BJES Basrah Journal for Engineering Sciences

Basrah Journal for Engineering Sciences, Vol. 21, No. 2, (2021), 45-52

Original Article

Journal homepage: www.bjes.edu.iq
ISSN (Online): 23118385, ISSN (Print): 18146120

OPEN ACCESS

Using PCM, an Experimental Study on Solar Stills Coupled with and without a Parabolic Trough Solar Collector

Hazim Jassim Jaber [1,*], Qais A. Rishak [2], Qahtan A. Abed [3]

[1] *Department of Mechanical Engineering, College of Engineering, University of Kufa, Najaf, Iraq*
[2] *Department of Material Engineering, College of Engineering, University of Basrah, Basrah, Iraq*
[3] *Technical Institute/Al-Rumaitha, Al-Furat Al-Awsat Technical University, Al-Muthanna, Iraq*
E-mail addresses: hazimj.altalqani@uokufa.edu.iq , qais.rashck@uobasrah.edu.iq , qahtan.abed@atu.edu.iq
Received: 10 May 2021; Revised: 22 June 2021; Accepted: 1 July 2021; Published: 11 July 2021

Abstract

Performance a double slope of the solar still Integrated With or without parabolic trough collector is investigated experimentally. To improve the output of a double slope solar still, a number of initiatives have been undertaken, using wax as a phase change material (PCM) with a parabolic trough collector. A parabolic trough collector (PTC) transfers incident solar energy to the solar still through a water tube connected to a heat exchanger embedded in used microcrystalline wax. Experiments were carried out after orienting the basin to the south and holding the water depth in the basin at 20 mm. According to the results obtained, the solar stills with parabolic trough collector have higher temperatures and productivity than solar stills without parabolic trough collector, as well as the ability to store latent heat energy in solar still, allowing fresh water to condense even after sunset. In addition, the parabolic trough collector with phase change material in the double slope solar improves productivity by 37.3 % and 42 %, respectively.

Keywords: Double slope, Solar still, Solar Desalination, Parabolic trough collector.

https://doi.org/10.33971/bjes.21.2.7

1. Introduction

Solar energy is a form of natural energy that is readily available in many places and can be used in a variety of industrial and domestic applications. Many authors have investigated various pollution treatment systems using solar energy in various fields, such as water desalination and heating, using various geometric designs and techniques, including active and passive solar systems, with or without collectors. So many researchers used solar parabolic trough collectors to heat water in order to increase output while lowering manufacturing costs.

Padilla et al. (2011) [1] the heat transfer of a parabolic trough solar receiver was investigated. They recommended a model with more accurate heat transfer correlations and a thorough heat transfer investigation. The envelope and receiver were divided into several parts, each with its own energy and mass balance. The results showed that the experimental and other heat transfer models were in good agreement. The heat transfer model's efficiency is improved by 41.8 percent because of the reduction in convective heat loss.

Tripathi and Tiwari (2004) [2] the principle of solar fractionation was used to test the still's performance. For design and climatic parameters, an experimental validation of the model established previously was carried out. They discovered that the solar fraction has a significant impact on the thermal modeling of the still. Furthermore, at lower values of the solar altitude angle, the solar fraction plays an important role.

Al-Hamadani et al. (2012) [3] the performance analysis of a solar distillation system with PCM storage was studied experimentally. During the months of April and May 2011, the empirical work was carried out in India under Indian climatic conditions. The productivity of solar stills containing Lauric acid is 22 % higher than that of solar stills containing Myristic acid, according to the findings. Rather, the findings revealed that the process of the thermal storage material has a significant effect on the system's productivity.

Ayoub et al. (2015) [4] an experiment with a solar still desalination system with increased productivity was investigated. The investigation's unique feature is a design for solar stills that is both efficient and cost-effective, particularly in areas where sunlight is abundant. According to the findings, the new system produces more with average in a daily productivity increase of 200 percent on, and it eliminates the stagnation issue that occurs in traditional stills basins.

Bacha et al. (2007) [5] numerical modeling of a desalination device with a storage tank and solar collectors was investigated. The mathematical models were created in order to be able to predict the system's efficiency under various climate conditions. Choosing the best template for the study. The entire research was conducted using real-world evidence from experiments. Furthermore, three different configurations of solar hot water systems were studied and simulated using mathematical models. The hot water storage tank had two internal heat exchangers in the first mode. The second mode was a single heat exchanger hot water storage tank. The results of the modeling and simulation revealed that a divided hot water tank with a heat exchanger significantly improves distilled water output compared to other designs.

Davani et al. (2017) [6] an evacuated parabolic solar trough with a solar tracker was used to test a multistage water desalination device. Experimental research has been conducted on the performance of multi-stage water. The desalination still connected to a solar parabolic trough with focal pipe. In comparison to other basin types, the results suggested a very good quality. The distillation capability can be greatly increased even though the tested device is only a two-stage laboratory prototype, and the yield was higher than that of traditional basin stills and even multi-stage stills combined with flat plate collectors. Since each stage starts to produce distilled water when the temperature reaches more than 42 degrees, high production can be achieved by increasing the number of stages.

Al-rukabie (2018) [7] built two identical double slope solar panels with the same specifications to improve productivity in the south of Iraq's environment. One of the solar stills was adjusted to maximize efficiency as compared to a non-modified solar still. The results show that modifying a double slope solar still with black fabric, charcoal powder, and reflection mirrors increases productivity, as well as increasing productivity with a low water depth in the solar still basin.

