An experimental study on the winter sustainable production of drinkable water from solar still using hot air by solar collectors in Algeria's dry areas

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Abstract

Fresh water and environmental pollution are great challenges to the sustainable development of human society. and the distillation process solves this problem. However, a second problem arises; this is a decrease in productivity in winter. The goal of This study aims to overcome this difficulty by modifying the experimental setting by adding air heat of a flat-plate solar air collector that lowers thermal loss in winter . The experimental data presented in this paper concerns three typical days in the south of Algeria (Ouargla City). The results show that the daily productivity of conventional solar still in the summer is 3.7 kg m−2 and in winter 1.5 kg m− 2. modified solar still with air heat in winter is 3.6 kg / m2 per Today .The productivity of conventional solar still without air heat in the summer is the best compared to others , but is not in winter because thermal loss . The thermal loss of conventional solar still and modified in Winter is equal to 20.670 W and 81.055 W, respectively .The change in heat loss from day to day is caused by a change in the medium temperature and the effect of wind speed. The lower the thermal loss, the higher the daily productivity for a conventional system, but for the modified system, there is no effect on it.

Keywords: Distillation, Solar air collector, heat loss, Thermal infusion, solar radiation

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1. Introduction

Drinking water is considered one of the necessities for its many uses and is utilized in agriculture and business. Fresh water consumption is increasing all over the world, and this is due to population growth and industrial and agricultural expansion. So, the desalination of saline water was done with its various technologies, linked to traditional energy sources polluting the environment through electric power plants using natural gas and coal. Because of the problems of the latter in the world, solar distillation was included as the first solution

to produce it, and it is environmentally friendly by using solar energy. In 1870, the first American patent on solar distillation was granted to Wheeler and Evans for their experimental work [9]. Two years later, the first "conventional" solar still plant was built by Charles Wilson in Chile in 1872. The wood basin has a surface area of 4.700 m^2 and produces 23.000 liters of pure water per day at a rate of 4.9 liters per solar square meter of distiller. This still was a large basin-type still used for supplying fresh water with very high salinity. It has been operational for over 40 years [12]. Distillation mimics how nature cleanses water; therefore, the basic principles of solar water distillation are simple but effective. Water is heated to the point of evaporation by the sun's energy. Water vapor rises when the water evaporates, condensing on the glass surface to be collected [29]. That is influenced by the basin's water depth, material, wind speed, solar radiation, ambient temperature, and inclination angle [10]. Although numerous modifications in geometry, materials, building methods, and functioning have been introduced [8], most stills created and analyzed have been founded on the same principles. Malik et al.[23]conducted a review of different solar still designs. A conventional basin-type still consists of an airtight basin with a shallow layer of saline water, a sloped top cover made of a transparent material (typically glass) to reflect solar radiation, and side metal frame walls. The behavior of basin-type stills has been widely researched [12]. When compared to more complex designs, the cost of building and running a traditional still is quite inexpensive. The typical or standard basin-type solar still [8,10,23,29] has, on the other hand, been shown to have a low thermal efficiency and low daily distillate productivity [16,17,43,46].Scientists attempted to improve the current sun stills, which are conventional solar distillers with low production. Using solar collectors as enhancers[35,46]. Also, a search was Includes conducted a variety of solar still designs, ranging from conventional (Single and double basin single slope solar still … etc) to hybrid models (solar still with collector thermal or PV…etc)[33,36,46].Such as Fourteen glass tubes with double walls were used. The angle of the evacuated tubes was 45 degrees from horizontal. The inside tubes of evacuated tubes were coated with a selective coating of Al-Ni/Al compound for improved solar radiation, while the outer tubes were transparent. As a result, the water temperature within the solar still was raised, resulting in an increase in distillate output[32]. A single basin solar still and an evacuated tube collector are used in this research. to absorb the most sun light, the inside side of the basin was painted black in case 50 kg of water mass, the potential daily yield is 6.8 kg, which is higher than the daily yield obtained by many scientists from passive solar stills[37].And Both Sampathkumar and Senthilkumar carried out an experiment, its goal is to make effective use of solar energy while still increasing productivity , and it works as a hybrid system. In comparison to a passive solar still, the evacuated tube collector model solar water heater was linked with a still, and the solar collector paired with the still after the storage tank water temperature reached 60 °C increased the yield by 77% [38].

In an experiment with a solar still and a flat plate collector in natural circulation mode, Dwivedi and Tiwari [13] discovered that the thermal efficiency of an active solar still was lower than the thermal efficiency of a passive solar still. When a single basin solar still was combined with a flat plate collector (FPC) in natural circulation mode, productivity increased by 30 to 52 percent [3,4,25,41].Also, a study was conducted on the performance of conventional single-slope solar stills and the impact of integrating a flat plate collector (FPC) as well as a parabolic trough collector (PTC) supported by a packaged glass ball layer (PLGB), which acts as a thermal storage medium for the systems. The results obtained with an FPC-PTC-PLGB are far superior to those obtained with a conventional solar still. For conventional winter and summer solar stills, daily freshwater productivities range from 1.02 kg/m^2 to 1.988 kg/m^2. On the other hand, the daily freshwater with the FPC-PTC-PLGB system, on the other hand, is 2.775 kg/m^2–6.036 kg/m^2 [5,27,28,40]. Solar thermal devices, such as solar air collectors, are widely used due to their simple design and excellent thermal efficiency. Solar air collectors could be employed in drying applications because they are simple to operate and inexpensive [1,2]. For Mennouche and Bouchekima [30], an indirect type of natural convection solar (solar air collector) drier was created, constructed, and tested experimentally to investigate the drying of peanuts in the weather conditions. During the experiments, the peanut samples were dried for three days to a final moisture content of 8.31%, with a decline of 34.1%. Also, the application of a solar air collector (SAC) in a rural dwelling is advantageous to the implementation of clean heating in rural areas as well as the increase of thermal comfort[19] Never the less, the problem that results is heat loss from the solar still. There are two types of losses in a passive solar still; external heat loss (top losses—bottom and side losses) and internal heat loss (radiative heat loss—convective heat loss—evaporative heat loss)[46].

