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An Experimental Study to Improve the Productivity of Solar Still Through a Hybrid System Integrated with a Solar Concentrator (PTC) in the Ouargla Region, Southern Algeria

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Since most of the health problems in society today are related to contaminated water, fresh water is essential for all life on Earth. For this reason, many researchers have been interested in desalination using solar energy in different ways. This research focuses on an experimental study conducted in May 2024 in Ouargla, southern Algeria. It analyzes the energy output of a single-slope solar still with and without a parabolic trough concentrator (PTC). The tests were conducted after placing the parabolic concentrator in the east and west and maintaining a water depth of 3 cm in the tank. Through a water pipe connected to the still, the parabolic trough concentrator transmits incoming solar energy to the solar still, accelerating evaporation. The results showed that the solar still with a parabolic trough concentrator (PTC) improved productivity by 37.06%, 28.42%, and 17.04% compared to the conventional solar still on May 27, 28, and 29, respectively.
Keywords: Solar energy, PTC concentrator, distillation,Conventional solar still.

1. Introduction

Clean water and energy are basic needs that affect civilized life on Earth. As a result of modern global industrial expansion, surface and groundwater sources of drinking water have been severely polluted. If the problem of drinking water scarcity is not adequately addressed, there could be a global war over water. If the water shortage crisis is not effectively addressed, water pollution is expected to cause more than 76 million deaths by 2020 due to water-related diseases[1].The global demand for fresh water is increasing, largely due to the population explosion and rapid industrial development, which is causing a rapid decline in freshwater sources. Fresh water is essential for life, and only 1% of the Earth's surface is fresh water, 97% is salt water, and 2.6% is glaciers [2].However, the majority of available water needs to be treated because it is inherently unclean or salty[3].There is also a decrease in rainfall in remote, rocky, desert, and arid areas of the world, which leads to a severe shortage of groundwater. For these reasons, desalination may be the only option available globally to extract fresh or potable water from a saltwater source[4].Solar stills are capable of providing enough potable water to meet a family's drinking needs, treating brackish or impure water with solar energy remains the oldest method of providing drinking water to communities[2].Solar energy heats the water to the point of evaporation. As the water inside the solar still evaporates, the water vapor rises and condenses on the surface of the glass to be collected. This process removes impurities such as salts and heavy metals[5].Distillers are classified into passive and active distillers. In addition, the main problem with traditional solar distillers is their low capacity to produce fresh water, with an average productivity of 2.5-5 L/m² per day [6]. So far, much research has been conducted to improve the productivity and efficiency of the water desalination process in solar distillers.

A.E. Kabeel (2009) conducted an experimental study on improving the performance of a solar still with a concave evaporation surface. This study used the concave wick surface for evaporation, while four sides of the pyramid shape were used for condensation. The evaporation surface area and the amount of solar energy absorbed increased when using the jute wick. Due to the capillary effect, according to the results, the average daily production of distillate products was 4.1 L/m², with the maximum instantaneous efficiency of the system being 45% and the average daily efficiency being 30%[7].

Dave and Tiwari (2009) conducted experiments to improve the performance of a single-tilt solar still at 0.04 m underwater depth with different angles of the condensing cover (15°, 30°, 45°), in summer and winter. The results showed that the highest water production occurred when the glass cover was tilted at 45°. The performance of the solar still in summer weather was observed at depths of 0.04 m, 0.08 m, 0.12 m, 0.16 m. The highest production was 0.04 m at 30° and the maximum production was estimated at 0.01 m at 15° inclination and 0.01 and 0.04 m water depth [8].

M. Sakthivel and S. Shanmugasundaram (2008) conducted an experimental study on the performance of a single-basin solar still modified with an energy storage medium of 6 mm black granite pebbles available in the basin at different depths (quantity). The black granite pebbles act as an energy storage medium and also act as an insulating layer to reduce the loss coefficients at the bottom and side. The black pebbles are used to absorb the excess thermal energy from solar radiation. The results conducted on the effect of black granite pebbles as a storage medium showed an increase of 17-20% compared to conventional stills [9].

A.A. El-Sebaii et al (2009) studied the thermal performance of a single solar still integrated with PCM as a storage medium. A large amount of heat is stored in the PCM during the sunlight hours, but after sunset, the PCM acts as a heat source until the basin water evaporates. Moreover, the temperature difference between the brine and the glass cover became larger because the ambient temperature at night was lower than the daylight temperature. The productivity of the system increased by about 5 kg/m²/day on sunny summer days[10].

Pankaj K. Srivastava & S. K. Agrawal (2013)An experimental and theoretical study of a single-slope solar pond consisting of multiple porous absorbers was carried out in India. They have incorporated a number of porous absorbers made of black jute cloth on the pond water with the help of thermal insulation and a double reflector booster by placing two plane mirrors perpendicular to each other. Through the porous absorbers, there is an increase in the pond water temperature and surface area. The results indicate that a 68% and 35% increase in the production of distillate products was found on clear and cloudy days by modified distillation. When a double reflector booster was used with a moving booster, a 79% increase in productivity was obtained as compared to a modified booster without a booster [11].

