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Comparative study of conventional solar still with and without black-painted wick materials: energy and exergy study

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ABSTRACT

In the present experimental investigation, a relative study of conventional solar still (CSS) and CSS with black-painted wick materials is studied. From the investigation, it is found that wick material augments the yield throughout the day. Furthermore, energy and exergy efficiencies of the CSS, CSS with black-painted wick materials were calculated to determine the CSS's performance. The diurnal yield of 2.04 and 2.86 kg was obtained from the CSS, and CSS with black-painted wick materials, respectively. The diurnal yield produced from the CSS with black-painted wick materials was increased by 40.4% more than the CSS. The diurnal energy efficiency of the CSS with black-painted wick materials is 20.16% and the CSS is 14.99%. Also, the exergy efficiency of the CSS with black-painted wick materials is 1.46% and the CSS is 0.95%. Experimentation proves that the use of black-painted wick materials in the CSS improves the yield, energy, and exergy efficiency as related to the CSS.

Keywords: Solar still; Distilled water; Wick materials; Absorptivity

1. Introduction

Water is a requirement for the existence of not only humans but all living organisms in the world. The availability of drinkable water is a basic criterion for survival and a mandatory requirement to stay fit and fine [1–3]. The lack of availability of pure drinking water is ever-increasing all over the world. The scarcity of availability of good drinking water has to be solved; particularly people in remote villages suffer a lot due to the non-availability of pure drinking water. Solar still (SS) can be used in those far-off villages where the supply of fresh water is not feasible. SS relies mainly upon the solar energy obtained from the sun and can be used in places where the sunshine is available almost all through the year. Since the installation of SS is less expensive and has low maintenance, it could be the best alternative when compared to other distilleries for acquiring potable drinking water [4–6]. The growth of industrialization, the density of the population, the usage of chemical fertilizers, etc. contaminate the layer of soil which in turn pollutes the groundwater. This contaminated water gives way to many diseases which affect the health of humans; particularly small children are often prone to water-borne diseases. The contaminated groundwater can be converted into potable fresh water using solar distillers. SS helps to get pure water using sun rays which is a renewable source of energy hence this is a simple,

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cost-effective device for filtering salt and other impurities from hard water. Solar distillers work just like the formation of rain which involves evaporation and condensation, the solar energy received from the sun warms the water, which evaporates and condenses when it passes a cool surface to get fresh water. The desalination process through SS is being encouraged as an eco-friendly way of obtaining freshwater without polluting the environment. Solar distillers are preferred to be less expensive and have minimum maintenance though a larger area is needed for their installation [7,8].

SS can be classified into different types such as single-effect SS, multi-effect SS, basin-type SS, wick basin type SS, multi-wick diffusion SS, etc. These stills could be utilized depending on the nature of the requirement. Advanced continuous research is being carried out in this field to augment the yield of these stills in terms of both qualitative and quantitative for the benefit of mankind. A remarkable growth in output was noticed in the yield of SS using double-layered wick materials, corrugated SS, reflectors to the still, inclined SS, floating wick SS, rotating solar wick SS, V-type SS, fin-type SS, etc. Thus, the difference in production capacity was noticed and always an enhanced output has been shown when compared with the output of traditional SS. SS with latent heat storage is used in industrial applications where thermal energy is used as phase change material (PCM) with high energy storage capacity for enhancing productivity [9,10].

