THERMAL PERFORMANCE EVALUATION OF SINGLE SLOPE SOLAR STILL WITH PCM AS THERMAL STORAGE MATERIALS

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ABSTRACT

The main objective of the present study was to improve the productivity of a single-slope solar still using phase change materials (PCM) as a heat energy storage material. Three identical single slope solar stills were constructed and functioned with and without PCM at the Agricultural Engineering Department, Faculty of Agriculture, Suez Canal University, Egypt (latitude angle of 30.62ºN and Longitude angle of 32.27ºE). Paraffin wax was used to store the solar thermal energy in the form of latent heat, which can offer high storage capacity per unit volume, and also due to its feasible general and economic properties. The basin of solar still was rectangular, with a net upper surface area of 1.04 m^2. It is painted with matt black paint to absorb the maximum possible amount of solar radiation incident on it. The solar still was covered with glass sheet 3 mm thick and inclined with a tilt angle of 31° of the horizontal plane. The three solar stills (solar still without PCM, solar still with 5 kg PCM and solar still with 10 kg PCM) were examined. The obtained results clarified that, the highest productivity of fresh water (207 ml/ m^2 h) was achieved from the solar still with 10 kg PCM followed by the still with 5 kg PCM (182 ml/ m^2 h) and the still without PCM (151 ml/ m^2 h). The thermal efficiency of the three solar stills with 5 and 10 kg PCM, and without PCM, respectively, was 34.9%, 39.6% and 28.9%. The obtained data also revealed that, the pH (7.46), EC (0.21 μs/cm), and TDS (134.4 ppm) values were lower than those of the brackish water (7.8, 48.5 μs/cm and 31040 ppm, respectively).

1. INTRODUCTION

The amount of solar energy reaching the earth surface is nearly thousand times greater than the availability of fossil fuels. Solar radiation can be the source of heat energy where brackish or sea water is evaporated and is then condensed as pure water **(El-Sebaii et al., 2009)**.

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Solar distillation is one of many processes that can be used for water purification. Solar still is a device that produces clean water from dirty water using the energy from the sun. This inexpensive device can easily be built using local materials **(Kantesh, 2012)**. There is a strong need to improve the solar still performance and increase the production of water distillation **(Sundaram et al., 2016)**. The thermal energy storage system has been widely used to increase energetic efficiency of different applications **(Ramasamy and Sivaraman, 2013)**. The thermal storage material can be classified into the latent and the sensible heat thermal storage material **(Kabeel and Abdelgaied, 2016)**. The latent heat thermal storage material has a significant advantage over sensible heat thermal storage material, including a large amount of energy storage per unit mass. Paraffin waxes used in solar still applications, due to its availability and low cost **(Sharma et al., 2009)**. Heat is absorbed when the material changes its phase from solid to liquid and vice versa. Here PCM is used to store heat in the day time and release the heat during night which gives continuous production of distilled water. Single slope stills considered as one of the cheapest solutions for purifying see water and suitable for the Middle East and Africa **(Goosen et al., 2000). Singh and Tiwari (2004)** found that the productivity of the solar still was maximized when the condensing glass cover inclination is equal to the latitude of the place. **Murugavel et al., (2008)** found that production of the solar still with 3 mm thick glass cover more than production that covered with 6 mm thick glass cover. Solar still with (PCM) had constructed by **Naim and Abd El Kawi (2002)**. They found that the use of storage material led to a larger productivity of fresh water. **Al-Hamadani and Shukla (2011)** found that the higher mass of (PCM) with lower mass of water in solar still basin significantly increased the daily productivity and efficiency. **Dashtban and Tabrizi (2011)** developed a theoretical model for solar still with and without (PCM). They concluded that the daily productivity of the solar still with and without the PCM was 6.7 and 5.1 kg/m^{2}day, respectively. Solar still with PCM was studied by **Kantesh (2012).** He found that the efficiency for solar still with PCM was higher than still without PCM. **Arunkumar et al. (2013)** studied the effect of thermal storage material on the solar still productivity. They found that, the productivity of the still with PCM was 26% higher than the still without PCM. Performance of solar still with PCM was also studied by **Al-Hamadani and Shukla (2014)**. The productivity of solar still with PCM was found increasing during post sunset operation which occurred. Solar still integrated with Paraffin wax as PCM was studied by **Sathyamurthy et al. (2014)**. They found an increase of about 35% in production of fresh water with PCM higher than that of solar still without PCM. Solar still integrated with PCM thermal storage was evaluated by **Sundaram et al. (2016).** The performance test is conducted with and without phase change material (PCM). The increased efficiency of desalinated water by using the paraffin wax as thermal energy storage material is 9.9 %. The aim of study is to evaluate the effect of paraffin wax as a phase change material on the productivity of solar stills, under climatic conditions of Egypt at Ismailia city during the period of the 24th September till the 3th October 2017.

