Optimization of the Hemispherical Solar Distiller Performance Augmented by Different Basin Materials (steel, zinc, and copper) and Reflective Mirrors

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Optimization of the hemispherical solar distiller performance augmented by different basin materials (steel, zinc, and copper) and reflective mirrors

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Abstract

The present comprehensive study aims to solve the problem of declining drinking water productivity from solar distillers. The hemispherical distillers are characterized by having the large condensing and receiving surface area, so the utilization of basin materials with high thermal conductivity and reflective mirrors are very effective to enhance a cumulative production of hemispherical distillation. To get the optimal basin materials with the reflective mirror that achieves the highest hemispherical distiller's performance, three high thermal conductivity basin materials (steel, zinc, and copper) with reflective mirror were tested at the same conditions and compared to reference hemispherical unit. To realize this idea, four distillers was fabricated and tested at a same climate condition namely: Hemispherical solar Distiller with Black Silicone Walls (HSD-BSW), Hemispherical Solar Distiller with Steel Plate and Reflective Mirror (HSD-SPRM), Hemispherical Solar Distiller with Zinc Plate and Reflective Mirror (HSD-ZPRM), and Hemispherical Solar Distiller with Copper Plate and Reflective Mirror (HSD-CPRM). The experimental results presented that the utilization of copper basin materials and reflective mirror (HSD-CPRM) represents the good option to achieve the highest performance of hemispherical distiller, use the copper basin materials and reflective mirror (HSD-CPRM) gives a cumulative production reached 9500 mL/m² day with improvement of 104.3% compared to reference hemispherical distiller (HSD-BSW). Also, use the copper basin materials and reflective mirror (HSD-CPRM) improves the daily thermal efficiency and exergy efficiency by 102.4% and 194.9%, respectively compared to HSD-BSW. The comprehensive economic analysis concluded that the use of copper basin materials

and reflective mirrors (HSD-CPRM) reduced the distillate water cost per liter by 44.1% compared to HSD-BSW.

Keywords: Hemispherical solar distillers; Optimal basin materials; Reflective mirror; Energy; Exergy, Economic analysis.

Introduction

One of the most important problems afflicting remote desert regions of the world is an acute shortage of safe drinking water. Dry desert areas have a significant stock of salty water that is not suitable for drinking, according to the World Health Organization, and a significant energy reserve is a solar energy (Chandrika et al., 2021; Kabeel and Abdelgaied, 2017; Kabeel and Abdelgaied, 2019). Scientists are turning to renewable energy (solar energy) in all areas of life, including the desalination of saltwater. Solar water desalination is a viable and economical solution to provide safe drinking water (Al-Molhem and Eltawil, 2020; Suraparaju and Natarajan, 2021a; Abdelgaied et al., 2021a; Attia et al., 2021a; Manokar et al., 2018a). Many researchers seek to improve the daily productivity of solar energy distillers, by innovating new designs for distillation devices or by adding the fins (Dhivagar and Mohanraj, 2021; Abdelgaied et al., 2021b; Suraparaju and Natarajan, 2021b), or by adding thermal storage materials (Mohammed et al., 2021; Ramalingam et al., 2021; Kabeel and Abdelgaied, 2016), or by adding some modifications to design solar distillers (Kabeel et al., 2016 ; Kabeel et al., 2019).

Attia et al. (2020) experimentally examined the influences of aluminum foil sheets as an absorber cover on the traditional solar distiller performance of traditional solar distiller. They are observed that the absorber covers in the solar distiller hence decreases the rate of evaporation. The productivity reported for the solar distiller with and without absorber cover (aluminum foil sheet) was 1004 ml/m²/day and 1528 ml/m²/day. Because of the negative results, the authors advise not to completely coat the solar distillate with an absorbent coating such as aluminum foil sheets. Panchal and Shah (2016) carried out an experimental analysis to investigate the impact of coupling double solar basin with evacuated tubes (to provide hot water) with/without black granite gravel. They found 56 and 65% increments in distillate output without and with the use of black granite gravel, respectively, compared to reference unit. Khechekhouche et al. (2021) experimentally conducted improvement of traditional solar distiller using a zinc plate of black metallic. The results presented that the utilization of zinc plates as thermal storage material increases the rate of evaporation. The production reported