Omara et al. [11] proposed a novel method using an evacuated solar water heater integrated with desalinated SS with jute fabrics for changing salt water to potable water. It was concluded that the proposed method produced annual distillate of 920; 1,948 and 4,148 L/m^2 through CSS, wick SS (WSS), and double layer square WSS (DLSWSS) supplemented with brackish water, respectively. The production of water increased by 114% in WSS and 215% in DLSWSS as compared to the CSS. Bisht et al. [12] have investigated the performance of CSS and modified SS with the integration of solar ponds and floating wicks into the basin of CSS. The solar energy captured in the daytime is shifted to the basin for the production of distillate during the night with the help of the integration of the solar pond into the CSS. The area of the evaporative surface is maximized by adding floating wicks to the basin. The performance was compared in the same weather conditions and observed that usage of solar ponds and wicks lead to an increased output of 3,864 and 2,288.9 g when compared to 2,533 and 1,474 g yielded through the CSS in the day and night, respectively. An enhanced yield of 53.5%, on the whole day, has been obtained by the proposed SS. Tuly et al. [13] have focussed a study on the comparison of the CSS, and modified SS. The output of modified SS was attached with solid rectangular fins and an external condenser in which paraffin wax and black cotton cloth were added as a source of thermal energy and wick materials were evaluated. The modified SS and CSS yielded potable water of 3.07 and 2.46 L/m^2, respectively. The modified SS produced a maximum efficiency of 39.74% with a condenser and 30% without a condenser. Omara et al. [14] conducted a study and compared the yield of CSS and corrugated WSS (CRWSS) with the usage of nanofluids to the SS when the vacuum was provided. The integration of CRWSS with internal reflectors and external condensers using various types of nanomaterials was examined and compared with CSS. The result showed that CRWSS with internal reflectors and when the vacuum produced a 180% higher yield than the CSS and the yield was increased approximately to 285.10% and 254.88% when cuprous and aluminum oxide nanoparticles were used. Pal et al. [15] have evaluated the integration of hanging wicks designed SS and fabricated modified basin (MB)-type SS. Modified basin types such as MB single slope SS (MBSSSS), MB double slope SS (MBDSSS) MB single slope multi wick SS (MBSSMWSS), and MBDSMWSS were taken. The study showed an annual yield of 861.55; 1,551.48; 1,172.03 and 2,583.99 kg for MBSSSS, MBDSSSS, MBSSMWSS with jute material, and MBDSMWSS with black cotton wick material, respectively. Pal et al. [16] built a thermal model of modified MW DSSS. MW DSSS with black cotton and jute wick material was examined in the terms of exergoeconomic and enviroeconomic analysis considering the energy matrices and exergy factors. The cumulative yield of experimental production obtained at Allahabad was 7,040 mL (3.52 L/m^2·d) per day which was 15.07% lower than the theoretical production yield of 8,101 mL (4.05 L/m^2·d) per day. Essa et al. [5] have proposed a new working mechanism to augment the output of a solar distiller of cords wick pyramid SS (CWPSS) with a parallel basin liner kept above the basin of 3.0 cm with numerous cracks. The distiller was integrated with reflectors, a cooling cycle, and a swing cord of wicks. The parallel basin liner was wrapped by jute wicks and hanging wick cords to optimize the mechanism of wick cords and remove the water collected in the basin and kept the surface moist at all times. The yield of the CWPSS was enhanced by 122% approximately which was 7,900 mL/m^2 when compared to the conventional PSS yield of 3,550 mL/m^2·d. A study was conducted with a different number of cords and mirrors as reflectors and found that maximum yield was obtained at 35 numbers of cords. Abdullah et al. [17] have examined the enhanced output of SS using reflectors, a sliding-wick belt of the rotating wick SS (RWSS), and a black jute belt that was made to rotate with a solar photovoltaic powered DC motor in the distiller in both vertical and horizontal directions. The performance of RWSS was observed at 0.02, 0.05, 0.1, 0.2, and 0.3 min^{-1} sliding speed levels of the belt in both straight and upside-down directions. To absorb more solar energy, mirrors were used with RWSS internally and externally. The freshwater productivity of RWSS was 10 L/m^2·d which is 300% (with reflectors) and 200% (without reflectors) greater than that of the CSS. Essa et al. [6] have published the performance of two designs of RWSS in which a black jute cloth belt was made to rotate in an L-shaped path (L-RWSS) and RWSS in which the belt was rotated in an L-shaped bath with a Chamfer (C) in the bottom (LC-RWSS). The yield of L-RWSS, and LC-RWSS depends largely on the areas of exposure and evaporated surface. LC-RWSS obtained a yield of 9,600 mL/m^2·d and L-RWSS obtained a yield of 8,200 mL/m^2. Younes et al. [18] conducted a study with four solar stills namely, flat wick SS (FWSS), CRWSS, half barrel wick SS (HBWSS), and CSS. The configuration of the absorber was changed to enhance the evaporation area for CWSS and BWSS thereby reducing the rate of evaporation and water flow rate. BWSS and CRWSS were examined with a mixture of PCM and CuO nanoparticles to augment the yield of SS. The overall yield of FWSS, HBWSS, CRWSS, and CSS was found to be 3,850; 4,250; 4,400 and 2,200 mL/m², respectively. The performance improvement was observed at 75%, 93%, and 100% for the FWSS, HBWSS, and CRWSS, respectively, as compared to the CSS. The CRWSS with PCM yielded 5.2 L/m²·d. Ahmed et al. [19] carried out a study in Ha'il City (27.66°N, 41.72°E), Saudi Arabia during December 2020 (winter season) to produce a highly competent solar water desalinate device at an economic cost to provide for the needs of remote village areas in Saudi Arabia. Continuous saline water flow is circulated through a small pump to the inclined SS added with black cotton fabric had produced 3.21 L/m²·d with 139.12% more effective and 21.13% enhancement in yield than the CSS.