The performance of a solar still can be substantially improved by adding recovered heat from a diesel engine to the saline water in the still, especially in the winter. As a result, the cost of the water produced is often half that of water generated by traditional methods[34]. Among those who have contributed to this work are Ouyang and Wang et al [31].The primary goal of this research is to look at waste heat recovery using flue gas from natural gas engines as a heat source. An integrated system consisting of a supercritical carbon dioxide Brayton cycle, a double effect absorption refrigeration system, and a Kalina cycle was developed. According to thermodynamic and economic research, the output power increased by 15.33% and the payback period was reduced by 25.6%. Was discovered by Panchal and Thakkar [32]. Using evacuated tubes decreases heat loss. The maximum amount of solar energy is used to raise the water temperature and hence, the distillate output. Where are the studies about waste heat recovery with the Organic Rankine Cycle (ORC). The ORC is a common choice in waste heat recovery technologies because this cycle can operate with low, medium, and high-temperature heat sources, and so this cycle presents a reduction of CO_2 emissions and creates sustainable and efficient systems [26]. Experiments with a floating wick basin type vertical multiple effect diffusion solar still with waste heat recovery (FW-BVMED-HR) were conducted in this work. The annual cost of operating this still was determined based on a life cycle of 10 to 25 years. The minimum distillate cost for the FW-BVMED-HR solar still is expected to be.Rs 5.45/kg[20].Heat Hipe Heat Exchangers (HPHEs), on the other hand, are becoming more widely employed in energy-intensive industries as a low-grade waste heat recovery technology. The effect of the heat exchanger within the system requires modeling prior to the installation of an HPHE to simulate the entire impact. Potential savings and emission reductions can be calculated as a result, and waste heat use can be optimized. TRNSYS is one such simulation program. The model forecasts outlet temperatures and energy recovery with a 15% accuracy and a 4.4 % error on average [6].

Only a few manuscripts were reported for the winter, while the majority of study was done during the summer. Therefore, the primary goal of the current experimental project is to create drinking water from the CSS in dry areas of Algeria throughout the winter. The idea is in this paper are to use the air heat from the solar still by placing it inside a wooden box connected to a flat plate solar air collector (FPAC) (Fig.1) [38] with air moving inside to keep the sections of the distiller (under natural circulation) at a constant temperature for experimental validation by considering the solar still element temperature and discussing the different thermal losses of a conventional and modified solar still. Salt water and distilled water were compared using single-slope solar stills (Table 1). According to complaints, the Ouargla region has a higher salt content in its water than the other regions of south Algeria.

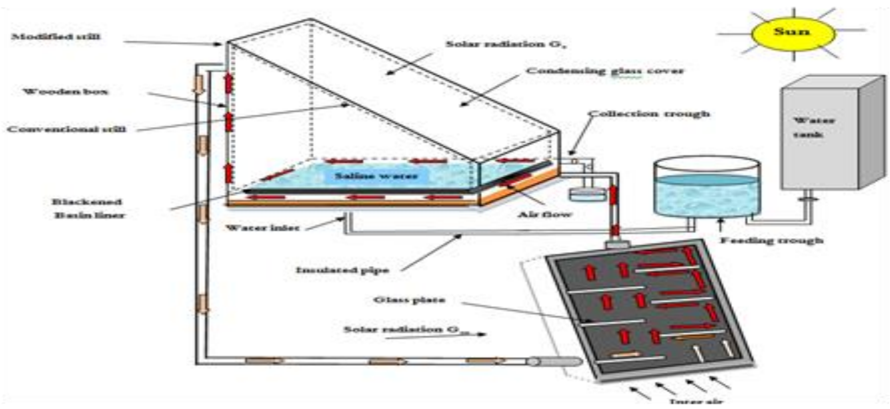
Nomenclature			
A	area (m^2)	Loss-b	thermal loss of conduction
Cp	(J/(kg·K))specific heat at constant pressure	v	Volume(m^3)
D	distance (m)	w	Water
G	Radiation solar (W/m^2)	Greek symbol	
H	heat transfer coefficient (HTC) basin($W/(m^2 \cdot K)$)	ε	Emissivity
		α	Absorptivity
K	thermal conductivity ($W/(m \cdot C)$)	τ	Transmissivity

L	length of the flat plate (m)	ρ	Reflectivity
m	Mass(Kg)	σ	Stefan–Boltzman constant (5.6697 ×10^8 $(W/(m^2 \cdot K^4))$
Q	heat transfer rate(HTR) (W/m^2)	Abbreviations	
T	temperature (°K)	NCC	Natural Circulation Circle
t	Time (s)	FPAC	Flat Plat Solar Air Collector
V	wind speed (m/s)	CSS	Conventional Solar Still
U	overall heat loss $(W/(m^2 \cdot K))$	CSS-FPAC	Conventional Solar Still with Flat Plat Solar Air Collector
Subscripts		WB FPAC	Wooden box coupled with Plat Solar Air Collector
a	Ambient		
B	Basin		
C	Convection		
R	Radiation		
ev	Evaporative		
g	Glass		
sky	Actual of the planetarium		
Box	Wooden box		
iso	Insulator		
coll	Collector		