Farshad Farshchi Tabrizi and Ashkan Zolfaghari Sharak (2010) conducted an experimental study of integrated solar still with a sand thermal tank in Iran. The integrated thermal tank significantly increases solar energy production during cloudy nights and days. An increase in daily productivity during cloudy nights and days was observed through this integration [12].An experimental study was conducted by Z.M. Omara et al., 2011, where they compared the performance of finned and corrugated solar stills with a conventional single slope still, still under the same climatic conditions with a depth of 50 mm of water and 30 L of saline water respectively, and the results showed that the efficiency of finned and corrugated solar stills is about 40% and 21% higher, respectively than the conventional stills[13].Phase change materials with and without pin fins were used as absorbers in a single solar pond energy and power cost experiment (Kateshia and Lakhera, 2021). Three examples were considered for analysis: a conventional solar still in case one, a solar still with a phase change material in case two, and a solar still with pin fins and a phase change material in case three. Several types of palmitic acid were used as PCM in the solar still. The aqueous masses (4.9 kg, 9.8 kg, 14.7 kg, 19.6 kg) and solid masses (0 kg, 3.67 kg, 7.34 kg, and 11 kg) were found to increase by 30% compared to 24% with PCM alone. When PCM was used with fins[14].

Some studies have aimed to improve the productivity of solar still by adding a device coupled to the passive solar still. (Omar and Eltawil, 2013) analyzed solar desalination systems using a hybrid of solar concentrator plate and conventional solar still. The system includes a raw water tank, solar water heater, photovoltaic system, boiler, condenser, CSS (single slope solar still), SDC, controller (tracking system, two-axis), and programmable PLC which facilitates the production of water by solar energy. A small single-slope solar still is built in the center of the concentrating plate. The brackish water is tested with or without preheating, and conventional solar still (CSS) is used. To evaluate and compare the existing desalination system, the results showed that the daily average of SDC distilled water with preheating of brackish water and CSS is 6.7 and 3 L/day, respectively. SDC and CSS had daily efficiencies of 68 and 34%, respectively[15].(Arunkuuma et al., 2013) studied the efficiency and productivity of distillation products in a hemispherical trough solar still coupled with a condenser with and without PCM to enhance productivity. Experiments were conducted on two different types, (1) a single slope solar still without PCM effect, and (2) a single slope solar still with PCM effect. The experimental results indicate that the thermal storage effect of the hemispherical trough solar still coupled with a condenser increases productivity by 26%. It was concluded that productivity was significantly increased due to the integration of PCM. The daily productivity of the single slope solar still with and without PCM was found to be

4460 ml/m²/day and 3520 ml/m²/day, respectively [16].(P. Pounraj et al., 2018) conducted an experimental study on a hybrid active solar PV/T still with a Peltier system, the Peltier used in this still enhances the production of distilled water during the evaporation and condensation processes, the proposed hybrid active solar PV/T still generates fresh water at a rate of 8.77 L/m², which is about 30% more efficient than the conventional solar still. In addition, it achieved a 38% increase in efficiency compared with the original solar PV system[17].(John Iskander et al., 2024) developed and implemented a new design for desalination using solar-powered photovoltaic panels by boiling and condensing to solve this problem in remote areas that do not have access to fresh water or electricity but have access to saltwater where the water vapor is then condensed through a heat exchanger to obtain fresh water. The output of the developed unit was compared with the output of passive and active solar stills that were developed and built. The results showed that the new desalination design produced approximately the same amount of fresh water per day, 4 L/day, compared to other solar power plants (2-4.75 L/day) [18].The coupling efficiency between a parabolic trough collector (PTC) and a double-slope solar still was evaluated by Fathi et al, 2018. Solar energy was transferred from the PTC to the solar still via oil tubes connected to a finned ring heat exchanger inside the still. Experiments were conducted on three systems: a conventional solar still, a solar still with manually tracked PTC integration, and a solar still with automatically tracked PTC integration, using two different basin water levels (20 mm and 30 mm). The results show that using the PTC integrated solar still increases by at least 28.1% the conventional solar in summer when the sea water level is 20 mm and the basin water temperature is higher. In winter and summer, respectively, the freshwater productivity of the fixed PTC integrated solar still is about 4.03 kg/m²/day and 8.53 kg/m²/day, respectively[19].In a study conducted by Subhedar et alin 2019, the performance of conventional single-slope solar energy connected to parabolic collectors was evaluated. Water and Al_2O_3 nanoparticles at concentrations of 0.05% and 0.1% were used as working fluids in the combined system. The results showed that the use of an integrated system significantly increases the production of a large amount of freshwater since the maximum water productivity of 1741 ml was achieved by using a secondary aqueous solution of Al_2O_3 with a concentration of 0.1% in a basin with an area of 1 m^2 and 3 cm depth of salt water, the combined Al_2O_3/water nanofluid solar distillation system showed an improvement in productivity and thermal efficiency of approximately 66% and 70%, respectively, compared to the conventional CSP system[20].(Rangbaran and Norouzi, 2019) Studied the efficiency of a hybrid system in Iran, consisting of a single-slope solar still, cascade solar still, and a parabolic trough collector (PTC), and reached a productivity of 6 kg/day. They found that the hybrid solar still system improves the overall energy efficiency by 41% [21].(Kumar et al., 2020) investigated the performance of PTC in three distinct water environments in New Delhi compared to conventional SS to evaluate the effectiveness of PTC compared to conventional SS. With three separate water depths and flow rate variations, they were able to obtain productivity of 24.1 L/m, 23.645 L/m, and 23.2 L/m at 5 cm, 10 cm, and 15 cm of water, respectively, using SS and PTC. At 5 cm water depth, the productivity increases by 22% compared to 10 and 15 cm [22].(Khairat Dawood et al., 2020) increased the productivity of a conventional single-slope solar still by connecting it to two parallel solar collectors connected in series. Phase change material was added in both the inner tubes of the evacuated tubes and under the sump area. The results showed that conventional solar still produced 3182 liters per day on average. However, when using oil flow rates of 1.5, 1.0, and 0.5 L/min and nano oil flow as the working fluid of 0.5 L/min, respectively, the system produced 4.7, 6.2, 8.8, and 11.1 liters per day[23].(Jassim Jaber et al., 2021) Showed that using wax as a transition material in double-slope solar still experiments, with or without a parabolic basin, enhances the distillation yield. After performing a 20 mm water depth test, they found that PTC with wax as PCM gives a 42% greater yield. Without PTC, the transition material improves performance after sunset compared to double-slope solar stills[24].(Amiri et al., 2021) studied a new independent technology in using solar energy for water desalination. This technology includes a parabolic basin collector, which acts as a solar reflector and concentrator for solar radiation directed to the solar still. A parabolic basin collector is installed below the conventional solar still in the new system throughout the four seasons in Kerman, Iran. The results showed that the system achieves the highest efficiency in water production during the summer and the lowest in the winter. The proposed fixed parabolic basin solar still generates 55% more clean water in summer compared to winter under the weather conditions in Kerman. The collection and tracking systems were able to produce approximately 1.266 L/m^2, which is a 70% increase during the summer compared to the winter[25].(Thakur et al., 2021) studied the performance of a solar still integrated with a parabolic solar collector, by adding activated carbon pellets as energy storage materials to enhance the evaporation process and thus increase the freshwater production of the solar still. According to the results, the use of the parabolic collector with porous carbon had the effect of increasing the efficiency of the solar still by 85.2%[26].(Aqlan et al., 2021) also evaluated the performance of coupling solar still with a solar parabolic tank. The results of field experiments showed that the total water productivity of the integrated solar still increased by 177% compared to the conventional still and the average amount of fresh water obtained per hour from the integrated and non-integrated models of the solar still was 0.67 $L/m^2/h$ and 0.38 $L/m^2/h$, respectively [27].