for distiller with/without absorber cover (zinc plate) was 3894 ml/m²/day and 2520 ml/m²/day. Dwivedi and Tiwari (2010) used different energy-absorbing materials (black rocks, coated sponge, and uncoated sponge) in three same solar distillers and the traditional solar distiller. They found that the use of energy-absorbing materials increased the productivity of solar distillers, they found a 20% increment in distillate output by use of black rocks, compared with the coated sponge and uncoated sponge and traditional solar distiller. Chandrika et al. (2021) used internal reflectors on a single slope solar distiller. The authors experimentally compared the performance of a solar distiller with a mirror reflector and an aluminum sheet reflector for distilled water augmentation. The authors concluded that a highest production of 5.9 kg/m² were collected for single slope solar distiller with mirror reflector and 5.2 kg/m² were collected for single slope solar distiller with an aluminum sheet reflector. El-Bialy (2014) studied the experimental of effect floating absorber plate on a single slope and compared it with the traditional solar distiller. He found the rate of improvement in productivity increases when the absorbent plate is above water, and the daily productivity decreases when the mass of water on the absorbent plate increases. Attia et al. (2021b) performed an experiment using materials basins (iron, zinc, and copper) integrated with hemispherical distillers. The authors founded that a production of hemispherical distiller with iron metal basin was 5500 ml/day, with zinc metal basin was 6300 ml/day and with copper, the metal basin was 7350 ml/day. Velmurugan et al. (2008) incorporated fins into the lining of the basin in order to increase the productivity of an individual solar basin. This method increases the surface area of the absorption (still base), and thus, increases the rate of heat transfer between the saltwater and the absorption surface and thus increases the rate of productivity. Omara et al. (2014) fabricated three solar stills (reference type, finned distiller, and corrugated distiller). They found that the productivity of solar panels when using the fins increases by about 40%, and when using the corrugated solar panels, the productivity increases by about 21% compared to the productivity of traditional distillation. Khechekhouche et al. (2020) experimentally investigated the improvement of traditional solar distiller by using an external refractor, under Algerian climatic conditions. The result was that the external refractor increases the rate of yield distiller. The productivity for the solar distiller with and without an external refractor was 4.8404 kg/m²/day and 3.4084 kg/m²/day, respectively. Omara et al. (2013) modified the stepped solar distillers by using internal reflectors. The yield of distillates was compared with/without reflectors and the yield of conventional distillates. The percentage improvement in the daily accumulation of stepped solar distillation with/without reflectors was about 75% and 57%, respectively, compared to

reference case. Much of the previous works confirmed that the use of external refraction to improve solar distillation devices has improved the productivity of solar stills by a rate ranging from 9-21% (Tanaka and Nakatake, 2017; Omara et al., 2017; Tanaka, 2009).

The aim of this comprehensive experimental study is to improve the output of solar distillation. Therefore, we are placing black painted steel, zinc, and copper plates at a bottom of basin with reflective mirrors on the inner surfaces of distillate. The presence of metal plates at the bottom of the basin enhanced the heat storage capacity, and a reflective mirror on the inner surfaces of the solar distillate increasing the reflection of the solar irradiation falling in the distillation basin. The hemispherical distillers are characterized by having a large condensing/receiving surface area, so the utilization of basin materials with high thermal conductivity and reflective mirrors are very effective to enhance a cumulative hemispherical distiller's production. To get optimal basin materials with the reflective mirror that achieves a highest hemispherical distiller's performance, three high thermal conductivity basin materials (steel, zinc, and copper) with reflective mirror were tested at the same conditions and compared to a reference case. To realize this idea, four distillers was fabricated and tested at same climate condition namely: Hemispherical solar Distiller with Black Silicone Walls (HSD-BSW), Hemispherical Solar Distiller with Steel Plate and Reflective Mirror (HSD-SPRM), Hemispherical Solar Distiller with Zinc Plate and Reflective Mirror (HSD-ZPRM), and Hemispherical Solar Distiller with Copper Plate and Reflective Mirror (HSD-CPRM).