2. Materials and methods

The simplest and cheapest device for converting brackish or contaminated water into pure, drinkable water. The hydrological cycle is modeled with this technique. Solar energy passes through the glass cover, is absorbed by the black plate, and then transferred to the seawater in the still evaporation basin. The present research focuses on improving the still's production by utilizing waste heat from the still via a solar collector. This experiment was based on two distillates. The first conventional solar still and the second modified one, the proposed solar still to work as a Natural Circulation Circle (NCC) operating under the effect of air (glass cover, absorber plate, water supply, insulation), the absorber plate, which was painted black and resistant to temperatures of up to 600 °C to increase the absorptivity of the solar radiation, The water depth is 0.01 m [42]. A glass sheet with a thickness of 4 mm is applied to the top surface. The glass cover and the air collector were angled at 30 degrees [7,24,45]. Thermocouples are used to measure temperature. The temperature of the glass cover, water, and absorber plate is measured using k-type thermocouples. The conventional solar still has a surface area of 0.185 m2 and a surface area of 0.823 m^2 with a flat plate collector (the conventional inter-the wooden box is 0.185 m2 and the wooden box is 0.421 m^2 and the flat plate air collector is 0.638 m2). The flat plate air collector is linked to a single slope solar still in such a way that hot air from the collecting plate passes via the natural circulation circle and into the wooden box. It entails slowly pouring saline water into the basin to maintain the water depth. A cross-sectional view and a snapshot of a single-slope solar still system Figure 1 shows the system in its native states (a and b, respectively).

a)



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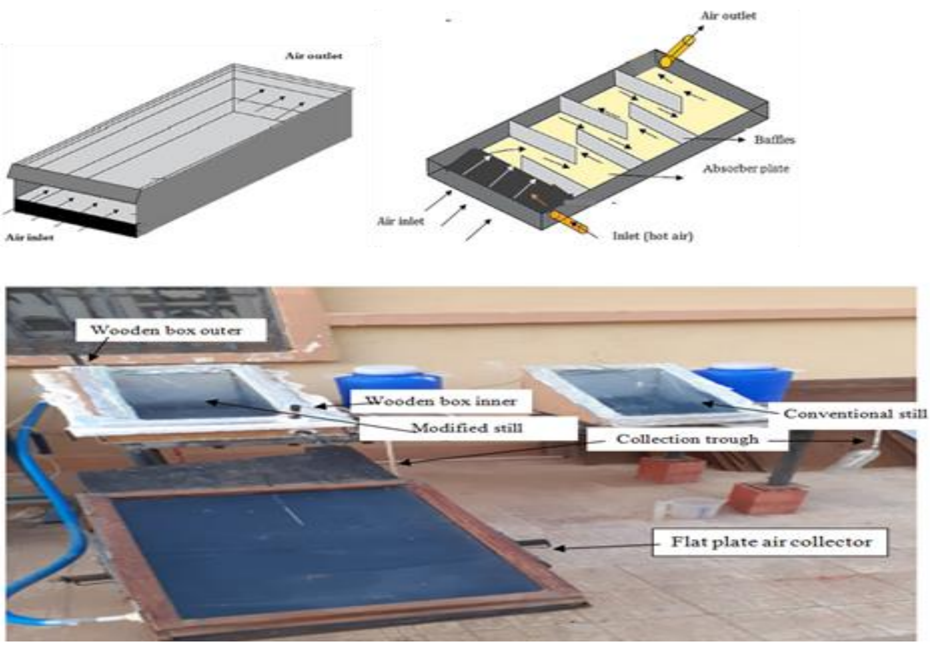


Fig.1. (a), Schematic diagram of the single slope solar still with the solar air collector

(b) Photograph of the solar still.

3. Equations for modeling single solar still coupled with energy balance

The statements bellow have been taken into account when creating energy balance equations for various components of a single slope passive solar still.

1-The system is operating in a quasi-steady state.

2-The tubing connecting the solar still to the flat plate collector is completely insulated.

3-Simplifications:

We neglect the heat transfer by connecting to the sidewalls. This is due to the thickness and quality of the wood insulating.

Ignoring the rays reflected by water is due to the fact that the reflectivity is low compared to the absorbance.

Ignoring the existence of heat loss between the Insulation under the basin and the environment is due to the equal external temperature of the insulator and the environment.

Writing energy balance equations (1), (2) and (3) for various elements of a single-slope solar still

Energy conservation equation glass

$$m_g C_g \frac{dT_g}{dt} = \alpha_g G_t + \left(Q_{ev,w-g} + Q_{r,w-g} + Q_{c,w-g}\right) - Q_{r,g-a} - Q_{c,g-a}$$

Energy conservation equation water

$$\mathrm{m_w C_w \frac{dT_w}{dt} = \tau_g \alpha_w G_t + Q_{c,b-w} - \left(Q_{ev,w-g} + Q_{r,w-g} + Q_{c,w-g}\right) \frac{A_g}{A_w}}$$

Energy conservation equation the basin

In conventional solar still

$$\mathrm{m_b C_b \frac{dT_b}{dt} = \tau_g \tau_w \alpha_b G_t - Q_{ev} - Q_{c,b-w} - Q_{loss-b_1}}$$

In modifier solar still with collector

$$\mathrm{m_b C_b \frac{dT_b}{dt} = \tau_g \tau_w \alpha_b G_t + Q_{ev} - Q_{c,b-w} - Q_{loss-b_2}}$$

4. Experimental setup

The experimental work was performed at the Lab. New and renewable energy development in arid and Saharan areas, LENREZA, Ouargla, Algeria (30°52′N, 5°34′E) Department of Physics, Faculty of Mathematics and Material Sciences, University of Ouargla, Algeria in the month of December in the year 2021 and January and February and July 2022 . From 08:00a.m to 18:30p.m, water productivity was measured with 1h intervals during all days of the experiment. The city of Ouargla, in Algeria's southeast, is facing (Fig.2) and has a total area of around 211 980 km2. Its climate is arid, and it is in the middle of the desert where the average temperature during the hottest months exceeds 45°C and the relative humidity does not exceed 19% [48].

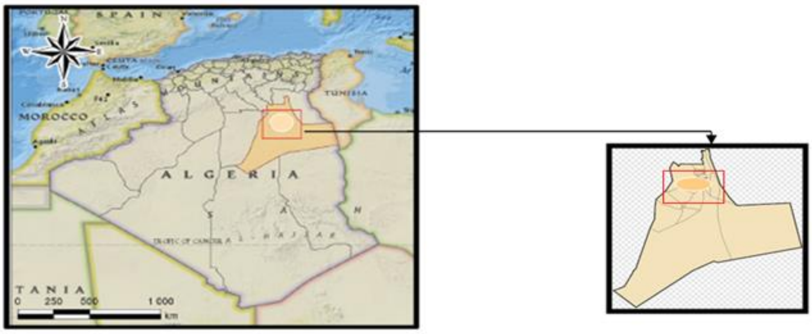


Fig.2. Geographical location of Ouargla city (the study region) .

