Comparative Study of Hemispherical Solar Still Using Different Novel Basin Materials With and Without Internal Reflector: Yield, Energy, Exergy, Water Quality and Cost Analysis

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Abstract

The present work deals with the experimental investigation of Hemispherical Solar Still (HSS) using different basin materials with and without Internal Reflector (IR). Three solar stills such as HSS with Steel Basin (HSS-SB), HSS with Zinc Basin (HSS-ZB), HSS with Copper Basin (HSS-CB) was fabricated. Experiments was conducted with and without IR. It was found that, the productivity of the HSS-CB (4.99 kg/m\(^2\)/day) was better than HSS-ZB (4.26 kg/m\(^2\)/day) and both of them were better than HSS-SB (3.64 kg/m\(^2\)/day). Also, It was found that the productivity of the HSS-CB&IR (5.67 kg/m\(^2\)/day) was better than HSS-ZB&IR (5.04 kg/m\(^2\)/day), and both of them were better than the HSS-SB&IR (4.28 kg/m\(^2\)/day). The results revealed that use of IR improves the yield of HSS from 12 to 15.6%. Also thermal and exergy efficiency of the HSS was improved by 14.4 to 20% and 21.1 to 25.4% using IR than the without IR. Furthermore, recovery period and water quality analysis has been carried out. The recovery period of HSS-SB, HSS-ZB, HSS-CB, HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are 43, 38, 33, 36, 32 and 29 days, respectively.

1. Introduction

Water is the basis of the life on the earth planet, and it is very necessary for durability of the human life on it. One of the biggest challenges encountered the human civilization was who can offer a healthy and fresh water in a reasonable cost especially in the third world countries (Hussein 2015; Rostami et al. 2020). In fact, the natural sources of the fresh water are decrease gradually day by day due to many causes such as effluence of river water by the factories waste, huge population growth, and climate change (Hussein et al. 2016). It is useful to mention that the freshwater quantity was about (1%), while the other available water (about 97%) in the ocean is salty and cannot be used for animals, planets and the human demand. The remaining water sources (2%) can be found in the north and south Polar Regions as an iceberg (Benabderrahmane et al. 2020). For all these reasons, the SS can be used efficiently to covert the brackish water to a fresh water by using free solar energy. The device which was used to manage this process is called the SS and the principle of its work depends on the famous physical evaporation- condensation concept (Ghodbane et al. 2021). The comprehensive details about the characterization and types of the SS was reviewed by Kabeel and El-Agouz 2011, Hussein et al. 2020, Chauhan et al. 2021, Alnaimat et al. 2021 and Jobrane et al. 2021. The conventional single or double slope SS produced low productivity due to shadow effect occurs by the basin walls. This leads to reduce the solar radiation absorption and decreases its efficiency (Taheri and Zahedi 2020). To get a solution to the above-mentioned drawbacks of the SS and enhances the SS productivity, many researchers are suggested several unconventional designs like regenerative (Sakthivel et al. 2010), air bubbled (Pandey 1984), stepped (Omara et al. 2014), wick (Minasian, A. and Al-Karaghouli 1994), V-type (Kumar et al. 2008), thermoelectric (Rahbar and Esfahani 2012), masonic (Navale et al. 2016), tubular (Rahbar et al. 2015), pyramid (Al-Madhhachi and Smaisim 2021), trays (Essa et al. 2021), hybrid (Mandi et al. 2021) and hemispherical (Ismail 2009) SS. In the latter design of SS, the cover has a hemispherical shape in order to increase the amount of the solar energy collected by the SS by reducing the shadow of still walls.
In hemispherical design, both the efficiency and productivity are inversely proportional with the depth of water. In spite of the large number of published papers related with different designs of SS, the number of works related with the HSS are very limited up to date. Ismail [23] designed, fabricated and experimentally tested a transportable HSS under climate conditions of Dhahran city (KSA). The SS consisted from a hemispherical cover, distillate collector of a conical shape, mobile support structure, absorber plate, fresh water container and a circular basin. It was deduced that, the SS was able to convert around 50% of the saline water to a fresh water and its daily efficiency was about 33%. Also, he concluded that this efficiency was decreased with increasing the water depth. (Arunkumar et al. 2012) researched HSS under the weather conditions of Coimbatore (India). Two cases were considered, in the first case, the water flowing to cool the HSS cover. While, in another case this flowing was not considered. They concluded that, the HSS efficiency was increased from 34 to 42% by adopting the cooling of its cover. The experimental study of the HSS with and without PCM was carried out by (Arunkumar et al. 2013). The SS was integrated with a concentrator, whereas the paraffin wax contained in a black painted copper balls were placed in the basin. The temperatures of PCM, air, water and inner and outer covers of the SS were measured. They found that the SS productivity was increased by about 26% by using PCM. (Raju et al. 2017) investigated HSS by coupling it with evacuated tubes, paraboloid concentrator and heat pipes under outdoor conditions of Bangalore city (India). The experimental investigation of the performance of a cylindrical SS with a hemispherical dome (CSSHD) was carried out in Najaf city (Iraq) by (Khadim et al. 2021). The cylinder height was varied as 5, 15 and 20 cm. It was found that, both the thermal efficiency and yield amount were increased with increasing the cylinder height until it reached respectively (23.3% and 7.25 L/m$^2$.day) compared with (15 % and 4 L/m$^2$.day) for single slope SS. Moreover, they suggested that (CSSHD) was more efficient in winter compared with summer. (Attia et al. 2021) reported the HSS with an iron-fins installed at its basin. The optimum number and length of these fins which are necessary to reduce the shadow effect were studied. They tested three different designs of the HSS under outdoors conditions of El-Oued city (Algeria). The first one was a conventional type without fins, whereas the second and the third types included respectively fins group at (5 cm) and (7 cm) distance between each fins. The fin length was varied as 3, 2 and 1 cm starting from the absorber plate of the basin, while its diameter was fixed at 1.2 cm. It was found that, the yield of the SS was increased up to 56.73% when the third design was utilized and the fin length was taken as 2 cm. The experimental investigation of the HSS by using respectively black metal trays of iron, zinc and copper in the bottom of their basins was performed by (Attia et al. 2021) under the climate conditions of El-Oued city (Algeria). It was observed that, the improvement in the productivity was increased by about (53.125%) when the copper trays used compared with the same SS without it. Also, they concluded that using of copper trays increased respectively the yield and thermal efficiency of the SS to their highest value (7.35 kg/m$^2$/day and 57.2%) compared with (4.8 kg/m$^2$/day and 37.4%) without using any trays.

