

Mechanical and Energy Engineering

Experimental Study of Solar Still Under Influence of Various Conditions

Mowaffaq Ali Hammadi *
College of Engineering- Baghdad University
Baghdad, Iraq
E-mail: mahs_90 @ yahoo.com

Dr. Najim Abid Jasim
Assistant Professor
College of Engineering- Baghdad University
E-mail: najmosawe @ yahoo.com

ABSTRACT

In the present work, experimental tests was done to explain the effect of insulation and water level on the yield output. Linear basin, single slope solar still used to do this purpose. The test was done from May to August 2017 in Mosul City-Iraq (Latitude:35.866°N, Longitude:43.296°E, Elevation: 200 m, and 23° South-East face). Experimental results showed that the yield output of the still increased by 20.785% and 19.864% in case of using thermal insulation at 4cm and 5cm respectively, also the yield output decrease by 15.134% as the water level increase from 4 to 5cm, with the presence of insulation and 14.147% without it. It has been conclude that the insulation and water level play important role in the process of passive solar desalination, also the desalination process has significant value at night and cannot be ignored.

Key Words: solar still, insulation, water level, and yield Output.

دراسة تجريبية لمقطر شمسي تحت تأثير شروط مختلفة

د. نجم عبد جاسم
أستاذ مساعد
كلية الهندسة- جامعة بغداد

موفق علي حمادي
كلية الهندسة- جامعة بغداد

الخلاصة

يعرض هذا البحث اختبارات عملية لتوضيح تأثير كل من العزل الحراري ومستوى الماء داخل المقطر على الإنتاجية وكذلك اختبار عملية التقطير خلال الليل. مقطر شمسي أحادي الميل والحوض أستخدم في هذه الدراسة العملية. الاختبارات تم إجراؤها في مدينة الموصل (خطوط الطول والعرض 35.866 و 43.296 درجة على التوالي وبارتفاع 200 متر عن سطح الأرض) خلال الفترة من شهر مايو إلى شهر أغسطس لعام 2017. النتائج العملية بينت أن الإنتاجية تزداد بمقدار 20.785% و 19.864% في حالة وجود العزل الحراري عندما يكون مستوى الماء داخل المقطر 4 سم و 5 سم على التوالي، كذلك فإن الإنتاجية تقل بمعدل 15.134% عند ازدياد مستوى الماء من 4 سم إلى 5 سم مع وجود العزل الحراري، وتقل بمقدار 14.147% بدون وجود العزل. يستنتج من ذلك ان العزل الحراري ومستوى الماء داخل المقطر تلعب دور مهم في عملية التقطير الطبيعي، كذلك بينت الدراسة ان عملية التقطير خلال المساء والليل لها قيم مؤثرة لا يمكن تجاهلها.

الكلمات المفتاحية: المقطر الشمسي، العزل، مستوى الماء، الإنتاجية.

*Corresponding author

Peer review under the responsibility of University of Baghdad.

<https://doi.org/10.31026/j.eng.2019.02.04>

2520-3339 © 2018 University of Baghdad. Production and hosting by Journal of Engineering.

This is an open access article under the CC BY-NC license <http://creativecommons.org/licenses/by-cc-nc/4.0/>.

Article received: 30/1/2018

Article accepted: 9/4/2018



1. INTRODUCTION

Solar desalination is the process of utilizes solar radiation to produce fresh water **Yousef, and Mousa, 2004** Solar desalination is simple and inexpensive method to transform brackish water into fresh water. There are two method used in the desalination process using solar radiation: direct method, using solar radiation directly to heat up the water, and this method used to produce small amount of fresh water, on the other hand indirect method, using pumps and modification equipment's with respect to solar radiation, and this method used to produce large quantities **Hazim, and Fawzi, 2008**.

Many researchers studied the behavior of solar still at various conditions, **Akash, et al., 1998**, showed the influence of adding some absorbing materials to the solar still to enhance system yield, results showed that the using of elastic carper and black ink may increase desalination rate by 38%, 45% respectively, and the best choice were black dye with desalination rate 60%. **Khalifa, and Hamood, 2009**, present experimental study to showed the effect of brine water depth on the system yield. Five water level (1, 4, 6, 8, and 10) cm have been tested in this case. Results shows that the productivity of solar still increased by about 48% in case of change water depth. **Sengoltain, et al., 2010**, studied the effect of adding square sponges to the solar still, two type of yellow and black color have been used in this case. Results showed that the system with black sponge better than that of yellow. Both of them enhance the productivity as compared to simple still. **Hashim, et al., 2010**, present experimental study and found the optimum still type, glass cover angle, and inner surface area to double slop, 45°, and 1.1645 m² respectively. **Agboola, and Egelioglu, 2011**, studied the thermal performance of simple solar still under the influence of weather conditions in winter and summer seasons. Conclude that the using of wick plat produce 6.14 kg/m²daily compare to 3.327 kg/m² in case of without wick. Also the daily system efficiency were 52.4% and 43.6% in the two seasons. **Khalifa, 2011**, studied theoretically the effect of glass cover inclination, conclude that the glass angle must be perpendicular to incident solar radiation as possible to improve yield output. **Panchal, and Shah, 2011**, studied the effect of class cover thickness on the system yield. Three type of glass cover (4, 8, and 12 mm) have been used in the experimental study. Results showed that the glass cover thick of 4mm represent the best choice of them. **Kabeel, et al., 2012**, mentioned that it can be increase the yield output of solar still up to 25% with the aided of fan. **Tenthani, et al., 2012**, design two similar stills with white day on the internal surfaces, results showed that the empirical and classical type daily output were 2.55, and 2.38 kg/m² respectively, and the efficiency increased by 6.8% in case of empirical type, conclude that the coating with color enhance the system productivity. **Raed, 2012**, showed the impact of various weather conditions on the yield, conclude that the productivity of the system changed directly to solar radiation, ambient temperature and wind speed, also using of PCM improve the productivity. **Gnanadason, et al., 2013**, conclude that the efficiency of the solar still improved by change the still material. **Al-Mashat, and Dhurgam, 2014**, Studied the effect of adding stearic acid and paraffin wax as phase change material (PCM) to improve the still productivity. Experimental results showed that adding PCM to the passive system enhance the productivity by 20.2% and 10% for sunny and cloudy days respectively. **Gubta, et al., 2015**, investigate experimentally the enhancement of the desalination in solar still by coupling evacuated tubes directly to the still and by adding float porous absorber inside basin also water high in the solar still was studied. **Kabeel, et al., 2016**, studied the possibility of increase the productivity of the system by blowing air over glass cover using Fan. **Kumar and Rajesh, 2016**, tried to enhanced the solar still productivity utilized the solar heater as well as evacuated tubes to increase the temperature of saline water and evaporate more water quantity.