Based on previous studies, in this experimental study, we propose to improve the efficiency of a simple solar still by integrating a single-slope solar still with a PTC solar collector, where PTC is used as an auxiliary device that heats the water before it enters the solar still basin. This study also aims to compare the daily productivity of distilled water between the PTC-integrated still and the conventional solar still in the Ouargla region of Algeria.

2. Experimental setup

The experiment is set up in two parts: the first part is coupling the parabolic collector (PTC) with the single slope solar still according to the following scheme as shown in Figure 1.

The second part of the experimental setup is a conventional solar still with the same dimensions and characteristics as the PTC still, to compare the amount of water produced by the active still and the conventional still.

1- water tank, 2 -water flow meter,3 – parabolic trough collector, 4 – absorber tube, 5 – Solar Still, 6 – Glass Cover, 7 - saltwater inside the basin, 8- water entering the solar still,9- Multi-measure" armfied", 10- computer, 11- Distilled water, 12- A . B . C . D. E (thermocouples)

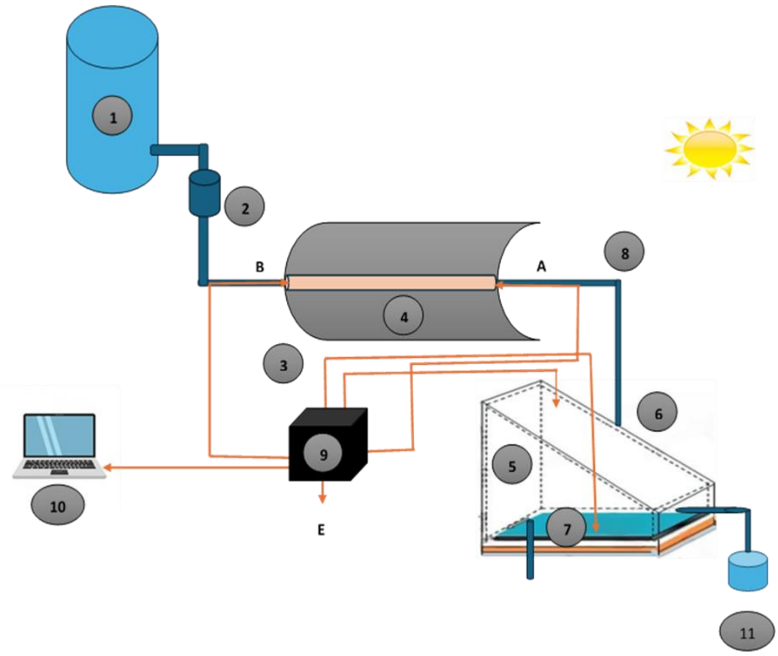

Figure 1: Schematic diagram of the solar still integrated with PTC.

