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Enhancement of solar still productivity using absorber plate with inclined perforated rectangular fins: an experimental study with economic analysis

Wissam H. Alawee[a,b], Hayder A. Dhahad[c], Thamer A. Mohammad[d,*]

[a]*Control and Systems Engineering Department, University of Technology, 10066 Baghdad, Iraq, Tel. +9647702512023; email: 10603@uotechnolgy.edu.iq*
[b]*Training and Workshops Center, University of Technology, 10066 Baghdad, Iraq*
[c]*Department of Mechanical Engineering, University of Technology, 10066 Baghdad, Iraq, Tel. +9647700685984; email: 10592@uotechnolgy.edu.iq*
[d]*Department of Water Resources Engineering, College of Engineering, University of Baghdad, 10070 Baghdad, Iraq, Tel. +9647735966373; thamer.a.m@coeng.uobaghdad.edu.iq*

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ABSTRACT

This work aimed to enhance the thermal performance of conventional solar stills by using perforated inclined fins that were integrated at the basin plate. To achieve this goal, two solar stills were designed, built and characterized on the basis of Iraqi climatic conditions. The first still was a conventional one, whereas the second was a double-slope solar still with inclined perforated rectangular fins. The designed solar stills had a basin area of 0.75 m^2 and a glass cover inclined at 30° with an orientation in the north–south direction. Results showed that the productivity of distilled water of the single basin conventional solar still was low. Moreover, the productivity of the finned solar still was higher than that obtained from the conventional one. The performance of the finned still was increased by 16%–54% when inclined perforated rectangular fins were used. The average yield in the months of February to August was approximately 3.9–5.7 L/d, and the estimated cost of the distillate output for conventional and finned solar stills was approximately 0.030$/L and 0.028$/L, respectively.

Keywords: Solar still; Conventional; Finned; Productivity; Economy

1. Introduction

One of the simplest and most direct applications of solar energy is the solar still. Desalination via solar energy is a practical solution to produce potable water especially in remote areas that experience a scarcity of potable water and where sunlight is available. Compared with other desalination processes, the use of conventional solar stills suffers from low productivity, which varies from 0.5 to 2.5 kg/m^2, and its efficiency usually ranges from 5% to 40% [1]. Therefore, the method has not cost-competitive with alternative methods. Researchers worldwide have conducted intensive studies on improving the productivity and efficiency of solar stills.

In recent years, many researchers have used fins in various ways to enhance the productivity of solar stills. The use of fins is one of the passive methods that are widely used in engineering disciplines to enhance the heat transfer process between surfaces and surrounding fluids. Fins are concerned with energy transitions that require heat movement.

Velmurugan et al. [2] showed that when fins were integrated to still basins, the productivity of solar stills was enhanced to approximately 53% higher than that of

* Corresponding author.

conventional stills. Velmurugan et al. [3] also compared the ordinary basin of conventional solar stills with three other types of solar still basins. The first basin contains wicks, whereas the second and third ones were sponge and fin basins, respectively. The comparison showed that productivity increases by 45.5%, 29.6% and 15.3% when fins, wick and sponges were used, respectively. Omara et al. [4] examined the productivity of solar stills integrated with the absorber plate of gilled and corrugated distilled bases under Egyptian weather conditions. The researcher found that the productivity of this type of solar still was increased by approximately 21%–40% in comparison with the conventional absorption plate. Ayuthaya et al. [5] studied the performance of ethanol solar stills integrated with a gilled absorption plate. Results showed that the productivity was increased by approximately 15.5% by using a gilled plate instead of a flat conventional absorption plate.

Many researchers had studied various factors that enhance the productivity and efficiency of conventional solar stills. Al-Mahdi [6] investigated the influence of the number of basins on the performance of solar stills and revealed that double-basin solar stills increase productivity by 45.5% compared with conventional solar stills.

Al-Hussaini and Smith [7] used vacuum technology inside solar stills and this technology was increased the water productivity of the solar stills by approximately 100%.

Jubran et al. [8] numerically studied a solar still with a multi-stage evacuation process. Their solar still was built from three insulated stages positioned on top of each other. A perfect sealing was used between the various stages such that the water vapor that evaporated within the boiling process can only move through a limited orifice connecting the two stages. They found that the still can generate up to 9 kg/m^2/d with an acceptable distillation efficiency of 87%. Nafey et al. [9] examined the effect of using a floating bored plate in the distillation tank on the productivity of stills and they found an improvement of 15%–40% in the productivity compared with the conventional solar still. Al-Hinai et al. [10] conducted a parametric study to investigate a double-effect solar still and the results were compared with that obtained from a single-effect solar still. They used a shallow water basin with an asphalt coating. The average annual energies obtained from single and double effect stills were 4.15 and 6 kg/m^2/d, respectively. Rajaseenivasan and Kalidasa [11] theoretically studied the effect of adding extra basins to a solar still with a single basin on productivity. Under the same circumstances, results showed that the productivity of modified solar still was 85% higher than that of a single basin. Tiris et al. [12] integrated a flat plate collector with a single-basin still and they found an increase in productivity by 45.5% compared with the conventional solar still.

