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Experimental investigation of Brackish Water Desalination using a Semi Spherical Solar Still

[a] Ali A. F. Al-Hamadani , [b] Mohammed G. Al-Azawyb ,[c] Mohammed Hameed Ghareeb Al Dulfi

[a,b,c]*Department of Mechanical Engineering, College of Engineering, Wasit University,*

*Corresponding author, aalhamadani@uowasit.edu.iq

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Abstract: The intensity of radiation reaches 930 W/m2 during April, 2016 in Kut city. Thus this city is suitable to use application of solar energy such as solar still. An experimental study was performed to evaluate the production of Semi Spherical Solar Still (SS-SS) with and without Charcoal. It was measured in the climatic conditions of Kut, Wasit (32o N latitude), Iraq. The still consists of square basin of length 0.3 m and area 0.09 m2 made of Aluminum. The square absorber basin is painted with black paint for maximum absorption of incident solar radiation. It was found that the productivity of Semi spherical solar still without charcoal is better than the using of charcoal at depth of basin water (dbw=1.5 & 2cm). The productivity of SS-SS without charcoal was 2.7 lit/m2 for 6 hours at total irradiation 5935 W/m2. Whereas 2.5 lit/m2 for SS-SS with charcoal at total irradiation 5845 W/m2 for dbw=1.5cm. In addition, the instantaneous efficiency reaches 58% without charcoal and 70% with charcoal at dbw=1.5cm at 3:00PM. The salinity of water before desalination in SS-SS was 999.54 ppm and becomes 4.06 ppm after desalination. It could be concluded that the semi spherical solar still can be used for distilled water production.

Keywords: *Desalination, Spherical Solar Still, charcoal absorber and productivity*

استقراء عملي لنظام تحلية المياه باستخدام محلى شمسي ساكن شبة كروي

علي عبد الرضا فرحان ، محمد غالب محسن ، محمد حميد غريب

الخلاصة: شدة الاشعاع وصلت في مدينة الكوت الى 930 واط/ م^2 في شهر نيسان 2016. لهذا هذه المدينة مناسبة لاستخدام تطبيقات الطاقة الشمسية ومنها التقطير الشمسي. دراسة عملية قدمت لحساب الانتاجية لمقطر شمسي شبه كروي مع وجود الفحم وبدونه. تم اخذ القياسات لظروف المحيطة لمدينة الكوت ، واسط (ارتفاع 32 درجة) ، العراق. المقطر يتكون من طاسة مربعة بطول 0.3 م ومساحة 0.09 م^2 مصنوعة من الألمنيوم. الطاسة المربعة الماصة تم طلائها بمادة ماصة للحرارة لامتصاص الاشعاع الشمسي الساقط. ووجد ان انتاجية المقطر الشمسي الشبه كروي بدون الفحم افضل من استخدام الفحم عند عمق ماء الطاسة (1.5و2) سم . الانتاجية للجهاز بدون الفحم كانت 2.7 لتر/ م^2 لستة ساعات مع اشعاع كلي 5935 واط/م^2، بينما الانتاجية 2.5 لتر/ م^2 للجهاز مع الفحم والاشعاع كلي 5845 واط/ م^2 لعمق ماء الطاسة 1.5 سم. بالإضافة لذلك فان الكفاءة الانية وصلت 58% بدون الفحم و 70% مع الفحم عند عمق 1.5 سم عند الساعة 3 بعد الظهر. ان ملوحة الماء قبل ازالة الملح عنها كانت في الجهاز 999.54 جزء من المليون واصبحت 4.06 جزء من المليون بعد عملية ازالة الملوحة . لذلك نستنتج ان جهاز التقطير الشبه كروي ممكن استخدام لتحلية الماء الصالح للشرب.