2. THEORETICAL DESIGN OF THE SOLAR STILL

If the daily consumption for one person of drinking water are (2-3) Liter/day/one, so it has been required to design solar still produce this quantity of fresh water. The procedure of design as follow, **Calbande, 2016**.

$$Q_r = Q_i A_b \quad (1)$$

$$Q_r = m_d h_{fg} \quad (2)$$

$$Q_i = 3600 G_i hr \quad (3)$$

$$Q_r = 3 \times 2257 = 6771 \text{ kJ/day}$$

$$Q_i = 0.6 \times 8 \times 3600 = 17280 \text{ kJ/m}^2 \cdot \text{day}$$

$$A_b = \frac{Q_r}{Q_i} = \frac{6771}{17280} = 0.391 \cong 0.4 \text{ m}^2 \text{ [Area of solar still required to produce 3 L/day].}$$

3. EXPERIMENTAL SETUP

The solar still system was designed and constructed to verify the acceptable operational requirements. All the component were designed and selected according to either researches or studies and as on-hand in the markets, to get the optimum design to each component, to ensure that the system operation in best conditions with maximum productivity.

3.1 Still Components

3.1.1 Still basin

This part of the system used as storage to store the saline water. It must be sealed and coating with black color as possible, in order to absorb the solar incident radiation, also it must be corrosive less, strong, smooth, cleanable and upload as possible. The present part constructed with the material of Galvanized Iron of (1.1 mm) thickness in order to be strength, no toxic, and non-corrosive and light weight. The dimension of the basin was (80cm x 50cm) and this dimensions have been selected according to specific design. **Fig.1** shows evaporation and condensation process in the simple solar still, and **Fig.2** shows the details of solar still. **Fig.3** shows the experimental device used in the present work. The coating were dark black in base and brilliant weight color on the another sides of the still to absorb and reflect sunshine light. These procedures according to recent studies in order to increase the saline water temperature and maximize the useful solar incident radiation absorbed in the system.

3.1.2 Glass cover

In order to allow the incident solar irradiation to passes through, Glass cover have been used in the present work due to its advantages such as high transparency, rigid, easy fabricated, and inexpensive. Glass cover of thickness (4mm) are used due to its advantages over another high dimension, and its tilted at 35.866° (Zone latitude). Glass cover consider one of the most important parts because of its relation to energy source and condensation process.



3.1.3 Condensate accumulator (trough)

Its small passage used to collect and transfer the condensed water, its designed to be integrated with still body of the same material GI sheet of 1.1 mm thickness, with ignore area. In present work the trough design as triangular section of (3x3x50) cm. It must be small to prevent shading, on the other hand must be enough to collect and transfer the compensated water.

3.1.4 Insulation

In order to prevent heat loss from the still body to the environment, thermal insulation have been used, because of the heat loss decrease the still performance and minimizes the productivity. In the present work Cork Board insulation of 60 mm thickness, and 0.043 (w/m.k) thermal conductivity have been used and fabricated around the stills, the choice of insulation type are necessary to improve thermal performance and must be have low thermal conductivity, light weight, available, inexpensive and easy fabricated.

3.1.5 Seal

Its a metal that used to prevent any leakage to or from the still, also it used to connect any two part or more as one structure in our study this metal are used to prevent water vapor leakage from the stills inside space to the atmosphere, and water or dusty particles leakage also. It has been used Silicon rubber to fill the gaps between glass cover and still body, this type have been used because of low coast, inexpensive, easy to use, easy to remove without side effects when we need and controllable, two type have been used. Also window putty have been used to prevent leakage and this metal become hard after used.

3.2 Experimental Instrumentations

3.2.1 Solar meter

The intensity of solar radiation have been measured using efficient solar meter of (TES-1333R) specifications as shown in the **Fig.4**.

3.2.2 Ambient conditions

The variable ambient conditions such (Ambient temperature and Wind speed and Relative Humidity) have been measured using (4 in 1 METER) portable measurement of (LM-8000A, Lutron Company-Taiwan) specifications, **Fig.4**.