Chaichan et al. [13] used a distillation system linked to a low-cost sunlight concentrator. The researchers also added paraffin as a heat storage material of the distillation and concentration systems. The proposed system increased the hours of distillation after sunset and causes an increase in concentrating efficiency, heating efficiency and system productivity by 50.47%, 157.8% and 783%, respectively.

Tanaka and Nakatake [14] conducted a theoretical study to examine different basin types in a solar still with external and internal reflectors. They found that the solar still with external and internal reflectors increased productivity by 48% compared with that obtained from the conventional solar still.

Gnanadason et al. [15] tested the effect of adding nanoparticles, that is, carbon nanotubes, to the water used inside the single basin of a solar still on its productivity. They reported that by adding the nanoparticles, productivity was increased by 50%. However, the amount of added nanoparticles was not mentioned in their study but they recommended to consider the economic viability. Chaichan and Kazem [16] added aluminum powder to the paraffin installed under the distiller basin. The addition of paraffin has improved the yield by 6.11% whereas the improvement of paraffin conductivity when the aluminum powder was added enhances distillate production by 25.51%.

Panchal et al. [17] conducted an experiment using a solar still with an evacuated glass tube collector under the climate conditions of Mehsana, Gujarat. They found that by using this technique, the distillate output obtained from the solar still was increased by 40%.

Awad and El-Agouz [18] experimentally investigated the effect of using open-loop continuous water flow with a humidification–dehumidification process on the performance of stepped solar still. The results displayed that the performance of solar still can significantly be increased by increasing the airflow rate. Egelioglu et al. [19] reported the experimental data of four various arrangements of inclined solar water desalination systems, including open-loop continuous water flow and spray jets. They investigated the influence of using spray jets on the thermal and economic performance of the solar water desalination system. The results revealed that the three major factors that can influence the performance of the desalination system were jet variation, wick material and solar radiation. Also, El-Agouz [20] experimentally investigated the performance of a stepped solar still with continuous water circulation employing a storage tank for salt and seawater to enhance productivity. The result showed that the daily efficiency of the modified stepped still was approximately 20% higher than that of the conventional still. Somwansh and Tiwari [21] studied the improvement in the productivity of the conventional solar still by utilizing cold air to cool the surface condenser. They found that productivity was increased by 41.3%. Alawee et al. [22,23] conducted an experimental study to augment the efficiency of a conventional solar still. For similar basin conditions, the results showed that the production of modified solar still was 18%–24% greater than that obtained from the conventional one.

Some researchers adopted the use of phase change materials with solar energy concentration systems to increase the productivity of solar distillery. Chaichan and Kazem [24] adopted a heat storage method by using a solar center linked to the distillate system. The researchers used paraffin wax to store this solar thermal energy and studied two important cases: solar concentrator tracking the sun and not tracking it. The distillation time increases by up to 5 h when the sun-tracking concentrator is used and when paraffin was added to the distillation system. In this case, the concentrating efficiency, heating efficiency and productivity of the system were increased by 64.07%, 112.87% and 307.54% respectively. The system that used paraffin without tracking sunlight was continued to operate 3 h after sunset.

The above studies have revealed that an increase in the basin area of a solar still leads to an acceptable enhancement in the productivity of the still. However, to the best knowledge of the authors, the use of perforated inclined fins to extend the basin surface area has yet to be investigated. Therefore, the present experimental work aims to investigate the augmentation in the thermal performance of a solar still by integrating perforated fins inclined by 45° at the basin plate under Iraqi climatic conditions.

2. Experimental setup and procedure

For the purpose of performance comparison, two types of single-effect double-slope solar stills were designed, built and investigated under the circumstances of Baghdad (Fig. 1). The first solar still was a conventional one, whereas the second was integrated with perforated inclined fins at the basin plate.

2.1. Conventional solar still

The conventional solar still system illustrated in Fig. 2 consists of the following parts: a feeding water tank, a distillation basin, a measuring jar and a pipe network. The basin of the solar still was made of galvanized iron with a thickness of 2 mm and a basin area of 0.75 m^2 (1.25 m × 0.60 m); the height of the sidewall is 40 cm. The still base and the interior of the side walls were painted with matte black paint to increase absorption. The solar still was positioned within a wooden container with a thickness of 2 cm, and the space between the still walls and the wooden box was filled with sawdust to minimize thermal losses. A 4 mm-thick glass panel was used to cover the solar still from the top, and it was fixed at a 30° angle with the horizontal. The glass cover was securely fastened using silicone rubber to prevent vapor from leaking out. The solar still was routed to the south geographical location to obtain maximum solar radiation throughout the year. A 40 L storage tank was used to feed the still. Condensed water flowed down through a glass cover into a collection canal and was stored in a storage bottle.