Table 1: Numerical parameter of PTC and solar still

Parameter	Value
Collector length L	2 m
	1.8 m
Collector widthW	0.8 m
Heighth$_c$	42.1
	126.8°
concentration ratioC	3.6 m²
	0.2 mm
Rim angleθ_R	0.22 mm
	(length 95 cm – width 95 cm)
Aperture areaA_{ap}	
Inner absorber diameter $D_{r,int}$	
Inner absorber diameter$D_{r,ext}$	
Basin dimension	

3. Description of the experimental system.

The experimental setup for this test consists of a single solar slope still connected to a parabolic collector (PTC). The water in the basin starts to evaporate with the rise of temperature and then condenses on the glass cover as water droplets so that the condensed water falls on the lower side and enters the collection tank. The inlet of the PTC absorber tube is fed with salt water at a constant flow of 0.029 L/min by a plastic tube connected to the water tank, where the incoming radiation is converted into heat energy and the water comes out hot. Its outlet is connected by another plastic tube to the saltwater inlet of the used still. Our study is based on calculating the different temperatures at different points of both the solar still and the PTC collector.

Figure 2: An image showing the experimental work.

4. Thermal modeling of PTC

The proposed system uses the calculations of the focal point, angle, and sink concentration ratio for its thermal design. In addition, the thermal properties of the evacuated tube receiver are also evaluated based on the heat loss coefficient, radiation coefficient, total heat transfer coefficient, and useful heat gain[28].

The useful power provided by the PTC is obtained by the receiver efficiency factor as follows [29].

$$Q_u = A_{ap} F_R \left[G_d \, \alpha \, \rho - \frac{A_{r,ext}}{A_{ap}} U_L \left(T_{p,int} - T_a \right) \right] \qquad (1)$$

Where G_d represents the direct radiation incident in the aperture area.

As for "F_R", it is the heat loss coefficient and can be calculated after calculating the efficiency coefficient of the collector F' as follows [30].

$$F' = \frac{1/U_L}{\frac{1}{U_L} + \left(\frac{D_{r,ext}}{h_{c,i} \, D_{r,int}} \right) + \left(\frac{D_{r,ext} \ln\left(\frac{D_{r,ext}}{D_{r,int}} \right)}{2K_r} \right)} \qquad (2)$$

$$F_R = \frac{m \cdot C_p}{A_{r,int} \, U_L} \left[1 - \exp\left(- \frac{A_{r,int} \quad U_L \, F'}{m \cdot C_p} \right) \right] \qquad (3)$$

U_L represents the total heat loss coefficient, which can be determined using the following equation[31].

$$U_L = h_c + h_{r,r-a} \qquad (4)$$

The convective heat transfer coefficient (h_c) resulting from the wind between the receiver and the ambient air can be calculated as follows[31].

$$h_c = \frac{NU_a K_a}{D_{r,ext}} \qquad (5)$$

The radiation heat transfer coefficient between the absorption tube and the ambient air can be expressed as follows [31].

$$h_{r,r-a} = \varepsilon \sigma (T_r + T_a)(T_r^2 + T_a^2) \qquad (6)$$

While heat is transferred to the brine from the working fluid (water)$Q_u$is as follows[32].

$$Q_u = m \cdot C_P \left(T_{p,out} - T_{p,int} \right) \qquad (7)$$

The outlet temperature of the working fluid (water) can be calculated using the equation [32].

$$T_{p,out} = T_{p,in} + \frac{Q_u}{m \cdot C_P} \qquad (8)$$

While the instantaneous thermal efficiency of PTC was obtained by [33].

$$\eta = \frac{Q_u}{G_d A_{ap}} \qquad (9)$$

5. Heat balance equations in a single solar still

Using the average temperatures of the covered glass, basin water, absorber plate and surrounding areas, solar energy always produces fresh water during the working period. In terms of solar energy, solar radiation G is always absorbed per unit surface area. The proposed solar still operates according to the following heat balance equations [32].

- Thermal balance for glass cover

$$m_g c_g \frac{dT_g}{dt} = (1-\rho_g)\alpha_g G_t + (Q_{e,w-g} + Q_{R,w-g} + Q_{c,w-g}) - Q_{R,g-a} - Q_{c,g-a} \qquad (10)$$

- Thermal balance for absorber plate

$$m_b c_b \frac{dT_b}{dt} = (1-\rho_g)(1-\alpha_g)(1-\rho_w)\alpha_b G_t - Q_{c,b-w} - (Q_{loss\,1} + Q_{losse\,2}) \qquad (11)$$

- Heat balance for saltwater

- For conventional solar still (CSS)

$$m_w c_w \frac{dT_w}{dt} = Q_{c,b-w} + (1-\rho_g)(1-\alpha_g)(1-\rho_w)\alpha_w G_t - (Q_{e,w-g} + Q_{R,w-g} + Q_{c,w-g}) \qquad (12)$$

- For active distiller (PTC with CSS)

$$m_w c_w \frac{dT_w}{dt} = Q_{c,b-w} + (1-\rho_g)(1-\alpha_g)(1-\rho_w)\alpha_w G_t - (Q_{e,w-g} + Q_{R,w-g} + Q_{c,w-g}) + m\cdot C_{p_w}(T_w - T_{p,out}) \qquad (13)$$

6. Results and Discussion

After conducting various experiments on single-slope solar still combined with PTC and without PTC at a depth of 3 cm during May 2024, some measurements were taken and analyzed for every hour from 7:00 am to 6:00 pm, including the solar radiation intensity, ambient temperature, glass temperature, water temperature inside the still, and the amount of water produced by both the active and conventional solar still, as well as the temperature of the working fluid (water) at the inlet and outlet of the PTC.

