Effect of different basin materials on the performance of hemispherical distiller with mirrors and energy storage material

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Abstract

Numerous studies are being conducted on solar desalination systems with creating new designs to improve the efficiency and yield of these systems. Hemispherical solar still has a relatively large throughput because of its large exposure and evaporation surface areas compared to the other distiller designs. To get the optimal conditions of the parameters that provide the highest productivity of the hemispherical still, three hemispherical basin stills were fabricated and tested. The experiments were performed in three stages: In the first one, the traditional hemispherical solar still THSS (a reference distiller) was compared by THSS with internal reflective mirrors (THSS-IRM). In the second stage, the effect of using different basin metals (THSS with basin metal of zinc (THSS-IRMZ) and basin metal of copper (THSS-IRMC)) with internal reflective mirrors was studied. In the third stage, the two distillers were investigated under using energy storage medium (30 g/L sand grains for each). The THSS with internal reflective mirrors, basin metal of zinc, and energy storage medium is abbreviated by THSS-IRMZSG. Also, THSS with internal reflective mirrors, basin metal of copper, and energy storage medium is abbreviated by THSS-IRMCSG. Moreover, THSS with internal reflective mirrors and energy storage medium is abbreviated by THSS-IRMSG. The results showed that the combination of using internal reflective mirrors, basin material (copper) and energy storage medium provided the best improvement of hemispherical distillation device. The maximum cumulative yield of THSS-IRMCSG was 11.9 L/m².day, while the reference distillation device gave a total yield of 4.65 L/m².day. So, the productivity was improved by around 156%.

Introduction

Although the food, energy, and water are the basic needs for the human beings, there is a big shortage of these stuffs all over the world (Tiwari & Sahota 2017). Also, any sustainability plan for any country is mainly dependent on the food-energy-water nexus. Various ways like solar-based multi-generation units and greenhouse-solar distillation units are proposed to solve the problems the people suffer from (Essa et al. 2020c). Solar thermal desalination like MSF (Harandi et al. 2017), HDH (Abdullah et al. 2020a, Essa et al. 2020f, Sharshir et al. 2016), MEB (Darwish et al. 2006), and solar stills (Kabeel et al. 2014b, a) is one of the methods that help solving the water shortage problem (Elsheikh et al. 2018).

The solar distillers are devices easy to fabricate and do not need intelligent skills, but they suffer from the low productivity (Essa et al. 2020d, Essa et al. 2020c). This motivated the scientists to find different methods to improve the productivity of the distillers. As a consequence, different designs and modifications can be found in the literature of solar stills, and all these modifications aimed to enhance the solar still performance. The modifications are like stepped (Essa et al. 2020b), disc (Essa et al. 2020e), tubular (Elashmawy 2020, Kabeel et al. 2020), drum (Abdullah et al. 2019b), PV/T active distiller (Hedayati-Mehdiabadi et al. 2020, Pounraj et al. 2018), finned (Omara et al. 2011a), trays (Abdullah et al. 2020b, Abdullah et al. 2020c), inclined (Kumar et al. 2017), wick (Abdullah et al. 2019a, Abdullah et al. 2018, Omara et al. 2015a), corrugated (Omara et al. 2016, Omara et al. 2015b), distiller with condenser (Kabeel et al. 2017), spherical (Modi et al. 2020), double-effect (Abderachid & Abdenacer 2013,

Rajaseenivasan et al. 2013, Rajaseenivasan & Kalidasa Murugavel 2013), multi-stage (El-Sebaei 2005), distiller with nanofluids (Shanmugan et al. 2020), distiller with heat exchanger (Yadav 1991), inverted still (Suneja & Tiwari 1999), and pyramid distillers (Modi & Nayi 2020, Nayi & Modi 2018). Moreover, the distillers were examined when utilizing nanomaterials (Kabeel et al. 2017, Thamizharasu et al. 2020), floating aluminum sheet (Valsaraj 2002), desiccant (Modi & Shukla 2018), glass cooling (Sharshir et al. 2017b), rocks (Abdallah et al. 2009), wicks (Omara et al. 2015a), PCM (Sharshir et al. 2017a), fins (Omara et al. 2011b), sun-tracker (Abdallah & Badran 2008), multi-effect basins (Al-Hinai et al. 2002), reflectors (Omara et al. 2016), and vapor extraction (Elashmawy & Alshammari 2020, Essa et al. 2020a, Scrivani & Bardi 2008).