2.2. Solar still with inclined perforated rectangular inclined fins

The use of fins in distilled bases increases its surface area, thus increasing the heat transfer between the water and the still base. The increased heat transfer increases water temperature, thereby leading to an increase in the difference between the temperature of the water and that of the glass cover. Consequently, productivity is increased. In this study, inclined perforated rectangular fins were integrated at the basin of the still. The use of inclined perforated fins has several advantages, namely, an increase in external surface area, an increase in heat transfer with the inner area of the perforated plate and an increase in the absorption of solar radiation.

Solar stills with perforated inclined fins are shown in Fig. 3. Finned and conventional stills have similar dimensions and external designs. The only difference lies in the absorber plates, where they were perforated finned and not flat. The finned absorber plate was made of galvanized iron and manufactured by a computer numerical control milling machine. The breadth, thickness and length of the fins used in this study were 14, 10 and 2 mm, respectively. The pitches between two neighboring fins were taken as 100 and 150 mm in the longitudinal and transverse directions,

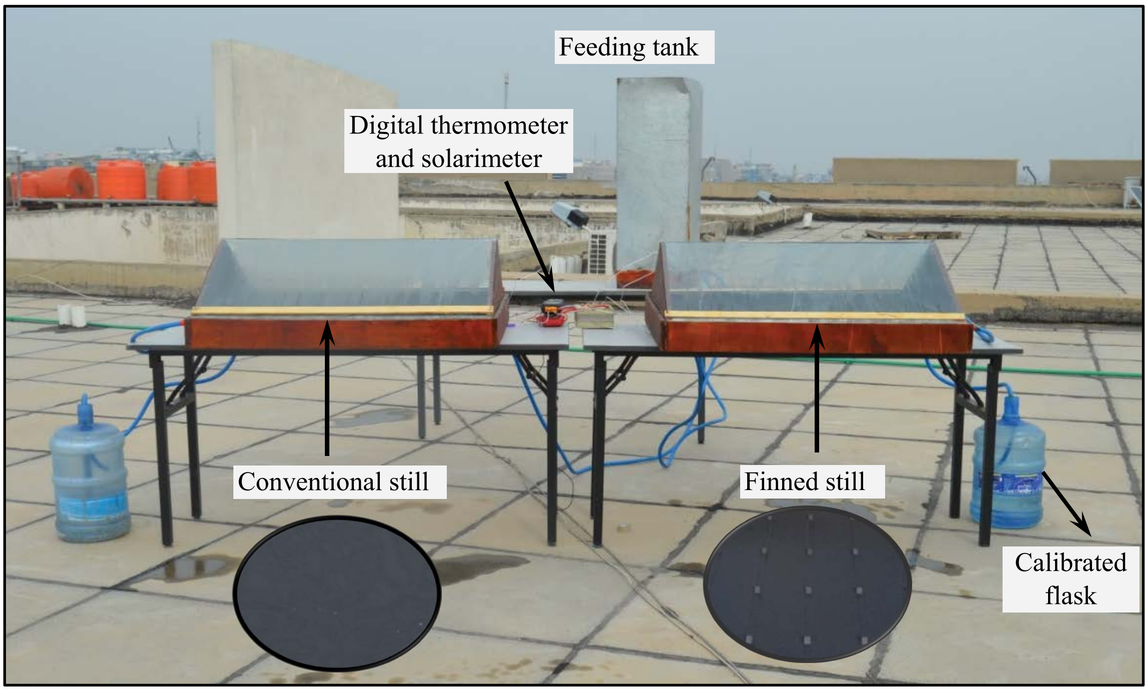

Fig. 1. Photograph of solar stills (a) conventional still and (b) finned still with perforated inclined fins.

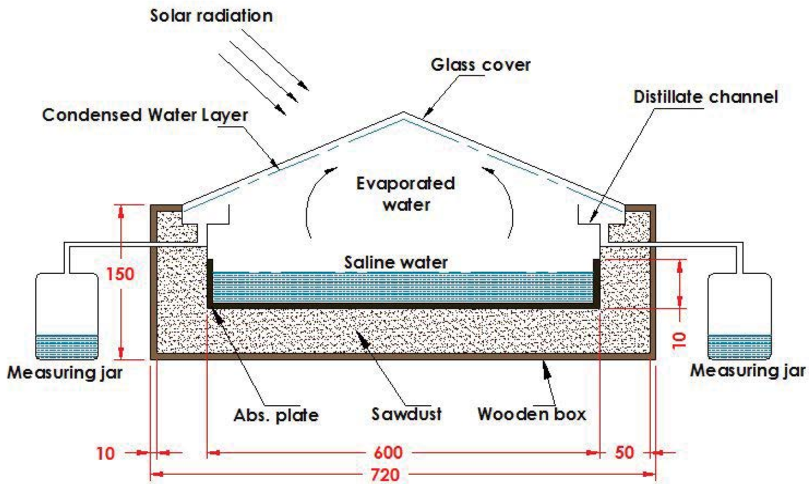

Fig. 2. Schematic of the conventional solar still.