Hammadi and Jasim (2019) [8] the experimental investigation of solar still in different conditions was presented. The effect of insulation and water level on yield production in a linear basin with a single slope was still investigated. The test was carried out in Mosul, Iraq, from May to August 2017. The results show that by using thermal insulation, the performance is still increasing. The water level and insulation are found to be important factors in the passive solar desalination process. In addition, the desalination method is extremely useful at night.

Ramanathan et al. (2017) [9] the productivity of a modified single-basin solar still with a flat plate absorber was investigated in an experiment. A flat mica plate was inserted in the solar still to help with water evaporation from the input saline water. To improve solar radiation absorption, the flat plate absorber was mounted parallel to the still's glass cover. As compared to the conventional, the modified has a higher performance. This is due to the fact that the absorber plate is parallel to the glass surface and roughly equal to the latitude of this location. As a result, optimum solar radiation absorption is achieved while the cavity volume between the glass surface and the absorber surface is reduced. More condensation and evaporation resulted as a result of this.

Alawee et al. (2015) [10] three methods that function in tandem were investigated for improving the efficiency of a double slope solar still. Two solar stills were made, one in the traditional design and the other in the proposed design. During the months of February to July 2014, the two solar stills were put to the test in Baghdad, Iraq, under a variety of weather conditions. According to the findings, using a solar still with internal reflective panels boosts water distiller productivity by 18.5 percent, whereas using a collector/storage solar heater and gravel content boosts productivity by 48 percent.

Sonawane et al. (2015) [11] experiments were conducted to see if the angle of the PCM embedded absorber surface could improve solar still productivity. The PCM was used as a thermal energy storage material, and it was also compared to a standard still. The results showed that enhancing the evaporation rate and thermal conductivity with angle variance and PCM with solar still is both cost efficient and feasible. In comparison to a traditional solar still, freshwater productivity improved on a regular basis. As compared to other angles, efficiency improved by 62 percent at 34 degrees.

Badran and Al-Tahaineh (2005) [12] by using fuzzy sets, the study indicated can learn about the effects of different atmospheric conditions on the solar distillation mechanism. Solar strength, water depth, air temperature, wind speed, sprinklers, integrated collectors, and solar concentration all have an effect on solar still productivity, according to the report.

Aondoyila et al. (2016) [13] the impact of thermal storage on desalination system productivity was discussed at various levels. Solar without PCM was compared to solar still with PCM to assess the impact of PCM. The temperature of the water, the air temperature, the temperature of the inner surface glass, and the temperature of the outer surface glass were all measured. They discovered that thermal storage improved productivity by 62 percent in the parabolic concentrator-coupled single slope solar system.

Arunkumar et al. (2013) [14] the effect of stored heat energy can also increase the production of solar still.

Rajaseenivasan et al. (2003) [15] at the same conditions, solar with an extra basin improves efficiency by 85 % this was improved theoretically and experimentally. The study aims to increase the rate of evaporation of saline water by adding extra heat from a parabolic trough solar collector to a heat exchanger tube submerged in a wax basin coupled with a solar still.

2. Experimental procedure

The experimental system was set up at the Kufa University in Najaf, Iraq (latitude 32' 026" N, longitude 44' 37" E). The experimental device consists of two double slopes solar still, one without PTC and the other with PTC.

2.1. Solar Still

The solar still system is formed as shown in Fig. 1. Two basins are made of galvanized iron sheets that have been painted black and are not gleaming. They are 1.5 mm thick and have the same width and length of 1.0 m and 1.5 m, but their height varies. In the first basin, microcrystalline wax was used as a phase change material (PCM) as a heat storage medium. Table 1 shows the characteristics of the wax used. Which are provided by the wax provider. The wax basin, which is 0.04 m deep and contains 42 kg of PCM. A heat exchanger is also submerged in the second wax basin, as shown in Fig. 2 (a) and (b). The heat exchanger pipe is made of copper tubing with a diameter of 11.28 mm and a length of 16 m, and it is placed 1 cm above the surface of the wax basin. To avoid heat leakage, a second basin of water with a 0.10 cm height was mounted over the wax basin and sealed with silicone. It is filled with saline water, and all of the basin's internal surfaces are painted with black paint materials to improve the basin's solar radiation absorptivity. Thermal insulation was used to avoid heat loss from the basin's bottom and sidewalls to the environment. In this study, glass wool insulation with a thickness of 25 mm and a thermal conductivity of 0.04 (w/m K) was used. The insulation type chosen must have a low thermal conductivity, be lightweight, be readily available, be inexpensive, and be simple to fabricate. Surface bottom and side walls to the basins were also fitted within a 0.03 m thick wooden frame with dimensions of 1.7 m length, 1.15 m width, and 0.24 m height. Both sides are supported by wooden frames sealed with silicone material to avoid any leakage between the basin box and the glass cover. The top is covered with two glasses of thickness 4 mm inclined at 32°, which is the latitude angle of Najaf city, Iraq. To get the most amount of incident solar radiation, the double slope solar system was positioned south-north of the city of Najaf. The collected fresh water is continuously drained through a flexible hose and collected in a measuring jar through a channel made of reinforced plastic installed within the solar still at the bottom of the solar still glass walls.

Table 1 Properties of used Microcrystalline wax.

Properties	Value	Unit
Congealing Point	60 - 66	°C
Melting Temperature	70 - 75	°C
Liquid Density (ρ)	900	kg/m^3
Solid Density (ρ)	930	kg/m^3
Thermal Conductivity (K)	0.26	W/m K

Fig. 1 The experimental system.