3.2.3 Data logger

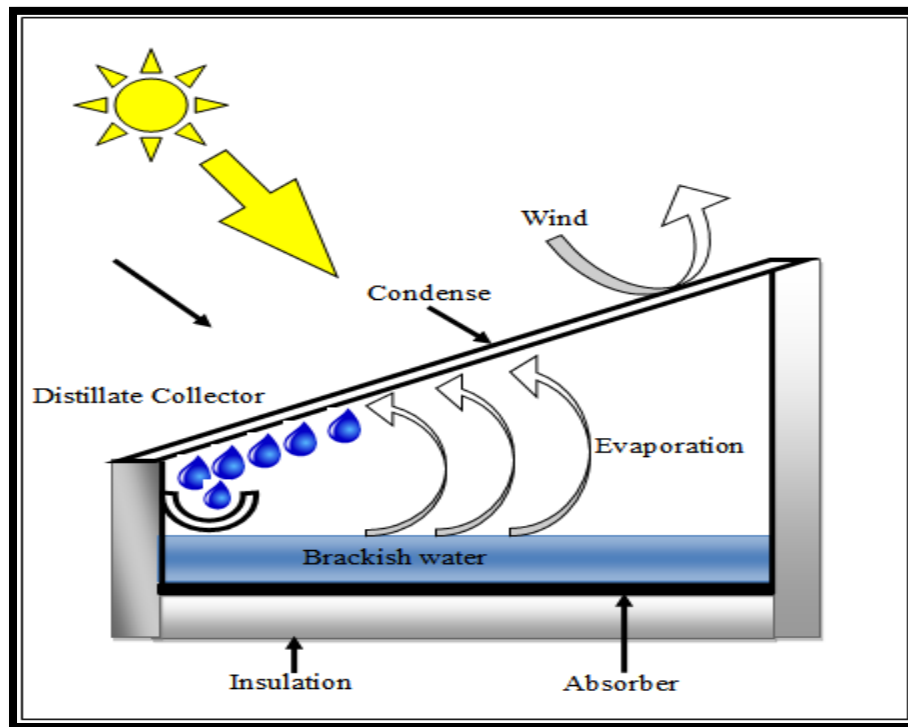
Temperatures of basin, saline water, Still's wall and glass cover have been recorded instantaneously using Data Logger of (BTM-4208SD, Lutron Company-Taiwan) specifications, with 8 point of thermocouples type-K, **Fig.4**.

3.2.4 Digital balance meter

The mass of desalinated water was measured hourly and accumulated using traditional type Digital balance meter. **Fig.4**.

Table 1. Design data.

Item	Name	Description
1	Solar still	Single Slop, Linear Basin, (50x80) cm
2	Basin type	Single
3	Area	0.4 m ²
4	Length	0.8 cm
5	Width	0.4 cm
6	Effective Area	0.4 m ²
7	Glazing material	Glass (0.485m ²)
8	Thickness of glass	4 mm
9	Inclination Angle of glass	35.866°
10	Orientation of the Still	South face
11	Trough	Triangular (50x3x3) cm
12	Insulation	Cork board (6 cm, 0.043 w/m.°C)
13	Solar still material	Galvanized, 1mm

**Figure 1.** Evaporation and condensation process in the simple solar still.

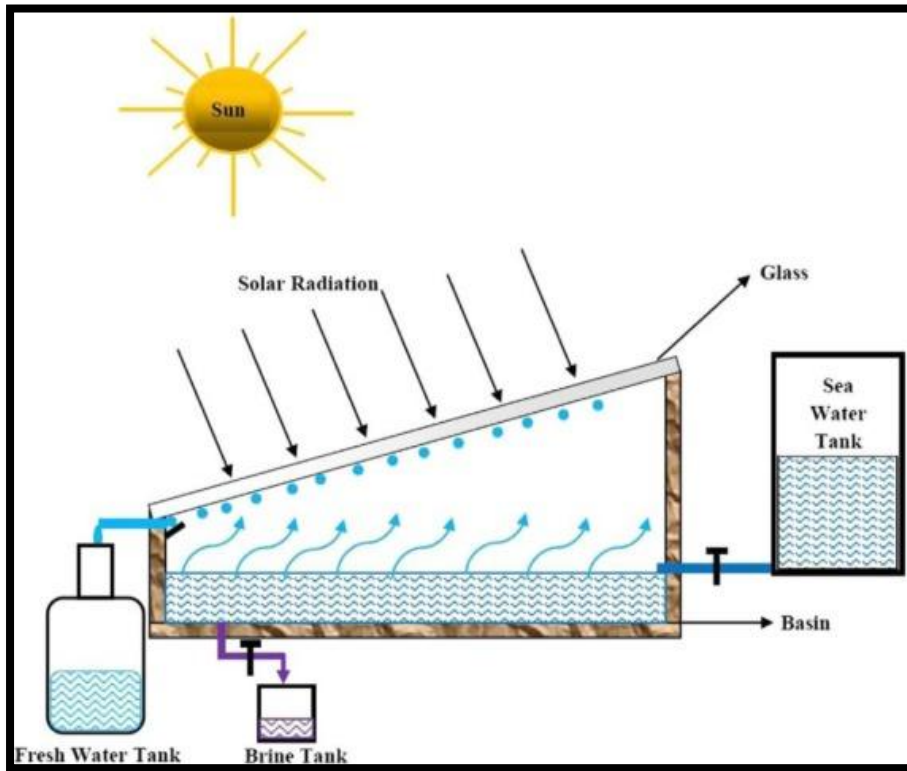


Figure 2. Details of the Simple Solar Still.



Figure 3. Experimental Device.



Figure 4. Measurements Used in the Experiment.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The tests were take place during the interval from May to August month 2017, in Mosul City-Iraq. **Figs. 5, 6, 7** shows weather conditions. Solar still (linear basin, single slope) of 0.4 m² area used in the experiment. The results have been recorded during tests, through 24 hour. The tests was done for different water levels (4cm and 5cm) with and without insulation.

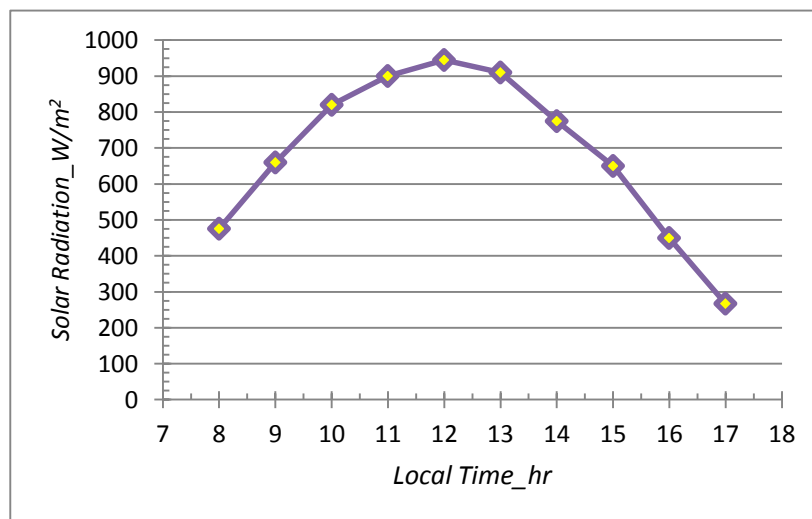


Figure 5. Incident Solar Radiation with Local Time (8 a.m-5 p.m) at 29/6/2017.