Experimental work

Experimental setup and description

The current empirical study aims to enhance a cumulative production of hemispherical distillers. This goal was done by utilizing high thermal conductivity basin materials and an inner reflective mirror. To get the optimal basin materials with the reflective mirror that achieves a highest hemispherical distiller's performance, three high thermal conductivity basin materials (steel, zinc, and copper) were tested at a same condition and compared to a reference case. To realize this idea, four distillers was fabricated and tested at the same climate condition namely: Hemispherical solar Distiller with Black Silicone Walls (HSD-BSW), Hemispherical Solar Distiller with Steel Plate and Reflective Mirror (HSD-SPRM), Hemispherical Solar Distiller with Zinc Plate and Reflective Mirror (HSD-ZPRM), and Hemispherical Solar Distiller with Copper Plate and Reflective Mirror (HSD-CPRM).

Figures 1 and 2 show the schematic and photo of four hemispherical distillers utilized in this empirical work. In this experiment, we made four hemispherical solar distillers presented in the study, each consists of a circular basin made of wood 50 mm thick, 0.38 m diameter, and 40 mm edge height. These circular basins are covered by a hemispherical transparent cover, which is 3 mm thick and 0.4 m in diameter. The effective area of each circular basin is 0.1 m². The saltwater depth for each hemispherical basin is taken constantly at 0.01 m. The resulting distilled water was collected in the distillate water tank.

Fig. 1. Schematic presentations of four hemispherical solar distillers.

Fig. 2. Photo of the experimental test of four hemispherical distillers.

Figure 3 shows the basin photo of four hemispherical solar distillers utilized in this empirical work. In this experiment, the basin of Hemispherical Solar Distiller with Black Silicone Walls (HSD-BSW) made from wood and coated by black silicone represents a reference case. In Hemispherical Distiller with Steel Plate and Reflective Mirror (HSD-SPRM), the basin was made from steel plate coated by black paint, and the Reflective Mirror was installed on the vertical side walls. In the Hemispherical Solar Distiller with Zinc Plate and Reflective Mirror (HSD-ZPRM), the basin was made from a zinc plate coated with black paint, and the Reflective Mirror was installed on the vertical sidewalls. In the Hemispherical Solar Distiller with Copper Plate and Reflective Mirror (HSD-CPRM), the basin was made from a copper plate coated with black paint, and the Reflective Mirror was installed on the vertical sidewalls.

Fig. 3. Photo of the basin configuration of the four hemispherical distillers.

System Operation and Measurements

To achieve the influences of utilizing the basin materials with higher thermal conductivity and the reflective mirror on hemispherical solar distiller's cumulative yield. The four hemispherical solar distillers are namely; HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM were tested at the same Algerian ambient conditions. Through the test days, the intensities of solar irradiation and temperatures, and cumulative yield are recorded from 7:00 AM to 6:00 PM.

The temperatures of inner and outer transparent cover hemispherical inside and out, ambient air, basin saltwater, and distillate water are measured by utilizing the K-type thermocouples. The intensity of solar irradiation is measured by a solar meter. By means of a graduated vessel, the distilled water collected in a tank is recorded. The range, accuracy, and standard uncertainty of measuring instrumentations are listed in Table 1.