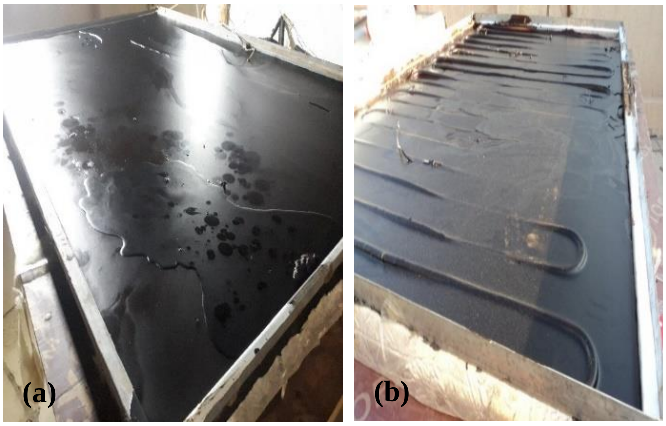

Fig. 2 (a) basin wax without heat exchanger. **(b)** basin wax with heat exchanger.

2.2. Parabolic Solar Concentrator

The used PTC consists of a parabolic solar concentrator that works as a reflector and concentrates solar radiation on the receiver tube as shown in the Fig. 3. The parabolic solar concentrator is made of reflective stainless-steel sheet with a focal length of 0.266 m and a length of 2 m, 1.06 m aperture, and 0.5 mm thickness. The Parabolic Trough Collector's receiver tube is made up of an absorber model SUS304 pipe that is 2 m long, 0.04 m in diameter, and 0.003 m thick, and is covered with an anti-reflective coating to absorb the most amount of incident solar radiation. Covered by a 1.9 m long and 10 cm diameter evacuated tube made of high borosilicate glass. The evacuated space between the steel and glass tubes is used to reduce convective heat losses and improve the receiver tube's solar radiation absorption. It is oriented to the south with a tilt angle equal to the latitude of Najaf, Iraq. The solar radiation absorbed by the receiver tube is transferred to water flowing through the tube, which is then used to transfer the heat gain to the microcrystalline wax in the double slope solar still connected with parabolic trough collector. The heated water is transferred from the receiver tube to the wax basin using the plastic tubes. The plastic tubes are made of low-thermal-conductivity plastic that is coated on the outside to reduce heat loss from hot water. The heat carried by the water at the soar's inlet is transferred to the wax basin through a heat exchanger. At a flow rate of 0.75 L/min, a small pump pumps hot water through the tubes of the used system between parabolic trough collectors with solar still. Thermal efficiency of PTC directly depends on the concentration ratio [16].

$$Cr = \frac{W_{ap}}{\pi D_o} \tag{1}$$

In addition, the experimental thermal efficiency of the collector is calculated by.

$$\eta_{exp} = \frac{\dot{m}\, Cp\, (T_{out} - T_{in})}{I.\ A_{ap}} \tag{2}$$

Fig. 3 the parabolic trough collector.

2.3 Experimental Measurements

The experimental measurements were conducted for two days in September and October 2020, from 9:00 AM to 4:00 PM. Temperature measurements at various locations on the solar still provide useful information and explanations about the still's efficiency. During the study period, temperatures of ambient air (T_a), temperature outside glass cover of south and north (T_{gs}), (T_{gn}), saline water (T_w), surface basin water (T_{sb}), water steam (T_s), and temperatures of water temperature at the inlet basin wax to heat exchanger from PTC (T_{po}), water at inlet the PTC (T_{pi}), and water at the outlet from basin wax ($T_{wax\text{-}o}$), and temperature wax (T_{wax}), surface basin wax (T_{swax}) were measured simultaneously. The glass temperature was measured on the south and north facing glass walls because they have a greater impact on solar still output than the other sides. The temperature of the saline water was measured at a distance of 1cm from the basin's bottom. The outputs of the thermocouples were recorded on a digital temperature system of type Mult-Channel Temperature Meter (AT4532) modular programmable logic control, and the temperatures were recorded using K-type thermocouples. The strength of solar radiation (I) was measured using a Digital Solar Power Meter, and the tracking device to solar tracker was used to be appropriate for solar tracking from south to north to capture as much solar radiation as possible. Throughout all of the experiments, the water flow rate was kept steady at 0.75 L/min. In a measured flask, condensed freshwater was stored. At a depth of 20 mm in salt water, the measurements were taken. Every 30 minutes, the temperatures and solar intensity were both measured and registered.

3. Results and Discussion

For two days in September and October, a variety of practical experiments were carried out with both distillates used in the study. Since the thermal behavior of all of the experiments was nearly identical, some of them were chosen to be graphically described. The current research is being conducted for the two solar still systems tested, a double slope solar still with PCM and a double slope solar still with PCM and PTC, as well as the depth of saline water in the basin, D_w (20 mm). The measurements are measured and recorded each 30 minutes from 9:00 AM to 4:00 PM. Increases in the rate of evaporation of the salt water in the basin and the rate of condensation of the evaporated water in the humid air zone improve solar productivity.

3.1. Temperatures

Temperature measurements at various locations on the solar still provide useful information and explanations about the still's performance, so all temperatures are recorded.

Figures 4 (a) and (b) depicts the evolution of ambient air temperatures (T_{amb}) and solar intensity (I) over time for a solar still without PTC at a depth of 20 mm. From the morning until around 12:00 PM., the solar intensity and ambient air temperature increase with time, and then the solar intensity decreases with time. It's worth noting that the intensity peaks at about 12:00 PM. If the ambient air temperature rises until about 2:00 PM., it then becomes semi-stable and gradually decreases over time.