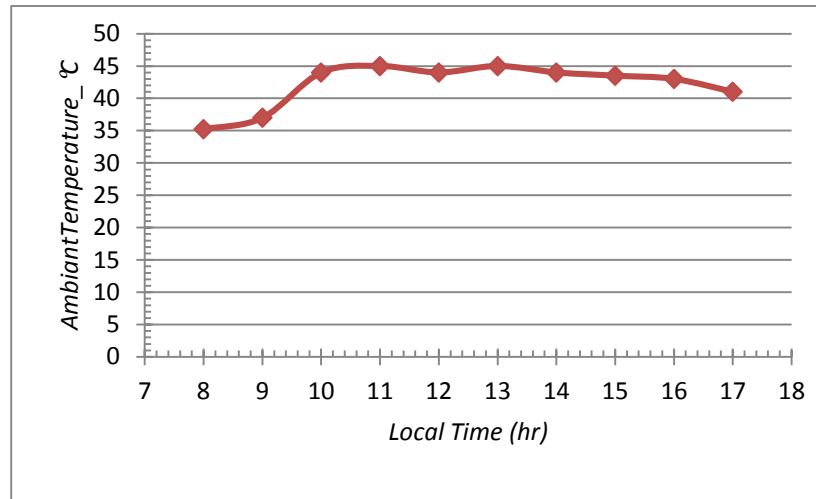


Figure 6. Ambient Temperature with Local Time (8 a.m-5 p.m) at 29/6/2017.

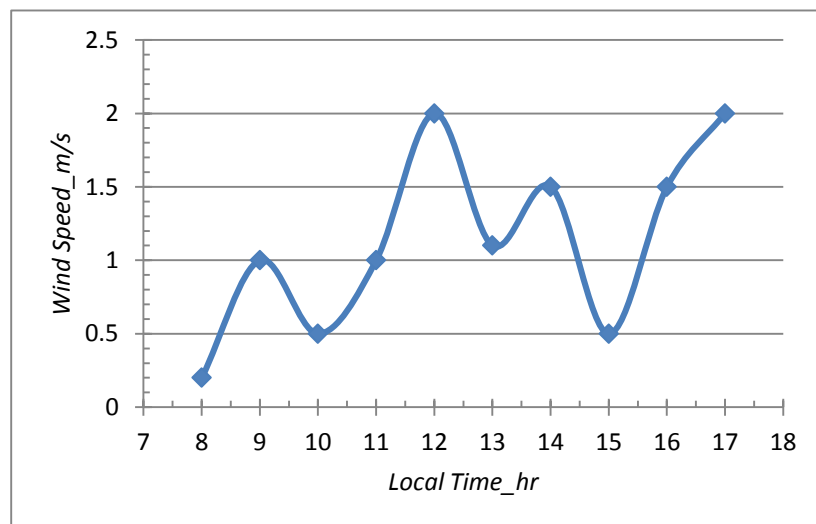


Figure 7. Wind Speed with Local Time (8 a.m -5 p.m) at 29/6/2017.

4.1 Effect of weather conditions on temperatures of solar still

Fig.8 to Fig.11, shows the variations of stills temperatures with weather conditions, and at local time. Its obvious that the solar radiation effect on temperature distribution, and the surface temperature be maximum with the presence of insulation that lead to produce more fresh water. Also it must be noted that the main effective temperatures are water temperature and glass temperature so the distillation process depends on them, and the productivity be maximum when the difference between water and glass temperatures be maximum because its represent the driven force.

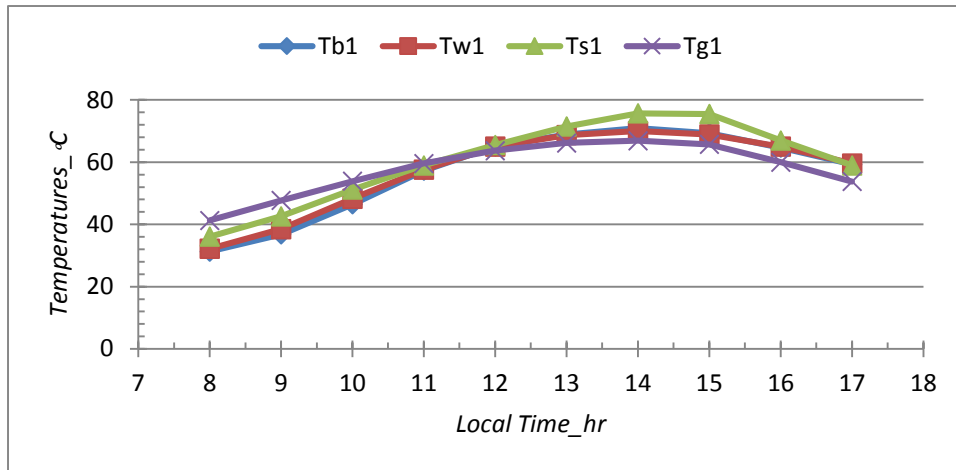


Figure 8. Temperatures variation of Basin, Water, Wall and Glass, With Insulation and at 4cm water level in the Solar Still.