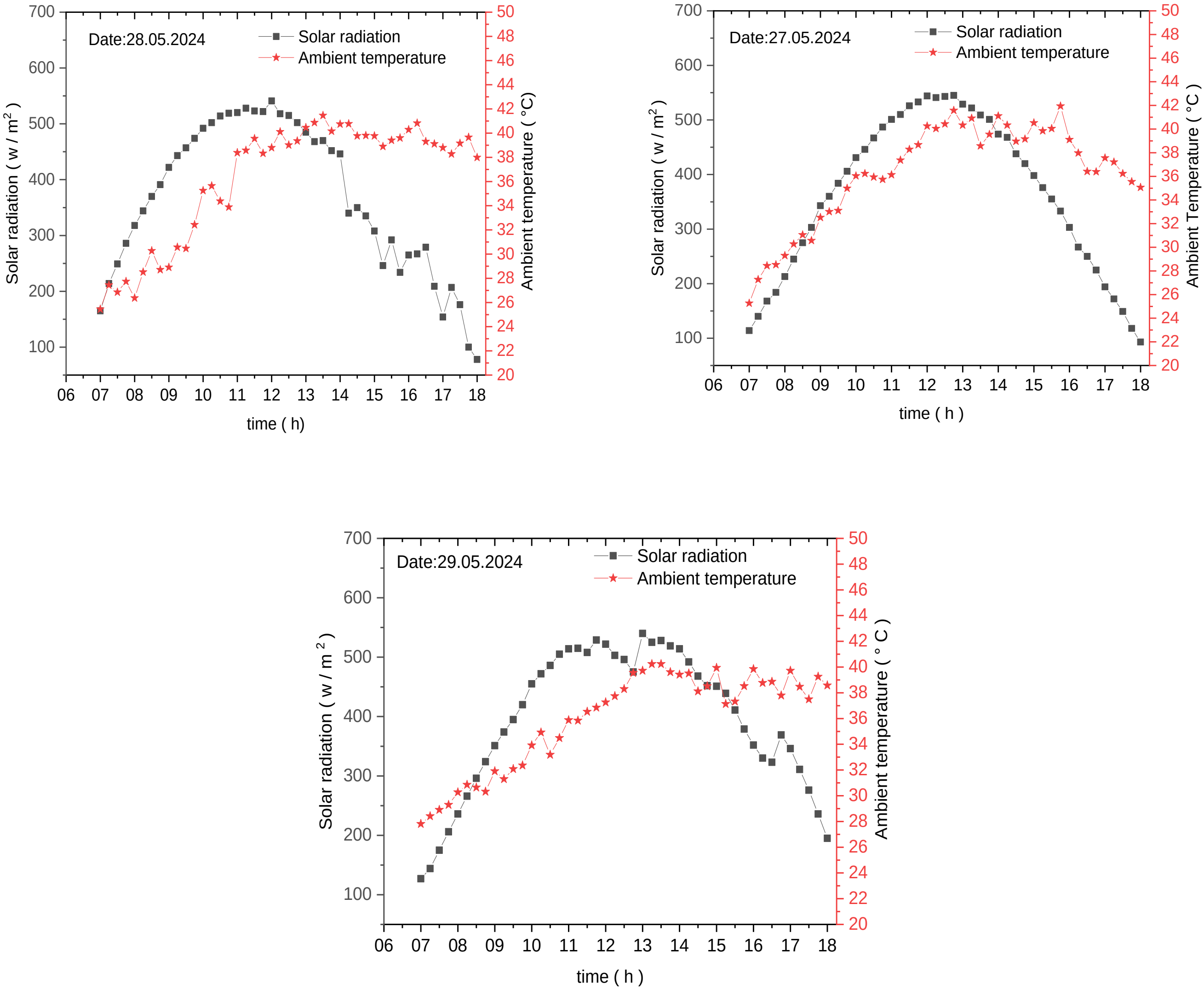

Figure 3: Hourly variation of both solar radiation and ambient temperature during the experiment in May 2024.

Figure 3: Represents the relationship between solar radiation and ambient temperature. On 2024.05.27, the maximum radiation value of 545 w/m² was reached at 12:45 noon and then started to decrease until it reached 93 w/m² at 18:00, while the ambient temperature started to rise and decrease until it reached the highest temperature of 41.94 °C. On 2024.05.28, the solar radiation reached 541 w/m² at noon and decreased until it reached 78 w/m² at 18:00, and the highest ambient temperature of 41.45 °C was obtained. On 2024.05.29, the maximum radiation value reached 540 w/m² and started to decrease until it reached 195 w/m² at 18:00 when the highest ambient temperature reached 40.23 °C As shown in the figure.