Attia et al. (Attia et al. 2021c) studied experimentally the effect of using metal trays (copper, zinc and iron) fixed on the bottom of a hemispherical solar distillation device to improve its productivity. They concluded that the productivity reached its highest value of 7.35 L/m².day when using the copper trays compared to 4.8 L/m².day for that of conventional distiller. While it was 6.3 and 5.5 L/m².day when using zinc and iron trays, respectively. Attia et al. (Attia et al. 2021a) tested experimentally the performance of hemispherical still with and without phosphate pellets placed homogeneously at two concentrations (10 and 20 g/L) at the bottom of the basin. It was observed that the increase in productivity reached 47.9% when using phosphate pellets with a concentration of (20 g/L) and reached 33.7% when using phosphate pellets with a concentration of (10 g/L). Moreover, Attia et al. (Attia et al. 2021b) studied experimentally the effect of different concentrations of sand grains (5, 10, 20, 30, 40, 50, 60 and 70 g/L) to improve the hemispherical solar still performance. The results obtained that the optimal concentration of sand particles was 30 g/L, where the yield reached 7.27 L/m².day compared to 4.78 L/m².day for the still without grains of sand.

In addition, Khechekhouche et al. (Khechekhouche et al. 2021) studied the effect of using zinc plate (black metallic) to enhance the efficiency of the solar distiller. It was found that the daily production was 3.894 L/m².day when using the zinc plate versus 2.52 L/m².day for the distiller without the zinc plate. Essa et al. (Essa et al. 2021a) examined the impact of using internal and external reflectors on the performance of the trays solar still. They obtained an improved productivity by 104%. Besides, Omara et al. (Omara et al. 2016) performed an experimental study of the corrugated solar still (CrSS) under outdoors conditions of Kafrelsheikh (Egypt). They investigated experimentally the possibility of using the layer wick and reflectors to enhance the productivity of the CrSS. It was observed that the productivity was enhanced by 145.5% as compared by the conventional still. Moreover, they deduced that the daily efficiency was 59% and 33% for the CrSS and conventional still, respectively.

The major goal of the current original paper is to examine experimentally for the first time, according to the authors' information, the effects of the parameters: different basin materials (basin metal of zinc and basin metal of copper), internal reflecting mirrors, and energy storage medium (30 g/L sand grains) on the hemispherical distiller performance. The tests were performed in El Oued, Algeria through August 2020.

Experimentations

Test-rig fabrication

Figure 1 shows the 2D design of the hemispherical solar basin still. This system had a circular base whose diameter was equal to 38 cm and height was 4 cm. The basin was made of wood, 2.5 cm thick, and greased on all sides with black silicone. The transparent cover had a diameter of 40 cm and thickness of 3 mm. Additionally, the distillate was collected with the help of a plastic tube fixed at the lower end of the suspended trough as illustrated in Figure 1.

To investigate the impact of using two different basin metal liners of copper and zinc that work as good thermal energy storing materials, we used the plates with the properties obtained in Table 1.

Table 1
Characteristics of investigated metals (Copper and Zinc).

Item (Unit)	Copper	Zinc
Density (g/cm ³)	8.96	7.14
Melting Point (K)	1356.6	693
Boiling Point (K)	2840	1180
Thermal conductivity W/(m·K)	401	116

Table 2 obtains the X-ray fluorescence (XRF) of El Oued sand. The results indicate that the silica (silicon oxide) has a high concentration of 97.63% among the other oxides of the sand. Also, the remaining other oxides are appeared at low concentrations.

Table 2
Chemical analysis of El Oued sand by X-ray fluorescence (XRF).

Concentrations of oxides (%)		Concentrations of trace elements (ppm)	
SiO ₂	97.63	Cl	425
MgO	0.613	Zn	44.0
CaO	0.564	Ba	21.0
Na ₂ O	0.542	Sr	6.00
Al ₂ O ₃	0.327	Nb	5.00
CO ₂	0.105	Bi	5.00
K ₂ O	0.0677	Ge	3.00
Fe ₂ O ₃	0.042		
SO ₃	0.037		
P ₂ O ₅	0.0138		
TiO ₂	0.0053		
MnO	0.0021		

Figure 2 shows a micro photo of El Oued sand. It is discerned by its golden yellow colour. This is because of its chemical composition and granular components. Figure 2 illustrates the sizes of the sand grains and their diameter which is between 1.5 and 2 mm.