2. MATERIALS AND METHODS

Experimental setup

Three similar single sloped solar stills were constructed and tested at the Agricultural Engineering Department, Faculty of Agriculture, Suez Canal University (Ismailia Governorate), Egypt (latitude angle of 30.62 ºN and Longitude angle of 32.27 ºE). The basin of solar still is rectangular in shape made of galvanized iron sheet having gross dimensions 1.30 m long, 0.80 m wide and 0.10 m deep with net surface area of 1.04. It is painted by red-lead primer thereafter by matt-type black paint in order to maximize the absorbed solar radiation. The solar still is covered with 3 mm thick of clear glass, and inclined by 31° of horizontal plane to transmit the maximum possible of solar radiation flux incident on it as revealed in **Figs (1)** and **(2)**. Otherwise, with this inclined angle (31°) condensation will run down the underneath of glass cover into the trough rather than dropping from the cover into the basin. Glass cover has been sealed with silicone rubber which plays an important role to promote efficient operation of condensation as it can accommodate the expansion and contraction between dissimilar materials. The supported frame for each still is made of iron posts. To minimize heat loss from the bottom, sides, and perimeter of the galvanized basins, each basin was fitted by an external wooden box of an identical shape with a slightly larger size. The gaps between each wooden and galvanized sheet were packed with 70 mm thick of styrofoam (thermal conductivity = 0.04 W $m^{-1}K^{-1}$). Paraffin wax is selected as the PCM due to its safety, good reliability, congruent melting and moderate cost.

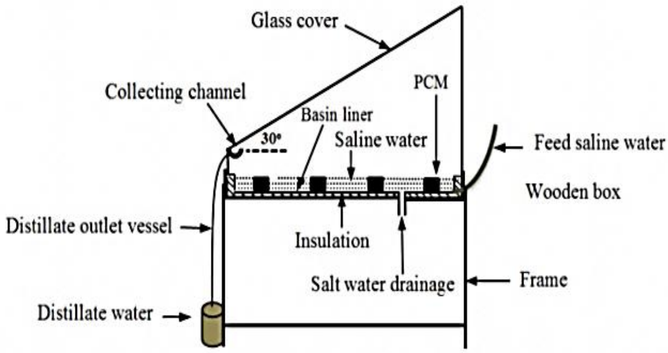

Fig. (1): Schematic diagram of experimental setup of solar still with PCM

Fig. (2): Three single slope solar stills with and without PCM

A phase change material tubes are installed with the solar still and filled by PCM. The walls of the PCM tubes are made of aluminum. The PCM tubes are rectangular in shape having gross dimensions of 120 cm long, 8 cm wide and 4 cm deep. A horizontal tube loaded with the PCM through a pipe has sufficient space for the volumetric expansion of the melting PCM. Paraffin wax with a mass of 5 and 10 kg were used because of its wide availability and its low cost. The thermo-physical properties of paraffin wax are summarized and listed in **Table (1) (Sathyamurthy et al., 2014)**. To collect the distilled water from the solar still a trough is placed along the three bottom sides (northern, southern and eastern sides) of the glass cover. The distilled water is continuously collected in a plastic vessel located outside the still and measured using a graduated cylinder. An inlet pipe is also fixed at the rear wall of the still for feeding brackish water.

Table (1): Thermo-physical properties of paraffin wax

Properties	Value
Solid / liquid density (kg m^{-3})	818/760
Melting temperature (ºC)	40 – 60
Latent heat of fusion (kJ kg^{-1})	226
Thermal conductivity (W m^{-1} ºC^{-1})	0.25
Specific heat of solid liquid (kJ kg^{-1} ºC^{-1})	2.95/2.51

Measurements and data acquisition

Meteorological station (Vantage Pro 2, Davis, USA) located above the roof of the Agricultural Engineering Department was used to measure different macroclimate variables such as incident solar radiation (pyranometer), ambient air temperatures and wind speed. Eight thermocouples with a range of 0 to 100ºC with an accuracy of ±0.1ºC were functioned to measure the temperatures of various points of each solar still system (basin water temperature, T_w, vapour temperature, T_v, inside glass temperature, T_g, paraffin wax temperatures inside the aluminum tube, T_p). These sensors were connected to a data-logger system (Lab-Jack logger, USA) to display and record the data during the experimental period. The output data were recorded every ten minutes and averaged every one hour using the data logging program.