5. Result and discussion

Experiments were carried out in order to better understand the performance of the solar still when used in conjunction with the solar air collector.

5.1. Climatic characteristics of the day of the experiment

Figure 3(a to d) depicts the environmental variables used in the modeling, such as solar radiation, ambient temperature, and wind speed, on the day of the experiment, December 2021, and January and February and July 2022, with analyzed solar radiation and wind speed. It calculates solar intensity and wind speed. The maximum during the peak was higher, up to 12.45 pm.

Fig. 3.a.the solar radiation is 487 W/m2 and the ambient temperature is 20.2 °C, with a wind speed of 1 m/s. In Fig. 3.b, the solar radiation is 530 W/m2, the temperature is 15.1 °C, and the wind speed is 1.3 m/s. Fig. 3.c. the solar radiation is 441 W/m2, the temperature is 21.2 °C, and the wind speed is 1.25 m/s. Fig. 3.d. the solar radiation is 1007 W/m2, the temperature is 34.47 °C, and the wind speed is 2.11 m/s.

5.2. Effect of CSS-FPAC of the different temperature on distillation

A comparison between the hourly variation of temperature for modified and conventional solar stills were performed and illustrated in Fig. 4 and Fig.5.

Fig.4.a. the temperature basin of 47.6.4°C - 51.4 °C and the temperature glass of 36. 4°C - 40.2 °C and temperature ambient 20.2 °C in December 30, 2021.Fig. 4.b. The temperature basin of 44.1°C - 45.0°C and the temperature glass of 26.0°C - 35.4 °C and temperature ambient 15.1 °C in January 17, 2022.Fig. 4.c. The temperature basin of 53.9.6.4°C - 54.2 °C and the temperature glass of 40.3°C - 42.6 °C and temperature ambient 21.2 °C in February 16, 2022**.**

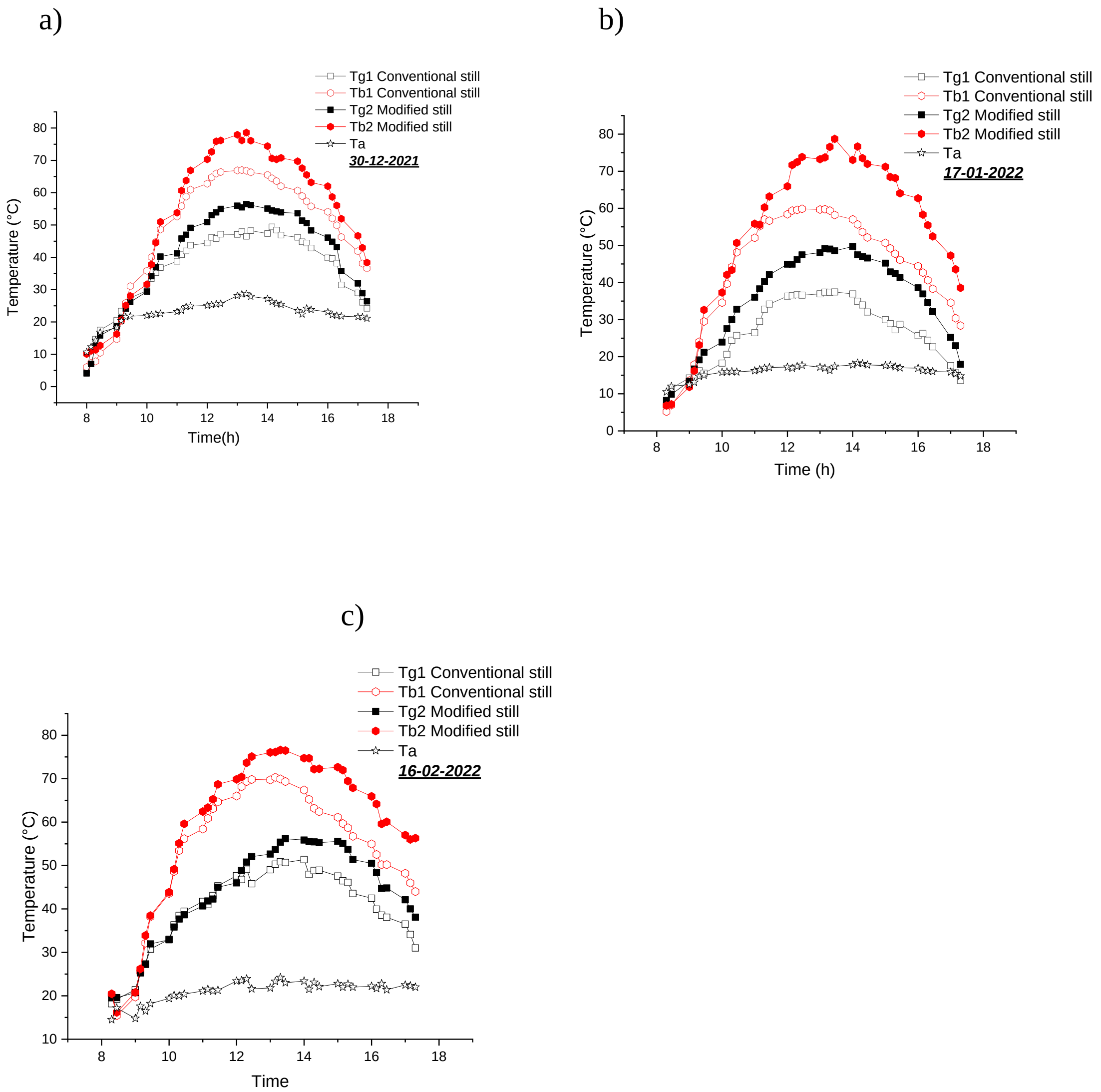


Fig.4. Hourly change of temperature differences in conventional and modified solar still of the day of the experiment in (a) December 30, 2021, (b) January 17, 2022, (c) February 16, 2022

The temperature differences in the CSS are lower than in the **CSS-FPAC**, therefore the modified one kept its elements temperature, but the conventional did not. The CSS is affected by the ambient temperature, but the **CSS-FPAC** is unaffected.