The experimental test-rig is shown in Fig. 3. The tests were managed for three days of 16th, 17th, and 18th August 2020 for 12 hours (from 07:00 to 19:00) in El Oued, Algeria (06° 47' E and 33° 30' N). The hemispherical distiller inner walls are covered by mirrors. Besides, the black painted liners of copper and zinc are fixed on the basin bottom to evaluate their impact on the daily output of the solar distillers. These plates metal liners present a circular area of 0.1 m². The experiments were conducted in three stages: In the first stage, the traditional hemispherical solar still THSS (a reference distiller) was compared and THSS with internal reflective mirrors (THSS-IRM). In the second stage, the two distillates were compared with basin metal of zinc (THSS-IRMZ) and basin metal of copper (THSS-IRMC) and the internal reflective mirrors with the THSS with the internal reflective mirrors only. In the third stage, the two distillates were compared with energy storage medium (30 g/L sand grains), the internal reflective mirrors and basin metal of zinc (THSS-IRMZSG) and basin metal of copper (THSS-IRMCSCG) and the THSS with the internal reflective mirrors and energy storage medium (30 g/L sand grains) (THSS-IRMSG). Table 3 obtains the errors occurred in the measuring instruments readings.

Table 3
Standard uncertainties of instruments.

Instrument	Unit	Accuracy	Range	Standard uncertainty
Solar power meter	(W/m ²)	± 10	0-1999	5.72
Thermocouple	(°C)	± 0.1	-100–500	0.07
Measuring jar	(mL)	± 1	0–250	0.6 ml

Results And Discussion

Effect of using internal reflective mirrors

The sun radiation and air temperature are the parameters that affect the performance of the distiller. Consequently, Fig. 4 shows the solar radiation and temperatures of air and elements of the system. The highest sun irradiance was at 12:00, where it was 1010 W/m². Also, Fig. 4 reveals that using the reflective mirrors increased the water temperature of THSS-IRM more than that of the THSS by 0 – 6°C. The water elevated temperature of THSS-IRM might be referred to the higher amount of focused solar radiations inside the THSS-IRM as compared to that of THSS. Also, the water temperature was maximum at noon time, where it was 68 and 72°C for THSS and THSS-IRM, respectively. This was due to that the solar radiation and ambient temperature were maximum at noon time. Additionally, Fig. 4 shows that the glass of THSS-IRM had a temperature more than that of THSS by 0 – 1°C. Furthermore, it was maximal at noon time, where it was 53 and 54°C for THSS and THSS-IRM, respectively. The increase in glass temperature of THSS-IRM was referred to the increased generated vapor inside THSS-IRM compared to that of the THSS.

Moreover, the productivity of the THSS and THSS-IRM is shown in Fig. 5. It can be revealed that the productivity of the solar still follows the solar radiation either by increasing or decreasing. Fig. 5 illustrates that the instantaneous yield is maximal at noontime (14:00), where it was 700 and 900 mL/m².hr for THSS and THSS-IRM, respectively. Also, it is obtained that THSS-IRM introduced better productivity than the THSS. This is due to the use of the internal reflective mirrors inside the THSS-IRM, which improves the vaporization of THSS-IRM compared to THSS. Then, the greater the evaporation in the solar still is, the higher the yield is. Also, using internal reflective mirrors improved the evaporation of the THSS-IRM. So, the instantaneous yield of THSS-IRM was greater than that of THSS, Fig. 5. Furthermore, the total distillates of the THSS and THSS-IRM when using internal reflective mirrors are calculated to get the daily yield rise of THSS-IRM over that of THSS. The results obtained that the cumulative daily yield of THSS-IRM was more than that of THSS. The distillates of THSS-IRM and THSS were 7000 and 4650 mL/m².day, respectively. So, THSS-IRM augmented the yield by 50.5% over THSS because of the well explained reasons above.