(Attia et al. 2021) examined experimentally the possibility of using aluminum foil sheet as an absorber cover to increase the yield of the greenhouse SS and compared it with a similar traditional SS which had an absorber of a black surface under the same outdoors conditions of El-Oued city (Algeria). They deduced that, the output of the modified still remain poor (1.004 kg/m$^2$/day) and an extra modification
need to be adopted. Based on the previous literature review, our deep experience in the solar energy and since there is a lack of the fresh water in most of the southeastern regions in Algeria such as El-Oued city (region of study) where a high population live there. Therefore, the major purpose of the present work is to investigate experimentally for the first time the effect of the reflective aluminum foil sheets on the performance of the HSS with various basin materials.

2. Experimental Work

2.1. Experimental setup and description

The present manuscript aims the experimental investigation of the reflective aluminum foil sheets effect on the performance of HSS with various basin materials. This was achieved by comparing the use of a reflective aluminum foil sheets by placing them on the inner surfaces of the HSS with various basin materials (Steel, Zinc and Copper). To realize this idea, two different experiments were carried out in the present work. In the first day, experiments was conducted on HSS-SB, HSS-ZB and HSS-CB without IR, as shown in Figure 1. In the second experiment three modified HSS were used and their walls were covered by the aluminum foil sheets. In the second day, experiments was conducted on HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR, as shown in Figure 2. The HSS was designed, fabricated and experimentally tested. The HSS consists of a transparent hemispherical cover of 40 cm in diameter, distillate collector and a circular basin 38 cm in diameter and 4 cm in height. The depth of basin saline waste water for each HSS was taken constant at 1 cm. These experiments were conducted in El Oued city (latitude of 33.3676°N and a longitude of 6.8516°E) under Algerian weather conditions. Aluminum foil sheet has a shiny side and a matte side. The reflectivity of bright aluminum foil is 88%. The thickness of aluminum foil sheet is about 0.2 mm. Figure 3 shows the photographic view of experimental test rig.