Table 1 Specifications of measuring instrumentations

Instrument	Range	Accuracy	Standard uncertainty
Graduated cylinder	0–500 ml	± 1 ml	0.5 ml
Solar power meter	0-1999 W/m ²	± 10 W/m ²	5.76 W/m ²
Thermocouple	–100 – 500 °C	± 0.1 °C	0.08 °C

System performance

Daily thermal efficiency $\eta_{daily.th.}$ of hemispherical distillers calculated as follows:

$$\eta_{daily.th.} = \frac{\sum(\dot{m}_d h_{fg})}{\sum(I(t) \times A_s) \times 3600} \times 100; \quad (\%) \quad (1)$$

where: $\dot{m}_d$ is the mass of distillate yield (kg/h); $I(t)$ is intensity of solar irradiation (W/m²); A_s is absorber surface area (m²); and h_{fg} is the latent heat (J/kg) which calculated as (Kabeel and Abdelgaied 2017):

$$h_{fg} = 10^3 \times [2501.9 - 2.40706 T_w + 1.192217 \times 10^{-3} T_w^2 - 1.5863 \times 10^{-5} T_w^3] \quad (2)$$

Exergy efficiency η_{exe} calculated as follows:

$$\eta_{exe} = \frac{\sum Ex_{output}}{\sum Ex_{input}} \times 100, (\%) \quad (3)$$

Input exergy to hemispherical distillers Ex_{input} calculated as follows (Manokar et al. 2018b):

$$Ex_{input} = A_s \times I(t) \left[1 - \frac{4}{3} \times \left(\frac{T_a + 273.15}{6000} \right) + \frac{1}{3} \times \left(\frac{T_a + 273.15}{6000} \right)^4 \right] \quad (4)$$

Output exergy from hemispherical distillers Ex_{output} calculated as follows (Manokar et al. 2018b):

$$Ex_{output} = \frac{\dot{m}_d h_{fg}}{3600} \left[1 - \frac{T_a + 273}{T_w + 273} \right] \quad (5)$$

where; T_w is the basin saltwater temperature ($^{\circ}\text{C}$), T_a is ambient air temperature ($^{\circ}\text{C}$), and T_g is glass cover temperature ($^{\circ}\text{C}$).

Results and discussions

Climatic conditions represented by solar irradiation and ambient air temperature are the main factors affecting the operation of hemispherical solar distillates. So, it is necessary to record the variations of solar irradiation and ambient air temperature throughout the test day started from 7:00 AM till 7:00 PM. Figure 4 shows the instantaneous variations of solar irradiation and ambient air temperature throughout the operating day during the period starting from 7:00 AM to 7:00 PM. It is evident from the instantaneous variations shows in the figure, the intensity of solar irradiation gradually increases until it reaches the maximum value of 1010 Watt/m² at 12:00 AM after that gradually decreases until it reaches zero at sunset. Also, it is evident from the instantaneous variations of ambient air temperature shows in the figure, the temperature of ambient air varying between 32-50 $^{\circ}\text{C}$ throughout the operating day.

Fig. 4 Hourly variations of ambient temperature and solar irradiation throughout the operating day

To achieve the influences of utilizing the high thermal conductivity basin materials and an inner reflective mirror on the performance of hemispherical solar distillates, as well as, to get the optimal basin materials (steel, zinc, and copper) with the reflective mirror that achieves a highest hemispherical distiller's performance. The instantaneous variations of basin saltwater temperatures were measured for both: Hemispherical solar Distiller with Black Silicone Walls (HSD-BSW), Hemispherical Solar Distiller with Steel Plate and Reflective Mirror (HSD-SPRM), Hemispherical Solar Distiller with Zinc Plate and Reflective Mirror (HSD-ZPRM), and Hemispherical Solar Distiller with Copper Plate and Reflective Mirror (HSD-CPRM) during the period from 7:00 AM till 7:00 PM. Where the temperature of the basin saltwater represents an important measure of the evaporation rate inside the basin of the hemispherical solar distiller and thus a measure of the cumulative distillate yield, as the rate of evaporation inside the distillation improves with the increase of the temperature of the saltwater in the basin. Figure 5 shows the utilization of high thermal conductivity basin materials and the reflective mirror has a great influence on the basin saltwater temperature, the temperature of basin saltwater varying between 32-68 °C, 32-74 °C, 32-76 °C, and 32-78 °C for HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM, respectively.