Effect of using different basin liner metals of zinc and copper

Figure 6 obtains the irradiance and temperatures of solar stills at internal reflective mirrors and different basin metals (zinc and copper). The highest sun irradiance was at 12:00. Also, Figure 6 reveals that using the reflective mirrors and basin metals increased the water temperature of THSS-IRMZ and THSS-IRMC more than that of the THSS-IRM by around 0 – 3°C and 0 – 6°C, respectively. The water elevated temperature of THSS-IRMZ and THSS-IRMC might be referred to the enhanced heat transfer properties due to using the basin metals of zinc and copper compared to the conventional basin material of iron. Also, the water temperature was maximum at noon time, where it was 72, 76, and 78°C for the THSS-IRM, THSS-IRMZ, and THSS-IRMC, respectively. This was due to that the solar radiation and ambient temperature were maximum at noon time. Additionally, Figure 6 shows that the glass temperatures of THSS-IRMZ and THSS-IRMC were almost the same, and they were more than that of THSS by 0 – 1°C. What is more, the glass temperature is maximal at noontime, where it was 52, 53, and 53°C for the THSS-IRM, THSS-IRMZ, and THSS-IRMC, respectively. The increase in glass temperature of THSS-IRMZ and THSS-IRMC was referred to the increased generated vapor compared to that of the THSS-IRM.

In addition, the hourly and total accumulated productivity of the solar stills (THSS-IRM, THSS-IRMZ, and THSS-IRMC) are drawn in Fig. 7. The freshwater yield has the same behavior of the solar radiation obtained in Fig. 6. The yield increases gradually from the morning time to noon and begins to decrease after that with decreasing the solar radiation. The instantaneous yield is maximal at 14:00, where it reported 900, 1100, and 1150 mL/m².hr for THSS-IRM, THSS-IRMZ, and THSS-IRMC, respectively. Also, the THSS-IRMC introduced more productivity than either THSS-IRM or THSS-IRMZ. This was due to the improved heat transfer characteristics of the copper basin materials as compared to that of the iron and zinc. This led to enhance the vaporization of the THSS-IRMC more than the other solar stills. So, the THSS-IRMC hourly yield was greater than that of either THSS-IRM or THSS-IRMZ as illustrated from Fig. 7. In addition, using internal reflective mirrors with copper and zinc basin materials augmented the freshwater yield of the distillers as illustrated in Fig. 7. The results obtained that the total distilled water of THSS-IRMC was more than that of either THSS-IRM or THSS-IRMZ. As a result, the accumulated distillate of the THSS-IRMC, THSS-IRMZ, and THSS-IRM was 9500, 8550, and 7000 mL/m².day, respectively. So, the productivity of THSS-IRMC and THSS-IRMZ was improved by around 35.7% and 22.1% over the THSS-IRM because of the above explicated causes of productivity enhancement. Moreover, the yield of THSS-IRMC and THSS-IRMZ was improved by around 104.3% and 84% over the THSS.

Effect of using sand grains

To avoid the repetition of results, we preferred to summarize the data of this section. The experimental results obtained that using the reflective mirrors with basin metals of zinc and copper and energy storage medium increased the water temperature of THSS-IRMZSG and THSS-IRMCSG more than that of the THSS-IRMSG by around 0 – 5°C and 0 – 8°C, respectively throughout the day. Also, using the energy storage medium only increased the water temperature inside the solar distiller by around 0 – 3°C. Besides, the water temperature was maximum at noon time, where it was 78, 81, and 84°C for the THSS-IRMSH, THSS-IRMZSG, and THSS-IRMCSG, respectively. Additionally, the glass temperatures of THSS-IRMZSG and THSS-IRMCSG were almost the same, and they were more than that of THSS by 0 – 1°C.

What is more, the glass temperature is maximal at noontime, where it was 54, 55, and 55°C for the THSS-IRMSG, THSS-IRMZSG, and THSS-IRMCSG, respectively.