2.2 Measurements

The range, uncertainty, and errors values for the experimental data’s are presented in Table 1.

| Instrument         | Accuracy | Range       | Standard uncertainty |
|--------------------|----------|-------------|----------------------|
| Solar power meter  | ± 10 W/m²| 0-1999 W/m²| 5.78 W/m²            |
| Thermocouple       | ± 0.1°C  | −100 – 500°C| 0.08°C               |
| Graduated cylinder | ± 1 ml   | 0–500 ml    | 0.5 ml               |

3. Results And Discussions
3.1 Time-wise variant of solar intensity \([I(t)]\) and atmosphere temperature \((Ta)\)

Figure 4 display the time-wise variant of \(I(t)\) and \(Ta\) for the experimental day 1 and day 2. From graph 4, it is identified that \(I(t)\) increase linearly in the morning and reached maximum of 1040 W/m\(^2\) at midday on 14-8-2020 and 1020 W/m\(^2\) at midday on 15-8-2020. Similarly, \(Ta\) increases in the morning and reached maximum of 50°C at 15:00 on 14-8-2020 and 51°C at 15:00 on 15-8-2020. The daily mean \(I(t)\) on 14-8-2020 is 671.54 W/m\(^2\), and on 15-8-2020 is 663.46 W/m\(^2\) and the daily mean \(Ta\) on 14-8-2020 is 42°C and on 15-8-2020 is 41.46°C.

3.2 Time-wise variant of saline waste water temperature \((Ts.w)\)

Figure 6 Time-wise variant of \(Ts.w\) for the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR

3.3 Variation of Evaporative Heat Transfer Coefficient (EHTC) and yield production per hour from the HSS-SB, HSS-ZB, HSS-CB, HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR

Figure 7 displays the time-wise difference of EHTC and hourly yield production from the HSS-SB, HSS-ZB and HSS-CB on 14-8-2020. The highest calculated EHTC of the HSS-SB, HSS-ZB and HSS-CB are 40.09, 43.46 and 45.25 W/m\(^2\)K on 14-8-2020. The everyday average EHTC of 21.49, 23.44 and 24.82 W/m\(^2\)K is calculated for the HSS-SB, HSS-ZB and HSS-CB, respectively. The everyday average EHTC of the HSS-CB is greater than the HSS-SB, HSS-ZB due to the greater thermal conductivity value of copper basin. The everyday mean EHTC value of the HSS-ZB and HSS-CB is 9.04% and 15.49% greater than the everyday mean EHTC of the HSS-SB and every day mean EHTC value of the HSS-CB is 5.9% greater than the everyday mean EHTC value of the HSS-ZB. In HSS-CB, copper material improves the \(Ts.w\) and so it has greater hourly and everyday EHTC than the HSS-ZB and HSS-SB. From figure 5, it is found that yield production from the HSS-SB, HSS-ZB and HSS-CB are increasing in the before noon and decreases in afternoon. The highest yield of 0.71, 0.81 and 0.94 kg was produced from the HSS-SB, HSS-ZB and HSS-CB, respectively. The everyday yield production from the HSS-SB is 3.64 kg, from the HSS-ZB is 4.26 kg and from the HSS-CB is 4.9 kg on 14-8-2020. While using the copper basin in the HSS, yield was augmented by about 37.23% and 17.22% related to the HSS-SB, HSS-ZB, respectively.

Figure 8 displays the time-wise difference of EHTC and hourly yield production from the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR on 15-8-2020. The highest calculated EHTC of the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are 43.42, 45.15 and 47.02 W/m\(^2\)K on 15-8-2020. The everyday average EHTC of 23.2, 24.94 and 26.58 W/m\(^2\)K is calculated for the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR, respectively. The everyday average EHTC of the HSS-CB&IR is greater than the HSS-SB&IR, HSS-ZB&IR due to the greater thermal conductivity value of copper basin and IR. The everyday mean EHTC value of the HSS-ZB&IR and HSS-CB&IR is 7.5% and 14.5% higher as compared to the everyday average EHTC of the HSS-SB&IR and
every day average EHTC value of the HSS-CB&IR is 6.5% higher than the everyday mean EHTC value of the HSS-ZB&IR. In HSS-CB&IR, copper material and IR improves the Ts.w and so it has greater hourly and everyday EHTC than the HSS-ZB&IR and HSS-SB&IR. From figure 6, it is found that yield production from the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are increasing in the before noon and decreases in afternoon. The highest yield of 0.82, 0.91 and 0.97 kg was produced from the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR, respectively. The everyday yield production from the HSS-SB&IR is 4.28 kg, from the HSS-ZB&IR is 5.04 kg and from the HSS-CB&IR is 5.67 kg on 15-8-2020. While using the copper basin and IR in the HSS, yield was augmented by about 32.49% and 17.9% related to the HSS-SB&IR, HSS-ZB&IR, respectively.