Figures 5 (a) and (b) for the solar still without parabolic trough collector, it shows the hourly temperature changes of basin water (T_w), basin surface (T_{sb}), PCM (T_{wax}), and basin surface to wax (T_{swax}). All of the temperature values show an upward trend as time passes, reaching a peak at 14:00 PM., for (T_w), (T_{sb}), and 16:00 PM., for (T_{wax}), (T_{swax}), and then gradually decreasing. The maximum temperatures for (T_w), (T_{sb}), and (T_{wax}) for 28 September (59.4, 58.4, and 48.8) °C and 3 October (62.1, 60.4, and 50.5) °C. Microcrystalline wax (PCM) absorbs heat from the absorber plate when solar radiation falls at the beginning of the experiment, and its temperature rises over time. Its temperature begins to drop as solar radiation decreases. Additionally, the PCM transfers its stored heat to basin water, keeping it hot during the sunsets and the distillation process continues for a longer period.

Figures 6 (a) and (b) shows the evolution of water steam temperatures (T_{s1}, T_{s2}, T_{s3}, T_{s4}) distributed vertically in various dimensions, as well as south glass cover (T_{gs}) and north glass cover (T_{gn}) over time. It shows that the temperature of water vapor increased over time and was higher than the temperature of the glass cover (T_{gs}, T_{gn}), which is consistent with the evaporation process. They also show that the water steam temperatures near the surface of the southern and northern glass covers (T_{s4}, T_{s3}) are higher than (T_{s1}, T_{s2}) and higher than (T_{gs}, T_{gn}). The solar's performance is still influenced by the temperature difference (T_s - T_a), where condensation increases as this value rises. It also depends on the temperature of the saline water (T_w), which increases as the temperature rises, speeding up the evaporation process. All of the parameters gradually decrease as the amount of solar radiation falls.

Figures 7 (a) and (b) shows the evolution of saline water (T_w), water basin surface (T_{sb}), PCM (T_{wax}) and wax basin surface (T_{swax}) temperatures over time, steam (T_{s1}, T_{s2}, T_{s3}, T_{s4}), south glass cover (T_{gs}), north glass cover (T_{gn}) temperatures for the solar still connected with tracked parabolic trough collector (PTC) at saline water depth 20 mm.

The pattern of the evolution with time in temperatures (T_w, T_{sb}, T_{wax}, T_{swax}, T_s, T_{gs}, T_{gn}) is close to the trend of the solar still without PTC, as shown in Figs. 8 (a) and (b). But, the solar still with tracked PTC, on the other hand, has the highest effective solar still temperatures, while the solar still without PTC has the lowest saline water, steam, and wax temperatures. This means that the evaporation rate of a solar still with PTC is higher than a solar still without PTC.

As a result, for all studied systems, water evaporation is greater than solar still without PTC, because humid air has a greater ability to carry vapor due to the increased temperature. Microcrystalline wax PCM was used in the current system to absorb heat from solar radiation falling on the water basin as well as from the parabolic trough collector PTC through a heat exchanger immersed in the PCM, and thus increasing temperatures (T_{swax}), (T_{wax}), basin surface (T_{sb}), steam (T_s), and water (T_w). In addition, the PCM is kept heat of resulting by solar radiation and the PTC even when the ambient temperature and solar intensity are reduced. Following that, as the sun sets lower in the sky, the PCM starts to release latent heat to the basin surface (T_{sb}) in the still basin. This aids in keeping the basin water hot for longer periods of time, allowing the condensation process to continue even through the night, increasing productivity. Maximum temperatures for (T_w), (T_{sb}), and (T_{wax}) for 28 September (60.5, 59.4, and 58.9) °C, and 3 October (61.9, 61.2, and 59.85) °C, respectively.

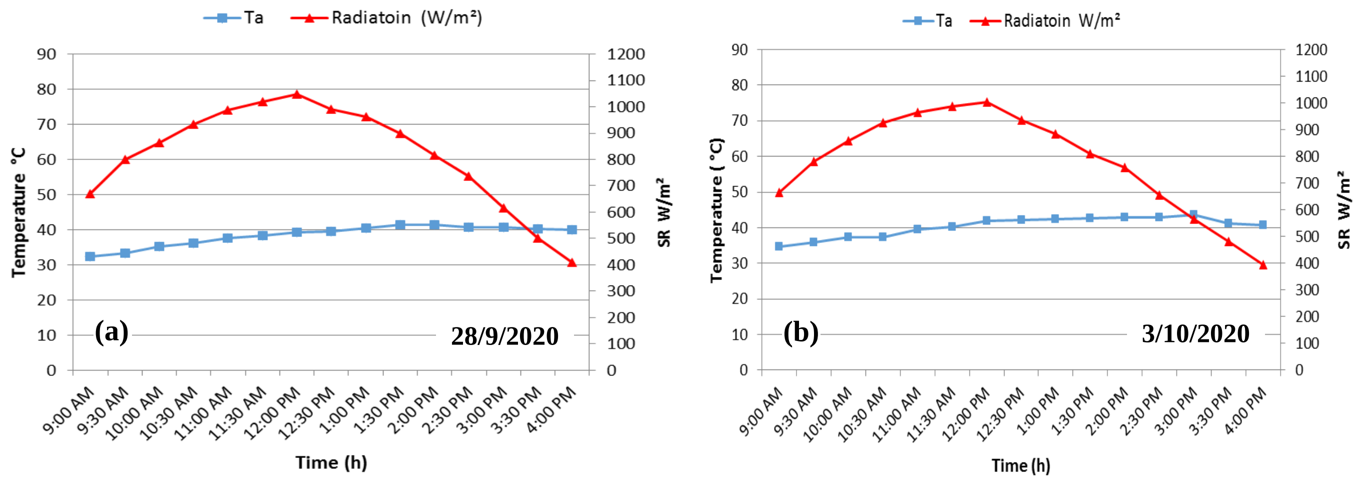

Fig. 4 Evolution of ambient air temperatures and solar intensity over time in September and October 2020.