Furthermore, the hourly and total accumulated yield of the distillers (THSS-IRMSG, THSS-IRMZSG, and THSS-IRMCSG) are drawn in Fig. 8. The hourly yield was maximal at 14:00, where it was 1150, 1300, and 1400 mL/m².hr for THSS-IRMSG, THSS-IRMZSG, and THSS-IRMCSG, respectively. Also, the THSS-IRMCSG introduced more productivity than either THSS-IRMSG or THSS-IRMZSG. This was due to the improved heat transfer characteristics of the copper basin materials as compared to that of the iron and zinc. Also, it was because the stored energy, by the energy storage medium, that released at the times of sun absence. This led to enhance the vaporization of the THSS-IRMCSG more than the other solar stills. So, the hourly yield of THSS-IRMCSG was superior to that of either THSS-IRMSG or THSS-IRMZSG as illustrated from Fig. 8. Besides, the results obtained that the total freshwater production of THSS-IRMCSG was better than that of either THSS-IRMSG or THSS-IRMZSG. As a result, the accumulated distillate of the THSS-IRMCSG, THSS-IRMZSG, and THSS-IRMSG was 11900, 10800, and 9400 mL/m².day, respectively. So, the productivity of THSS-IRMZ and THSS-IRMZ was improved by around 26.6% and 15% over the THSS-IRMSG. Moreover, the yield of THSS-IRMCSG and THSS-IRMZSG was improved by around 156% and 132.3% over the THSS.

Comparison of present work with published similar works

A comparison between the findings of the current work and the published similar works is obtained in Table 4. It is revealed that the total yield of THSS-IRM (solar still with internal mirrors) was increased by 50.5% compared to the traditional hemispherical solar distiller (THSS). Also, the cumulative yield was increased by 84% when using metal basin of zinc and internal reflective mirrors (THSS-IRMZ), by 104.3%, when using metal basin of copper and internal reflective mirrors (THSS-IRMC), by 132.3% when using internal reflective mirrors, metal basin of zinc and sand grains (THSS-IRMZSG), and by 156% when using internal reflective mirrors, metal basin of copper and sand grains (THSS-IRMCSG). Thus, the internal reflective mirrors, metals sheets and sand grains greatly augmented the yield of the solar still.

Data of Table 4 obtained that the corrugated distiller productivity (Kumar et al. 2008) was minimal (11.92%). Nevertheless, the trays distiller had maximal value (75%) (Abdullah et al. 2020c).

Table 4
Comparison between the findings of previous published works and current study.

Author name	Type of SS	Enhancement techniques	Productivity (%)
Our results	Hemispherical still	- Internal reflective mirrors	50.5
		- Zinc basin metal and internal reflective mirrors	84
		- Copper basin metal and internal mirrors	104.3
		- Internal mirrors, Zinc basin metal and sand grains	132.3
		- Internal mirrors, Copper basin metal and sand grains	156
Attia et al. (Attia et al. 2021c)	Trays Hemispherical SS	- Tray of Iron	14.6
		- Tray of Zinc	31.25
		- Tray of Copper	53.125
Attia et al. (Attia et al.)	Single slope SS	Bed Phosphate	16.8
Kumar et al. (Kumar et al. 2008)	"V" type SS	- Mirror	11.92
		- Mirror and charcoal	14.11
Abdullah et al. (Abdullah et al. 2020c)	Trays SS	- Internal reflectors	58.00
		- External reflectors	75.00
Chandrika et al. (Chandrika et al. 2021)	Single slope still	- Reflective glass mirror	68.57
		- Reflective aluminum sheet	48.57

Economic Analysis

Daily yield

Table 5 presents the daily yield of the THSS, THSS-IRM, THSS-IRMZ, THSS-IRMC, THSS-IRMSG, THSS-IRMZSG and THSS-IRMCSG. The experiments were recorded during 12 hours on August 16, 17 and 18, 2020. Then, the maximum daily yield was obtained with the THSS-IRMCSG (internal reflective mirrors and basin metal of copper and sand grains).

Table 5
Cumulative yield of the solar stills under different conditions.

Date	THSS (kg/m ²)	THSS-IRM (kg/m ²)	THSS-IRMZ (kg/m ²)	THSS-IRMC (kg/m ²)	THSS-IRMSG (kg/m ²)	THSS-IRMZSG (kg/m ²)	THSS-IRMCSG (kg/m ²)
16/08/2020	4.65	7.00	-	-	-	-	-
17/08/2020		7.00	8.55	9.50	-	-	-
18/08/2020					9.40	10.80	11.90

Economic Evaluation

Table 6 obtains the costs of THSS and THSS-IRM. From these data, the daily water produced from THSS is 4.65 kg/m²/day with a daily water production price of 279 DZD, while the daily water produced from THSS-IRM is 7.00 kg/m²/day with a price of 420 DZD.

