal efficiency were calculated from collected data. Fig.3. shows the variation of distillate output with depth of basin water. As depth of basin water increase the distillate output decrease. From table 5 and fig.3, it is clear that distillate output is maximum 0.684 kg at 2 pm for water depth 0.03 m and minimum 0.17 kg at 10 am for water depth 0.04 m. Fig.4 shows the variation of instantaneous thermal efficiency with depth of basin water. The maximum instantaneous thermal efficiency is 46.96 at water depth of 0.04 m.

Table 5. Hourly yield and instantaneous thermal efficiency

Time	Water Depth					
	0.03 m		0.04 m		0.05 m	
	m_w	η_{th}	m_w	η_{th}	m_w	η_{th}
9am	0.037	1.35	0.034	1.14	0.032	1.07
10am	0.026	0.71	0.017	0.41	0.023	0.61
11am	0.213	4.73	0.096	1.92	0.083	1.67
12 Noon	0.379	6.91	0.216	3.72	0.162	2.89
1pm	0.541	8.67	0.417	7.07	0.249	4.07
2pm	0.684	11.23	0.571	11.43	0.437	6.78
3pm	0.679	18.74	0.649	19.32	0.628	14.05
4pm	0.582	25.01	0.552	26.65	0.517	17.92
5pm	0.475	39.01	0.455	46.96	0.433	32.25

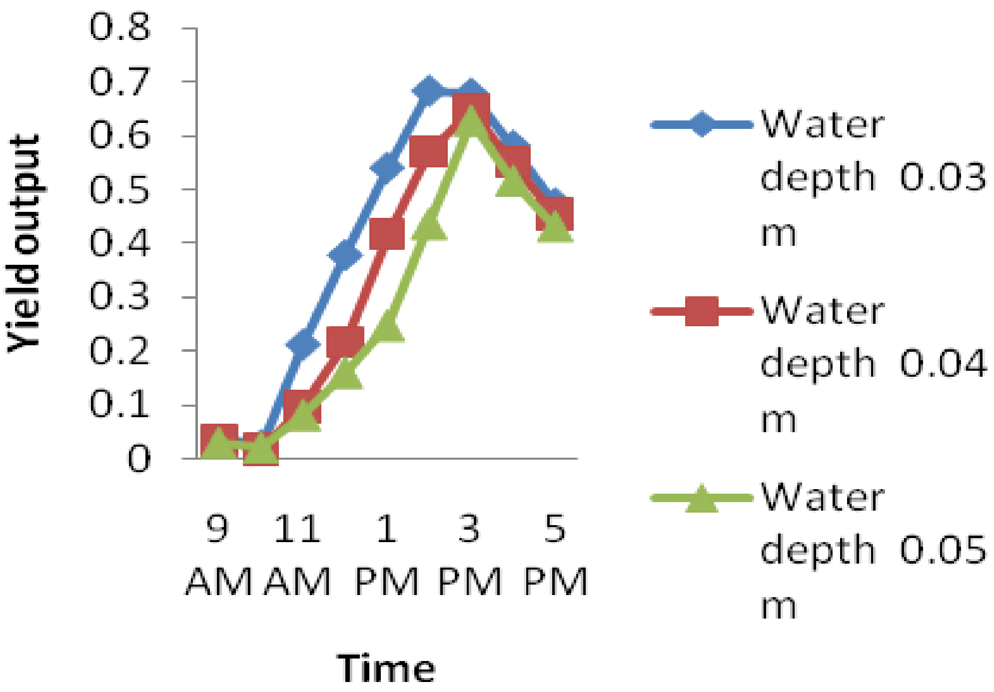

Fig.3. Hourly yield

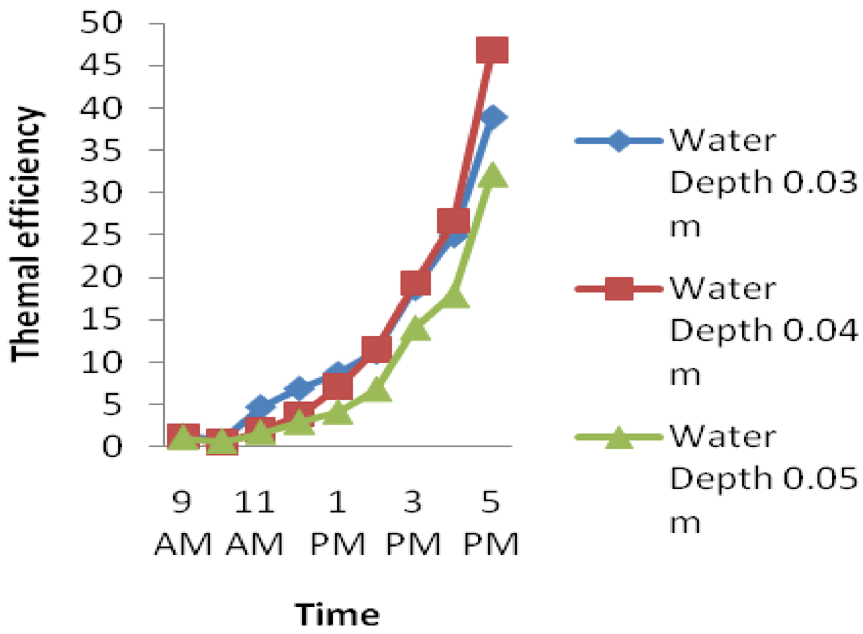

Fig.4. Instantaneous thermal efficiency

8. CONCLUSION

The distillate output is varies with the water depth and it decreased with increase of water depth in the basin.
Instantaneous thermal efficiency varies from 0.41 to 46.96.
Solar distillation presents a promising alternative to produce fresh water from saline water with free solar energy.

Symbols

- I_t Incident Solar radiation on solar still, W/m^2
- I_C Incident total radiation on collector plate, W/m^2
- L Latent heat of vaporization, J/kg
- m_W Hourly yield, kg
- A_s Basin area of solar still, m^2
- A_C Collector plate area, m^2
- T_a Ambient air temperature, ^{0}C
- T_{ci} Inner temperature of condensing cover, ^{0}C
- T_W Water temperature, ^{0}C
- η_{th} Instantaneous thermal efficiency

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