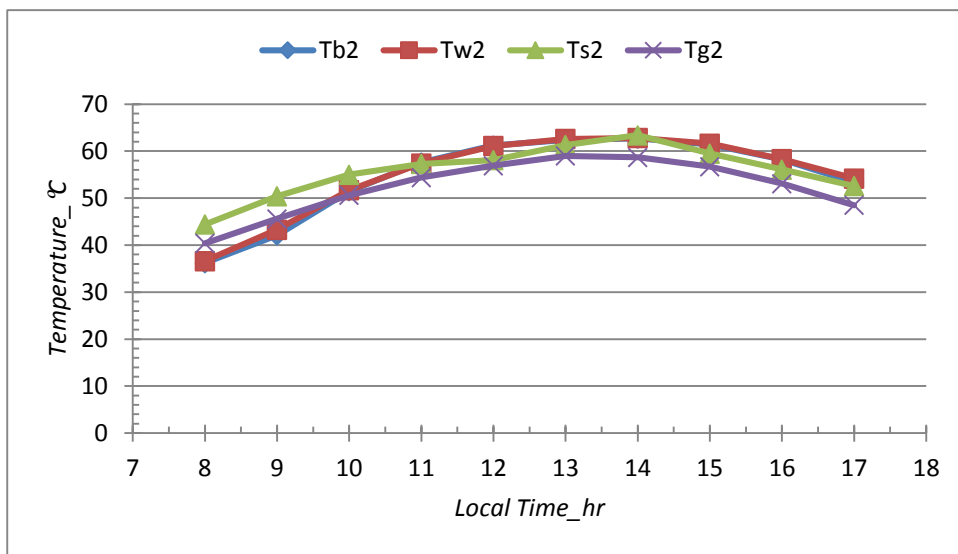


Figure 9. Temperatures variation of Basin, Water, Wall and Glass, Without Insulation and 4cm water level in the Solar Still.

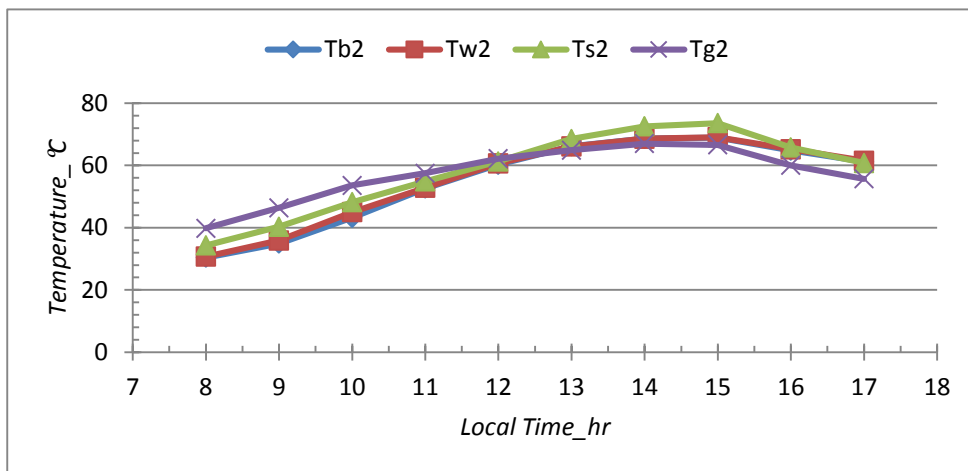


Figure 10. Temperatures variation of Basin, Water, Wall and Glass, With Insulation and 5cm water level in the Solar Still.

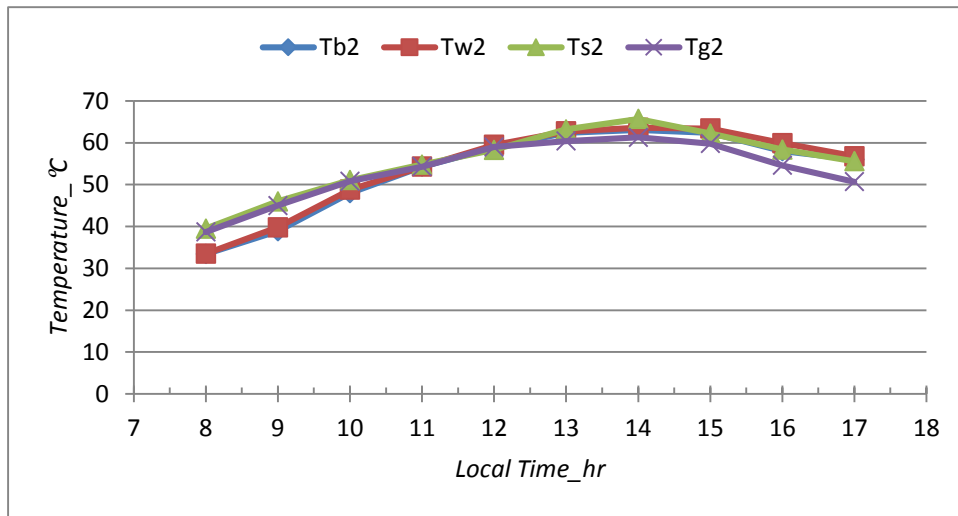


Figure 11. Temperatures variation of Basin, Water, Wall and Glass, Without Insulation and 5cm water level in the Solar Still.

4.2 Effect of Insulation

Fig.12 and Fig.13, shows that the productivity of solar still without insulation be more than that of with insulation during the interval (12:30 a.m – 8 a.m) at the two water levels, because of increase of water temperature quickly as the solar radiation strikes the still surface directly, on the other hand, insulation prevent this process in case of solar still with insulation. During the interval (8 a.m – 5 p.m), sunshine pass through the glass and no or small heat loss in case of insulation, that lead to all heat absorbed used to evaporates the water and produce more fresh water. In the interval (5 p.m – 12:30 a.m) insulation store energy and still evaporates the water more than the still without insulation.