Methods

During operating the solar stills, solar radiation was transmitted through the glass cover and absorbed by both the brackish water and the black metallic surface of basin bottom. Part of the absorbed energy by the basin bottom is transferred by convection to the brackish water. Another part of the heat energy was used to melt the paraffin wax. As the tubes are heated the heat is transferred to PCM and charging process is started to store solar energy as a sensible heat till PCM reaches its melting temperature. Additional charging heat is stored as the latent heat during the melting process. When the absorber surface temperature is lower than that the PCM (prior to sunset), reverse process is occurred (discharging process) till the PCM layer is completely solidified. Condensate water was flowed by gravity into the collection trough at the lower edges of the tilted glass cover (glass cover was at sufficient slope 31º). Therefore, surface tension of the water was induced to flow the condensed water into the trough without dropping back into the basin. Plastic container was used for collecting the distilled water coming out from the solar still. Suez Canal water was used as feed. Experimental work was carried out on successive days during August month of 2017. The experiments were continued until 8 h of the next day. The yield from the still was collected and measured every 1 h during the day time and night period. The three stills were positioned on a suitable steel structure and facing south direction. The first solar still was used without PCM as a control unit. The second still was functioned with the 5 kg PCM. The third still was operated with the 10 kg PCM. The concentration of hydrogen ion (pH), electrical conductivity (EC, µs/cm), and total dissolved solids (TDS, ppm) of the brackish water, respectively, were 7.8, 48.5 µs/cm and 31040 ppm.

Overall thermal efficiency of the solar still

The daily average overall thermal efficiency (η_d) for the solar still was computed based on the daily average condensate production (M in kg), latent heat (L in kJ/kg) at an average basin water temperature (T_w), daily average incident solar radiation (I in W/m^2), surface area of the solar still (A in m^2).The overall thermal efficiency of solar still is calculated using the following formula **Kantesh (2012):**

$$\eta_d = \frac{M\ L}{3.6\,I\ \ A} \, x100 \quad \%$$

The average latent heat (L) was determined by **Kabeel and Abdelgaied, (2016)** as follows:

$$\mathbf{L = 10^{-3}\,(2501.9 - 2.40706\,T_w + 1.192217 \times 10^{-3}\,T_w^2 - 1.5863 \times 10^{-5}\,T_W^3)}$$

3. RESULTS AND DISCUSSION

For the duration of the experimental work, the three similar solar stills were operated satisfactorily without malfunction. The hourly average incident solar radiation on the saline water inside the solar still, temperatures and distillate productivity were simultaneously measured and recorded. The hourly average incident solar radiation and the hourly average ambient air temperature is plotted in **Fig**. **(3)**. The hourly average intensity of solar radiation gradually increased from sunrise until reaching the maximum value at noon, and then it gradually decreased until reaching the minimum value prior to sunset. During the experimental tests, the hourly average incident solar radiation was 396.1 W m^{-2}, whilst, the hourly average air temperature outside the solar stills was 26.9ºC.

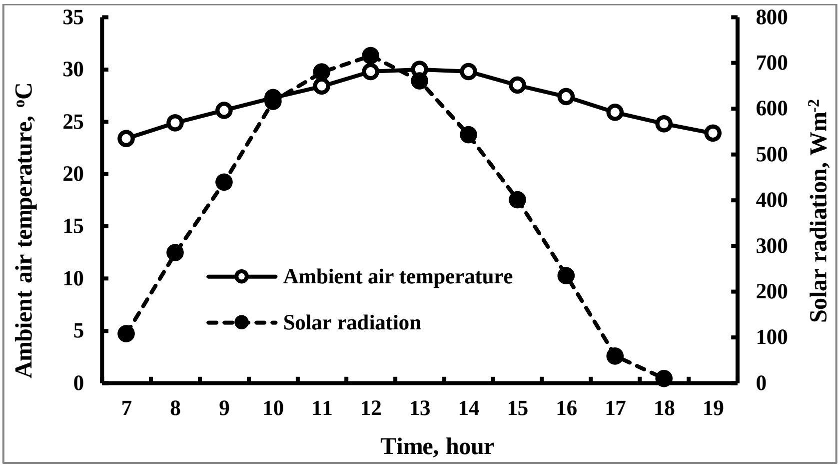

Fig. (3): Hourly average incident solar radiation and ambient air temperature versus solar time on the 24th September 2017