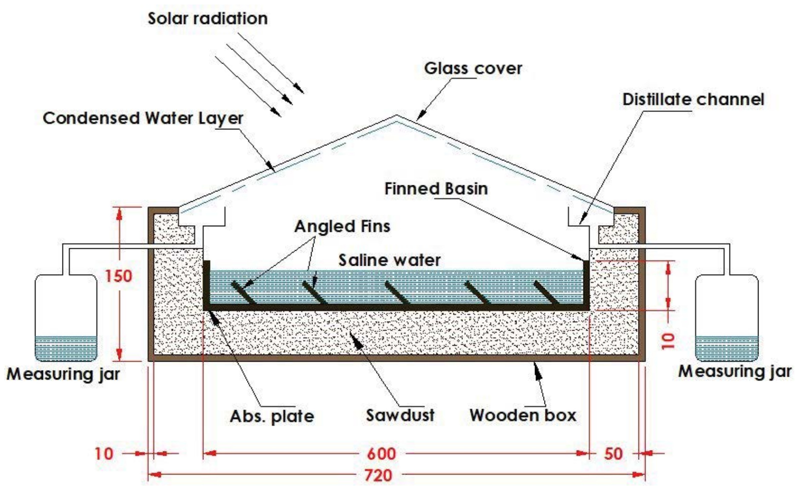

Fig. 3. Schematic of the solar still with perforated inclined fins.

respectively. The dimensions and other details of the finned basin are shown in Fig. 4.

The water depth in the basin was maintained at 10 mm, and the plate fins were tilted at an angle of 45°. A pyrometer was used to measure the flux density of the solar radiation in the desired location. Copper–constantan thermocouples were used to measure the water temperature inside the distillation basin. However, the ambient temperature was measured by using a mercury thermometer. The quantity of collected water was measured by using a 5 L measuring beaker.

The finned solar still with perforated inclined fins was tested and compared with a conventional solar still. In all the experiments, the hourly recorded variables were as follows: solar radiation intensity, average water temperature in the distillation basin, glass cover temperature and ambient air temperature.

2.3. Uncertainties in the measuring devices

Measurements of any physical quantity are always subject to some uncertainties. The main sources of experimental uncertainties can be related to low accuracy in the measuring instruments and assumptions in the experimental procedure. The propagation of uncertainty is the method used to calculate the combined uncertainty from each experimental parameter. In this study, the propagated uncertainty analysis was conducted according to the method proposed by Kline and McClintock [25]. The result, R of the experiment was assumed to be calculated from a set of measurements represented by:

$$R = R\left(X_1 + X_2 + X_3 \ldots\ldots X_n\right) \quad (1)$$

Let W_R be the uncertainty in the result and W_1, W_2, W_3, …, W_n are the uncertainties in the independent variables. The uncertainty in the result was proposed by Kline and McClintock [25] as a root-sum square combination of the effects of each of the individual inputs as shown below:

$$W_R = \left\{ \sum_{i=1}^{n} \left(\frac{\partial R}{\partial X} W_n \right)^2 \right\}^{1/2} \quad (2)$$

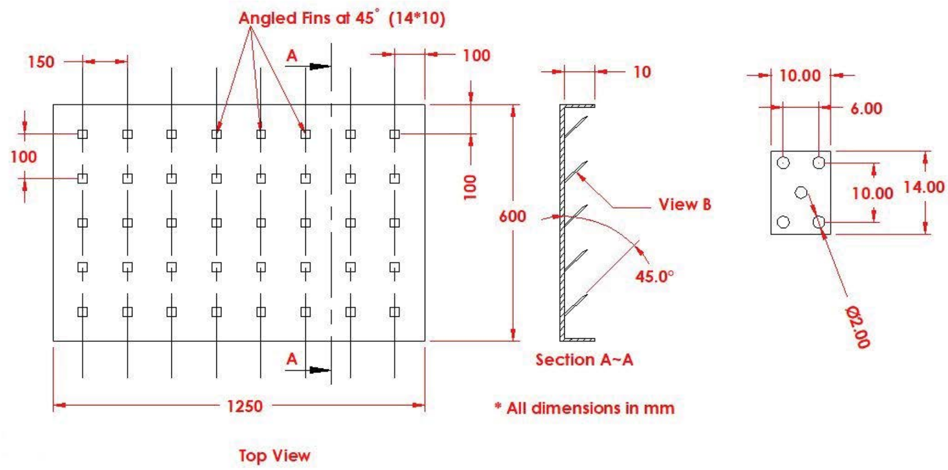

Fig. 4. Plan view and sectional side view of the elevated finned basin.

In this study, the uncertainties associated with using the apparatus are given in Table 1. The apparatus used in this study were for thermocouples, solarimeter and measuring beaker. The minimum error was equal to the ratio between its least count and the minimum value of the measured output [26].

The hourly productivity, m ($m = f(h)$) where h is the depth of water in the calibrated flask. Following Eq. (1), total uncertainty for the hourly condensate production can be written as:

$$W_m = \left[\left(\frac{\partial m}{\partial h} W_h\right)^2\right]^{1/2} \quad (3)$$

The total uncertainty in the current experimental measurements was found to be within ±8%.