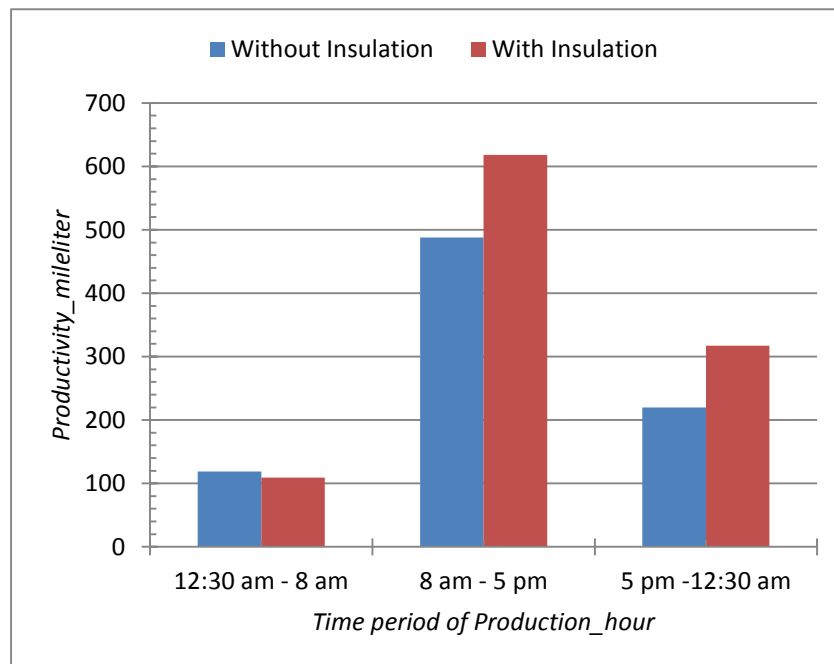


Figure 12. Production Rate Through 24 hour and at 4cm Water Level in the Solar Still.

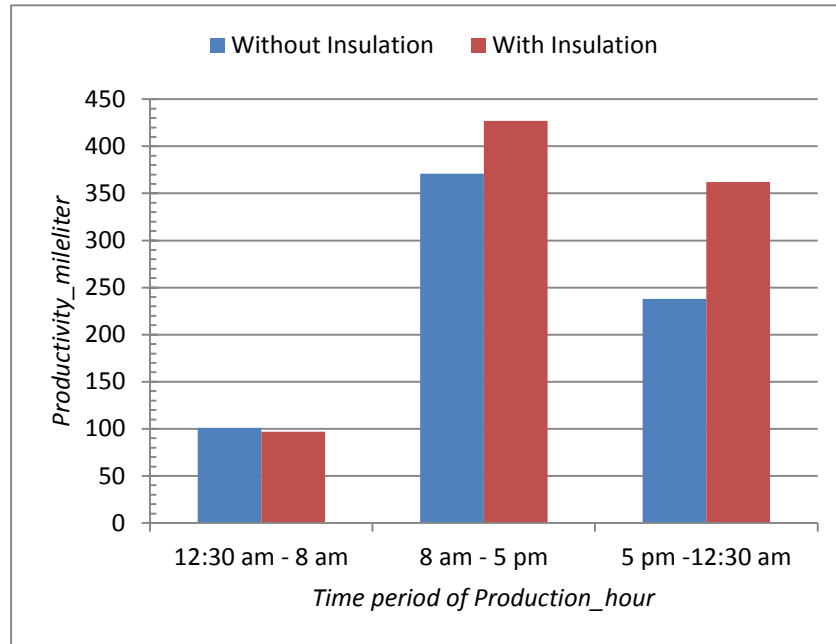


Figure 13. Production Rate Through 24 hour and at 5cm Water Level in the Solar Still.

4.3 Effect of Insulation on the Heat Storage

Fig.14 and Fig.15, shows the percentage of water desalination during 24 hour interval, so its obvious that there are significant amount of water desalination during the interval (12 a.m-8 a.m), and this value be greater than at the presence of insulation in case of the two water levels because the effect of insulation on the heat storage, so insulation store the heat as possible with small heat loss, on the anther hand the ambient temperature reduced an night that lead to increase the temperature difference between water-glass temperatures and increase the productivity.

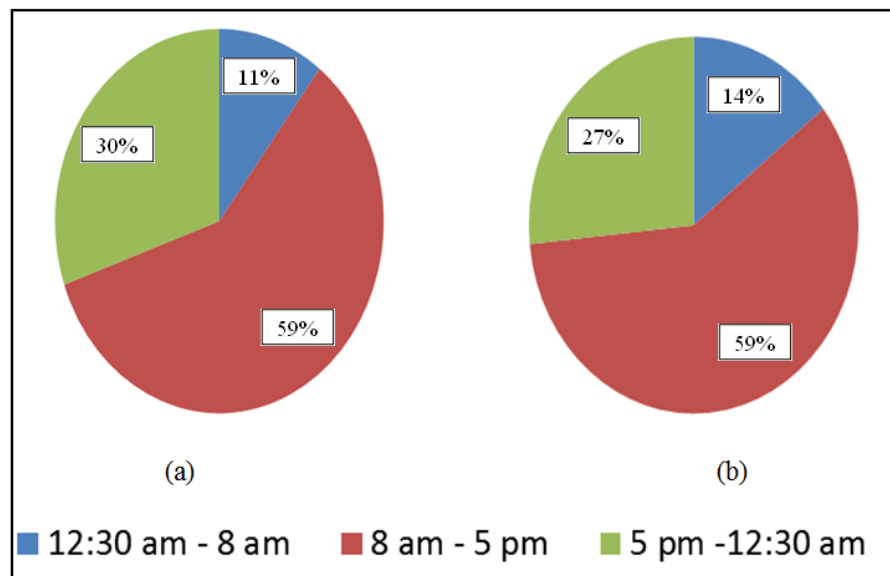


Figure 14. Percentage of Production Rate through 24 hour and at 5cm Water Level in the Still. (a) Without Insulation, (b) With Insulation.