Fig (4) specifies the variations in saline water temperatures for the three solar stills during the day. It observed that, the saline water temperatures were reached to the maximum values at and around the solar noon and lowered during the morning and late afternoon hours. This occurred according to the intensity of incident solar radiation. As a result higher evaporation rate of the basin water was achieved. It also observed that, the maximum saline water temperatures for the solar stills without PCM, with 5 kg PCM, and with 10 kg PCM, which achieved at solar noon, respectively, were 60.1, 60.5 and 59.8°C due to the maximum amount of absorbed solar radiation at that time. Afternoon, saline water temperatures for the three solar stills were decreased because the heat energy losses from the solar stills to the convective surrounding environment increased, particularly when the water temperatures were higher than the absorbed solar radiation rate. The hourly average saline water temperatures for the three solar stills were 44.3, 46.2 and 47.6ºC, respectively. The highest hourly average saline water temperature during the daylight-time was achieved from the solar still with 10 kg PCM. The saline water temperature can be considered as one of the most important parameters that substantially affecting the productivity of fresh water.

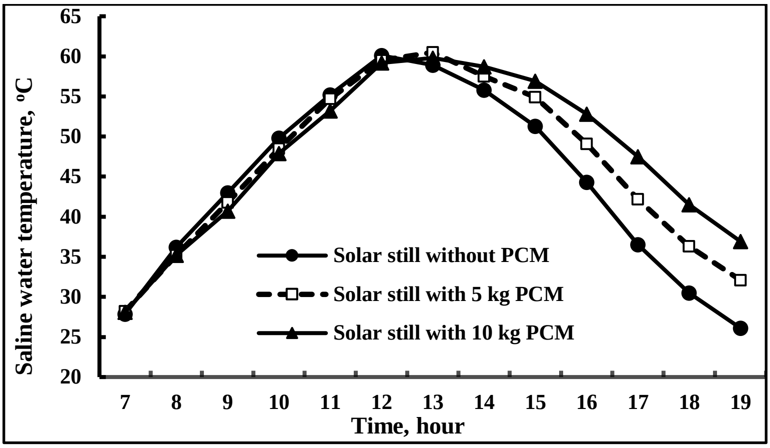

Fig. (4): Hourly average saline water temperatures for the three solar stills

The water vapour temperatures were found to be the highest operating temperatures for the three different solar stills due to the particles of vapour have enough heat energy (comprises sensible and latent heat) to evaporate. The distributions of the hourly average water vapour temperatures for the three solar stills were plotted in **Fig. (5)**. It clearly revealed that, the water vapour temperatures were reached to their peak values at 13 h. It is noticed that, the hourly average water vapour temperatures for the three solar stills, respectively, were 47.4, 49.3 and 50.8ºC.

The hourly average inner glass temperatures for the three solar stills are plotted in **Fig. (6).** As the glass cover temperature is lower than the dew point temperature of water vapour, much more condensation of water vapour on the inner surface of glass cover occurred. In the early morning (from 7 – 8 h), the glass temperature was closest to the water vapour temperatures resulting in lower productivity due to the lower heat energy absorbed by the water at these times. The hourly average inner glass temperatures for the three solar stills (without PCM, with 5 kg PCM, and with 10 kg PCM), respectively, were 40.7, 44.4 and 42.2ºC.

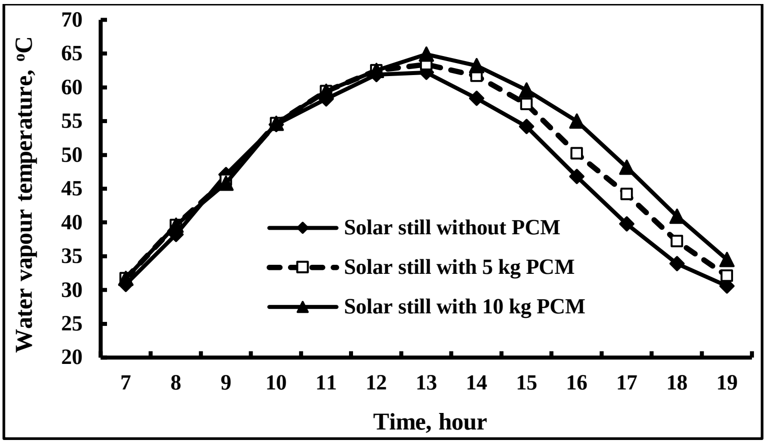

Fig. (5): Water vapour temperature for the three solar stills versus solar time

The temperature difference between the water and glass acts as a driving force of desalination process. Higher the temperature difference increases the productivity and evaporation rate. **Fig (7)** depicts the temperature difference between water and glass cover. It clearly revealed that, in the early morning the glass cover temperature is slightly higher than the water temperature because at that period glass is directly faces the solar radiation and its temperature rises faster as compared with the water temperature, as a result the difference has a negative values. These differences remained negative till water temperature exceeded the glass cover temperature. The maximum positive differences for the three solar stills were 7.6, 9.0 and 9.7°C, respectively.