2.4. Experimental procedure

The performance of the solar stills was examined under various Baghdad weather conditions (latitude: 33° 18′ N, longitude: 44° 21′ E). The experiments were carried out at stills which were oriented to the south during winter and summer from February to the end of July 2019. Three experiments were conducted every month on different days. The data of the ambient temperature, the basin water temperature, the solar radiation, and the productivity of distilled water were gathered every hour from 8 a.m. to 6 p.m. Before an experiment was made, the stills were feed with water, the glass cover was cleaned, and the measuring devices and thermocouples were investigated.

2.5. Economic analysis of solar stills

A complete evaluation of the constructed desalination system should consider economic principles in addition to experimental performance. Economic analysis provides the appropriate cost value of the distillate water associated with the capital investment and operating and maintenance costs of the desalination system. Although studies on the enhancement of still productivity abound, only a few have addressed the economic aspects. The goal of the present economic analysis of the solar still system is to estimate the mean cost of 1 L of distillate water in \$/L. Solar stills were characterized by their low annual operating costs and high initial costs. According to the Iraqi market, the capital costs (P) of the conventional and finned stills were 125.7\$ and 151.9\$, respectively, as listed in Table 2.

The unit cost of the distilled water (UC_{dw}) of the solar still can be computed using the formula from Kabeel et al. [26].

$$UC_{dw} = \frac{TAC}{M_{yearly}} \quad (4)$$

where M_{yearly} is the average annual productivity in L/m², and TAC is the total annualized cost of the solar still and is calculated as follows:

Table 1
Measuring devices with their accuracies and ranges

No.	Instrument	Range	Accuracy	% Error
1	Thermocouple T-Type	0°C–100°C	±0.2°C	0.25%
2	Thermometer	0°C–100°C	±1°C	0.5%
3	Solarimeter	0–2,500 W/m²	±2 W/m²	2%
4	Measuring beaker	0–2,000 mL	±3 mL	1%

Table 2
Cost of the fabrication of two solar stills

Components	Cost in $	
	Conventional type solar still	Finned type solar still
Galvanized iron	15	25
Water tank	20.6	20.6
Wooden box	19.3	19.3
Pipe network	12.4	12.4
Iron stand	13.6	13.6
Paint	8	8
Glass cover	16.2	16.2
Silicon rubber	5	5
Fabrication	15.6	31.8
Total capital cost (P)	125.7	151.9

Total annualized cost (TAC) = First annual cost (FAC) + Annual maintenance cost (AMC) – Annual salvage value (ASV) (5)

The FAC of a solar still is given as:

$$\text{FAC} = P \times (\text{CRF}) \tag{6}$$

where the capital recovery factor is calculated as:

$$\text{CRF} = \frac{\left(i(1+i)^n\right)}{\left((1+i)^n - 1\right)} \tag{7}$$

where n is the number of life years, and i is the interest per year, which are assumed as 10 y and 12%, respectively.

AMC is assumed to be 15% of the fixed annual cost; hence,

$$\text{AMC} = 0.15(\text{FAC}) \tag{8}$$

ASV can be expressed as:

$$\text{ASV} = S \times (\text{SFF}) \tag{9}$$

where the salvage value (S) is assumed to be 10% of the annualized capital cost (P) of the solar still, and the sinking fund factor (SFF) is calculated as:

$$(\text{SFF}) = \frac{i}{(1+i)^n - 1} \tag{10}$$

3. Results and discussion

To investigate the influence of the finned absorber plate on the enhancement of the still productivity, perforated inclined fins were attached to the base of the still. Their results were compared with the results of the conventional solar still. The experiments were conducted on different days between February and July from 8 am to 6 pm. The water depth inside the distillation basin was fixed to 2 cm for both two stills. However, the inclination angle of the perorated fins was fixed and it was taken as 45°.

The use of fins in solar still increases the area of heat transfer between the water and distillation basin which finally increases the evaporation rate. In this study, the other advantage of using rectangular perforated fins inclined with an angle of 45° was to increase the thermal gain from solar radiation particularly during winter in Baghdad, Iraq (the solar radiation is normal to fin surface). Many investigations have been carried out to determine the optimum tilt angle for fix solar collectors [27,28].

Many studies were concluded that the productivity of the solar still was increased when the water depth in the distillation basin was decreased [29,30]. In this study, a fixed water depth of 2 cm in the distillation basin was used. This depth made the inclined fins to be totally submerged with water. The disadvantages of using a depth less than 2 cm are the fins will be unsubmerged besides the difficulties in maintaining such a small depth.

3.1. Variation of solar intensity and ambient air temperature

The hourly alteration of the solar irradiance, basin water temperature and ambient air of the two types of solar stills are displayed in Fig. 5. Solar irradiance begins to rise in the morning, attains the maximum value in the afternoon and then commences reduction after 1 pm. The maximum value recorded was 867 W/m^2 for 21 April 2019.