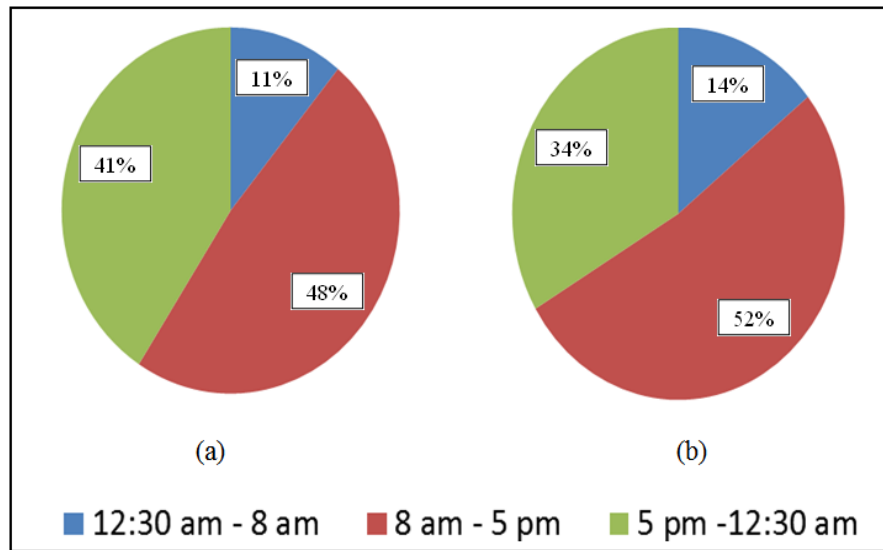


Figure 15. Percentage of Production Rate through 24 hour and at 5cm Water Level in the Still. (a) Without Insulation, (b) With Insulation.

4.4 Effect of water level

From the Fig.16 and Fig.17, it has been noted that, when the water level be 4cm, the yield output in case of insulation and without insulation be more than that at 5cm level, this is logically result, because the small quantity of water absorb large amount of energy, and evaporates large water quantity.

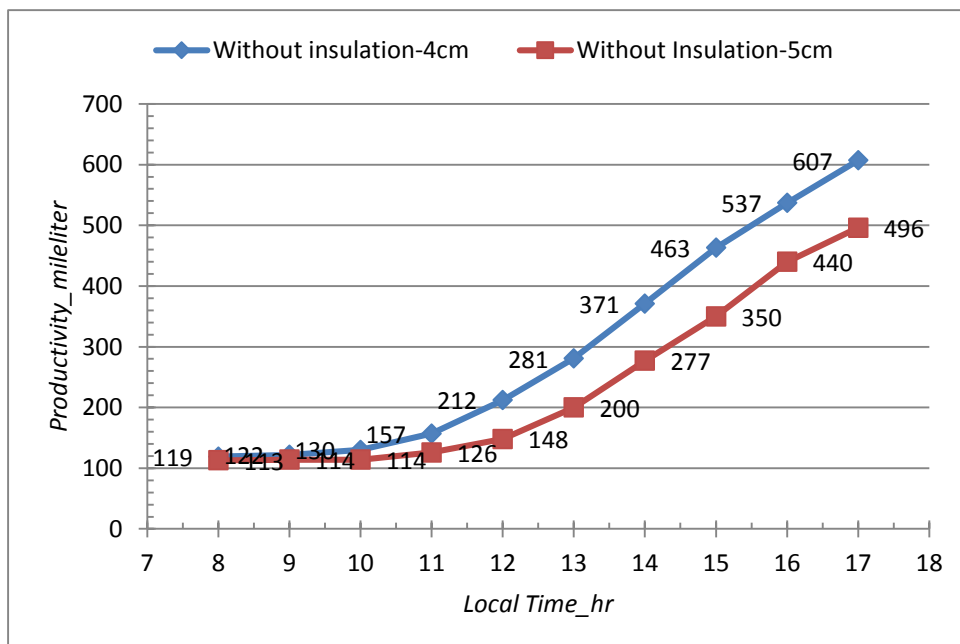


Figure 16. Variation of Production Rate with Water Level in the Solar Still.

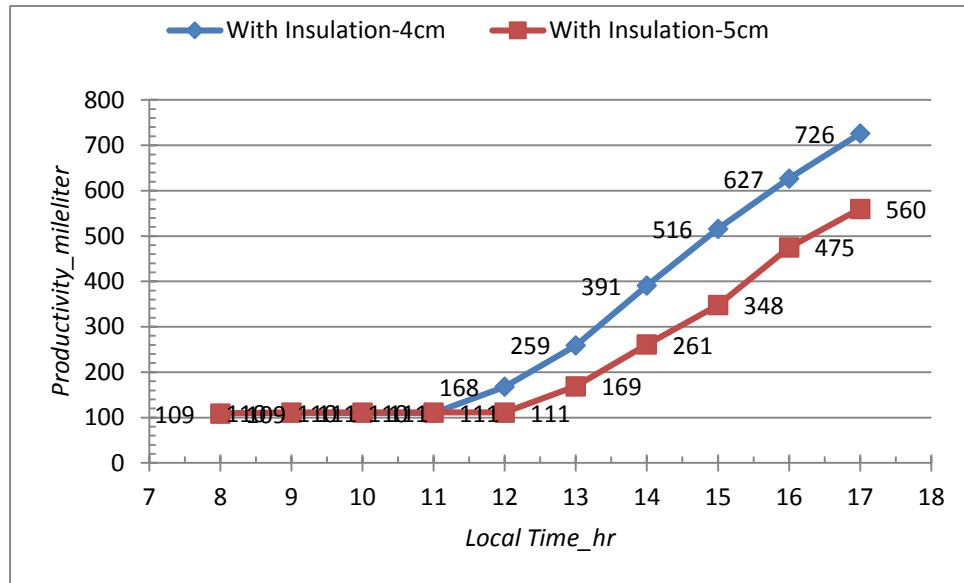


Figure 17. Variation of Production Rate with Water Level in the Solar Still.