Table 6
Fabrication cost of the THSS and THSS-IRM. (1\$=132.78 DZD, 1€=156.03 DZD)

Parameter	HSS-WBS	HSS-RAS
Total cost of manufacturing (DZD)	9000	9000
Cost of internal mirrors	-	400
Maintenance cost (DZD)	50	50
Total fixed cost (DZD)	9050	9450
Distillate productivity during the day (kg/m ² /day)	4.65	7.00
Cost per liter of distilled water on the market (DZD)	60	60
The price of daily water production (DZD)	279	420
Recovery period	33 Days	23 Days

In addition, Table 7 presents the cost of THSS-IRM, THSS-IRMZ and THSS-IRMC. From these results, it is clear that the daily water produced from THSS-IRM is 7.00 kg/m²/day with a price of 420 DZD, while the daily water obtained from THSS-IRMZ is 8.55 kg/m²/day with a price equal to 513 DZD. Also, the daily water obtained from THSS-IRMC is 9.50 kg/m²/day with a price of 570 DZD.

Table 7

Fabrication cost of the THSS-IRM, THSS-IRMZ and THSS-IRMC. (1\$=132.78 DZD, 1€=156.03 DZD)

Parameter	THSS-IRM	THSS-IRMZ	THSS-IRMC
Total cost of manufacture (DZD)	9000	9000	9000
The price of basin metal	-	600	900
The price of internal reflective mirrors	400	400	400
Maintenance cost (DZD)	50	50	50
Total cost (DZD)	9450	10050	10350
The amount of water produced during the day (kg/m ² /day)	7.00	8.55	9.50
Market water cost for one liter (DZD)	60	60	60
The price of daily water production (DZD)	420	513	570
Recovery period	23 Days	20 Days	18 Days

Besides, Table 8 shows the fabrication costs of the THSS-IRMSG, THSS-IRMZSG and THSS-IRMCSG. From these results, the daily water produced from THSS-IRMSG is 9.40 kg/m²/day with a price of 564 DZD, while the value of the daily water obtained from THSS-IRMZSG is 10.80 kg/m²/day with a price equal to 648 DZD. Moreover, the daily water produced from THSS-IRMCSG is 11.90 kg/m²/day with a price of 155.91 DZD.

Table 8

Fabrication cost of the THSS-IRMSG, THSS-IRMZSG and THSS-IRMCSG. (1\$=132.78 DZD, 1€=156.03 DZD)

Parameter	THSS-IRMSG	THSS-IRMZSG	THSS-IRMCSG
Total cost of manufacture (DZD)	9000	9000	9000
The price of basin metal	-	600	900
The price of sand free	00	00	00
The price of internal reflective mirrors	400	400	400
Maintenance cost (DZD)	50	50	50
Total cost (DZD)	9450	10050	10350
The amount of water produced during the day (kg/m ² /day)	9.40	10.80	11.90
The cost per liter of distilled water on the market (DZD)	60	60	60
The price of daily water production (DZD)	564	648	714
Recovery period	17 Days	15 Days	14 Days

Efficiency of solar stills

The thermal efficiency of the distiller is evaluated by (Abdullah et al. 2019b, Kabeel et al. 2017);

$$\eta_d = \frac{\sum \dot{m} \times h_{fg}}{\sum A \times I} \quad (1)$$

Where η_d is the daily efficiency, $\dot{m}$ is the hourly yield, h_{fg} is the latent heat, A is the projected area, and I is the daily average irradiance. Moreover, h_{fg} is calculated based on the water temperature (T_w) as following (Essa et al. 2021b, Tiwari & Sahota 2017);

$$h_{fg} = 3.1625 \times 10^6 + [1 - (7.616 \times 10^{-4} \times T_w)] \text{ for } T_w > 70^\circ \text{C} \quad (2)$$

$$h_{fg} = 2.4935 \times 10^6 [1 - (9.4779 \times 10^{-4} \times T_w) + (1.3132 \times 10^{-7} \times T_w^2) - (4.7974 \times 10^{-9} \times T_w^3)] \text{ for } T_w < 70^\circ \text{C} \quad (3)$$

Based on the above equations, the highest thermal efficiency was obtained for the THSS-IRMCSG, where it was 48% compared to 28% for the traditional hemispherical solar still (THSS).