The average water temperature in the distillation basin was measured and found to be 45.30°C and 52.3°C for the conventional and the finned solar stills, respectively. Fig. 5 shows that the water temperature was significantly affected by coupling perforated inclined fins with the solar still absorber. Moreover, the still with perforated inclined fin absorbers provides an absorber temperature larger than that of the conventional still. This result was expected because the use of inclined fins increased the surface area of the absorber plate. Thus, the rate of heat absorbed by the finned absorber was increased owing to the increase in the surface exchange. Hence, the absorber's temperature is increased.

3.2. Variation of distillate output for two solar stills

The hourly productivity of the two solar stills is shown in Fig. 6. The average hourly productivity is a function of solar intensity. Productivity was low during hours of low radiation (in the morning hours) and was reached the maximum during hours of high radiation, that is, afternoon hours. The greatest hourly productivity was recorded at 2 pm for the two stills. This can be attributed to the solar radiation that reaches its peak value between 2–3 pm at the chosen location. Furthermore, the productivity of the solar still with inclined fins during daytime was higher than that of the conventional solar still. On 21 April 2019, the average hourly yields of the conventional and finned solar stills were found to be 320 and 410 mL/m^2 h, respectively. The maximum hourly distillate outputs of the conventional and finned basin solar stills were found to be

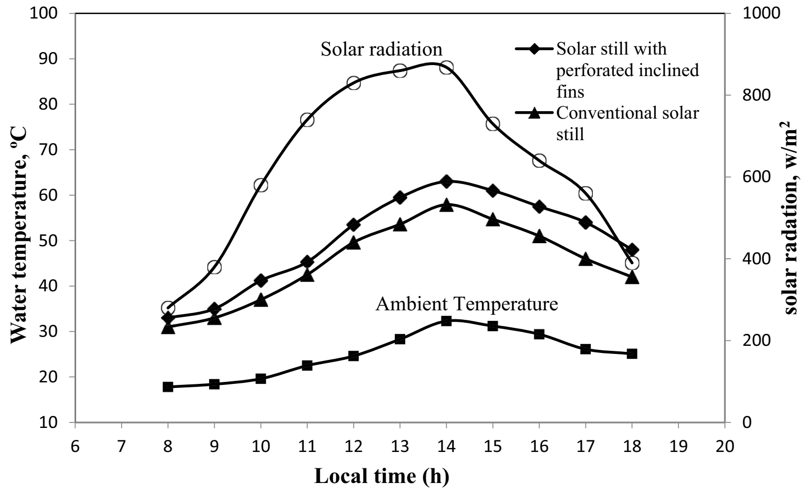

Fig. 5. Variation of different hourly temperatures for conventional and finned solar stills.

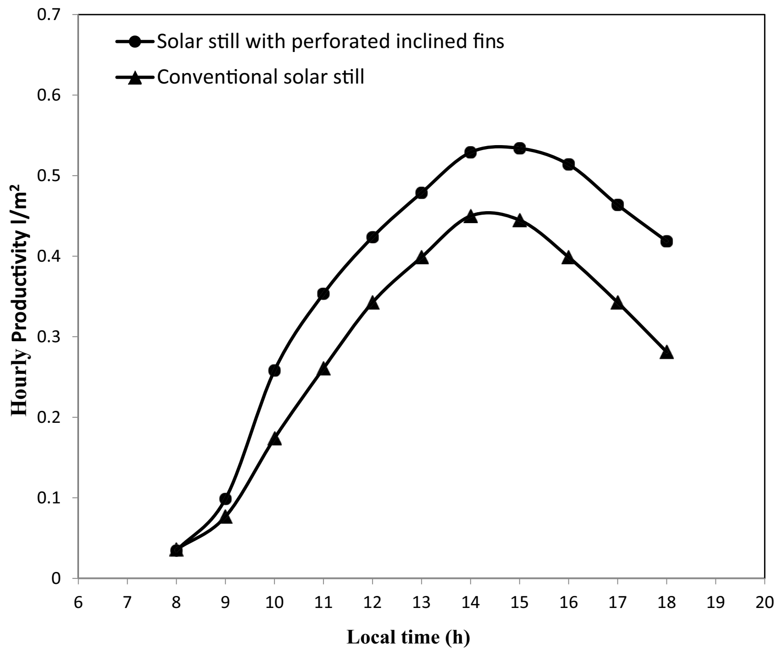

Fig. 6. Hourly variation productivity for the conventional and finned absorber solar stills.

449 and 587 mL/m²/d, respectively. Fig. 7 presents the cumulative water output (in mL) against time in a day from 8 am to 6 pm. As shown in the figure, the volume was increased from 39.3 mL at 8 am to 3,525 mL at 6 pm for the conventional solar still and from 37.1 mL at 8 am to 4,516 mL at 6 pm for the solar still with angled fins. The perforated inclined fins attached to the base of the solar still have a significant effect on the productivity of the distilled water; this effect is attributed to the high absorption of the solar radiation incident on them. The solar still with perforated inclined fins gave an average increase of 28% in the amount of produced distilled water compared with the conventional still. This increase is due to the fins' inclination angle, which is perfect for solar ray absorption during winter in the Iraqi region. During the time when fins were used, the surface area of the absorber plate increased, and the preheating time for the saline water was decreased. Thus, productivity increased. The average monthly performance is shown in Table 3. The improvement in the performance of the finned solar still was found between 16.6%–53.6%. Moreover, the yield in several typical days (3 clear days) in February, March and April was approximately between 3.9 and 4.5.7 L/d.