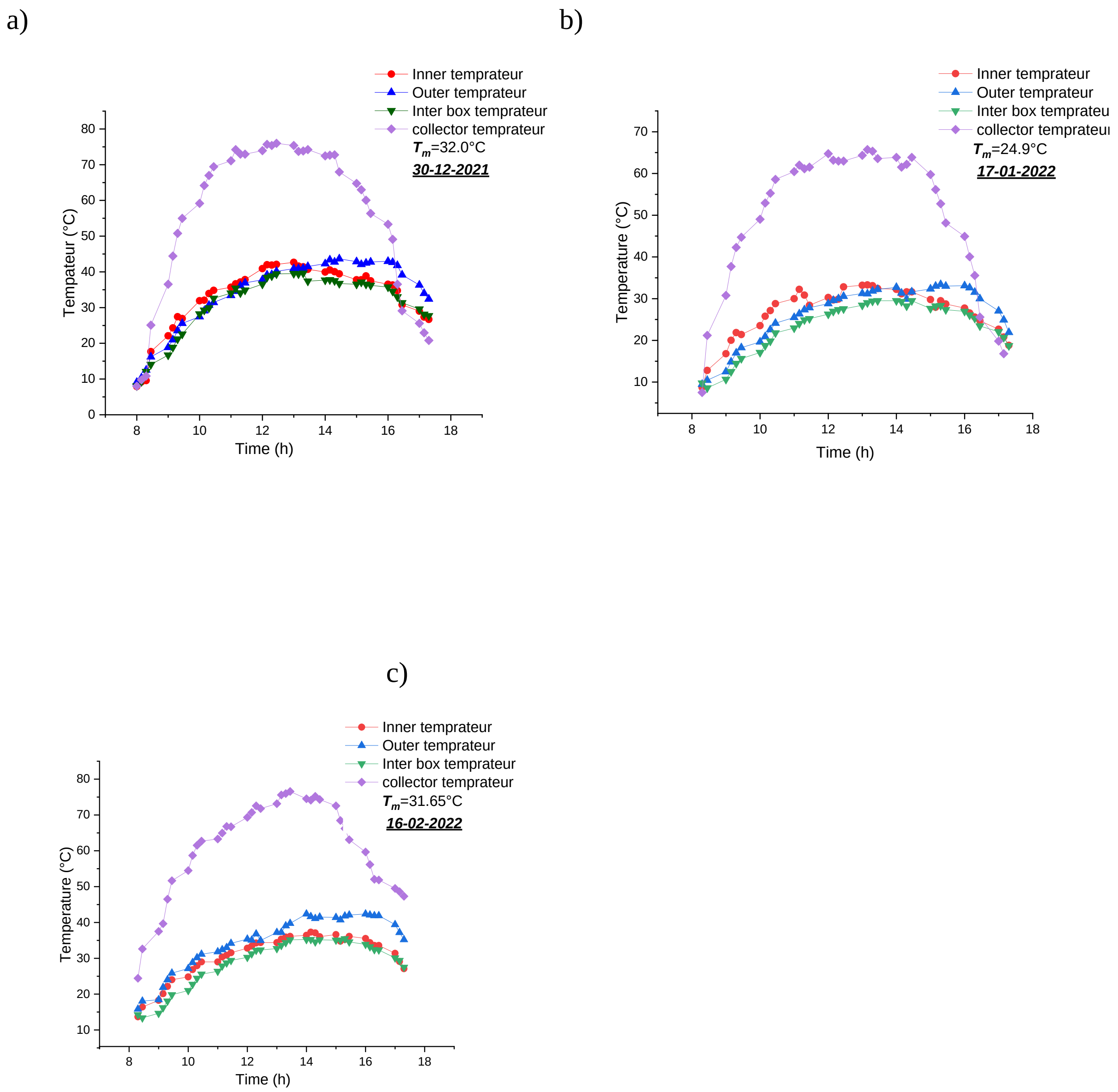


Fig.5. Variations in basin temperature, as well as inner and outer , inside of the wooden box temperature, and collector temperature , hourly

Figure 5(a to c) Shows that inner and outer and inside of the wooden box temperature, and collector temperature for the month of December 2021 and January and February 2022 daily experiments of slope solar stills. Fig.5. a. the collector is 55.3°C. and inner 34.0°C and outer 34.1°C and inside wooden box °C . Fig.5. b. the collector is 49.3 °C and inner 26.8°C and outer 26.7°C and inside wooden 26.7°C . Fig.5. c. The collector is 60.4°C. and inner 30.7°C and outer 34.6°C and inside wooden box 32.6°C.

The temperature of the inner and outer, as well as the inside of the wooden box, is identical in the morning. From Fig.5, it can be noticed that at Tm = 32.0°C and Tm = 31.65°C, the outer temperatures are higher than the inner temperatures and the inside temperatures of the wooden box after 1.00 p.m. and the outer temperatures of the experimental day are 40.8°C–40.2°C, while at Tm = 24.9°C, after 2.00 p.m., the outer temperature is 30.6°C.Because the system is in a condition of heat storage in the morning, but after 1.00 p.m. On December 30 and February 16, but on January 17, after 2:00 p.m., it reaches saturation and begins to lose heat, which explains the high temperature of the exit wooden box. Therefore, the flat plate solar air collector can be set aside after this time.