Essa et al. [20] have studied the productivity of tubular SS (TSS) and convex TSS (CVTSS). The area of vapourization and surface exposed inside the SS was maximized by the utilization of a specially designed convex absorber. Further, the utilization of jute and cotton wick materials, TiO_2, and graphene nanocomposites in improving the productivity of the SS were also examined. It was observed that the performance of CVTSS was more than the TSS in all aspects. CVTSS produced the highest yield of 9,000 mL/m² with the integration of jute cloth and nanocomposites while the TSS yielded 4,200 mL/m². The CVTSS increased productivity by 114% when both jute cloth and nanocomposites were used and yielded 92.5% when jute cloth alone was used. Omara et al. [21] examined the output factor of CSS and corrugated SS (CRSS) bounded by double-layer wick fabric and reflectors inside the CRSS. The total yield of CRSS was more than CSS at about 55.36%. At the same time, when the wick was added to the corrugated base, the yield, and efficiency of the CRSS were increased to 90% and 49.3%, respectively. The water productivity increased to 145.5% more than the CSS by the integration of wick and internal reflecting mirrors to CRSS. The average productivity per day of the CSS was 2.5 L and the CRSS was 5 L. Younes et al. [22] have compared the yield of CSS, HBWSS, and CRWSS by placing a vertical wick fabric inside the walls of HBWSS and CRWSS to stop the direct falling of solar energy which would decrease the heat loss and increase the evaporation and condensation. It was found an increased output of 5.4 L/m²·d in CRWSS-PCM, and 5.6 L/m²·d in HBWSS-PCM which are 43% and 52% more than CSS productivity of 2.2 L/m²·d. Haddad et al. [23] examined the improvement of production when a vertical rotating wick (VRW) was used in the CSS. The back wall of the SS was connected to a rotating black wick belt to maximize the evaporation area. The VRW augmented the yield per day to 5.03 and 7.17 kg/m² which was higher than the yield of CSS of 3.33 and 6.25 kg/m² during winter and summer, respectively. The result revealed that the output was 51.1% and 14.72% greater than the productivity of CSS in winter and summer, respectively. Abdullah et al. [24] have investigated the effect of CSS, corrugated trays SS (CRTSS) with absorbers covered by wick fabric, and flat trays SS (FTSS) integrated with nano-enhanced PCM and photovoltaics-powered heaters. The surface area between the absorber and saline water and the rate of heat transfer was raised. The use of wick materials pushed the porous materials upward and slowed the rush of water. The overall average yield obtained for CSS, CRTSS, CRTSS with heaters, CRTSS with PCM, CRTSS with heaters, and PCM were 2.2, 4.1, 5.5, 4.9, and 6.2 L/m², respectively. The whole distillate obtained with the usage of electric heaters was 6,000 mL/m² with 150% of increased productivity. The integration of PCM and CuO nanoparticles with CRTSS increased productivity by 150%, and the overall output of 180% more than the CSS was obtained with the usage of a mixture of PCM with CuO nanoparticles and electrical heaters. Sharshir et al. [25] have experimented with the influence on the thermal performance of inclined wick SS (IWSS) by using a new wick material chips pad made up of various metals such as aluminum, copper, and steel. The performance of improved IWSS and conventional IWSS were investigated. The output of a copper basin with a copper chip wick pad, an aluminium basin with an aluminum chip pad, and a steel basin with a steel chip pad was found to be 6.3, 5.13, and 5.28 L/m² with increased efficiency of 60.9%, 50.5% and 46.12%, respectively. Further, the increased productivity of the basin with double-layered wick materials made of copper, aluminum, and steel was 6.34, 5.13, and 4.12 L/m² with an increase in efficiency of 56.5%, 49.7% and 6%, respectively. Lawrence et al. [26] have presented a paper about the improved performance of adding nickel oxide nanoparticles extracted from the stem and leaf of *Acalypha indica* to the saline water of the water storage area of the single-slope wick-type SS. The production was increased by absorbing more solar energy during daytime and the utilization of the absorbed solar energy during night-time by nickel oxide nanoparticles. The enhancement still produced an overall daily production of 5.8 L/m² from the stem extract and 5.75 L/m² from the leaf extract of nickel oxide nanoparticles and 4.2 L/m² without nanoparticles in 24 h. Modi and Modi [27] have made two double-basin single-slope SS (DBSSSS) of the same structure of which one was integrated with a wick made of jute cloth. A comparative analysis was conducted to derive the impact of variation in the production of simple DBSSSS and DBSSSS integrated with jute cloth. The research was conducted in India @ 20.61°N, 72.91°E at a depth of brackish water of 10 mm in the lower basin and 2,700 mL in the upper basin. An overall production obtained for continuous 3 d in summer by DBSSSS added with wick pile was estimated to be 712.7, 942.25, and 835.59 mL/m² and by DBSSSS was 699.2, 777.97, and 675.46 mL/m², respectively. The production enhanced for wick pile added DBSSSS was found to be 1.93%, 21.12% and 23.71%, and the increase in efficiency for the same was 8.89%, 28.90% and 29.37%, respectively. A recent review on WSS by Maheswaran et al. [28] was studied.