3.3. Overall performance of solar stills

The overall performance of the solar still is usually evaluated by its productivity and thermal efficiency. Tables 3 and 4 summarize the improvements in daily yield of the finned still compared with the conventional still including thermal efficiencies of both distillers.

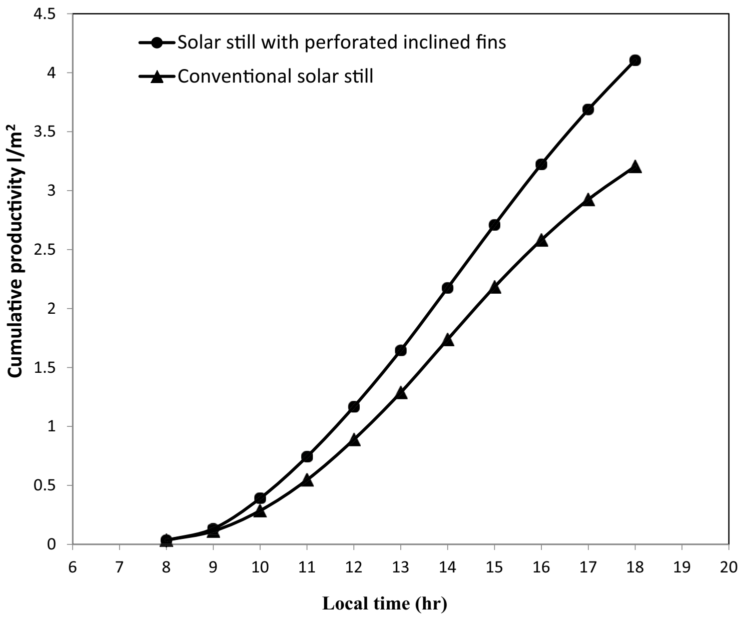

Fig. 7. Hourly variation productivity for the conventional and finned absorber solar stills.

Table 3
Comparative study of conventional still and finned still on a monthly basis

Month	Total average daily yield (mL) (Average of three clear days)		Average improvement (%)	Weather conditions		
	Conv. solar still	Finned still		Ta, max. (°C)	Ta, min. (°C)	Mean daily intensity (MJ/m^2)
Feb., 2019	2,550	3,917.65	53.6	23.3	8.2	13.70
Mar., 2019	3,293.2	4,435	34.7	30.5	15.8	17.38
Apr., 2019	3,782.8	4,916.4	30.0	33.7	22	18.61
May, 2019	3,993	5,137.4	28.7	35.3	26.1	20.74
June, 2019	4,389.4	5,229.2	19.1	36.8	26.6	22.46
July, 2019	4,618.9	5,615.1	21.6	39.9	27.2	24.70
Aug., 2019	4,930	5,749.1	16.6	40.5	28.7	25.09

Table 4
Average thermal efficiency of tested solar stills during tested months

Average efficiency	Feb., 2019	Mar., 2019	Apr., 2019	May, 2019	June, 2019	July, 2019	Aug., 2019
Finned still	41	39.5	39	39.5	38	38.5	38
Conventional still	34	34.5	34.5	34	34.5	35	35.5

As observed from Table 3, the freshwater production of the finned still was higher than that of the conventional still by about 16.6%–53.6% depending on the month. The daily productivity rise is defined by the following equation:

$$\text{DPR},\% = \left(\frac{\text{DPMS} - \text{DPCS}}{\text{DPCS}}\right) \times 100 \tag{11}$$

where DPR is daily productivity rise, DPMS is daily productivity of modified still and DPCS is the daily productivity of conventional still.

On other hand, the thermal efficiency is evaluated using the following formula [31]:

$$\eta_d = \frac{\sum \dot{m} \times h_{fg}}{\sum A \times I(t)} \tag{12}$$

where η_d, $\dot{m}$, h_{fg}, $I(t)$, and A are the efficiency, freshwater production, vaporization latent heat, solar radiation, and system projected area, respectively.

Besides, the vaporization latent heat is defined by:

$$h_{fg} = \begin{bmatrix} 25,019 - 2.40706 \times T_w + \left(\dfrac{1.192217}{10^3}\right) \times \\ T_w^2 - \left(\dfrac{1.5863}{10^5}\right) \times T_w^3 \end{bmatrix} \times 10^3 \quad (13)$$

Table 4 shows that the thermal efficiency of the conventional distiller was ranged from 34% to 35.5%. In addition, the efficiency of the finned solar still was ranged from 38% to 41% depending on the month.