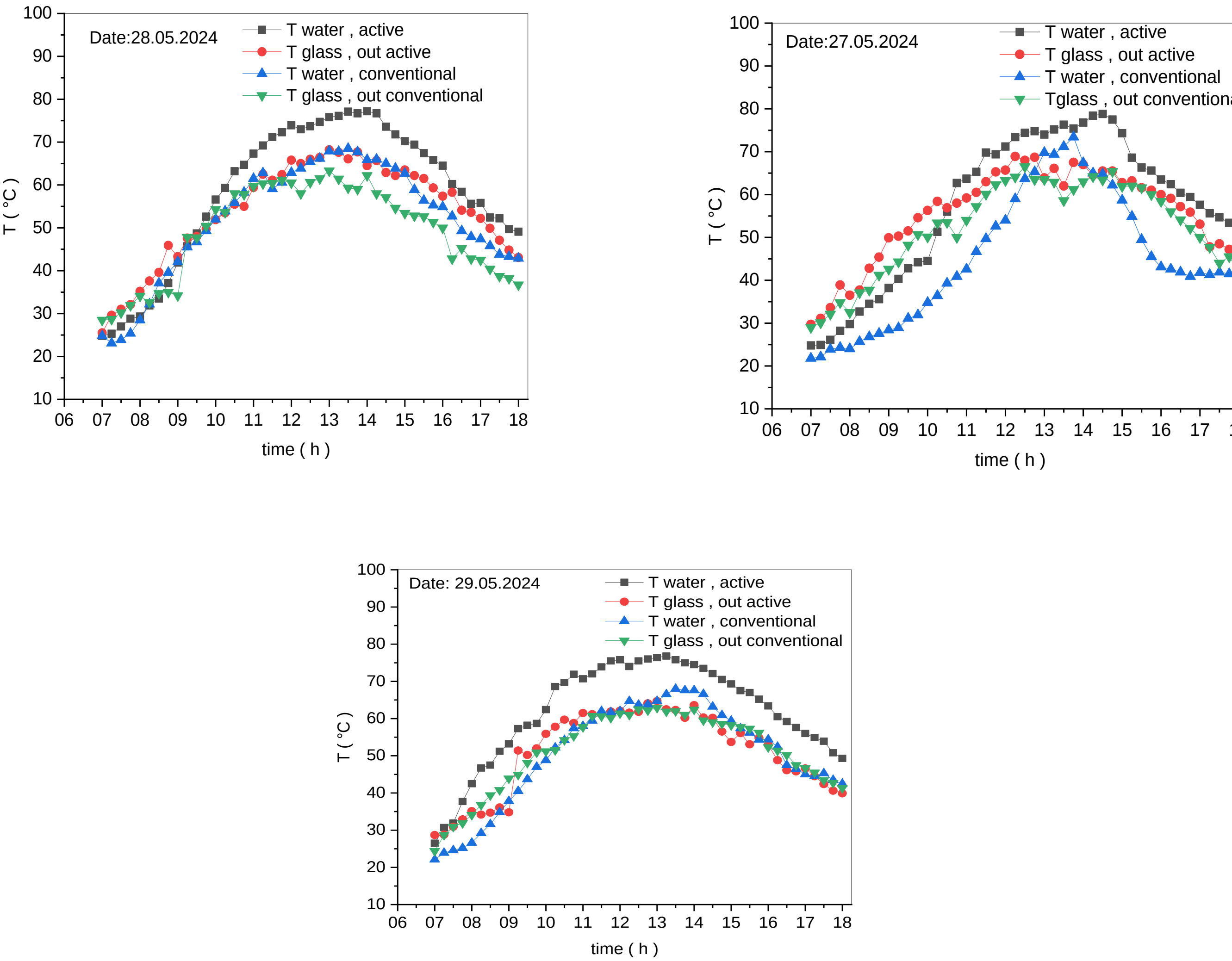

Figure 4: Hourly changes in glass and basin water temperatures for active and conventional solar stills in May 2024.

Figure 4: Hourly changes of glass cover temperature Tg and basin water temperature Tw of solar still. It is obvious that with the change of solar radiation, all temperatures rise and start to decrease after 15:00. According to the results, the temperature values of basin water and glass cover of active solar still are higher than those of conventional solar still. The maximum temperature of basin water from 12:15 to 14:30 was about 78.8 °C, 77.2 °C, 76.8 °C, while the maximum temperature of glass cover was 68.9 °C, 68.2 °C, 64.7 °C for solar still integrated with PTC. As for the conventional solar still, the maximum temperature of the basin water was 73.4°C, 68.5°C, 68°C, and the maximum temperature of the glass cover was about 66.5°C, 63.3°C, 62.9°C during the experimental days.