The performance of inclined WSS was studied by Aybar et al. [29] and Abdullah et al. [30], and Sharon et al. [31]. The results of double slope WSS were published by Gnanaraj and Velmurugan [32], and Rajaseenivasan et al. [33]. Only a few researchers studied the performance of the pyramid SS with wick materials (Prakash et al. [34], Alawee et al. [35], and Saravanan & Murugan [36]). V-type WSS was published by Suneesh et al. [37]. Tubular WSS was reported by Elashmawy [38]. Rectangular grooves, and ridges basin wick type ISS was published by Anburaj et al. [39]. Various wick materials such as a small pile of wick (Modi and Modi [40]), partially covered wick (Suneesh et al. [41]), corrugated wick (Matrawy et al. [42] and Kassem [43]), stepped wick

(El-Agouz [44]), multiple V-shaped floating wicks (Agrawal and Rana [45]), moving controlled wick (Abdullah et al. [46]), multi–wicks (Pal et al. [47]). Porous materials were used in floating SS [48,49]. Floating porous absorbers were used in the CSS [50]. The SS performance was improved by an internal reflector and concave steps [51]. Some researchers reported the entropy generation [52–54], nanofluid in SS [55], and partitioning of SS [56,57]. From the literature, it is known that only a few research was published on black-painted wick materials as absorbing materials in the CSS. Therefore, the present study is to experimentally examine the performance of the CSS, CSS with black-painted wick materials.

2. Experimental set-up

A CSS unit with a glazing glass cover operated as a solar energy transmitter as well as a condensing surface for the water vapors generated in the CSS basin. The basin is composed of galvanized iron and has a 0.49 m² effective area. Three holes at 0.11 and 0.8 m in height enable thermocouples to be inserted into the SS to measure the temperatures of the basin and water. Over the water collection portion, the top cover is composed of 4 mm thick plain glass. The CSS's external box is made of wood with a thickness of 12 mm and dimensions of 0.85 m × 0.85 m × 0.381 m. Sawdust is used to insulate the gap between the bottom and sides of the metal basin and the outside wooden box. The snapshot of the set-up is shown in Figs. 1 and 2 shows the photo of black-painted sponges. The thermal conductivity of the sponges is 0.3 W/mk.