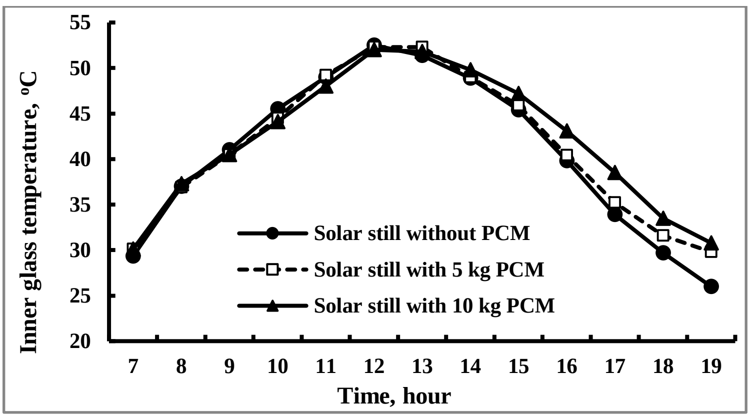

Fig. (6): Hourly average temperatures of inner glass cover for the three solar stills with and without PCM

The hourly average paraffin wax temperatures are plotted in **Fig. (8).** The paraffin wax starts to melt in the early morning due to the high intensity of incident solar radiation. It evidently showed that, the increase in temperature is directly proportional to the input energy which is similar to the trends of solar radiation. The hourly average paraffin wax temperatures for the two solar stills were 45.1 and 46.5ºC, respectively. The PCM temperatures which measured and recorded were approximately closed to the basin water temperature at 15 h after reaching the melting point of PCM (54°C). Thereafter, the paraffin wax was under the charging mode of heat transfer. As a result, the PCM increase the basin water temperature and consequently the productivity throughout the day. Subsequently, with a decrease in temperature, it becomes solid again releasing sensible heat into water, even after the sunset. The latent energy stored in the paraffin wax kept the system to be operated during the nighttime and delivered distillate water output.

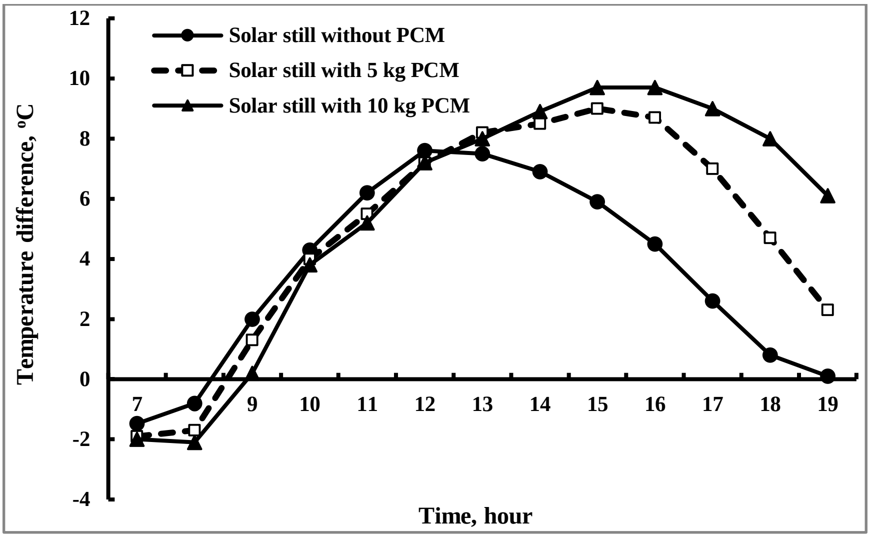

Fig. (7): Hourly average temperature difference between saline water and inner glass cover for the three solar stills

The economical productivity rate of fresh water reflects how much the solar stills were adapted to the heat storage material. The productivity rate of fresh water in ml/m^2 h for the three solar stills is shown in **Fig. (9)**.

