Enhancing The Hemispherical Solar Distiller Performance Using Internal Reflectors And El Oued Sand Grains As Energy Storage Mediums

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Abstract

The current comprehensive work deals with different solutions, all of which aim to overcome the problem of low productivity of drinking water from solar distillers. Experimental work was carried out on hemispherical distillers which are characterized by a large area of receiving and condensation. This study presented the results of two experimental scenarios to illustrate the influences of internal reflective on hemispherical distiller's performance in the first scenario. In the second scenario, the influences of internal reflective with El-Oued sand grains as the energy store medium on hemispherical distiller performances was studied. Two experimental scenarios aim to achieve the best configurations that achieve a highest hemispherical distillers performances. To achieves this goal, we designed and fabricated the three hemispherical distillers, the first distiller represents the reference case (Conventional Hemispherical Solar Still - CHSS), the second is the Hemispherical Solar Still with Internal Reflective Mirrors and El-Oued sand grains (HSS-IRM & SG), and a third is the Hemispherical Solar Still with Internal Reflective Aluminum Foil and El-Oued sand grains (HSS-IRAF & SG). The results presented that the cumulative production of reference distiller (CHSS) up to 4750 mL/m², while use of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) increases the production to 9400 mL/m² day. The maximum improvement in cumulative distillate production, exergy efficiency, and thermal efficiency was recorded for utilization of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) which reached 98, 200.9, and 96%, respectively, compared to reference case (CHSS).

Introduction

Algeria produces more than two million cubic meters per day of potable water using desalination plants, which is nearly a fifth it consumes. The main problem with desalination technologies is their high cost because they consume great energy. Desalinating one cubic meter consumes approximately 4 kilowatt hours (Kabeel et al., 2020a; Attia et al., 2020a; Abdelgaied et al., 2021a,b; Al-Molhem and Eltawil, 2020). Therefore, the continuous reduction in the production of electricity from solar energy will directly affect the cost of desalination. The Dubai Water and Electricity Agency recently announced the achievement of the world record for the lowest price per cubic meter of water produced with desalination technology, which is 0.277 \$ per cubic meter, less than a third of a dollar (Attia et al., 2020b, 2021a; Kabeel et al., 2017, 2018; Chandrika et al., 2021; Mohammed et al., 2021). The location of Algeria is important as it is located in the sunbelt. It is among the regions in the world that have the largest amount of solar energy. From this, Algeria can benefit from this site and these resources (renewable energy, especially solar energy and the development of desalination technologies) and can be transformed into productive economic sectors that create revolution and contribute to economic growth (Ramalingam et al., 2021; Suraparaju and Natarajan, 2021; Bellila et al., 2021; Kabeel and Abdelgaied, 2019; Attia et al., 2016). One of the strategic areas for research and development is desalination of saline water with solar energy, because we are concerned with economic and climate change and its dangerous effects.

Attia et al. (2021b) compared a modified single-slope solar distillation device (completely wrapped on the inside with aluminum foil sheets as an absorbent cover) to a conventional distillation device. They found