2.1. Theoretic analysis

The evaporative heat transfer coefficient and convective HTC from water to glass were calculated by Eqs. (1) and (2), individually, [58]. Fig. 3 shows the energy and exergy efficiency for the CSS, CSS with black-painted wick materials.

$$h_{e,w-g} = 16.273 \times 10^{-3} \times h_{c,w-g} \left[\frac{P_w - P_{cc}}{T_{b\text{-}w} - T_g} \right] \quad (1)$$

$$h_{c,w-g} = 0.884 \left[\left(T_w - T_g \right) + \frac{\left(T_w + 273.15 \right)\left(p_w - p_g \right)}{\left(268900 - p_w \right)} \right]^{1/3} \quad (2)$$

Partial vapor pressure on the water and glass was calculated by Eqs. (3) and (4), individually,

$$P_w = \exp\left(25.317 - \left(\frac{5144}{273 + T_{s.w}} \right) \right) \quad (3)$$

$$P_{cc} = \exp\left(25.317 - \left(\frac{5144}{273 + T_{cc}} \right) \right) \quad (4)$$

The comprehensive computations of the energy and exergy efficiency for the CSS, CSS with black-painted wick materials are shown in Fig. 3.

3. Results and discussion

Hourly variations of solar intensity, air, water, and glass temperatures of the CSS, and CSS with black-painted wick materials are shown in Figs. 4 and 5, respectively. From Figs. 4 and 5, it is found that all the varying profiles of Figs. 4 and 5 have got peak value at 14:00 and after 14:00 it has reduced trends. The peak intensity, air, water, and glass temperatures for the CSS are 995 W/m², 37°C, 62°C, and 45°C, respectively. Similarly, the CSS with black-painted wick materials is 1,010 W/m², 37°C, 66°C, and 47°C, respectively. The mean value of solar intensity during experimentations of the CSS, CSS with black-painted wick materials is 714.54 and 715.5 W/m², respectively. Similarly, the mean value of air temperature during experimentations of the CSS, and CSS with black-painted wick materials are 32.4°C and 32.8°C, respectively. The mean value of water temperature for the CSS, and CSS with black-painted wick materials are 45°C and 48.33°C. The use of black-painted wick materials in the CSS increases the water temperature throughout the day due to the absorbing capacity of black-painted wick materials in the basin of the CSS. The diurnal average water

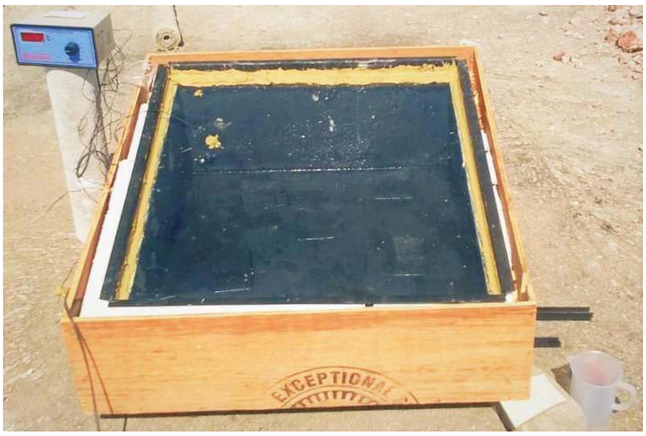


Fig. 1. Experimental photo.

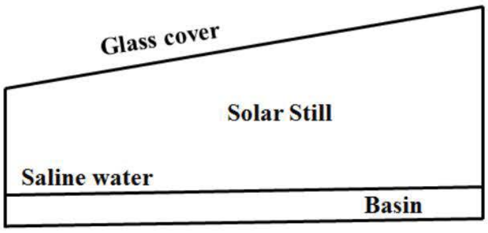
Fig. 2. Photo of the black-painted wick materials used in the CSS basin.