Conclusions

This experimental work investigates the effects of using internal reflective mirrors, basin metals and sand grains on the productivity and efficiency of the hemispherical solar still. This simple technique involves placing an internal reflective mirror on the inner walls of the hemispherical solar still with different basin liner metals (zinc and copper) and sand grains. The obtained conclusions can be written as follows:

The internal reflective mirrors increased the heating of the saline water inside the basin by reflecting extra solar radiation on it.

Using the internal reflective mirrors and high thermal conductivity basin metals (zinc and copper) and phosphate granules enhanced significantly the performance of the solar still.

The distilled water production from the THSS and THSS-IRM was 4.65 and 7.00 kg/m²/day, respectively.

The distilled water production from the THSS-IRMZ and THSS-IRMC was 8.55 and 9.50 kg/m²/day, respectively.

The distillate production from the THSS-IRMSG, THSS-IRMZSG, and THSS-IRMCSG was 9.40, 10.80, and 11.90 kg/m²/day, respectively.

Using the internal reflective mirrors improved the productivity by 50.6% as compared to that of the THSS.

Using the basin metal of zinc and copper with internal reflective mirrors enhanced the distillate by 84 and 104.30% compared to that of the THSS, respectively.

The daily distillate of THSS-IRMSG, THSS-IRMZSG and THSS-IRMCSG was augmented by 102.15, 132.3 and 156% as compared to that of the THSS, respectively.

The best thermal performance of the solar still was obtained when using the basin metal of copper, sand grains, and internal reflective mirrors.

Based on the above conclusions, it can be reported that the reflective mirrors, high thermal conductivity basin metals, and sand grains improved greatly the productivity and efficiency of the solar distillation unit. Therefore, these modifications are recommended to be used in such applications.

Abbreviations

SS	Solar Still
THSS	Traditional Hemispherical Solar Still
THSS-IRM	Traditional Hemispherical Distiller with Internal Mirrors
THSS-IRMZ	Traditional Hemispherical Distiller with Internal Mirrors and basin metal of Zinc
THSS-IRMC	Traditional Hemispherical Distiller with Internal Mirrors and basin metal of Copper
THSS-IRMSG	Traditional Hemispherical Solar Still with an Internal Reflective Mirrors and sand grains
THSS-IRMZSG	Traditional Hemispherical Solar Still with an Internal Reflective Mirrors, basin metal of Zinc sand grains
THSS-IRMSG	Traditional Hemispherical Solar Still with an Internal Reflective Mirrors, basin metal of Copper and sand grains

Declarations

Ethical Approval

Not applicable

Consent to Participate

Not applicable

Consent to Publish

Not applicable

Authors Contributions

Author's full name Authors Contributions

1 *Mohammed El Hadi Attia*, Expermental work, , Writing - original draft, preparation.

2 Fadi Abdelmonem Essa, Formal analysis and investigation. Writing -Review & Editing.

3-*Mohamed Abdelgaied*, Conceptualization, Me 441 thodology, Writing -,Review & Editing.

4 *Abd Elnaby Kabeel*, Conceptualization, Writing – Review &Editing.Supervisor

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Competing Interests

No competing interests

Availability of data and materials

Not applicable

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Figures

Figure 1

2D model of the hemispherical solar distiller.

Figure 2

Micrograph of El-Oued sand grains.

Figure 3

Investigated solar distillers.

Figure 4

Environmental conditions for the test of using internal reflective mirrors.

Figure 5

Hourly productivity of the THSS and THSS-IRM.

Figure 6

Environmental conditions for the test of solar stills at internal reflective mirrors and different basin metals (zinc and copper).

Figure 7

Instantaneous and total accumulated yield of the distillers (THSS-IRM, THSS-IRMZ, and THSS-IRMC).

Figure 8

Instantaneous and total accumulated yield of the distillers (THSS-IRMSG, THSS-IRMZSG, and THSS-IRMCSG).