5.3. Effect of using CSS-FPAC of the thermal losses

Using **CSS-FPAC** may have advantages (solar still inside the wooden box coupled with Plat Solar Air Collector). Low thermal losses are shown in Fig.6. Thermal loss variation in conventional and modified buildings in December 2021, January and February 2022. Fig.6. a. The difference was large; the thermal loss of the conventional varies between -6.794 W – 57.122 W and the rate from -6.254 – W 24.252 W . g.6.b. the thermal loss between -5.70 W – 73.727 W and -4.191 W – 20.670 W. c. the rate of heat loss reduction between -1.992 W – 81.055 W and -2.428W – 23.308 W is 62.7%, 69.97%, and 69.72%. and in comparative the three days of the experiment for modified solar still show of Fig .6.d. The day February 16, 2022, and December 30, 2021, is height of thermal loss.

The change in heat loss from day to day is caused by a Tm, which is regulated by ambient temperature and sun radiation and determines how much heat is lost from day to day. The thermal loss is proportional to T_m.

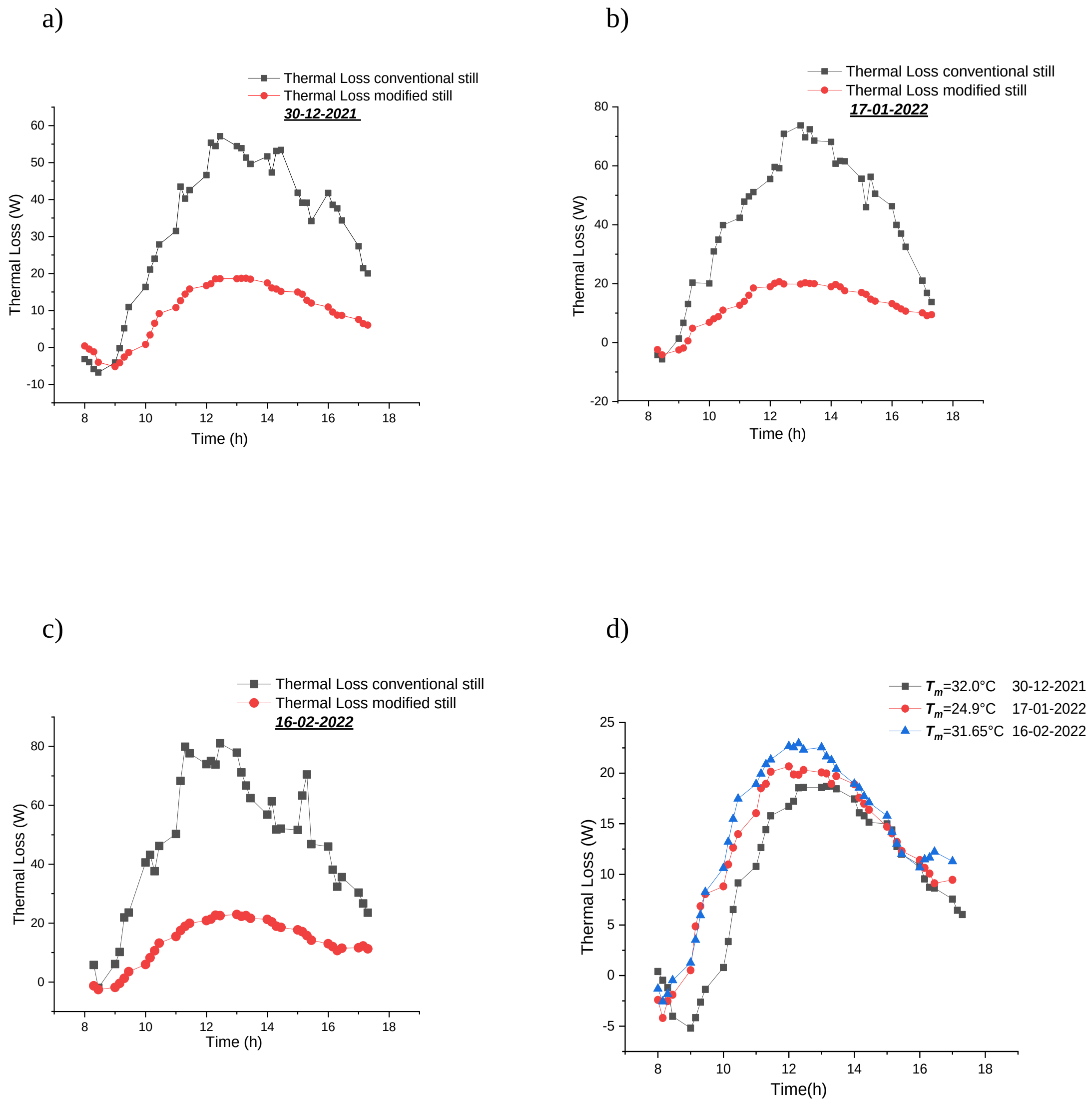


Fig.6. Differences of thermal losses in to conventional and modified of the day of the experiment in (a)December 28, 2021, (b) December 29, 2021, (c) December 30, 2021.

The lower ambient temperature and higher wind speed (Figur.3) increased the heat loss in conventional solar stills compared to the modified ones because of the exploitation of heat loss. The high thermal loss in the conventional solar still means the difference between basin and ambient temperature, but the modified solar still lowers the difference. because of the lack of direct contact with the environment .