1. INTRODUCTION

In many countries, the need for filtered and clean drinking water is crucial. One of the processes used for purification of water is distillation, which involves an energy input such as solar radiation. Then water will be separated as water vapor which finally condensed as a pure water. The living in the earth depends on some parameters. The important one is water. Thus, keeping water clean, drinkable and pure is principle duty. The developed country is measured, how it treats water, especially drinking water. Fuel used for purification the saline water becomes costly and impact the environment. Renewable energy is another source available to distillate the water. Solar energy is available, free and friendly with the environment. Therefore, the solar energy is an important key to distillate the waste water. There are many types of solar still devices which is simple, self-working and inexpensive. One of these solar stills the spherical solar still (SSS). The researchers working in solar still use different method to get enhanced in the productivity of solar still. The research in [1] modeled solar still with and without phase change material. The new solar still has augmented the distillate water by 35-40%. Tenthani1 et al.,2012 designed solar still painted with white color and compared with conventional solar still [2]. It concluded the productivity of water were 2.55 kgm^{-2} and 2.38 kgm^{-2} for the painted still and CSS respectively. Furthermore, the efficiency of the painted solar still was increased compared with CSS. Arunkumar et al., 2012 fabricated seven types of solar stills to enhance the productivity of saline water [3]. The performance and output were larger one compared with another. The research in [4] performed experimental work of flat plate solar water heater coupled with the passive solar still. It was found that the distilled water of it is extra than the conventional solar still. But the cost is higher than conventional one. Manoj, et al. 2013 analyzed experimented solar still with inverted absorber solar still to increase the productivity of drinking water, Effective basin area of still is 1m^2 [5]. They used different depth of saline water for the climatic condition of Jaipur, Rajasthan. Further the efficiency was increased by 7 % of the new solar still. It was improved by the use of reflectors. Omar Badran, 2011 conducted theoretical studies of active solar still [6]. The author used different parameter such as effective absorptivity and transmissivity, different insulation, etc. to enhance the productivity of the system. It concluded the productivity enhanced with increasing the difference of temperature between the evaporating and the cover glass. Arunkumara, et al., 2012 presented experimental work for two types of solar still [7]. The hemispherical and pyramid solar still were fabricated and compared. It was concluded that the yield and efficiency of hemispherical more than pyramid solar still were 3.3 l/m^2.day with 32.02% and 2.73 l/m^2.day with 26.59% respectively. Hitesh, et al.,2012 designed hemispherical solar still in climate conditions of India [8]. The productivity was 3.2 lit/m^2/day. It was concluded when the depth of saline water is low, this will give more efficiency. Karroute and Chaker, 2011conducted numerical study for three types of solar still, single, double and spherical [9]. They compared between them to select perfect system. The results showed that the output of drinking water from spherical solar still is better than other solar still. Gowrisankar .et al ., 2011 studied improve spherical solar still by using charcoal within the basin water [10]. The still area was 0.30 m^2, they used cover of still from polyethylene sheet which has 0.107 mm as thickness. The charcoal increased the productivity of solar still compared with another one without charcoal. They concluded that the output is high with spherical solar still and with add the charcoal in saline water. Dhiman (1988) made analytical model of spherical solar still to determine the performance of it [11]. The author concluded the efficiency enhanced for solar still by 30% than the conventional solar still. The productivity had been affected by the absorptivity of the liner basin.

In this paper, a conventional spherical solar still was developed theoretically and modeled. The Performance of system was compared with another system which has added coal to the basin water under the same condition such as solar radiation, ambient temperature and wind speed under out door condition. The aim of the present work was to investigate the effect of adding the charcoal on the productivity.

2- EXPERIMENTAL ISSUES.

2.1. Description of Semi Spherical Solar Still (SS-SS).

The Semi Spherical Solar Still (SS-SS) was designed with a frame of semi-spherical shape (0.6m height) as shown in Figure 1. The SS-SS includes water storage square basin of (30cm length, 5cm height), manufactured of steel (see Figure 2). The absorber basin was painted with black paint for maximum absorption of incident solar radiation and fixed at the middle of the SS-SS, the storage capacity of the basin is around 4.5 liters. The thickness of plastic sheet is 0.5 mm which cover the SS-SS. Figure 3 illustrates the evaporated water which is condensed at the top cover and departures down towards the distilled water collection. The temperature was measured at different position of the still such as upper plastic cover (see Figure 1) and in the basin using calibrated thermocouples type k.

Figure 1: Snapshot of Semi Spherical Solar Still (SS-SS).

Figure 2: water storage basin.

2.2. Experimental setup.

The experimental tests of the SS-SS were investigated within the clear climatic conditions of Kut, Wasit, Iraq (32 ºN latitude). Firstly, the basin filled with saline water. Then, pieces of charcoal are allowed to residence on the water surface. The tests are accomplished between 9:00 AM and 4:00 PM and the readings were recorded every half an hour. In addition, the inside air, water and basin temperatures, radiation were recorded at same intervals. Furthermore, the same investigation was repeated without charcoal absorber through the system. Because of the water evaporation, the water level in the basin will decrease; therefore in order to keep the water at the same level for all tests, the still was connected to a water tank.