Energy Efficiency

$$\eta_{energy} = \frac{M_w * L}{(A_s * \sum I_{t(s)} * 3600)}$$

$$M_w = \left(\sum_{i=1}^{i=9} m_w\right)$$

$$L = 2.4935 * 10^6 * \left[1 - (9.4779 * 10^{-4} T_w + 1.3132 * 10^{-7} * {T_w}^2 - 4.794 * 10^{-9} * {T_w}^3\right]$$



Exergy Efficiency

$$\eta_{Ex} = \frac{\sum \dot{E}_{x_{evap}}}{\sum \dot{E}_{x_{sun}}}$$

$$\sum \dot{E}_{x_{evap}} = \frac{M_w * L * \left[1 - \left(\frac{T_a + 273}{T_w + 273}\right)\right]}{3600}$$

$$\sum \dot{E}_{x_{in}} = \sum \dot{E}_{x_{sun}} = \left(\left(A_s * \sum I_t\right)\right) * \left[1 - \frac{4}{3} * \left(\frac{T_a + 273}{T_s}\right) + \frac{1}{3} * \left(\frac{T_a + 273}{T_s}\right)^4\right]$$

m_w	hourly distillate yield (kg)	T_a	ambient air temperature (K)
M_w	daily distillate yield (kg)	T_w	water temperature (K)
L	latent heat of vaporization (J /kg)	T_b	basin temperature (K)
A_s	basin area of solar still (m²)	T_{gi}	inner glass temperature (K)
$I_{t(s)}$	hourly incident solar radiation (W /m²)	T_{go}	outer glass temperature (K)
$\sum I_{t(s)}$	Total incident solar radiation (W /m² / day)	T_{sky}	sky temperature (K)
$\sum \dot{E}_{x_{in}}$	exergy input of solar still (W)	α_g	Absorptivity of glass cover
$\sum \dot{E}_{x_{out}}$	exergy output of solar still (W)	α_b	Absorptivity of basin liner
$\sum \dot{E}_{x_{dest}}$	exergy destructed in solar still (W)	α_w	Absorptivity of water
$\sum \dot{E}_{x_{sun}}$	exergy input from the sun on solar still (W)	τ_g	Transmissivity of glass cover
$\sum \dot{E}_{x_{evap}}$	exergy evaporated on solar still (W)	τ_w	Transmissivity of water
$\sum \dot{E}_{x_{work}}$	exergy work rate for solar still (W)	ε_{eff}	Effective emissivity
η_{Ex}	exergy efficiency (%)	σ	Stefan – Boltzmann constant
η_{energy}	daily energy efficiency (%)		

Fig. 3. Energy and exergy efficiency for the CSS, CSS with black-painted wick materials Vaithilingam et al. [59].

temperature of the CSS with black-painted wick materials is 7.41% higher than the diurnal average water temperature of the CSS. The variation of glass temperature is nearly similar for both CSS and CSS with black-painted wick materials. The reason for the variation between the water temperature of the CSS with black-painted wick materials and CSS is that black-painted materials absorb more solar energy than the CSS without black-painted wick materials.

Hourly variations of EHTC and yield from the CSS and the CSS with black-painted wick materials are shown in Fig. 6. From the EHTC calculation, it is found that EHTC increases for the period morning and reached its maximum at 14:00 and after 14:00 it has a trend of reduction. The highest EHTC of 26.4 and 31.29 W/m²·K is found for the CSS, and CSS with black-painted wick materials, respectively. The average diurnal EHTC of 13.03 and 15.62 W/m²·K is found for the CSS, and CSS with black-painted wick materials, respectively. The value of EHTC is always higher for the CSS with black-painted wick materials as compared to the CSS. The presence of black-painted wick materials absorbs

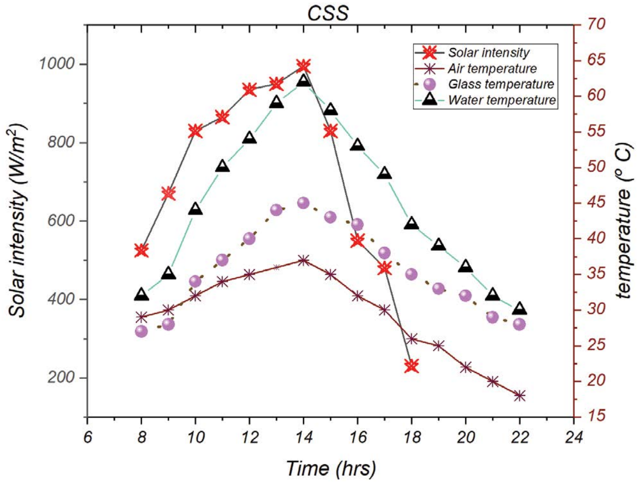


Fig. 4. Hourly variation of solar intensity, air, water, and glass temperatures for the CSS.