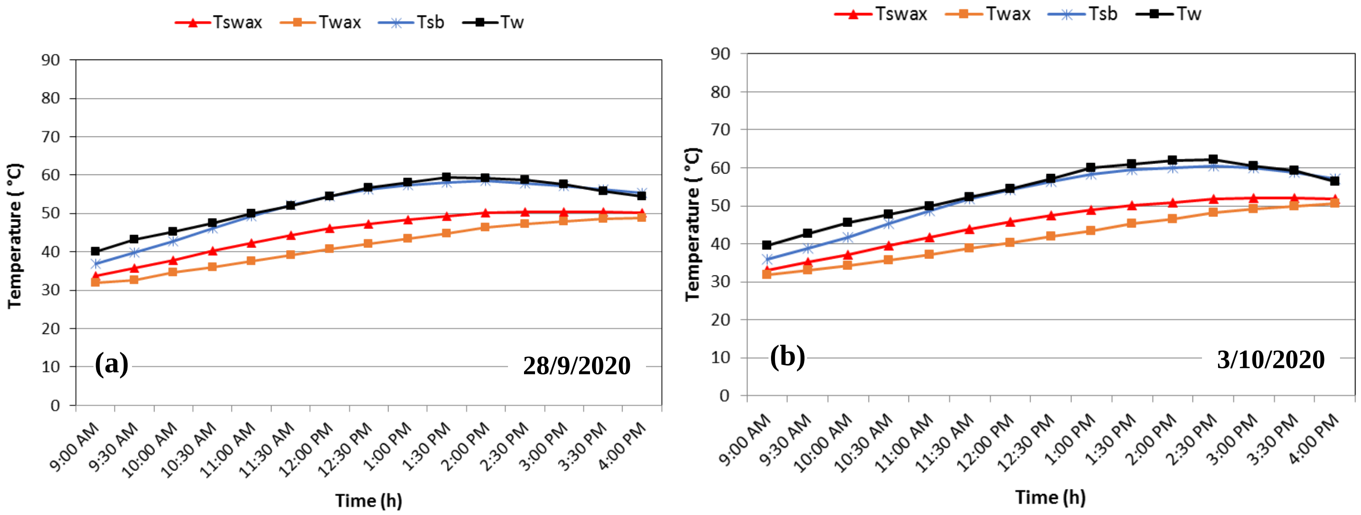

Fig. 5 Temperature change over time for a solar still without PTC at a depth of 20 mm in September and October 2020.

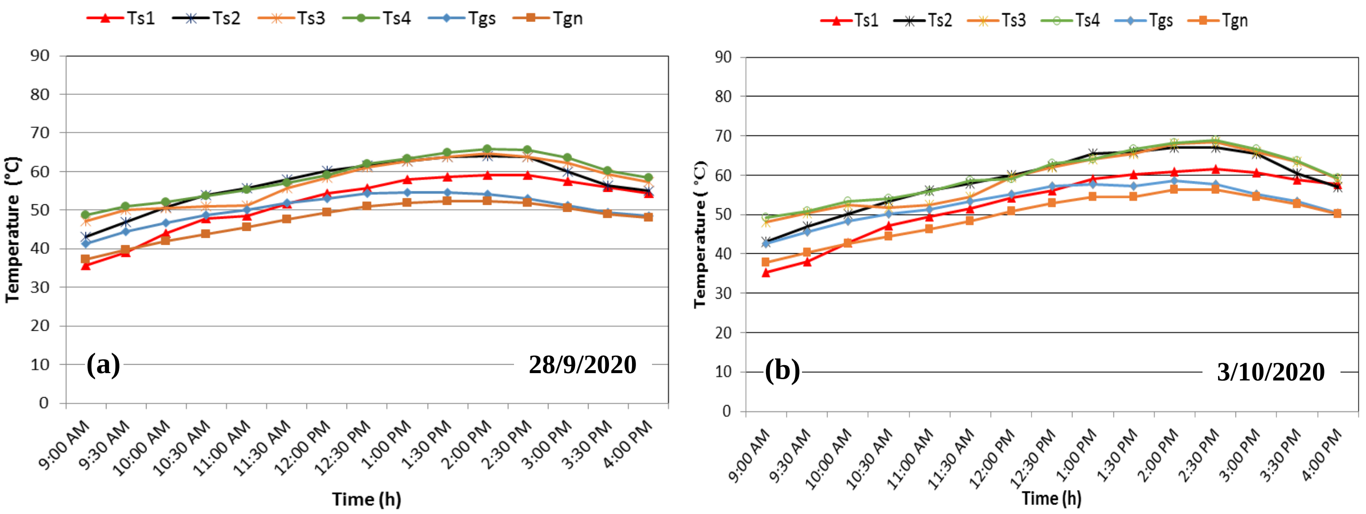

Fig. 6 Temperature change over time for a solar still without PTC at a depth of 20 mm in September and October 2020.