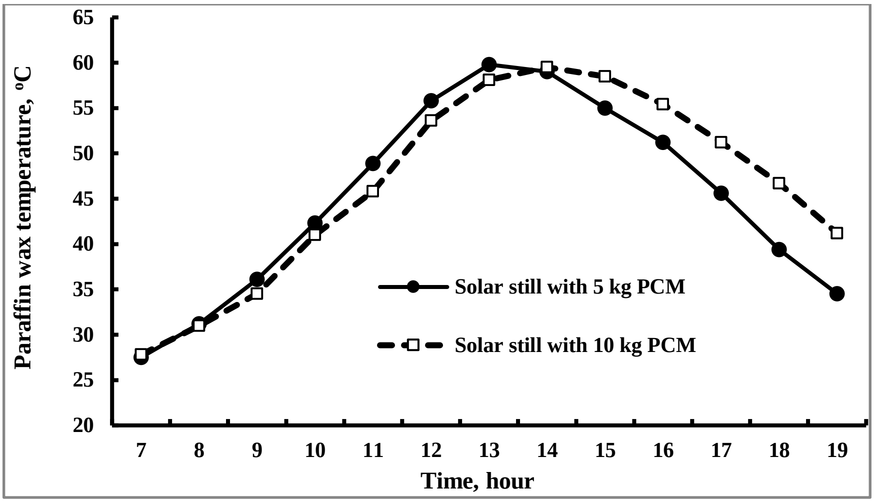

Fig. (8): Hourly average temperatures of paraffin wax

Results showed that, the solar intensity is directly proportional to the yield of fresh water from the solar still due to the increase in heat energy gained by the saline water at which vaporization inside the stills increased **(Sathyamurthy et al., 2014)**. It can be seen that, the productivity of fresh water for the three solar stills gradually increased from early morning until reached the maximum values afternoon. Daily average productions of fresh water from the three solar stills (without PCM, with 5 kg PCM and 10 kg PCM), respectively, were 151, 182 and 207 ml/ m^2 h.

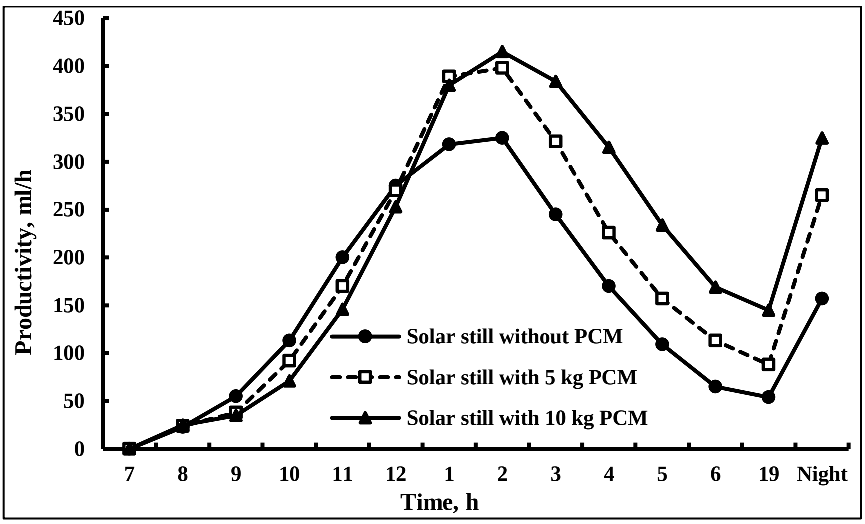

Fig. (9): Hourly average productivity rates for the three solar stills

The accumulated fresh water yield for the solar stills with and without heat storage material is plotted in **Fig**. **(10)**. The daily average productivity of fresh water from the three solar stills approximately reached to 2109, 2551, and 2897 ml/m^2 day, respectively. The experimental results showed that, the daily average productivity of fresh water for the two solar stills with PCM was higher than that of the conventional solar still. The highest productivity rate was achieved from the solar still with 10 kg PCM due to the higher specific heat capacity, better latent heat of fusion, and thermal conductivity of paraffin wax. Therefore, the productivity rate of fresh water at nighttime and during the daylight-time for the two solar stills with PCM increased by 21.0 and 37.4% as compared with the conventional solar still , respectively. As a result, using PCM in solar still was found to be the best option to increase the solar still productivity not only during the daylight-time but also at the nighttime. These data are in agreement with that published by **Kabeel and Abdelgaied (2016).**