that the productivity of a modified distillation device (1004 ml/m^2) was much lower than that of a conventional distillate (1528 ml/m^2). An experimental work was conducted by Mu et al. (2019) they have incorporated the Fresnel lens (FRL) was integrated with a single-basin to improve its performance. Due to effect the FRL, there is increase in basin temperature and thus it was found increase of 467% in distillate yield by the conventional system with FRL. Plus an 84.7% improvement in daily efficiency, compared to the traditional system without FRL. Srivastava and Agrawal (2013) conducted a single basin solar still coupled with the porous absorbers (blackened jute cloth), with the two plane reflector mirrors. The porous absorbers acted as energy source for basin to warm. In addition, the difference in temperature between basin water and glass became greater because a plane reflector mirrors. The productivity of the system increased 68 and 79% without and with the twin reflector mirrors, respectively. Tanaka (2009) designed a modified distillation basin with internal/external reflectors. Reflectors were added to introduce more solar radiation into the modified still and compare of conventional still. He conducted experiments every day of the year and found that the daily productivity increase improved by 70–100% on winter days. Tanaka and Nakatake (2006) conducted theoretical analyzes on the same experiment (modified distillation basin with internal/external reflectors) and over the course of the year, they observed that the average increase in daily productivity was about 48%. Dev et al. (2011) experimentally studied the inverted distillers consists of (curved shaped reflector and traditional solar distiller). The result concluded that the inverted solar still yielded $6.302 \text{ l/m}^2/\text{day}$. Abdul-Wahab and Al-Hatmi (2012) tested an inverted still with refrigeration cycle. A refrigeration cycle was added for increase the temperature gradient between the absorber and the condenser. The productivity of the inverted still was $10 \text{ l/m}^2/\text{day}$ at the feed temperature of 35°C . Khalifa and Ibrahim (2011) tested a conventional solar still without and with reflectors mirrors (of thickness 4 mm). A refrigeration cycle was added for increase the temperature gradient between the absorber and the condenser. The productivity of the solar still were 6.26 and $6.70 \text{ l/m}^2/\text{day}$ when using external reflector and internal and external reflector together, respectively. While the maximum productivities of no reflector were $6.08 \text{ l/m}^2/\text{day}$. Hiroshi (2010, 2011) conducted experiments in a single-basin still with mirrors. The use of reflectors increases the amount of solar energy that reaches the basin still to improve distillation productivity. Also, studied the placed the reflector during the days of the year. It was found that the crop of distillate products increased by tilting the external reflector backward when used in the summer and by tilting it forward when used in the remaining seasons. Boubekri and Chaker (2011) numerically studied the effect of adding internal and external reflectors on the productivity of solar still. They concluded that the increase in productivity was 72.8% when using internal and external reflectors. They also found that the optimum inclination angle for external reflectors should be less than 25 degrees and that the optimum inclination angle for the (condensed) glass cover ranges between 10–50 degrees depending on the season. Chandrika et al. (2021) experimentally studied the effect of using different reflectors (mirrors and aluminum foil) on the inner walls of a distilled basin in order to improve the efficiency of the traditional solar still. They concluded that the daily productivity was 5200 ml/m^2 and 5900 ml/m^2 when using aluminum sheets and mirrors, respectively, compared to still without reflectors (3500 ml/m^2). Attia et al. (2021c) examined experimentally the yield and the daily efficiency of the hemispherical solar still that remains when sand grains are used as energy storage materials under the external conditions of the

city of El-Oued (Algeria). The concentration of used valley sand particles was changed successively (5, 10, 20, 30, 40, 50, 60 and 70 g/L). Based on the results achieved, they concluded that the yield and daily efficiency reached the highest value 7.27 L/m², 59.1% when concentration of 30 g/L, compared with the still without sand grains.

The current comprehensive work deals with different solutions, all of which aim to overcome the problem of low productivity of drinking water from solar distillers. This study presented the results of two experimental scenarios to illustrate the influences of internal reflective (mirrors and aluminum foil sheets) on hemispherical distiller's performance in the first scenario. In the second scenario, the influences of internal reflective (mirrors and aluminum foil sheets) with El-Oued sand grains as the energy store medium on hemispherical distiller performances was studied. Two experimental scenarios aim to achieve the best configurations that achieve a highest hemispherical distillers performances. To achieves this goal, we designed and fabricated the three hemispherical distillers, the first distiller represents the reference unit (Conventional Hemispherical Solar Still - CHSS), second is a Hemispherical Solar Still with Internal Reflective Mirrors placing on the inner vertical surfaces (HSS-IRM), and the third is the Hemispherical Solar Still with Internal Reflective Aluminum Foil sheets placing on the inner vertical surfaces (HSS-IRAF) in the first experimental scenario. In the second experimental scenario we added the El-Oued sand grains as the energy store medium, the three hemispherical distillers utilized is, the first distiller represents the reference case (CHSS), the second is the Hemispherical Solar Still with Internal Reflective Mirrors and El-Oued sand grains (HSS-IRM & SG), and a third is the Hemispherical Solar Still with Internal Reflective Aluminum Foil and El-Oued sand grains (HSS-IRAF & SG). The three hemispherical distillers were tested at the same Algerian weather conditions in from 7 AM to 7 PM, during August 2020

Experimental Work

Experimental setup and description

The present empirically test rigs were constructed for two experimental scenarios with the aim of achieves the maximum possible hemispherical solar distillers performances. In the first experimental scenario, effect of utilizing the internal reflective (mirrors and aluminum foil sheets) on the performance of hemispherical solar distillers was investigated. In the second experimental scenario, the effect of utilizing the internal reflective (mirrors and aluminum foil sheets) and El-Oued sand grains as heat store medium on a performance of hemispherical solar distiller were investigated. To achieves this goal, we designed and fabricated the three hemispherical solar distillers, the first distiller represents the reference case (Conventional Hemispherical Solar Still - CHSS), second is the Hemispherical Solar Still with Internal Reflective Mirrors placing on the inner vertical surfaces (HSS-IRM), and the third is the Hemispherical Solar Still with Internal Reflective Aluminum Foil sheets placing on the inner vertical surfaces (HSS-IRAF) as shown in Fig. 1. The hemispherical solar still consisted of a transparent hemispherical cover 40 cm in diameter, distillate collector, and a circular basin 38 cm in diameter and 4 cm in height. The basin saltwater depth of each hemispherical solar still is taken constantly at 1 cm. The inner surface of the