Fig. 5 Hourly temperature variations of basin saltwater within the test day

The heat transfer by convection is the main driver in the solar desalination field. Whereas, the difference in a temperature between basin saltwater and glass cover is a measure of natural buoyancy inside the distillation. As the temperature difference increases, both the buoyancy force and the rate of heat transfer by natural convection will be increases, thus improving the yield of hemispherical solar distillation. Fig. 6 presented the temperature difference ($T_w - T_g$) through the four hemispherical solar distillers (HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM). As presented in Fig. 6, a temperature difference in reference hemispherical distiller (HSD-BSW) ranged between 1-19 °C, while the utilization of steel plate and reflective mirror (HSD-SPRM) improved the temperature difference to 1-24 °C, with improvement varying between 23.5-71.4% as shown in Fig. 7. While the utilization of zinc plate and reflective mirror (HSD-ZPRM) improved the temperature difference to 1-25 °C, with improvement varying between 15.8-100% as shown in Fig. 7. While the utilization of copper plate and reflective mirror (HSD-CPRM) improved the temperature difference to 1-26 °C, with improvement varying between 368-142.9% as shown in Fig. 7. The temperature analysis results evident that the utilization of copper plate and reflective mirror (HSD-CPRM) represent the good obtain to investigate the highest temperature difference and thus will obtain the highest distillate production of hemispherical solar distiller.

Fig. 6 Temperature difference variation between saltwater and cover within the four hemispherical solar distillers

Fig. 7 Effect of high thermal conductivity basin materials and reflective mirror on (Tw-Tg) of hemispherical solar distillers

Based on the analysis presented in Figs. (5-7), the utilization of steel plate and reflective mirror (HSD-SPRM) increases the temperature difference (Tw-Tg) with the rate reached 1.71 times HSD-BSW; while utilization of zinc plate and reflective mirror (HSD-ZPRM) increases

the temperature difference ($T_w - T_g$) with the rate reached 2 times HSD-BSW. But the utilization of copper plate and reflective mirror (HSD-CPRM) increases the temperature difference ($T_w - T_g$) with the rate reached 2.43 times HSD-BSW. Based on the recorded data of instantaneous distillate yield presented in Fig.8, its found that the instantaneous distillate yield has the same trend for HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM, but at a higher rate in presence of copper plate and reflective mirror (HSD-CPRM). The measured recorded peak instantaneous distillate yield was recorded in 2:00 PM which reached 700, 1000, 1100, and 1150 mL/m² h for HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM, respectively. It is evident from this that the use of copper plate and reflective mirror (HSD-CPRM) improved the instantaneous distillate yield of hemispherical solar distillers.

Fig. 8 Instantaneous distillate yield for the four hemispherical distillers

To get optimal basin materials with the reflective mirror that achieves a highest hemispherical solar distiller's performance, Fig. 9 shows cumulative distillate production of four hemispherical solar distillers. As shown in Fig. 9, the utilization of high thermal conductivity basin materials and an inner reflective mirror is the good option, which HSD-SPRM give the high cumulative distillate yield which up to 7600 mL/m² day, HSD-ZPRM give cumulative distillate yield which up to 8550 mL/m² day, and HSD-CPRM give cumulative distillate yield which up to 9500 mL/m² day while the HSD-BSW give 4650 mL/m² day. The results presented that the improvement in cumulative distillate yield for utilization of high thermal

conductivity basin materials and an inner reflective mirror reached 63.4, 83.9, 104.3 % for HSD-SPRM, HSD-ZPRM, and HSD-CPRM, respectively compared to HSD-BSW.

Fig. 9 The cumulative distillate yield for the four solar distillers.