In the HSS-CB and HSS-CB&IR, due to copper properties and IR it stores the more heat energy in the basin and water. Also it decreases the heat losses from the HSS basin to the air so yield production from the HSS-CB is greater than the HSS-SB and HSS-ZB and yield production form the HSS-CB&IR is greater than the HSS-SB&IR and HSS-ZB&IR.

3.4 Time-wise variant of Thermal efficiency (TE) and Exergy efficiency (EE) of the HSS-SB, HSS-ZB, HSS-CB, HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR

Time-wise variant of TE and EE of the HSS-SB, HSS-ZB and HSS-CB are shown in Figure 9. The TE of the HSS-SB, HSS-ZB and HSS-CB are rises in morning and got peak value at 14:00 and then it record low value till 19:00. The TE of the HSS-SB starts with 4.40% at 07:00, had a raising trend and got 55.61% at 14:00 and then it had a reducing trend till 19:00 (14.47%). Also TE of the HSS-ZB starts at 5.12% at 07:00, had a rising trend and got 61.3% at 14:00 and then it had a reducing trend till 19:00 (22.72). Similarly the TE of the HSS-CB starts at 6.94% at 07:00, had a raising trend and got 65.91% at 14:00 and then it had a reducing trend till 19:00. The daily TE of the HSS-SB, HSS-ZB and HSS-CB are 25.14, 30.23 and 35.19% on 14-8-2020. The TE of the HSS-CB is 39.97 and 16.4% higher than TE of the HSS-SB and HSS-ZB. Similarly, the TE of the HSS-ZB is 20.26% higher than the TE of the HSS-SB. The use of copper basin in the HSS-CB enhances the water temperature, EHTC, yield and hence it had greater TE than the TE of the HSS-ZB and HSS-SB. The EE of the HSS-SB, HSS-ZB and HSS-CB are raises in morning and got peak value at 14:00 and then it decreases till 19:00. The EE of the HSS-SB starts at 0.03% at 07:00, had a raising trend and got 3.75% at 14:00 and then it had a reducing trend till 19:00 (0.22). Also EE of the HSS-ZB starts with 0.06% at 07:00, had a raising trend and got 4.6% at 14:00 and then it had a reducing trend till 19:00 (0.48%). Similarly the EE of the HSS-CB starts with 0.07% at 07:00, had a raising trend and got 4.96% at 14:00 and then it had a reducing trend till 19:00 (0.94%). The daily EE of the HSS-SB, HSS-ZB and HSS-CB are 1.26, 1.62 and 1.98% on 14-8-2020. The EE of the HSS-CB is 56.87% and 21.88% higher than EE of the HSS-SB and HSS-ZB and EE of the HSS-CB is 16.4% higher than the HSS-ZB. The EE of the stills is maximum for the HSS-CB because EE directly related to yield and available solar intensity. For the period of noon hours, the difference between Ts.w and Tg is greater so at the time of noon hour EE is higher than the evening.

Time-wise variant of TE and EE of the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are shown in Figure 10. The TE of the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are rises in morning and reached peak value at
14:00 and then it decreases till 19:00. The TE of the HSS-SB&IR starts with 5.71% at 07:00, had a raising trend and got 63.75% at 14:00 and then it had a reducing trend till 19:00 (28.66%). Also TE of the HSS-ZB&IR starts at 9.02% at 07:00, had a rising trend and reached 69.3% at 14:00 and then it had a reducing trend till 19:00 (29.96). Similarly the TE of the HSS-CB&IR starts at 11.53% at 07:00, had a raising trend and reached 72.16% at 14:00 and then it had a reducing trend till 19:00. The daily TE of the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are 31.45, 36.62 and 41.12% on 15-8-2020. The TE of the HSS-CB&IR is 30.76 and 12.29% higher than TE of the HSS-SB&IR and HSS-ZB&IR. Similarly, the TE of the HSS-ZB&IR is 16.45% higher than the TE of the HSS-SB&IR. The use of copper basin and IR in the HSS enhances the water temperature, EHTC, yield and hence it had greater TE than the TE of the HSS-ZB&IR and HSS-SB&IR. The EE of the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are raises in morning and reached peak value at 14:00 and then it decreases till 19:00. The EE of the HSS-SB&IR starts at 0.05% at 07:00, had a raising trend and got 4.28% at 14:00 and then it had a reducing trend till 19:00 (0.6%). Also EE of the HSS-ZB&IR starts with 0.08% at 07:00, had a raising trend and got 4.83% at 14:00 and then it had a reducing trend till 19:00 (0.72%). Similarly the EE of the HSS-CB&IR starts with 0.19% at 07:00, had a raising trend and got 5.21% at 14:00 and then it had a reducing trend till 19:00 (1.05%). The daily EE of the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are 1.69, 2.12 and 2.51% on 15-8-2020. The EE of the HSS-CB&IR is 48.31% and 18.29% higher than EE of the HSS-SB&IR and HSS-ZB&IR. The EE of the HSS-ZB&IR is 16.45% higher than the EE of the HSS-SB&IR. The use of the HSS is maximum for the HSS-CB&IR because EE directly related to yield and input. For the period of noon hours, the difference between Ts.w and Tg is higher so at the time of noon hour EE is higher than the evening.