basin was painted with black silicon. The aluminum foil sheet has a shiny side and a matte side. The reflectivity of bright aluminum foil is 88%. The thickness of aluminum foil is about 0.2 mm. While the reflectivity of mirrors is 99% (Chandrika et al., 2021). The location of placing the inner reflective inside basin of hemispherical solar still is shown in Fig. 2.

In the second experimental scenario, to achieve the maximum benefit from the high intensity of solar rays falling on a surface of basin saltwater resulting from use of internal reflective, the El-Oued sand grains were added to basin saltwater where it is used as energy store materials to store part of the heat energy in a period of high solar intensity and is recovery it in the periods of lower solar radiation, El-Oued sand grains are also used to increase a solar radiation absorption rates.

To achieves the influences of the El-Oued sand grains and internal reflective on cumulative yield of hemispherical distillers, we designed and fabricated the three hemispherical solar distillers, the first distiller represents the reference case (Conventional Hemispherical Solar Still - CHSS), second is the Hemispherical Solar Still with Internal Reflective Mirrors and El-Oued sand grains (HSS-IRM & SG), and third is the Hemispherical Solar Still with Internal Reflective Aluminum Foil and El-Oued sand grains (HSS-IRAF & SG) as shown in Fig. 3. The El-Oued sand grains concentration utilized in this study is 3%. Sand is available in several countries of a world, as it is an energy storage material thanks to its components and properties. The color of sand depends on its region. The Algerian El Oued city is distinguished by its sand dunes. The sands of the valley are distinguished by yellow color. In Fig. 4, a micrograph of sand grains exposing size between 1.5–2 mm. Table 1 presented the Algerian sand grains characteristics (Meftah and Mahboub, 2020). Figure 5view a photographic of test bench.

Table 1
Algerian sand grains properties

	Bulk density (g/ml)	pH	Conductivity (µs/cm)	Porosity (%)	TDS (mg/l)
Sand grains	1.6	9.3	130.1	34.09	59

Measurements

To achieves the influences of utilizing the internal reflective and El-Oued sand grains as the heat store medium on accumulative production of the hemispherical distiller. In the first experimental scenario, the CHSS, HSS-IRM, and HSS-IRAF where tested at a same Algerian weather conditions in from 7 AM to 7 PM, during August 2020. In the second experimental scenario, the CHSS, HSS-IRM & SG, and HSS-IRAF & SG where tested at a same Algerian weather conditions in from 7 AM to 7 PM, during August 2020. The uncertainty, range, and errors of recorded data are presented in Table 2.

Table 2
Standard uncertainties and errors for measuring instrumentation

Instrument	Accuracy	Range	Standard uncertainty
Solar power meter	$\pm 10 \text{ W/m}^2$	0-1999 W/m ²	5.78 W/m ²
Thermocouple	$\pm 0.1^\circ\text{C}$	-100–500°C	0.08°C
Graduated cylinder	$\pm 1 \text{ ml}$	0–500 ml	0.5 ml

System performance

The exergy efficiency and thermal efficiency of the CHSS, HSS-IRM, HSS-IRAF, HSS-IRM & SG, and HSS-IRAF & SG are calculated as follows:

The exergy efficiency $\eta_{\text{daily,exe}}$ can be calculated by (Manokar et al., 2018);

$$\eta_{\text{daily,exe}} = \frac{\sum Ex_{\text{output}}}{\sum Ex_{\text{input}}} \times 100; (\%) \quad (1)$$

The input exergy energy Ex_{input} can be calculated by (Manokar et al., 2018);

$$Ex_{\text{input}} = A_s I(t) \times \left[1 - \frac{4}{3} \left(\frac{T_a + 273}{6000} \right) + \frac{1}{3} \left(\frac{T_a + 273}{6000} \right)^4 \right]; (\text{W}) \quad (2)$$