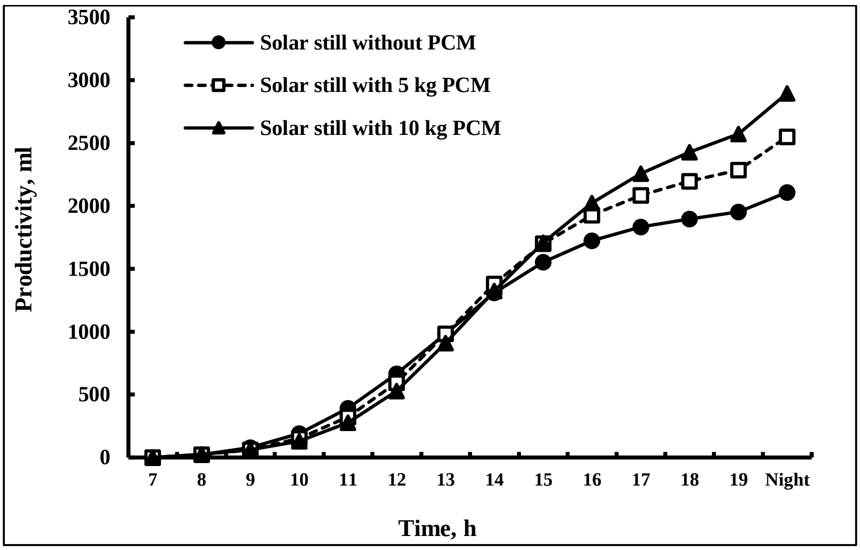

Fig. (10): Effect of PCM on the accumulated productivity of solar stills

The thermal efficiency of the solar still is considered the most important factor could be used to evaluate the thermal performance. The hourly average thermal efficiencies for the three solar stills were 28.9%, 34.9%, and 39.6%, respectively. The addition amount of the storing materials was definitely improving the thermal performance of the single slope solar still by increasing the overall water collection over 24 h. Therefore, the hourly average thermal efficiency for the two solar stills with 5 and 10 kg PCM increased by 20.8 and 37 %, as compared with the conventional solar still, respectively.

Quality of distilled water

The pH, EC and TDS values of the brackish water and the solar distilled water which obtained from the experimental work are summarized and listed in Table (2). These values were found to be much lower (7.46, 0.21 µs/cm and 134.4 ppm, respectively) than those of the brackish water (7.8, 48.5 µs/cm and 31040 ppm, respectively). The quality of potable water distilled from solar still is suitable for drinking particularly in remote areas.

Table (2): Quality parameters (pH, EC, and TDS) of the solar distilled water and brackish water during the experimental tests

Parameter	Brackish water	Distilled water
pH	7.8	7.46
Electrical conductivity (EC), µs/cm	48.5	0.21
Total Dissolved Solids (TDS), ppm	31040	134.4

4. CONCLUSION

In this present research work, several conclusions can be obtained and drawn as follows:

1- Hourly average temperatures of saline water for the three solar stills (without PCM, with 5 kg PCM and with 10 kg PCM) were 44.3, 46.2 and 47.6ºC, respectively.

2- Hourly average water vapour temperatures for the three solar stills, (without PCM, with 5 kg PCM and with 10 kg PCM) respectively, were 47.4, 49.3 and 50.8ºC.

3- The productivity rate of distillated water at nighttime and during the daylight-time for the two solar stills with 5 kg and 10 kg PCM increased by 15.9 and 29.5 % as compared with the conventional solar still, respectively.

4- The hourly average thermal efficiency for the three solar stills was 28.9%, 34.9%, and 39.6%, respectively.

5- The pH (7.46), EC (0.21 μs/cm), and TDS (134.4 ppm) values were lower than those of the brackish water (7.8, 48.5 μs/cm and 31040 ppm, respectively).

6- Using PCM in solar still was found to be the best option to increase the solar still productivity not only during the daylight-time but also at the nighttime.

5. REFERENCES

Al-Hamadani, A. A. F.; and Shukla, S. K. (2011) "Water distillation using solar energy system with Lauric acid as storage medium" International Journal of Energy Engineering, 1(1): 1-8.

Al-Hamadani, A. A. F.; and Shukla, S. K. (2014) "Modelling of solar distillation system with phase change material storage medium" Thermal science, 18 (2): 347-362.

Arunkumar, T.; Denkenberger, D.; Ahsan, A.; and Jayaprakash, R. (2013) "The augmentation of distillate yield by using concentrator coupled solar still with phase change material" Desalination, 314, 189–192

Dashtban, M.; and Tabrizi, F. F. (2011) "Thermal analysis of a weir-type cascade solar still integrated with PCM storage" Desalination, 279, 415–422.

El-Sebaii, A. A.; Al-Ghamdi, A. A.; Al-Hazmi, F. S.; and Faidah, A. S. (2009) "Thermal performance of a single basin solar still with PCM as a storage medium" Applied Energy, 86, 1187-1195

Goosen, M. F. A.; Sablani, S. S.; Shayya, W. H.; Paton, C.; and Al-Hinai, H. (2000) "Thermodynamic and economic considerations in solar desalination" Desalination, 129: 63-89

Kabeel, A. E.; and Abdelgaied, M. (2016) "Improving the performance of solar still by using PCM as a thermal storage medium under Egyptian conditions" Desalination, 383: 22–28.