4. Assessment Of Current Study With Available Related Works

In Table 2 shows the comparison of our results with published similar works. From the Table 2, it can be noticed that the productivity of “V” type SS with mirror [31] is minimum with a value equal to 11.92%. However, for the double SS with reflector, it is maximum with a value equal to 93.39% [32]. The present study produced maximum yield of 4.28, 5.04 and 5.67 kg/m² using HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR, respectively.
Table 2
Assessment of current study with available related works

| Author name            | Type of SS      | Enhancement techniques                                      | Productivity improvement (%) |
|------------------------|-----------------|-------------------------------------------------------------|-----------------------------|
| Our results            | Hemispherical SS| - Steel Basin                                               | -                           |
|                        |                 | - Zinc Basin                                                | 17.03                       |
|                        |                 | - Copper Basin                                              | 37.08                       |
|                        |                 | - Steel Basin and Internal Reflector                        | 17.58                       |
|                        |                 | - Zinc Basin and Internal Reflector                         | 38.46                       |
|                        |                 | - Copper Basin and Internal Reflector                        | 55.77                       |
| (Kumar et al. 2008)    | “V” type SS     | - Mirror                                                    | 11.92                       |
|                        |                 | - Mirror and charcoal                                        | 14.11                       |
| (Gnanaraj et al. 2019) | Double slope SS | - Reflector                                                 | 93.39                       |
| (Omara et al. 2013)    | Stepped SS      | - Internal reflectors                                        | 75.00                       |
| (Abdullah et al. 2020) | Trays SS        | - Internal reflectors                                        | 58.00                       |
|                        |                 | - External reflectors                                        | 75.00                       |
| (Chandrika et al. 2021)| Single slope SS | - Reflective glass mirror                                   | 68.57                       |
|                        |                 | - Reflective aluminum foil sheet                            | 48.57                       |

5. Water Quality Analysis

Table 3 depicts the properties of saline and distilled water. It is observed that pH value of saline water is 8.12 and distilled water is 7.12 which is within the consumable levels. After distillation, salt content (2.86 g/l) presents in the saline water was completely removed so that electrical conductivity of the distilled water was drastically decreased from 5300 to 28 µS/cm and TDS of the distilled water was drastically decreased from 7042 to 22 mg/l.
6. Economic Evaluation

6.1 Daily yield

Table 4 presents the daily yield of the HSS-SB, HSS-ZB, HSS-CB, HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR recorded during the 12 Hrs of the day of the experiment on August 14 and 15, 2020. From these results, it is clear that the maximum value of the daily yield is obtained for the HSS-CB&IR.
6.2 Economic Evaluation

In Table 5, the recovery period of HSS-SB, HSS-ZB, HSS-CB, HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR is summarized. The payback period of HSS-SB is 43 days, HSS-ZB is 38 days and HSS-CB is 33 days. The amount invested is returned in the case of the HSS-SB&IR is 37 days, HSS-ZB&IR is 32 days and HSS-CB&IR is 29 days.