The output exergy energy Ex_{output} can be calculated by (Manokar et al., 2018);

$$Ex_{\text{output}} = \frac{\dot{m}_{ev} h_{fg}}{3600} \left[1 - \frac{T_a + 273}{T_w + 273} \right]; (\text{W}) \quad (3)$$

Thermal efficiency $\eta_{\text{daily,th}}$ can be calculated by:

$$\eta_{\text{daily,th}} = \frac{\sum \dot{m}_{ev} h_{fg}}{\sum I(t) A_s \times 3600} \times 100, (\%) \quad (4)$$

Latent heat h_{fg} can be calculated by (Kabeel and Abdelgaied, 2017);

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

Where; A_s is absorber area (m^2); $I(t)$ is solar radiation (W/m^2); T_w is basin saltwater temperature ($^{\circ}C$); T_a is ambient temperature ($^{\circ}C$); $\dot{m}$ is hourly distillate production ($kg/m^2 h$); h_{fg} is a latent heat (J/kg).

Results And Discussions

The test days for the first and second experimental scenarios was starting from 7:00 am till 7:00 pm, Fig. 6 depicts the hourly variation of ambient temperature and solar intensity. The solar intensity of the two test days (19-08-2020 and 20-08-2020) is almost identical, which increases until it reaches to the maximum value at noon, then dramatically decreases until it reaches its lowest value near sunset. Also, the highest recorded ambient temperature was recorded between 1:00 pm and 5:00 pm. This means that all cases of CHSS, HSS-IRM, HSS-IRAF, HSS-IRM & SG, and HSS-IRAF & SG can be compared to one another because all was exposed to very similar ambient climate conditions, allowing for a more accurate comparison.

Fig. 7 shows the influences of utilizing the internal reflective, as well as, the internal reflective and the El-Oued sand grains on basin saltwater temperature of the distillers from 7:00 am to 7:00 pm on August 19, and 20, 2020. The highest basin saltwater temperature was recorded for utilization of the internal reflective mirrors and the El-Oued sand grains (HSS-IRM & SG). The maximum recorded basin saltwater temperature was reached to 68, 72, 74, 78, and 80 $^{\circ}C$ for CHSS, HSS-IRAF, HSS-IRM, HSS-IRAF & SG, and HSS-IRM & SG respectively, between 2:00 pm and 3:00 pm. This because that the increases the intensity of absorbed solar rays filling on the basin saltwater for utilization internal reflective mirrors, as well as, use El-Oued sand grains as energy store material. Fig. 8 shows glass cover temperature of different distillers (CHSS, HSS-IRAF, HSS-IRM, HSS-IRAF & SG, and HSS-IRM & SG) through the period 7:00 am to 7:00 pm on August 2020.

In the solar distillers, the convection heat transfer represents the main driven in the distillation field. Whereas, the temperature difference between the saltwater and glass ($T_w - T_g$) is a measure of natural buoyancy inside solar distillers. With increasing the temperature difference, the buoyancy force will be increases, and thus will be improving the rate of distillate production inside the hemispherical solar distillers. Figure 9 shows the variations of the temperature difference ($T_w - T_g$) within the different cases of hemispherical distillers (CHSS, HSS-IRM, HSS-IRAF, HSS-IRM & SG, and HSS-IRAF & SG). As shown in Fig. 9, in the reference case (CHSS) the temperature difference ranged between 1–19 $^{\circ}C$, while the use of internal reflective aluminum foil (HSS-IRAF) increases this difference to 1-23 $^{\circ}C$, with the average improvement of 25.8%. While the use of internal reflective mirrors (HSS-IRM) increases this difference to 1-24 $^{\circ}C$, with the average improvement of 48.1%. While the use of internal reflective aluminum foil and El-Oued sand grains (HSS-IRAF & SG) increases this difference to 1-26 $^{\circ}C$, with the average improvement of 61.9%. While the use of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) increases this difference to 1-28 $^{\circ}C$, with the average improvement of 83.8%. The results of temperature analysis evident that the use of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) represent the good obtain to achieves the highest distillate production of hemispherical solar distiller.

Based on the recorded data of the hourly distillate production of the different cases of hemispherical distillers presented in Fig. 10, it is found that the hourly distillate production has the same trend for CHSS, HSS-IRM, HSS-IRAF, HSS-IRM & SG, and HSS-IRAF & SG, but with the higher rates for utilizing of the internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG). The recorded peak hourly distillate production which reached 750, 800, 900, 1100, and 1150 mL/m² h for CHSS, HSS-IRM, HSS-IRAF, HSS-IRM & SG, and HSS-IRAF & SG respectively was recorded within the period 2:00 pm till 3:00 pm. It is evident from this that the use of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) represent the good option to achieve the highest instantaneous distillate production of hemispherical solar distillers.