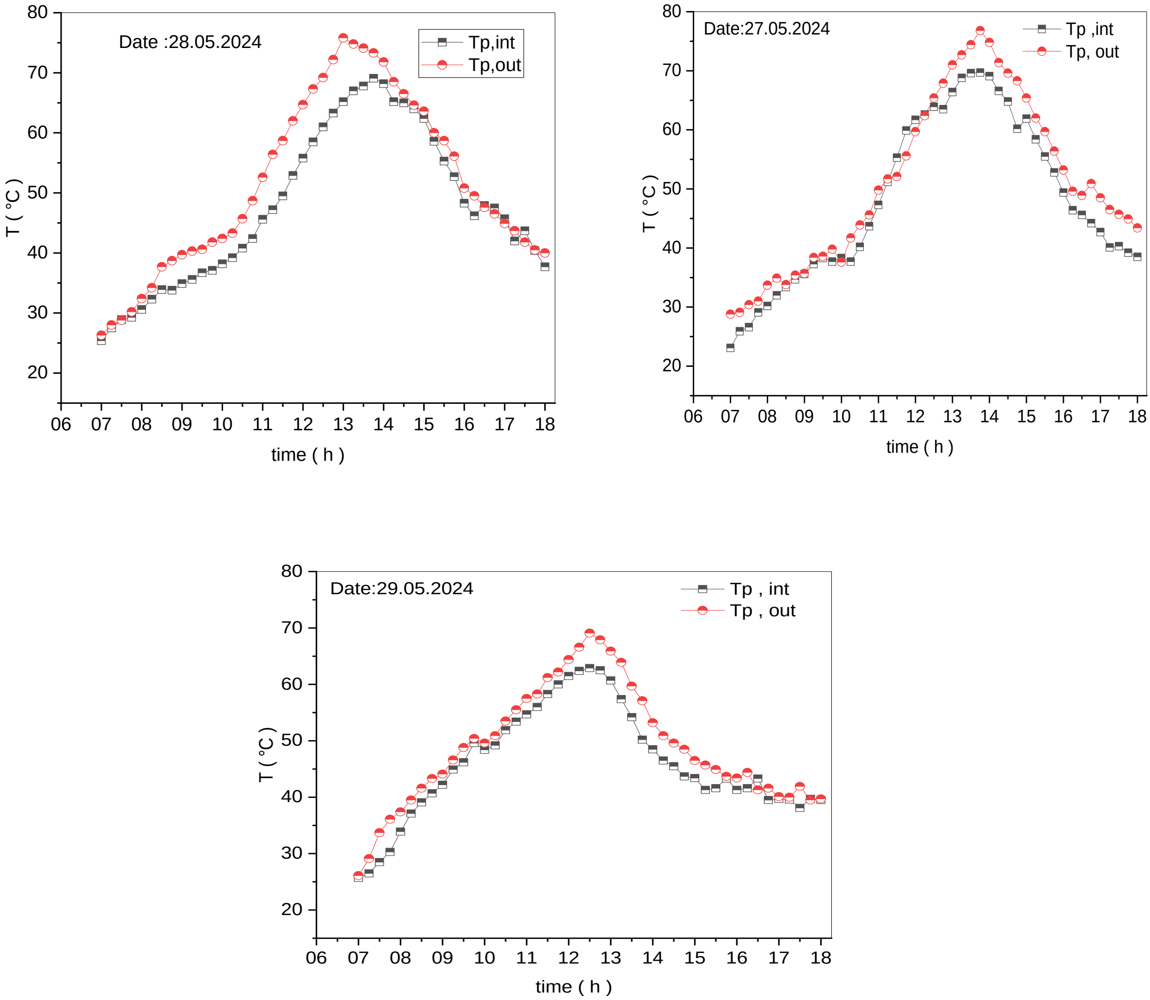

Figure 5: Hourly temperature changes for a parabolic trough (PTC) solar collector in May 2024.

Figure 5: The temperature variation of the working fluid (water) at the inlet and outlet of the PTC during the experimental days. The inlet and outlet temperatures rise until they reach their maximum value from 12:30 to 13:45, where the inlet temperature reaches 69.7°C, 69.1°C, and 62.9°C. while, the outlet temperature reached 76.8°C, 75.8°C, and 69.1°C on May 27, 28, and 29, respectively.