The distillate output of the SS-SS system is evaluated by a measuring glass instrument

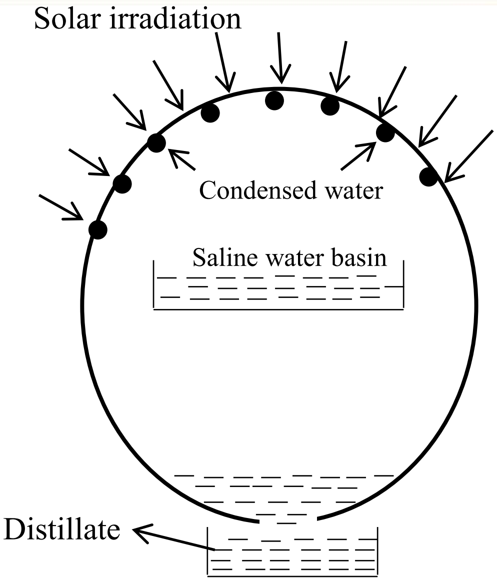

Figure 3: Schematic of Desalination system.

3. RESULTS AND DISCUSSION.

The whole experimental results were obtained during April 2016 from 17 to 26/04/2016 at College of Engineering, Wasit University, Al-Kut city, Iraq.

3.1. Outdoor conditions analysis.

The climate conditions were first investigated within the area of experiments on 18/04/2016. Figure 4 presents the solar irradiation and ambient temperature with time from 9am to 4pm. From the figure, it can be seen that the maximum solar irradiation was 1010 W/m^2 at 12pm as expected and the average ambient temperature was 36 ^{O}C. In addition, the effect of wind speed on SS-SS was investigated as shown in Figure 5. The average wind speed was .approximately 0.54 m/s which is best for reduce heat losses from system. erefore, Al-Kut city was suitable area for investigation and evaluation applications of solar energy such as solar desalination.

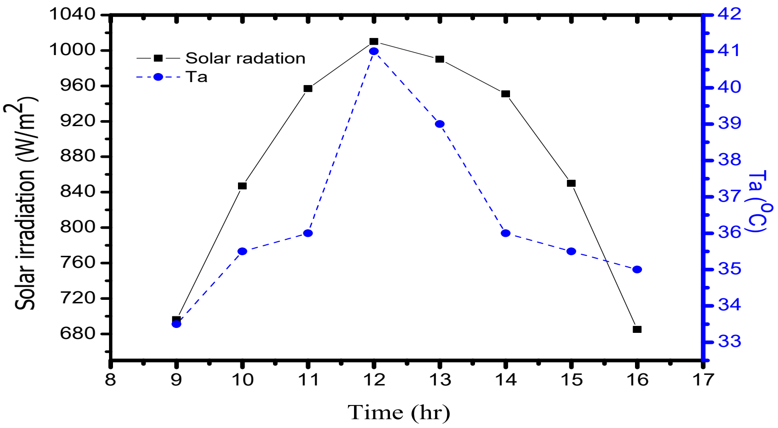

Figure 4. relation between temperature glass and solar irradiation with Time for d_{bw} =1.5 cm during 18/04/2016.

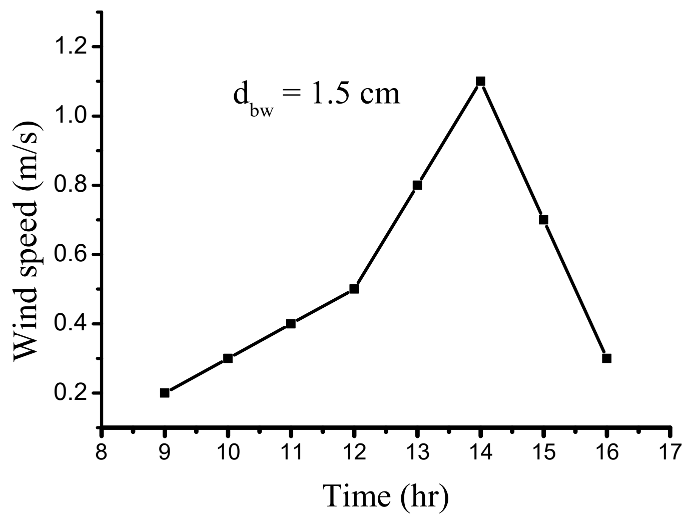

Figure 5: Variation of wind speed for d_{bw} = 1.5 cm

Table 1. The productivity and the total irradiation for different cases.