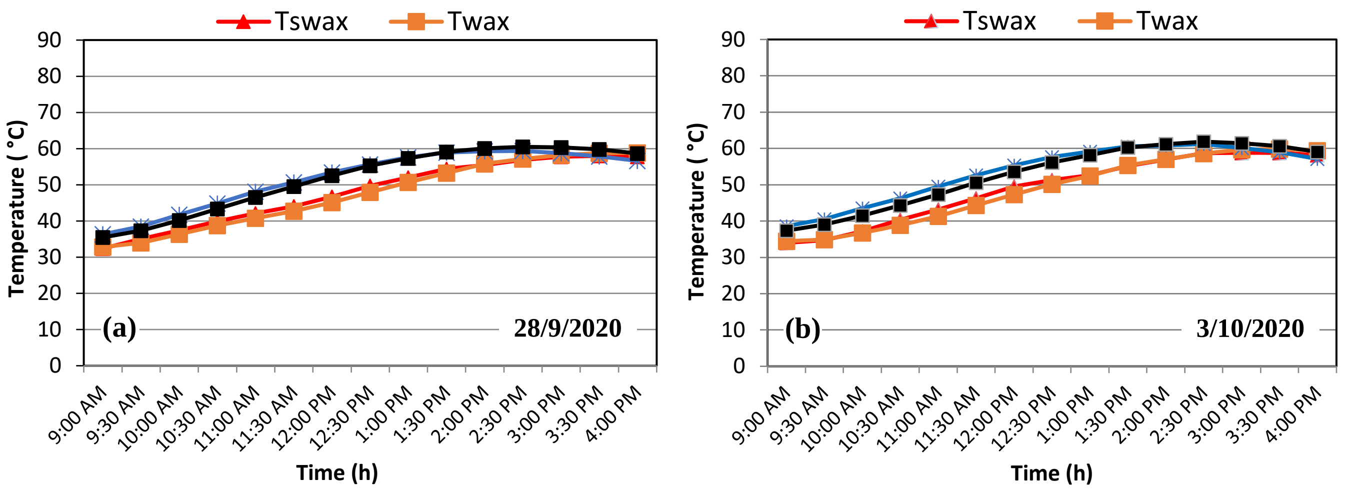

Fig. 7 Temperature change over time for a solar still with PTC at a depth of 20 mm in September and October 2020.

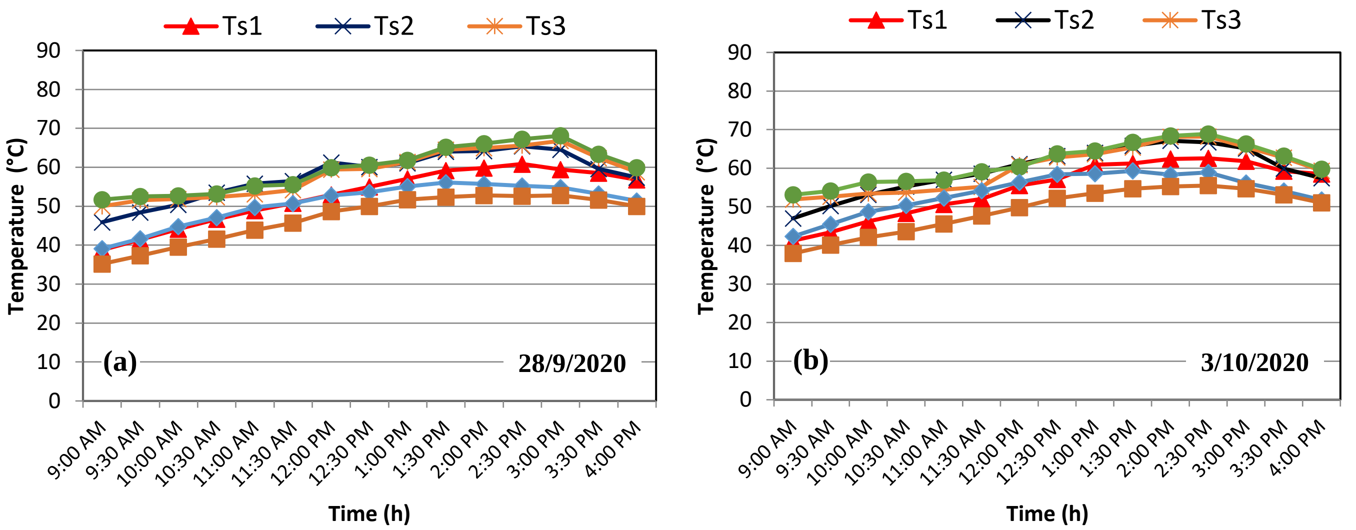

Fig. 8 Temperature change over time for a solar still with PTC at a depth of 20 mm in September and October 2020.

3.2. Production

The output of fresh water from a double slop solar still with a phase change material (PCM) and a tracked parabolic trough collector is greater than that of a double slop solar still with a phase change material (PCM) and no parabolic trough collector, where this accords the values of solar still temperatures for these systems, as shown in Fig. 9.