To get the influences of the internal reflective and the El-Oued sand grains on cumulative distillate production of the hemispherical distillers, Fig. 11 shows cumulative distillate production of five hemispherical solar distillers (CHSS, HSS-IRAF, HSS-IRM, HSS-IRAF & SG, and HSS-IRM & SG). As presented in Fig. 11, the cumulative distillate production of reference unit (CHSS) reached 4750 mL/m², while use of internal reflective aluminum foil (HSS-IRAF) increases the cumulative distillate production to 6200 mL/m² day, with the improvement of 30.5%. While the use of internal reflective mirrors (HSS-IRM) increases the cumulative distillate production to 7150 mL/m² day, with an improvement of 50.5%. While the use of internal reflective aluminum foil and El-Oued sand grains (HSS-IRAF & SG) increases the cumulative distillate production to 8350 mL/m² day, with an improvement of 75.8%. While the use of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) increases the cumulative distillate production to 9400 mL/m² day, with an improvement of 98%. The results concluded that the utilization of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) represent the optimal design configuration to achieve the highest cumulative distillate production of hemispherical solar distillers.

Figure 12 shown the exergy efficiency and daily thermal efficiency CHSS, HSS-IRAF, HSS-IRM, HSS-IRAF & SG, and HSS-IRM & SG. As shown the exergy efficiency and thermal efficiency of the reference distiller (CHSS) reached 2.2% and 38.9%, respectively. While the use of internal reflective aluminum foil (HSS-IRAF) increases the exergy and thermal efficiencies to 3.44% and 50.65%, respectively. While the use of internal reflective mirrors (HSS-IRM) increases the exergy and thermal efficiencies to 4.4% and 58.3%, respectively. While the use of internal reflective aluminum foil and El-Oued sand grains (HSS-IRAF & SG) increases the exergy and thermal efficiencies to 5.4% and 67.9%, respectively. While the use of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) increases the exergy and thermal efficiencies to 6.62% and 76.3%, respectively.

Figure 13 shows the influences of the utilization of the internal reflective, as well as, internal reflective and El-Oued sand grains on hemispherical distillers performance improvement. The results presented that the maximum improvement in cumulative distillate production, exergy efficiency, and thermal efficiency was recorded for utilization of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) which reached 98, 200.9, and 96%, respectively, compared to reference case (CHSS). This is mainly because of the higher reflectivity of the mirrors utilized in this empirically work as well as the good thermal properties

of El-Oued sand grains, and then utilization of both internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) together represent the good options to achieves a highest hemispherical distillers performances.

Comparison of present study with published similar works

In Table 3, we compared our results with published similar works. Through the results, compared to the reference distiller (CHSS), it has been noted that the yield of hemispherical solar still containing internal reflective aluminum foil sheets (HSS-IRA) increases by 30.5%, the yield of hemispherical still containing reflective mirrors (HSS-IRM) increases by 50.5%, the yield of hemispherical still containing internal reflective aluminum foil sheets and El-Oued sand grains (HSS-IRAF & SG) increases by 75.8%, the cumulative yield of hemispherical solar still containing internal reflective mirrors and El-Oued sand grains increases by 98%. From Table 3, it can be noticed that the productivity of "V" type SS with mirror [28] is minimum with a value equal to 11.92%. However, for the single slope SS with reflective glass mirror, it is maximum with a value equal to 75% [22].

Table 3
Comparison of improvement rates of distillate production of previously published works and our experimental work

Author name	Classification	Modifications	Gain in distillate production (%)
Our results	Hemispherical SS	- Internal reflective aluminum foil	30.5
		- Internal reflective mirrors	50.5
		- Internal reflective aluminum foil and El-Oued sand grains	75.8
		- Internal reflective mirrors and El-Oued sand grains	98
Chandrika et al. (2021)	Single slope SS	- Reflective glass mirror	68.57
		- Reflective aluminum foil sheet	48.57
Attia et al. (2021d)	Hemispherical SS	- 10 g/L of Phosphate granules	33.7
		- 20 g/L of Phosphate granules	47.9
Attia et al. (2021e)	Single slope SS	- Bed Phosphate granules	16.8
Kumar et al. (2008)	"V" type SS	- Mirror	11.92
		- Mirror and charcoal	14.11