Depth	Condition	Date	Total irradiation W/m2	Total productivity lit/m2
dbw=1cm	With charcoal	24/04/2016	4865	3.2
	Without charcoal	18/04/2016	5354	2.2
dbw=1.5cm	With charcoal	25/04/2016	5845	2.5
	Without charcoal	17/04/2016	5935	2.7
dbw=2cm	With charcoal	26/04/2016	5496	3.1
	Without charcoal	19/04/2016	6986	3.6

3.2. The Productivity analysis

In this section, the authors compare the productivity of SS-SS with and without charcoal for 8 hours (8am-4pm) on 23, April 2016. Figure 6 provides the productivity with (P_{wc}) and without charcoal (P_{woc}) for different depth of saline water (d_{bw}). In general, it was observed from the three figures that the differences of the productivity with and without adding the charcoal were too small for the three figures except in case the depth 1cm (Figure 6a), the authors noticed the difference was big during the peak time (3 pm). In addition, in this Figure (6a) the productivity with charcoal was higher than without charcoal comparing with the other Figures (6b and 6c), which the productivity were high without charcoal. This is expected because the evaporation is faster in case the small depth of water comparing with the bigger depth, in addition, adding the charcoal increases the absorbability of solar energy. As a result this is increased the productivity as observed in Figure 6a. This is clear, as well, in Table 1, the productivity was 3.2 lit/m^2 with depth 1cm, while the productivity were smaller with higher depths 2.5 and 3.1 lit/m^2 at 1.5 and 2 cm d_{bw} respectively.

Table 1 illustrates the productivity and the total irradiation for different cases. The authors noticed that the productivity is decreased with increasing the depth with charcoal as expected, whereas the productivity increased with increase the depth without charcoal. This is because the total irradiation was high (6986 W/m^2) with depth 2

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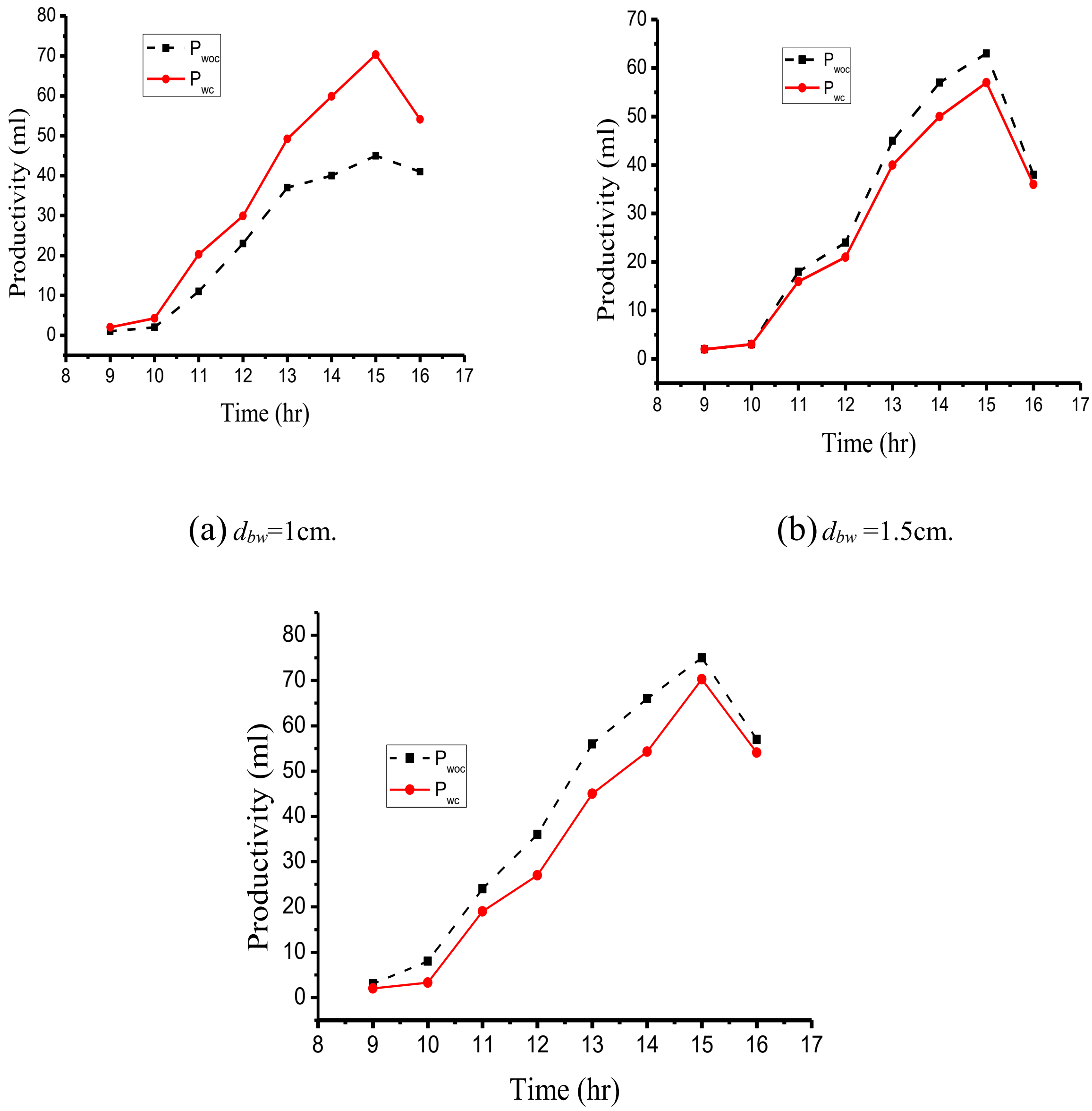
cm, while the total irradiation was 5354 and 5935 W/m^2 with depth 1 and 2 cm respectively as clear in the table. The productivity with charcoal is produces more drinking water than the one without charcoal for d_{bw}=1cm.