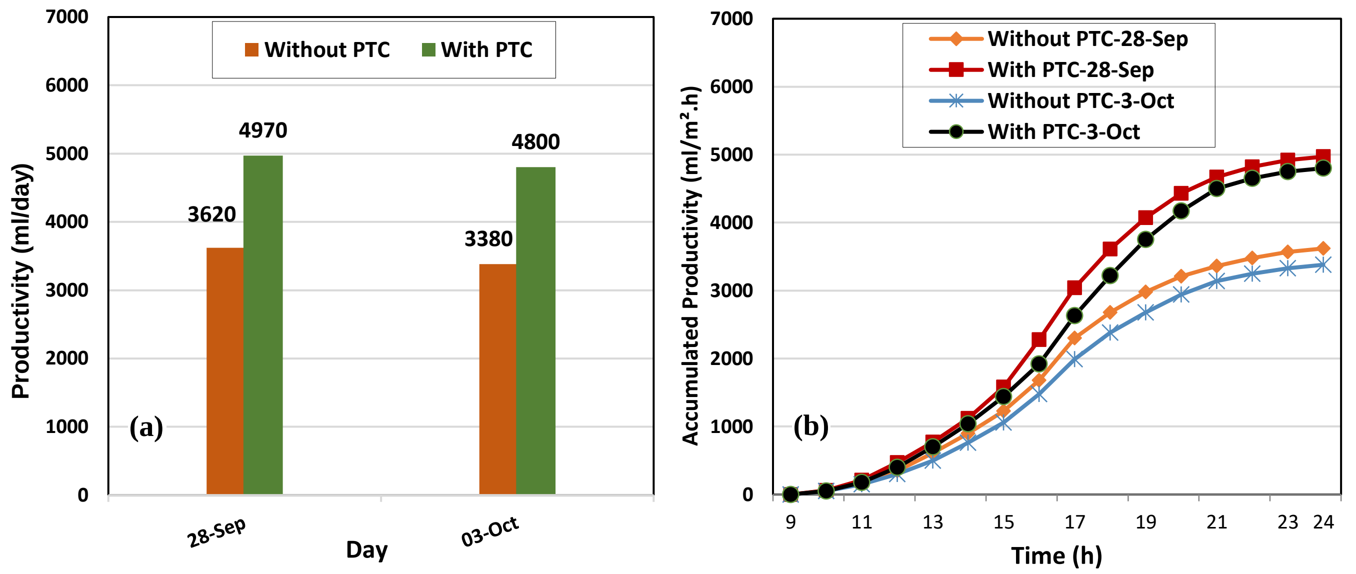

Fig. 9 Hourly freshwater productivity variations for solar still without PTC and with PTC at 20 mm water depth in September and October 2020.

Figures 9 (a) and (b) show that total freshwater output in solar stills with PTC is greater than production in solar stills without PTC. This results in a higher saline water temperature and, as a result, an increase in condensation rates in solar stills as opposed to solar stills without PTC, as previously discussed. This results in increased productivity during the day and evening. The effect of PCM with various solar still designs as phase change materials PCM and thermal energy storage materials play an important role in this work to improve the system's internal energy. One of the methods for inducing faster condensation within the solar still is to use the PCM. Even as the ambient temperature and solar intensity fell, the microcrystalline wax kept hot, and the PCM began to release latent heat into the still basin water as sunset approached. The productivity output of solar still without PTC. It is (3620 and 3380) ml/day, and the solar still tracks PTC. It is (4970 and 4800) ml/day respectively. This means that the total output of potable water from the solar still with tracked PTC is higher than the total output of potable water from the solar still without PTC for all systems, implying that the solar still with tracked PTC improves the performance the solar still without PTC. This high operating temperature was achieved due to the fall of solar radiation and the heat contained in a phase change material (PCM) that was transferred by conduction through the basin to evaporate the water at a high temperature. Furthermore, the temperature increase seen in the still at 16:00 PM is caused by heat emitted by the PCM. Because of the high solar intensity and the heat added to the PCM by PTC.

3.3. The efficiency of the solar stills

The thermal efficiency of the solar still system for passive solar still can be obtained by [17].

$$\eta_{Dp} = \frac{\sum m_{ew} \ L}{A_g \ \sum I(t)} \times 100 \qquad (3)$$

Also, thermal efficiency of active solar still is,

$$\eta_{Da} = \frac{\sum m_{ew} \ L}{A_g \ \sum I_s(t) + A_c \sum I_c(t)} \times 100 \qquad (4)$$

4. Conclusions

Experiments to improve solar still productivity, as well as a comparison of the performance of a solar still with and without a parabolic trough collector using microcrystalline wax at a water depth of 20mm, were conducted. As shown by the findings.

1. The temperature increases of the basin water and wax, because of a solar radiation incident. In addition to the parabolic trough collector provides heat to the Microcrystalline Wax by way of a water heat exchanger.
2. The temperatures in the solar still with a parabolic trough collector are higher than the temperatures of the solar still without a parabolic trough collector.
3. Result for using a phase change material for heat storage. It helps to keep the water basin hot, allowing the condensation process to last longer. And lead to an increase in productivity.
4. Indicated to the practical results a productivity daily of double slope solar still with the Parabolic Trough Collector higher than the double slope solar still without the Parabolic Trough Collector. Daily freshwater yields are measured at 4970 and 4800 ml/m^2 for solar stills with the parabolic trough collector and 3620 and 3380 ml/m^2 for solar stills without the parabolic trough collector for two selected days at 20 mm saline water depth.
5. When comparing the solar still with PTC to the solar still without PTC, the solar still with PTC has the largest percentage increase in daily productivity, ranging approximately 37.3 % to 42 %.

References

[1] R. V Padilla, G. Demirkaya, D. Y. Goswami, E. Stefanakos and M. M. Rahman, “Heat transfer analysis of parabolic trough solar receiver”, Applied Energy, Vol. 88, Issue 12, pp. 5097-5110, 2011. https://doi.org/10.1016/j.apenergy.2011.07.012

[2] R. Tripathi and G. N. Tiwari, “Performance evaluation of a solar still by using the concept of solar fractionation”, Desalination, Vol. 169, Issue 1, pp. 69-80, 2004. https://doi.org/10.1016/j.desal.2004.08.008

[3] A. Al-Hamadani, S. K. Shukla and A. Dwivedi, “Experimental Performance Analysis of a Solar Distillation System with PCM Storage”, International Journal of Research in Engineering and Technology (IJRET), Vol. 1, No. 6, pp. 307-311, 2012.