Conclusions

This study presented the results of two experimental scenarios to illustrate the influences of internal reflective (mirrors and aluminum foil sheets) on the performance of hemispherical solar still in the first experimental scenario. In the second experimental scenario, the influences of internal reflective (mirrors and aluminum foil sheets) with El-Oued sand grains as the energy store medium on hemispherical solar still performances was studied. The two experimental scenarios aim to achieve the best configurations that achieve highest hemispherical solar stills performances. The obtained conclusions can be written as follows:

- The cumulative distillate production of the reference (CHSS) reached 4750 mL/m², while use of internal reflective aluminum foil (HSS-IRAF) increases the cumulative distillate production to 6200 mL/m² day. Also, the use of internal reflective mirrors (HSS-IRM) increases the cumulative distillate production to 7150 mL/m² day.
- The improvement in cumulative distillate production reached to 30.5% and 50.5% for use the internal reflective aluminum foil and internal reflective mirrors, respectively.
- Use the internal reflective aluminum foil and El-Oued sand grains (HSS-IRAF & SG) increases the cumulative distillate production to 8350 mL/m² day, with an improvement of 75.8%.
- Use the internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) increases the cumulative distillate production to 9400 mL/m² day, with an improvement of 98%.
- The exergy and thermal efficiencies of the reference distiller (CHSS) reached 2.2% and 38.9%, respectively. While the use of internal reflective aluminum foil (HSS-IRAF) increases the exergy and thermal efficiencies to 3.44% and 50.65%, respectively. While the use of internal reflective mirrors (HSS-IRM) increases the exergy and thermal efficiencies to 4.4% and 58.3%, respectively.
- Use the internal reflective aluminum foil and El-Oued sand grains (HSS-IRAF & SG) increases the exergy and thermal efficiencies to 5.4% and 67.9%, respectively.
- Use the internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) increases the exergy and thermal efficiencies to 6.62% and 76.3%, respectively.
- The results presented that the maximum improvement in cumulative distillate production, exergy efficiency, and thermal efficiency was recorded for utilization of internal reflective mirrors and El-Oued sand grains (HSS-IRM & SG) which reached 98, 200.9, and 96%, respectively, compared to reference case (CHSS).

Abbreviations

SS	Solar Still
CHSS-PBS	Conventional Hemispherical Solar Still Painted with Black Silicon
CHSS-IRM	Conventional Hemispherical Solar Still with an Internal Reflective Mirrors
CHSS-IRA	Conventional Hemispherical Solar Still with an Internal Reflective Aluminum foil sheets
CHSS-PBSSG	Conventional hemispherical solar still painted with black silicon and sand grains
CHSS-IRMSG	Conventional Hemispherical Solar Still with an Internal Reflective Mirrors sand grains
CHSS-IRASG	Conventional Hemispherical Solar Still with an Internal Reflective Aluminum foil sheets and sand grains

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>	Expermental work, , Writing - original draft preparation.
2	<i>Abd Elnaby Kabeel</i>	Conceptualization, Writing - Review & Editing.Supervisor
3	<i>Mohamed Abdelgaied</i>	Conceptualization, Methodology, Writing - Review & Editing.
4	<i>Ahmed Refat. Shmouty</i>	Formal analysis and investigation. Writing - Review & Editing.

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Figures

Figure 1

Layout of three hemispherical solar distillers utilized in experimental test rig for a first experimental scenario

Figure 2

Photographic view of three basins with internal reflective of the hemispherical solar stills.

Figure 3

Layout of three hemispherical solar distillers utilized in experimental test rig for the second experimental scenario

Figure 4

Micrograph of sand grains

Figure 5

Photo of experimental test rig

Figure 6

Variation of ambient temperature and solar intensity for the two test days 19, 20-08-2020

Figure 7

Hourly temperature variations of basin for different cases of the hemispherical distillers

Figure 8

Hourly temperature variations of glass cover for the different cases of the hemispherical distillers

Figure 9

Hourly variations of temperature difference (Tw-Tg) for the different cases of the hemispherical distillers

Figure 10

Instantaneous hourly variations of distillate production for the five different cases of hemispherical distillers

Figure 11

Cumulative distillate production for the five different cases of hemispherical distillers

Figure 12

Exergy and thermal efficiencies of the CHSS, HSS-IRAF, HSS-IRM, HSS-IRAF & SG, and HSS-IRM & SG.

Figure 13

Performance improvement in cumulative production, thermal efficiency, exergy and efficiency of HSS-IRAF, HSS-IRM, HSS-IRAF & SG, and HSS-IRM & SG.