Fig. 10 shown the daily thermal efficiency and exergy efficiency of HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM. As shown the daily thermal efficiency of reference hemispherical distiller (HSD-BSW) reached 38%, while the utilization of high thermal conductivity basin materials and reflective mirror improved the daily thermal efficiency to 61.9%, 69.5%, and 77% for steel plate and reflective mirror (HSD-SPRM), zinc plate and reflective mirror (HSD-ZPRM), and copper plate and reflective mirror (HSD-CPRM), respectively. Also, Fig. 10 show the exergy efficiency of reference distiller (HSD-BSW) reached 2.24%, while the utilization of high thermal conductivity basin materials and reflective mirror improved the daily thermal efficiency to 4.55%, 5.44%, and 6.62% for steel plate and reflective mirror (HSD-SPRM), zinc plate and reflective mirror (HSD-ZPRM), and copper plate and reflective mirror (HSD-CPRM), respectively.

Fig. 10 Daily thermal efficiency and exergy efficiency of HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM

Fig. 11 shows the influences of the utilization of the high thermal conductivity basin materials (steel, zinc, and copper) with reflective mirror on performance improvement of the hemispherical solar distillers. the results presented that the improvement in daily thermal efficiency, exergy efficiency, and cumulative yield reached 62.7, 102.6, and 63.4 %, respectively for use of the steel plate and reflective mirror (HSD-SPRM). But for using the zinc plate and reflective mirror (HSD-ZPRM), the improvement in daily thermal efficiency, exergy efficiency, and the cumulative yield reached 82.7%, 142.5%, and 83.3%, respectively. While the utilization of copper plate and reflective mirror (HSD-CPRM) represent the good options that improved the daily thermal efficiency, exergy efficiency, and cumulative yield by 102.4%, 194.9%, and 104.3%, respectively.

Fig. 11 improvement in daily thermal efficiency, exergy efficiency, and cumulative yield of HSD-SPRM, HSD-ZPRM, and HSD-CPRM

5. Comparison with published similar works

To demonstrate the importance of using high thermal conductivity basin materials (steel, zinc, and copper) and reflective mirror and its effect on the performance of hemispherical solar distillates. Table 2 presents a comparison between our results and the results of the amendments proposed in the previous papers. From the results of the comparison, it is clear that the use of high thermal conductivity basin materials (steel, zinc, and copper) with reflective mirrors is very effective for improving the performance of the hemispherical solar distillers.

Table 2 Comparison our results with previous studies

Authors and reference	Types of solar distiller	The rise in cumulative yield (%)
Khalifa and Ibrahim (2011)	Single-Slope SS with internal reflectors	2.8
	Single-Slope with external reflectors	10.56
Kumar et al. (2008)	“V” type SS with Mirror	11.92
	“V” type SS with Mirror and charcoal	14.11

Gnanaraj and Velmurugan (2019)	Double slope SS with reflector	93.39
Omara et al. (2013)	Stepped SS with Internal reflectors	75
Abdullah et al. (2020)	Trays SS with Internal reflectors	58
	Trays SS with External reflectors	75
Present experimental work	HSS with Steel plate and reflective mirror	63.4
	HSS with Zinc plate and reflective mirror	83.9
	HSS with Copper plate and reflective mirror	104.3

Economic Evaluation

A comprehensive economic study was conducted to demonstrate the economic feasibility of using high thermal conductivity basin materials (steel, zinc, and copper) with reflective mirrors and the extent of their impact on the total cost of distillates produced from hemispherical solar distillates. The economic analysis was performed using the equations mentioned by Kabeel and Abdelgaied (2017a). Based on the cost analysis shown in Table 3, the total cost of distilled water per liter of HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM reached 0.01, 0.0071, and 0.0062 \$/Liter. The comprehensive economic study presented that the total cost per liter of distillate water produced from HSD-SPRM, HSD-ZPRM, and HSD-CPRM reduced by 33.9%, 39%, and 44.1%, respectively compared to HSD-BSW.

Table 3 Cost details of HSD-BSW, HSD-SPRM, HSD-ZPRM, and HSD-CPRM.