(a) d_{bw}=1cm. (b) d_{bw} =1.5cm.

(c) d_{bw} =2cm.

Figure 6: The productivity of SS-SS with and without charcoal for different d_{bw} .

3.3. Efficiency estimation

The thermal efficiency of SS-SS was investigated for d_{bw}=1.5cm (see Figure 7) as follows:

$$\eta_{v} = \frac{\Sigma\, \dot{m}.\ h_{fg}}{\Sigma I.\tau.\alpha.A} \tag{1}$$

Where I is the hourly solar radiation, $\sum \dot{m}$ is the total productivity of the day, h_{fg} is the latent heat of vapor (with inclusion of the temperature in the calculations), and A is the still area. τ andα are the transmittance and the absorptance of the material cover (in this paper, these values were assumed to be 1 as [12]). The authors noticed that the efficiency increased with time till around 15pm with and without charcoal then decreased because of decreasing the solar radiation.

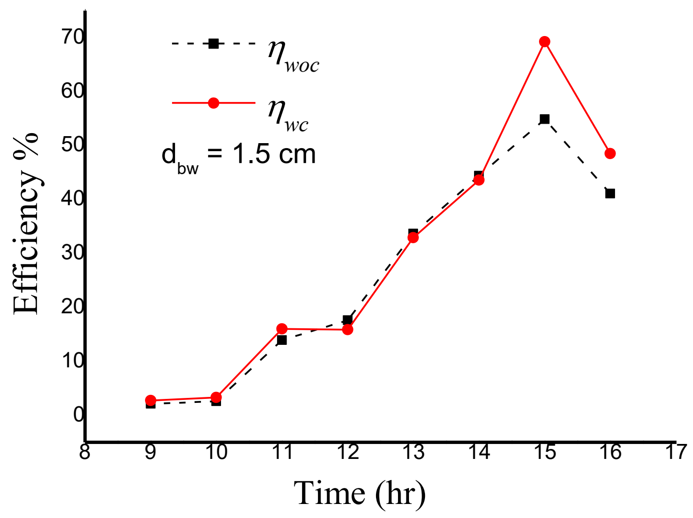


Figure 7: Instantaneous efficiency of SS-SS with and without charcoal for d_{bw}=1.5cm.

3.4. Evaluation the Salinity of Water and validation

Table 2 summaries the salinity of water before and after desalination from spherical solar still. The output of the SS-SS is suitable for drinking water for both cases. In addition, the modified of spherical solar still was compared with Sain, et al. work [5] as shown in Table 3. The results of the present work show that the Saltiness ascription was lower as compared with Sain, et al.