4.5 Desalination Process at Night

At night (off Sunshine) there are no energy source to increase water temperature but depends on the heat storage only. In the present work the desalination process during (12 a.m– 8 a.m) because of in summer season, sun rise at 5 a.m and the system absorbs the solar radiation and evaporate from sunrise until 8 a.m.

5. CONCLUSIONS

From the experimental study, it has been conclude that:

1. The yield output of the still increased by 20.785% and 19.864% in case of using thermal insulation at 4cm and 5cm respectively.
2. The yield output decrease by 15.134% as the water level increase from 4 to 5cm, with the presence of insulation.
3. The yield output decrease by 14.147% as the water level increase from 4 to 5cm, without insulation.
4. The desalination process before 8 a.m has significant amount, and cannot be ignored.

6. REFERENCES

- Agboola, O. P., and Egelioglu, F., 2011, an Experimental Investigation of an Improved Incline Solar Water Desalination System in Famagusta, Scientific Research and Essays Vol.6, PP. 3298-3308.
- Akash, B. A., Mohsen, M. S.,Osta, O., and Elayan, Y.,1998, Experimental Evaluation of a Single-Basin Solar Still Under Different Absorbing Materials, Renewable Energy, Vol. 14, Nos, 1-4, PP. 307-310.



- Al-Mashat, S. M., And Hussein, D. I., 2014, Theoretical and Experimental Investigation of Single Basin Solar Still with PCM Storage Medium, Ms.C Thesis, Department of Mechanical Engineering, University of Baghdad, Baghdad.
- Duffie, and Beckman, W.A., 2013, Solar Engineering of Thermal Processes”, A Wiley-inter Science Publication Co., John Wiley and Sons, Solar Energy Engineering Processes and Systems.
- Gnanadason, M. K., Kumar, P. S., Sivaraman, G., Daniel, J. E., 2013, Design and Performance Analysis of a Modified Vacuum Single Basin Solar Still, Smart Grid and Renewable Energy, vol.2, PP.388-395.
- Gubta, M., Sinph, J., and Katyal, P., 2015, Solar Still Coupled with Evacuated Tube Collector with and without Porous Absorber: An Experimental Study, International Journal of Thermal Technologies, Vol.5, No.4, pp.324-330.
- Hashim, A.Y., Al-Asadi, J. M., and Taha Alramdhan, W.A. , 2010, An Attempt to Solar Still Productivity Optimization; Solar Still Shape, Glass Cover Inclination and Inner Surface Area of a Single Basin Solar Still, Optimi-Zation, Basrah Journal of Scienec, Vol.28(1),PP.39-48.
- Hazim M. Q., and Fawzi B., 2008, Solar Thermal Desalination Technologies, Desalination, vol.220, PP.633-644.
- Kabeel, A. E., Abdelgaied, M., and Mahgoub, M., 2016, The Performance of a Modified Solar Still Using Hot Air Injection and PCM, Desalination, Vol.379, pp.102-107.
- Kabeel, A.E., Mofreh H., Hamedb, Z.M., and Omara, 2012, Augmentation of the Basin Type Solar Still Using Photovoltaic Powered Turbulence System, Desalination and Water Treatment, vol.48, PP.182–190.
- Kalbande S. R., Khambalkar V. P., Priyankanayak, Sneha D. D., 2016, Development and Evaluation Solar Still Integrated with Evacuated tubes, International Journal of Research in Applied, Vol.4, PP. 99-106.
- Khalifa, A. N., 2011, On The Effect of Cover Tilt Angle of The Simple Solar Still On Its Productivity In Different Seasons And Latitudes, Energy Conversion And Management vol. 52, PP. 431–436.
- Khalifa, A. N., and Hamood, A. M., 2009, Effect of Insulation Thickness On the Productivity of Basin Type Solar Stills: An Experimental Verification Under Local Climate, Energy Conversion and Management vol.50, PP. 2457–2461.
- Kumar, M. A., and Rajesh, S., 2016, Performance Evaluation of a Solar Still Coupled to an Evacuated Tube Collector Type Solar water Heating", International Journal of Mechanical Engineering and Technology (IJMET), Vol.711-25.



- Panchal, H. N., and Dr. Shah, P. K., 2011, Effect of Varing Glass Cover Thickness on Performance of Solar Still in Winter Climate Conditions, International Journal of Renewable Energy Research, Vol.1, PP.212-223.
- Raed, F. L, 2012, Performance Evaluation of Solar Desalination under Baghdad Climatic Conditions, M.Sc. thesis, collage of engineering-university of Baghdad.
- Sengottain, S., Balasundaram, J., and Joseph, C., 2010, Thermal Asymmetry Model of Single Basin with Sponger Liner, Department of Physics, Karpagam University, India.
- Tenthani, C., Madhlopa1, A., and Kimambo, C.Z., 2012, Improved Solar Still for Water Purification, Journal of Sustainable Energy & Environment, vol.3 PP. 111-113.
- YousefH. Z., and Mousa K. A., 2004, Modeling and Performance Analysis of a Regenerative Solar Desalination Unit, Applied thermal engineering, vol.24, PP.1061-1072.

7. NOMENCLATURE

A_b = area of still basin, m^2 .

G_i = average daily solar radiation, $6 \text{ kWh}/m^2/\text{day}$ (Assume).

h_{fg} = latent heat of vaporization, $2257 \text{ kJ}/\text{kg}$ (Constant).

h_r = run hours, (8 hr).

m_d = desalinated water, $3 \text{ kg}/\text{day}$ (Assume. **Calbände, 2016**).

Q_i = daily energy incident, $\text{kJ}/m^2.\text{day}$.

Q_r = energy required, kJ/day .