3.4. Comparison of present work with previous research studies

A comparison between the distillate output results obtained in the present work and those obtained from previous experimental investigations is illustrated in Table 5. These investigations have been conducted to study the effect of integrating fins with different configurations to the basin of ordinary solar still under different climatic conditions. As shown in Table 4, the overall behavior of the hourly and accumulated distillate output by other research is similar to the curves of the experimental results of the present work. Omara et al. [4] obtained an increase in the productivity of modified single-effect solar stills (3.6 and 3.9 kg/m²/d for finned and corrugated stills, respectively at Kafrelsheikh, Egypt). Chaichan and Kazem [24] conducted similar experiments and obtained experimental productivity of 5.3 kg/m²/d. The experimental results of the productivity of the present study for the finned solar still are close to the above values. Similarly, the experimental results obtained by Kline and McClintock [25] are close to those of the present study.

3.5. Cost evaluation

Economic analysis was conducted to evaluate the cost per liter of the distillate water by two stills. The total fixed cost of conventional stills was approximately 125.7$, and the total fixed cost of finned solar stills with inclined fins was approximately 151.9$. Analysis of the experimental data showed that the average daily productivities were 3,936 and 4,983 mL/d for conventional and finned stills, respectively. The stills were assumed to have a life span of 10 y, given that the stills operated 340 d in a year (as per the sunshine duration in the Baghdad region). The cost per liter from the conventional still was 0.030$, whereas that for the finned still was approximately equal to 0.0286$. These values showed that despite the increased cost of the absorber plate with perforated inclined fins, the increase in output became greater; thus, the total cost of water was decreased. Therefore, investment in the fins is worthwhile. Table 6 shows the economic analysis of solar stills. It indicates that the cost of distilled water per liter from the conventional solar still was higher than that of the finned solar still by approximately 7.14%. Compared with the conventional still, the initial cost for the finned still was 21% higher and the productivity of the finned still was enhanced by up to 54%. The average daily solar radiation during the period of experimentation was 547.82 W/m², whereas the annual average solar radiation for the Iraqi region (as reported on the website) was 5.2 kWh/m²/d. Therefore, the average daily irradiation during the period of experimentation was assumed to be equivalent to the annual average solar radiation.

4. Conclusions

In this study, experimental work was conducted to evaluate the performance of conventional and finned solar

Table 6
Economic analysis of the conventional and finned solar stills

Parameters	Still type	
	Conventional still	Still with angled fins
Capital cost, P	125.7	151.9
Capital recovery factor, CRF	0.177	0.177
First annual cost, FAC	19.133	24.1251
Salvage value, *S*	10.81	13.63
Sinking fund factor, SFF	0.057	0.057
Annual salvage value, ASV	0.61617	0.77691
Annual maintenance cost, AMC	2.870	3.618765
Total annualized cost, TAC	21.387	26.96696
Average annual yield, *M*	1,043	1,043
Unit cost UC_{dw}	0.030	0.0286

Table 5
Comparison of the performance in the present work and previous research

No.	References	Enhancing method	Productivity mL/m²/d	Production increase
1	Velmurugan et al. [3]	Solar still with fin	2,800	45%
2	Omara et al. [4]	Finned and corrugated stills	3,633 and 3,916	47% and 35%
3	Ayuthaya et al. [5]	Solar still with fin plate		15.5%
4	El-Sebaii et al. [32]	Solar still with fins integrated at the still basin	5,330	13.7%
5	El-Naggar et al. [33]	Modified solar still with finned-basin liner	4,802	11.8%
6	El-Sebaii et al. [34]	Solar still with baffle suspended absorber	5,737	20%
7	Appadurai and Velmurugan [35]	Fin type single basin solar still	2,900	45.5%
8	Present work	Inclined perforated rectangular fins	3,900–5,700	16.1%–53.6%

stills under the climatic conditions of Baghdad City, Iraq (33° 18′ N, 44° 21′ E). The key findings of this study are:

- Daytime output was increased with the increase in the basin water temperature. The average water temperature in the distillation basin was measured and found to be 45.30°C and 52.3°C for the conventional and finned solar stills, respectively.
- Daytime productivity of the solar still with inclined fins was found higher than that obtained from the conventional solar still. The average yields for the conventional and finned solar stills were 320 and 410 mL/m^{2}h, respectively. The maximum hourly distillate outputs of the conventional and finned basin solar stills were found to be 449 and 587 mL/m^2/d, respectively.
- The overall performance of the solar still with perforated inclined fins was evaluated based on its productivity and thermal efficiency. Depending on the month, the production of freshwater from the finned still was higher than that obtained from the conventional still by about 16.6%–53.6%. However, the thermal efficiency of the conventional solar still was ranged from 34% to 35.5% while the efficiency of the finned solar still ranged from 38% to 41%.
- Simple cost analysis showed that the unit cost of distilled water obtained from conventional solar still was \$30/m^3 while the unit cost of distilled water obtained from solar still with inclined fins was lower and found to be \$28.6/m^3.
- Although fixed values for the fin inclination angle and depth of water in the distillation basin were used in the experiments of the present study it is recommended to study the effect of fin inclination angle, depth of the water in the distillation basin, fin dimension and number on the performance of solar still in the future work.

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