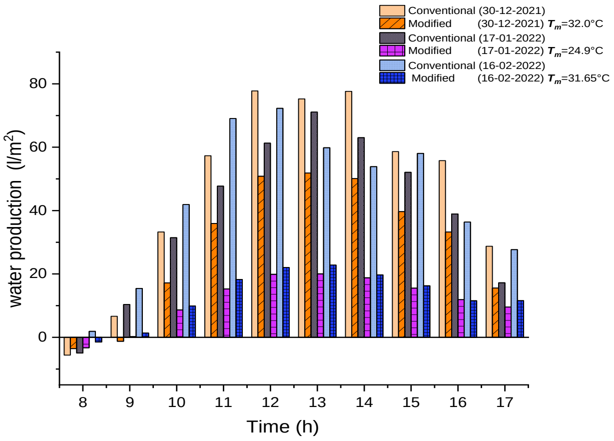


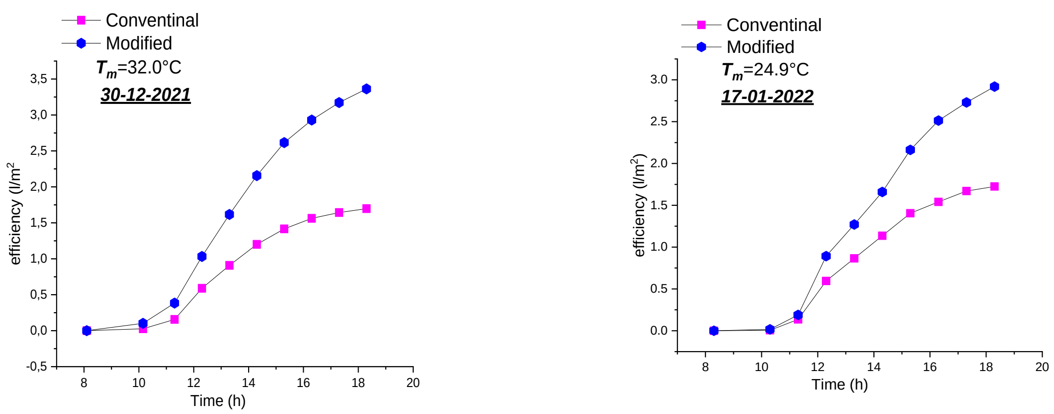
Fig.7. Hourly change of thermal losses in conventional and modified solar still of the day of the experiment in (a) December 30, 2021, (b) January 17, 2022, (c) February 16, 2022.

On the day of the experiment, the thermal loss in the conventional solar still is greater than that in the modified solar still, while the thermal loss in the modified solar still is lower. Also, heat loss is high from 12:30 to 14:00 compared to other times of the day. Because in the conventional solar still, there is an effect of wind speed, but in the modified solar still, the exploitation of heat loss is Through the solar still placed inside the wooden box coupled with the solar air collector [11,14,15,18,39,44,47].

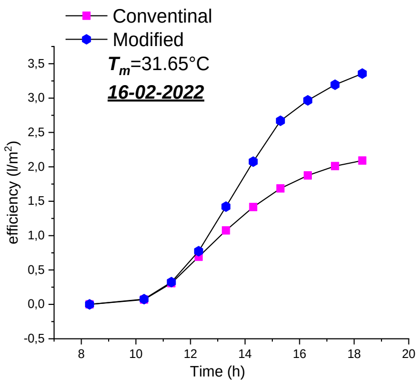
5.4. Effect of using CSS-FPAC of the productivity

A comparison of daily productivity (10h and 30 min) for both conventional and modified solar stills at different medium temperature of the wooden box (Tm) is shown in Fig. 8.

a) b)



c)



d)

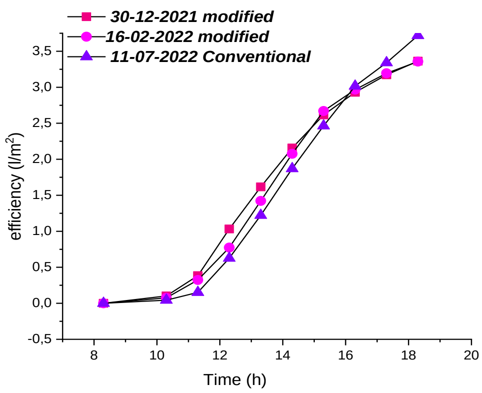


Fig.8.Hourly fluctuations in medium temperature and water productivity rate predicted and measured during the month of (a) December 30, 2021, (b) January 17, 2022, (c) February 16, 2022, (d) Comparative the three days .

Fig. 8.a. shows that the productivity of **CSS** and **CSS-FPAC** crops has increased significantly and clearly from 1.697 l m-2 to 3.362 l m-2, with a difference of 1.573 l m-2 at Tm = 32.0 °C. In this case, the increase in water productivity for modified solar stills was 98.09% greater than that for conventional solar stills. Fig. 8. b. The increase in modified is much greater than the increase in conventional, 1.724 l m-2 to 2.919 l m-2 and the difference is 1.195 l m-2 at Tm = 24.9 °C and the improvement percentage was 69.28% greater than that for conventional solar stills, Fig. 8.c. the productivity from 2.092 l m-2 to 3.357 l m-2 and the difference is 1.265 l m-2 at Tm = 31.65 °C and 60.46% of the advance percentage.

It can be observed that the hourly yield for **CSS-FPAC** is higher than **CSS**. which could be owing to the thermal loss exploited by the solar still temperature conservatism. On the other hand, the decrease in productivity is due to the decrease in ambient speed, which contributes to the lack of cooling of the glass, i.e., the lack of condensation. Productivity is reduced when the medium temperature (Tm) is lower. It increases the water productivity because of the elevated Tm.

Fig.8.d. show the comparative of the water productivity between the **CSS-FPAC** of month February 16, 2022, and December 30,2022 on winter and **CSS** of month July 07,2022, on summer. Where the productivity of the month December was is 3.3622 l m-2 and February is 3.357 l m-2 of the modified and comparative with July is 3.719 l m-2 of the conventional.

Table 1 Represents the analysis of salt water with distilled water for the Ouargla region – Algeria.

	Salt water	Distilled water
Conductivity($\mu s/cm$)	488	57.6
Hydrogen ion concentration(pH)	6.8	5.9
Salinity	0.23	0.02
Salinity rate (mg/l)	250	30
Oxygen quantity (mg/l)	6.08	6.00
Total hardness ($CaCO_3$)(mg/l)	1100	12
Chlorides (Cl^-) (mg/l)	24	2
Fluorides(F^-) (mg/l)	0.82	0

When distilled water is compared to ordinary water, the proportion of salts in distilled water is negligible, and the conductivity is low, so the acidity does not change.