|                          | HSS-SB | HSS-ZB | HSS-CB | HSS-SB&IR | HSS-ZB&IR | HSS-CB&IR |
|--------------------------|--------|--------|--------|-----------|-----------|-----------|
| Total cost of manufacture (DZD) | 9000   | 9000   | 9000   | 9050      | 9050      | 9050      |
| The price of metal tray   | 300    | 600    | 900    | 300       | 600       | 900       |
| Maintenance cost (DZD)    | 50     | 50     | 50     | 60        | 60        | 60        |
| Total cost (DZD)          | 9350   | 9650   | 9950   | 9410      | 9710      | 10010     |
| The amount of water produced during the day (kg/m$^2$/day) | 3.64   | 4.26   | 4.99   | 4.28      | 5.04      | 5.67      |
| cost per liter of distilled water on the market (DZD) | 60     | 60     | 60     | 60        | 60        | 60        |
| The price of daily water production (DZD) | 218.4  | 255.6  | 299.4  | 256.8     | 302.4     | 340.2     |
| Recovery period (Days)    | 43     | 38     | 33     | 36        | 32        | 29        |

Conclusions

This work highlights the positive effect of an IR on the performance of HSS with various basin materials. This simple technique includes a reflective aluminum foil sheets on the inner walls of the HSS with various basin materials (steel, zinc and copper). The conclusions are as follows:

- Using the reflective aluminum foil sheets and high thermal conductivity metal basins (copper) enhances the efficiency of HSS. Aluminum foil sheets increase the reflection of the solar radiation inside the basin, and the trays increase the absorption of solar radiation resulting increases in temperature of the brine water.
- The distilled water production from the HSS-SB, HSS-ZB and HSS-CB are 3.64, 4.26 and 4.99 kg/m$^2$.
- The distilled water production from the HSS-SB&IR during the day is equal to 4.28 kg/m$^2$. However, it is equal to 5.04 kg/m$^2$ from the HSS-ZB&IR and it is equal to 5.67 kg/m$^2$ from the HSS-CB&IR.
- The daily accumulation of HSS was improved by 17.03 and 37.08% by using the zinc and copper basin as compared to the HSS-SB.
The daily yield was improved by 17.58, 38.46 and 55.77% by using the steel, zinc and copper basin and reflective aluminum foil sheets as compared to the HSS-SB.

The invested amount is recovered from a HSS-SB, HSS-ZB, HSS-CB, HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR are 43, 38, 33, 37, 32 and 29 days.

The productivity of the distillate with the copper basin and reflective aluminum foil sheets is much better than other solar stills.

Reflective aluminum foil sheets and high thermal conductivity metal trays greatly improve the yield of the solar distillation and increases the yield and efficiency.

### Abbreviations

| Abbreviation | Description                                      |
|--------------|--------------------------------------------------|
| SS           | Solar Still                                      |
| IR           | Internal Reflector                               |
| HSS-SB       | Hemispherical Solar Still with Steel Basin       |
| HSS-ZB       | Hemispherical Solar Still with Zinc Basin        |
| HSS-CB       | Hemispherical Solar Still with Copper Basin       |
| HSS-SB&IR    | Hemispherical Solar Still with Steel Basin and Internal Reflector |
| HSS-ZB&IR    | Hemispherical Solar Still with Zinc Basin and Internal Reflector |
| HSS-CB&IR    | Hemispherical Solar Still with Copper Basin and Internal Reflector |

### Declarations

**Ethical Approval**

Not Applicable

**Consent to Participate**

Not Applicable

**Consent to Publish**

Not Applicable

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**Competing Interests**
The authors declare that there is no competing interest

**Availability of data and materials**

Not Applicable

**Authors Contribution**

Mohammed El Hadi Attia - Project administration, Writing original manuscript & Software

Ahmed Kadhim Hussein - review & editing

Prabha Ramadoss - Formal analysis, review & editing

Sivakumar Vaithilingam - Writing original manuscript, review & editing

Asif Afzal - review & editing

Obai Younis - review & editing

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Figures

Figure 1
Schematic of the HSS
Figure 2

Layout of the three HSS utilized in the experimental test rig for the second test case
Figure 3

Photographic view of experimental test rig
Figure 4

Time-wise variant of I(t) and Ta
Figure 5

Time-wise variant of Ts.w for the HSS-SB, HSS-ZB and HSS-CB
Figure 6

Time-wise variant of Ts.w for the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR
Figure 7

Time-wise variant of EHTC and yield production from the HSS-SB, HSS-ZB and HSS-CB on 14-8-2020
Figure 8

Time-wise variant of EHTC and yield production from the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR on 15-8-2020
Figure 9

Time-wise difference of TE and EE of the HSS-SB, HSS-ZB and HSS-CB on 14-8-2020
**Figure 10**

Time-wise difference of TE and EE of the HSS-SB&IR, HSS-ZB&IR and HSS-CB&IR on 15-8-2020