Kantesh, D. C (2012) "Design of solar still using Phase changing material as a storage medium" International Journal of Scientific & Engineering Research, 3, 12.

Murugavel, K. K.; Chockalingam, K. S. K.; and Srithar, K. (2008) "Progresses in improving the effectiveness of the single basin passive solar still" Desalination, 220: 677-686.

Naim, M. M;. and Abd El Kawi, M. A. (2002) "Non-conventional solar stills part 2, Non-conventional solar stills with energy storage element" Desalination 153, 71-80

Ramasamy, S.; and Sivaraman, B. (2013) "Heat transfer enhancement of solar still using phase change materials (PCMs)" International Journal of Engineering and Advanced Technology, 2, 3

Sathyamurthy, R.; Nagarajan, P. K.; Kennady, H. J.; Ravikumar, T. S.; Paulson, V.; And Ahsan, A. (2014) "Enhancement of fresh water production on triangular pyramid solar still using phase change material as storage material" Frontiers in Heat And Mass Transfer, 5, 3.

Sharma, A.; Tyagai, V. V, Chen,; C. R.; and Buddhi, D. (2009)" Review on thermal energy storage with phase change materials and applications" Renewable and Sustainable Energy Reviews, 13, 318 – 345.

Singh, H. N.; and Tiwari, G. N. (2004) "Monthly performance of passive and active solar stills for different Indian climatic conditions" Desalination, 168, 145 – 150

Sundaram, P.; Mohan, D. S.; and Kumar, M. P. (2016) "Evaluation of pyramidal slope solar still integrated with PCM thermal storage" International Journal of Chem. Tech. Research, 9 (9): 230 – 236.

الملخص العربي

تآثير المواد متعددة الأطوار على الأداء الحرارى للمقطرات الشمسية

سامح سعيد كشك [١]

أجري هذا البحث بقسم الهندسة الزراعية - كلية الزراعة - جامعة قناة السويس ويهدف إلي تقييم ثلاثة وحدات تقطير شمسي من النوع الجمالونى ذات الميل الواحد. الأولي بدون مادة مخزنة للحرارة (كنترول) ، الثانية تحتوى على ٥ كجم من شمع البرافين كمادة مخزنة للحرارة، الثالثة مضاف إليها ١٠ كجم من شمع البرافين. و تتكون جميع الوحدات من حوض التبخير المصنوع من الصاج المجلفن بسمك ١،٠ مم ومساحة سطحه ١،٠٠٤ م^{2} وعمقه ٠،٠١ م مطلي باللون الأسود، موضوع داخل صندوق من الخشب بسمك ٠،٠٠٢ م، تم عزل حوض التبخير من الجوانب ومن أسفل بطبقة من الفوم سمكها ٠،٠٠٣ م. أما سطح التكثيف الرئيسي فهو عبار عن غطاء من الزجاج الشفاف بسمك ٣ مم. ويتم تجميع القطرات المتكاثفة عن طريق قنوات التجميع الموجودة أسفل الغطاء في جميع الوحدات. ولإجراء التجارب تم تغذية الوحدات بمياه مالحة من قناة السويس بتركيز ٣٤٥٠٠ جزء في المليون.

وقد أوضحت النتائج مايلي:

١- متوسط درجات الحرارة للماء المالح في وحدات التقطير عل مدار اليوم ٣،٤٤ ، ٢،٤٦ و ٦،٤٧ م° لكل من الوحدة الأولي والثانية والثالثة علي الترتيب.

٢- متوسط درجات الحرارة للبخار في وحدات التقطير عل مدار اليوم ٤،٤٧ ، ٣،٤٩ و ٨،٥٠ م° لكل من الوحدة الأولي والثانية والثالثة علي الترتيب.

٣- وجد أن متوسط الإنتاجية الكلية خلال اليوم زادت بمقدار ١٥،٩ و ٢٩،٥ % لكل من الوحدة الثانية والثالثة عن الوحدة الأولي علي الترتيب.

٤- وجد أن متوسط الكفاءة الحرارية على مدار اليوم ٠،٣١ ، ٧،٢٤ ، ١،٢١ % لكل من الوحدة الأولي والثانية والثالثة علي الترتيب.

٥- تم خفض محتوى الماء المالح من الأملاح الذائبة الكلية من ٣١٠٤٠ جزء فى المليون إلى ١٣٤،٤ جزء فى المليون للماء المقطر

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