On the other hand, the water in the Ouargla region is extremely high in fluorine, Monitoring drinking water and controlling fluorosis is essential to avoid potential. [21,22].There are some risks to one's health.Increase the Hardncos water in distilled water through the waste of a solar still insulated pipe.

6. Conclusion

The followings are some of the conclusions we have reached:

6.1. Loss of heat

Higher daytime wind speeds and lower ambient temperature increased heat loss in conventional solar stills compared to modified ones due to heat waste.

The idea consists of generating an air flow through a natural circulation circle attached to the rear side of the still.

The change in heat loss from day to day is caused by the Tm, and thermal loss is proportional to the Tm.

Through this, experimental work can be set aside after 1.00 p.m. on the flat plate solar air collector because of the exploitation of heat loss before the wooden box.

The thermal performance of a single-single basin passive solar still was investigated under the following conditions: ambient temperature and wind speed. The conditions are variable, so the best solution is to couple the solar still with a flat-plate solar air collector.

6.2. The daily productivity

When the slope of the glass cover (solar still and solarair collector) is equal to the latitude of the location, the annual yield is at its highest.

The daily production of both **CSS** and **CSS-FPAC** was measured and found to be in proportions of 1.697 l m-2- 1.724 l m-2and 3.357 l m-2 - 3.362 l m-2on month December, January, February. and the improvement percentages were 98 %, 69.28%, and 60.46%.

Productivity is reduced when the medium temperature (Tm) is lower. The elevated Tm It increases the water productivity.

The yield of water productivity is higher during the summer than in the winter of **CSS** still, Also water productivity for **CSS-FPAC** in winter is equal to that of **CSS** in the summer, Where the modified was 3.357 l m-2- 3.3622 l m-2, and conventional, it is 3.719 l m-2.

The water in the Ouargla region is extremely high in fluorine. Monitoring drinking water and controlling fluorosis is essential to avoid potential health risks.

6.2. The economic aspect

The materials used in the experiment are represented in the table

Table 2; The table shows the local pricing of the materials used in the experiment prepar

Used equipments	The amount (USD)
Wood	13.06
Galvanizes	6.76
Aluminum	7.14
glass	10.06
plastic connection tubes	2.85
Water tank	4.28
Total	44.15

The cost of the materials that make up the distillation device has decreased, as shown in table 2. As a result, it is used by people from the middle to the lower classes.

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Appendix A

In equations (1)-(3) different Heat Transfer and Heat Transfer coefficients are follows:

$$Q_{r,w-g} = h_{r,g-a} A_g \left(T_g - T_{sky}\right)$$

Where $h_{r,g-a} = \varepsilon_g \sigma\left(T_g^4 - T_{sky}^4\right) = 0{,}9\ \sigma\left(T_g^4 - T_{sky}^4\right)$ (1)

$$T_{sky} = T_a - 6$$

$$Q_{c,g-a} = h_{c,g-a} A_g \left(T_g - T_a\right)$$

$$h_{c,g-a} = 2{,}8 + 3.VV \leq 5\ m/s$$

$$Q_{r,w-g} = \varepsilon_w \sigma\left(T_w^4 - T_g^4\right) = 0,9\,\sigma\left(T_w^4 - T_g^4\right)$$

$$Q_{c,w-g} = h_{c,w-g} A_g \left(T_w - T_g\right)$$

$$h_{c,w-g} = 0,884\left[\left(T_w - T_g\right) + \frac{\left(P_w - P_g\right)\left(T_w + 273,15\right)}{268,9.10^3 - P_w}\right]^{1/3}$$

$$Q_{ev,w-g} = h_{ev,w-g} A_b \left(T_w - T_g\right)$$

$$h_{ev,w-g} = 16,273.10^{-3} h_{c,w-g} \frac{p_w - p_g}{T_w - T_g}$$

(2)

$$Q_{c,b-w} = h_{c,b-w} A_b (T_b - T_w)$$

$$h_{c,b-w} = 0,54\,\frac{K_w Ra^{1/4}}{L_w}\quad 10^4 < Ra < 10^7 \qquad (3)$$

In conventional solar still

$$Q_{ev} = Q_{r,b-a} + Q_{c,b-a}$$

$$Q_{r,b-a} = \varepsilon_{iso}.\sigma.(T_b^4 - T_a^4) = 0.11.\sigma.(T_b^4 - T_a^4)$$

$$Q_{c,b-a} = h_{c,b-a}.(T_b - T_a)$$

$$Q_{loss-b1} = U_{b_1}(T_b - T_a)$$

Where

$$U_{b_1} = \left(\frac{e_1}{k_1} + \frac{e_2}{k_2} + \frac{e_3}{k_3}\right)^{-1}$$

Then

$$Q_{loss-Total\,1} = Q_{r,g-a} + Q_{c,g-a} + Q_{loss1} + Q_{r,b-a} + Q_{c,b-a}$$

In modifier solar still with collector

$$Q_{r,b-a} = \varepsilon_{iso}.\sigma.\left(T_b^4 - T_{coll_{(moy)}}^4\right) = 0.11.\sigma.\left(T_b^4 - T_{coll_{(moy)}}^4\right)$$

Where

$$T_{coll_{(moy)}} = \frac{T_{coll1} + T_{coll2}}{2}$$

$$Q_{c,b-a} = h_{c,b-a}.\left(T_b - T_{coll_{(moy)}}\right)$$

$$Q_{loss-b2} = U_{b_2}\left(T_b - T_{coll_{(moy)}}\right)$$

Where

$$U_{b_2} = \left(\frac{e_1}{k_1} + \frac{e_2}{k_2} + \frac{e_3}{k_3}\right)^{-1}$$

Then

$$Q_{loss-Total\ 2} = Q_{r,g-a} + Q_{c,g-a}$$

The following are the saturated vapour pressure expressions as a function of temperature (°C). $P(T) = \exp\left(25{,}317 - \frac{5144}{T+273.15}\right)$