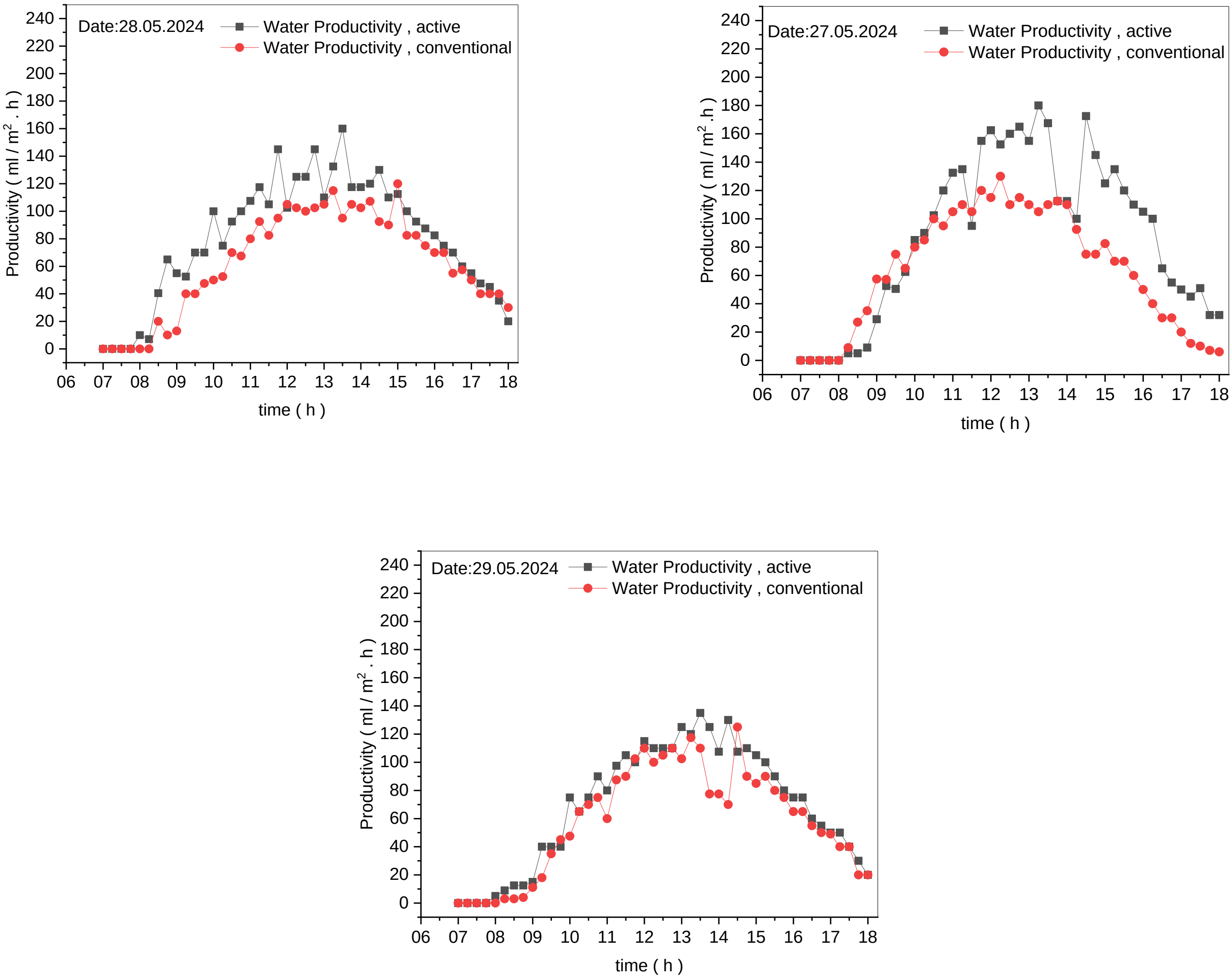

Figure 6: Freshwater productivity for both active and conventional solar stills in May 2024.

Figure 6: The total freshwater production of the PTC-assisted solar still is higher than that of the conventional solar, which is due to the higher temperature of the basin water, and the condensation rate of the PTC-assisted solar still is higher than that of the conventional solar. However, the maximum production from 7:00 am to 6:00 pm reached 3938.62 ml/m², 3589.78 ml/m², and 3096.5 ml/m² of the PTC-assisted solar still, while it reached 2873.52 ml/m², 2795.3 ml/m², and 2645.58 ml/m² of the conventional solar still at 3:00 pm on May 27, 28, and 29, 2024, respectively.

7. Conclusion

Local weather conditions affect the production of the solar still, which depends on several variables and differences, in addition to that it depends mainly on the phenomenon of evaporation and condensation that occurs inside the solar still. Experiments were conducted to improve the productivity of the solar still by connecting the single slope solar still to the parabolic collector (PTC) to obtain the highest temperatures according to the weather conditions of the city of Ouargla in southern Algeria. Based on the experimental studies, the following conclusions can be drawn:

- The temperature of the basin water rises due to the solar radiation falling on the PTC and reflected on the receiving tube, which helps to heat the basin water in the solar still, where the temperatures in the solar still integrated with PTC are higher than the temperatures in the conventional solar still. The highest temperature of the basin water inside the active solar still from 13:15 to 14:30 was 78.8 C°, 77.2 C°, 76.8 C°, while it was 73.4 C°, 68.5 C°, 68 C° from 1:30 to 1:45 p.m. for the conventional solar still during the experiment days.

- The daily distilled water productivity of the integrated solar still with PTC is higher than that of the conventional solar still, as the daily productivity reached 3938.62 ml/m², 3589.78 ml/m², and 3096.5 ml/m² for the integrated solar still with PTC, while it reached 2873.52 ml/m², 2795.3 ml/m², and 2645.58 ml/m² for the conventional solar still during the trial days.

- The daily productivity improvement of the solar still with PTC during May in the trial days was 37.06%, 28.42%, and 17.04%.

Nomenclature

A: area $[\mathrm{m}^2]$

T: temperature $[\mathrm{C}^{\circ}]$

D: Diameter

K: Thermal conductivity $\left[\frac{\mathrm{w}}{\mathrm{m}^2.\mathrm{C}^{\circ}}\right]$

G: Solar radiation $\left[\frac{\mathrm{w}}{\mathrm{m}^2}\right]$

$\dot{m}$: mass flow rate $\left[\frac{\mathrm{kg}}{\mathrm{S}}\right]$

$\mathrm{C_P}$: specific heat capacity $\left[\frac{\mathrm{J}}{\mathrm{kg}\,.\,\mathrm{C}^{\circ}}\right]$

Nu: Nusselt number[/]

$\mathrm{Q_u}$: Useful heat [w]

$\mathrm{U_l}$: Total heat loss coefficient $\left[\frac{\mathrm{w}}{\mathrm{m}^2.\mathrm{C}^{\circ}}\right]$

$\mathrm{F_R}$: Heat removal factor [/]

$\mathrm{F'}$: Collector efficiency factor [/]

h_c : Convection transfer coefficient between the receiver and the environment $\left[\frac{w}{m^2.C^\circ}\right]$

h_{r,r_a} : Radiation heat transfer coefficient between the receiver and the environment $\left[\frac{w}{m^2.C^\circ}\right]$

Lower guide

a: ambientair

ap: aperture area

p, int: Internal

p, out External

r, ext: External absorber

r, int: Internal absorber

r: The absorbent

w: water

g: glass

e: evaporation

c: convection

b: basin

loss1: Heat loss through the substrate

loss2: Heat losses through the sides (insulators)

Greek symbol

η: Efficiency

ρ: Reflectivity

α: absorptivity

ε: emissivity

σ: Stefan Boltzmann constant

Abbreviations

CSS: conventional solar distillation

PTC: Parabolic trough collector

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