[4] G. M. Ayoub, M. Al-Hindi and L. Malaeb, “A Solar Still Desalination System with Enhanced Productivity”, Desalination and Water Treatment, Vol. 53, Issue 12, pp.3179-3186, 2015. https://doi.org/10.1080/19443994.2014.933040

[5] H. B. Bacha, T. Dammak, A. A. Ben Abdalah, A. Y. Maalej and H. Ben Dhia, “Desalination unit coupled with solar collectors and a storage tank: modelling and simulation”, Desalination, Vol. 206, Issue 1-3, pp. 341-352, 2007. https://doi.org/10.1016/j.desal.2006.05.018

[6] A. Davani, M. Kashfi and V. Mozafary, “Experimental analysis of a multistage water desalination system utilizing an evacuated parabolic solar trough with a solar tracker”, 2017.

[7] J. S. Abd Al-rukabie, “Double Slope Solar Still: Study, Design and Improve Productivity”, Journal of Thi-Qar University, Vol. 13, No.1, pp. 139-154, 2018.

[8] M. A. Hammadi and N. A. Jasim, “Experimental Study of Solar Still Under Influence of Various Conditions”, Journal of Engineering, Vol. 25, No. 2, pp. 57-71, 2019. https://doi.org/10.31026/j.eng.2019.02.04

[9] V. Ramanathan, B. Kanimozhi and V. K. Bhojwani, “Experimental study on productivity of modified single-basin solar still with a flat plate absorber”, IOP Conference Series: Materials Science and Engineering, Vol. 197, pp. 1-7, 2017. https://doi.org/10.1088/1757-899X/197/1/012032

[10] W. H. Alawee, H. A. Dahad and T. A. Mohamed, “An Experimental Study on Improving the Performance of a Double Slope Solar Still”, The 7th International Conference on Sustainable Agriculture for Food, Energy and Industry in Regional and Global Context, ICSAFEI 2015.

[11] D. Sonawane, O. Jadhav and M. Patil, V. Jambuti, “Research Paper on Enhancing Solar Still Productivity by Optimizing Angle of PCM Embedded Absorber Surface”, International Journal for Science Technology and Engineering, Vol. 2, pp. 192-196, 2015.

[12] O. O. Badran and H. A. Al-Tahaineh, "The effect of coupling a flat-plate collector on the solar still productivity", Desalination, Vol. 183, Issue 1-3, pp. 137-142, 2005. https://doi.org/10.1016/j.desal.2005.02.046

[13] A. Kuhe and A. O. Edeoja, "Distillate yield improvement using a parabolic dish reflector coupled single slope basin solar still with thermal energy storage using beeswax", Global Journal of Researches in Engineering, Vol. 15, Issue 4, 2016.

[14] T. Arunkumar, D. Denkenberger, A. Ahsan, R. Jayaprakash, "The augmentation of distillate yield by using concentrator coupled solar still with phase change material", Desalination, Vol. 314, pp. 189-192, 2013. https://doi.org/10.1016/j.desal.2013.01.018

[15] T. Rajaseenivasan, K. K. Murugavel, "Theoretical and experimental investigation on double basin double slope solar still", Desalination, Vol 319, pp 25-32, 2003. https://doi.org/10.1016/j.desal.2013.03.029

[16] M. A. Rehan, M. Ali, N. A. Sheikh, M. S. Khalil, G. Q. Chaudhary, T. ur Rashid, M. Shehryar, "Experimental Performance Analysis of Low Concentration Ratio Solar Parabolic Trough Collectors with Nanofluids in Winter Conditions", Renewable Energy, Vol. 118, pp. 742-751, 2018. https://doi.org/10.1016/j.renene.2017.11.062

[17] G. N. Tiwari, V. Dimri, U. Singh, A. Chel, B. Sarkar, "Comparative thermal performance evaluation of an active solar distillation system", International Journal of Energy Research, Vol. 31, Issue 15, pp. 1465-1482, 2007. https://doi.org/10.1002/er.1314

Nomenclature

Symbol	Quantity	Unit (SI)
PTC	Parabolic Trough Solar Collector	-
PCM	A Phase Change Material	-
DSSS	Double Slope of Solar Still	-
SSS	Stainless Steel Sheet	-
T_a	Ambient air temperature	°C
T_w	Water temperature inside still	°C
T_s	Steam temperature	°C
T_{gs}	Glass cover temperature of the south side	°C
T_{gn}	Glass cover temperature of the north side	°C
T_{wax}	Temperature wax	°C
T_{swax}	Surface basin wax temperature	°C
T_{sb}	Surface basin water temperature	°C
$\dot{m}$	Water mass flow rate	(L/min)
Dw	Water depth	m
I	Solar radiation	W/m^2
s	Steam	m
T	Temperature	°C
g	Glass	-
s	South	-
n	North	-
C	Concentration ratio	-
W_{ap}	Width of the collector	m
D_o	Outer diameter of the receiver	m
T_{out}	Outlet temperature	°C
T_{in}	Inlet temperature	°C
A_{ap}	Aperture area	m^2
m_{ew}	Yield	kg/s
η_D	Distillation efficiency	%
L	Latent heat of vaporization of water	J/kg
A_g	Area of glass cover	m^2
A_c	Area of collector	m^2
$I_s(t)$	Hourly average of incident total radiation on still	W/m^2
$I_c(t)$	Hourly average of incident total radiation on collector	W/m^2