Table 2. Salinity of water

Saltiness ascription		dbw =1cm	dbw =1.5cm	dbw =2cm
Before distillation (ppm)		950	999.54	950
After distillation (ppm)	With charcoal	6.65	4.6	4.61
	Without charcoal	7.5	4.04	4.96

Table 3. Saltiness ascription of the present work and Sian et al. work [5]

Saltiness ascription (ppm)		dbw =1cm		dbw =2cm	
		Present work	Sain, et al. [5]	Present work	Sain, et al. [5]
Before distillation		950	610	950	580
After distillation	With charcoal	6.65	-	4.61	-
	Without charcoal	7.5	33	2.96	36

CONCLUSION

The behavior of SS-SS was investigated with and without charcoal. The results show that Al-Kut city was a suitable area for applications of solar energy such as solar desalination, the solar irradiation reaches 1010 W/m^2. The differences of the productivity with and without adding the charcoal were too small, the productivity with charcoal was higher than without charcoal at low depth of saline water basin.

The productivity of SS-SS without charcoal was 2.7 lit/m^2 for 6 hours at total irradiation 5935 W/m^2 and 2.5 lit/m^2 for SS-SS with charcoal at total irradiation 5845 W/m^2 for d_{bw}=1.5cm. whereas the productivity with charcoal was higher the one without charcoal at d_{bw}=1cm (3.2 lit/m^2 with charcoal and 2.2 lit/m^2 without charcoal). Furthermore, the instantaneous efficiency reaches 58% without charcoal and 70% with charcoal at d_{bw}=1.5cm. The salinity of water before desalination in SS-SS was 999.54 ppm and becomes 4.06 ppm after desalination.

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REFERENCE

[1] Al-Hamadani, A.A.F. and S.K. Shukla, " Water Distillation using solar energy system with lauric acid as storage medium", International Journal of energy engineering, 1(1): 1-8, 2011.

[2] Tenthani1, C., A. Madhlopa1 and C.Z. Kimambo , " Improved Solar Still for Water Purification", Journal of Sustainable Energy & Environment 3 (2012) 111-113.

[3] Arunkumar, T., K. Vinothkumar, Amimul Ahsan, R. Jayaprakash, and Sanjay Kumar. "Experimental study on various solar still designs." ISRN Renewable Energy 2012 (2012).

[4] Chetan Thakur and Rashid Ali," Experimental Investigation of Double Sloped Solar Still Coupled with Flat Plate Solar Water Heater", International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE), Volume: 2 Issue: 5,pp52-55, May 2015.

[5] Manoj Kumar Sain, Mahendra Singh Rajpoot, Vishnu Kr. Sharma,"Experimental Study of Inverted Absorber Type Solar Still with Water Depth and Total Dissolved Solid", International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 4, April 2013.

[6] Omar Badran, "Theoretical Analysis of Solar Distillation Using Active Solar Still", Int. J. of Thermal & Environmental Engineering, Volume 3, No. 2 (2011) 113-120 .

[7] Arunkumara, T., R. Jayaprakasha*, Amimul Ahsanb"A comparative experimental testing in enhancement of the efficiency of pyramid solar still and hemispherical solar still", International Journal of Renewable Energy, Vol. 7, No. 2, July - December 2012

[8] Hitesh N Panchal, Vinod Prajapati, Ranvirgiri Goswami and Nilesh Pancholi, " PERFORMANCE ANALYSIS OF HEMISPHERICAL SOLAR STILL IN CLIMATE CONDITION OF MEHSANA, GUJARAT", International Journal of Advanced Engineering Research and Studies, Vol. I/ Issue III/April-June, 2012/210-213

[9] S. Karroute and A. Chaker, " Effect of orientation of solar still on the productivity of fresh water", Revue des Energies Renouvelables ICESD’11 Adrar (2011) 25 – 31.

[10] G.Gowrisankar and R. Jayaprakash, " Thermal performance and analysis of low cost spherical solar still with charcoal absorber", Indian Streams Research Journal, Vol - I , ISSUE - IV May 2011.

[11] Dhiman, Naresh K. "Transient analysis of a spherical solar still." Desalination 69, no. 1 (1988): 47-55.

[12] Haruna, Ibrahim U., Maksha Yerima, Abalis D. Pukuma, and Ibrahim I. Sambo. "Experimental investigation of the performance of basin type single-slope solar still." International Journal of Scientific & Technology Research 3, no. 3 (2014): 169-174.