	HSD-BSW	HSD-SPRM	HSD-ZPRM	HSD-CPRM
Capital cost, \$.	68	73.4	75.7	78
Annual capital cost, \$.	12	12.99	13.39	13.8
Annual salvage value, \$.	0.77	0.84	0.86	0.89
Annual maintenance cost, \$.	3.6	3.89	4.02	4.14
Annual total cost, \$.	14.83	16.04	16.55	17.05
Annual productivity, L/m ² /year	1256	2052	2309	2565

Cost of distillat water per litres, \$/Liter	0.0118	0.0078	0.0072	0.0066
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Conclusions

The current comprehensive study aims to solve a problem of declining drinking water productivity from hemispherical solar distillers. This goal was done by utilizing high thermal conductivity basin materials and an inner reflective mirror. To get the optimal basin materials with the reflective mirror that achieves a highest hemispherical distiller's performance, three high thermal conductivity basin materials (steel, zinc, and copper) were tested at a same condition and compared to reference case. To realize this idea, four hemispherical distillers was fabricated and tested at a same climate condition namely: Hemispherical solar Distiller with Black Silicone Walls (HSD-BSW), Hemispherical Solar Distiller with Steel Plate and Reflective Mirror (HSD-SPRM), Hemispherical Solar Distiller with Zinc Plate and Reflective Mirror (HSD-ZPRM), and Hemispherical Solar Distiller with Copper Plate and Reflective Mirror (HSD-CPRM). The conclusions can be written as follows:

- The utilization of high thermal conductivity basin materials and reflective mirror give the high cumulative distillate yield which up to 7600, 8550, and 9500 mL/m² day for HSD-SPRM, HSD-ZPRM, and HSD-CPRM, respectively, while the HSD-BSW give 4650 mL/m² day.
- The improvement in cumulative distillate yield for utilization of high thermal conductivity basin materials and reflective mirror reached 63.4, 83.9, 104.3 % for HSD-SPRM, HSD-ZPRM, and HSD-CPRM, respectively compared to HSD-BSW.
- The comprehensive economic study presented that the total cost per liter of distillate water produced from HSD-SPRM, HSD-ZPRM, and HSD-CPRM reduced by 33.9%, 39%, and 44.1%, respectively compared to HSD-BSW.
- Use the copper basin materials and reflective mirror (HSD-CPRM) improves the daily thermal efficiency and exergy efficiency by 102.4% and 194.9%, respectively compared to HSD-BSW.

The productivity of the distillate with the copper plate and reflective mirror is much better than that of the distillate with steel plate and reflective mirror or zinc plate and reflective mirror.

Reflective mirror and high thermal conductivity materials greatly improve a production of solar distillation and increases the production and efficiency. Therefore, it is recommended that they be used in such applications.

Nomenclature

SS	Solar Still
HSS-BPW	Hemispherical Still with Black Painted Walls
HSS-RM	Hemispherical Still with a Reflective Mirror
HSS-SPRM	Hemispherical Still with Steel Plate and Reflective Mirror
HSS-ZPRM	Hemispherical Still with Zinc Plate and Reflective Mirror
HSS-CPRM	Hemispherical Still with Copper Plate and Reflective Mirror

Declarations

-Ethical Approval

Not applicable

-Consent to Participate

Not applicable

-Consent to Publish

Not applicable

-Authors Contributions

No.	Author's full name	Authors Contributions
1	<i>Mohammed El Hadi Attia</i>	Formal analysis and investigation, Writing - original draft preparation.

2	<i>Abd Elnaby Kabeel</i>	Conceptualization, Writing - Review & Editing.
3	<i>Mohamed Abdelgaied</i>	Conceptualization, Methodology, Writing - Review & Editing.
4	<i>Abdelkader Bellila</i>	Conceptualization, Methodology, Writing - Review & Editing.

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No competing interests

-Availability of data and materials

Not applicable

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