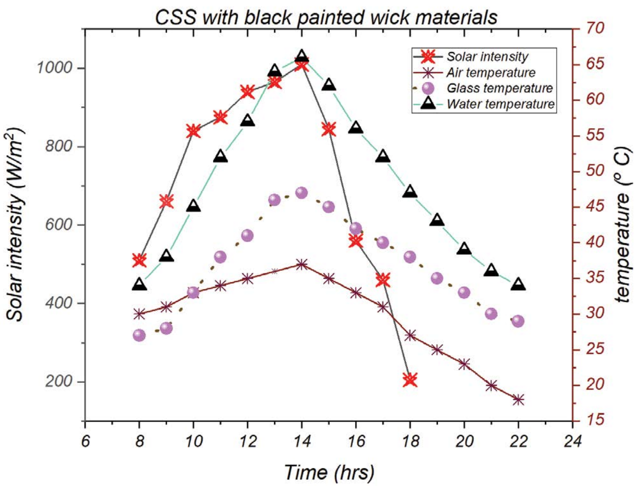


Fig. 5. Hourly variation of solar intensity, air, water, and glass temperatures for the CSS with black-painted wick materials.

solar intensity, enhances the surface area, and enhances the EHTC. The daily EHTC of CSS with black-painted wick materials is 20% higher than the daily EHTC of the CSS. Similarly, the highest water droplets collected from the CSS and CSS with black-painted wick materials are 0.4 and 0.53 kg, respectively. The water droplets collected from 08:00 to 18:00 were 1.9 and 2.67 kg, water droplets collected from 19:00 to 22:00 were 0.09 and 0.19 kg, and daily (08:00–22:00) yield collected from CSS, CSS with black-painted wick materials, are 2.04 and 2.86 kg, respectively. The hourly yield of the CSS with black-painted wick materials is always higher as compared to the hourly yield of the CSS. The daily yield of CSS with black-painted wick materials is 0.8 kg higher than the daily yield of the CSS. The CSS with black-painted wick materials has produced a 40.4% higher yield than the CSS. The day-time (08:00–18:00) yield was improved by 37.3% using black-painted wick materials as compared to the CSS. Similarly, night-time (19:00–22:00) yield was improved by 110% using black-painted wick materials than the CSS. The reason for the higher yield for the CSS with black-painted wick materials is that black-painted materials absorbed more heat energy and enhances the water temperature than the CSS. The use of black-painted wick materials was used to improve the water temperature, EHTC, and yield significantly than the CSS.

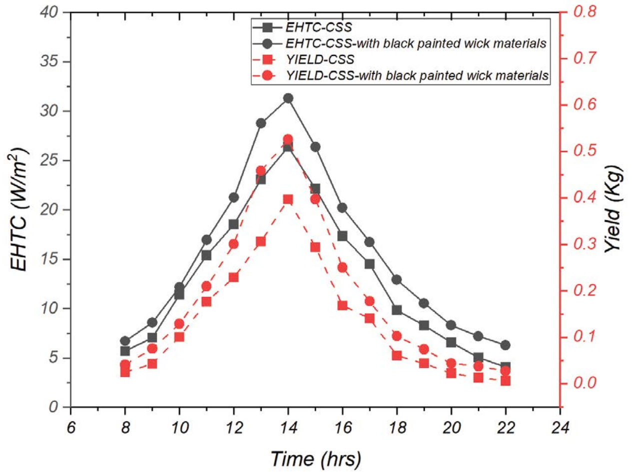


Fig. 6. Hourly variation of EHTC and yield from the CSS, CSS with black-painted wick materials.

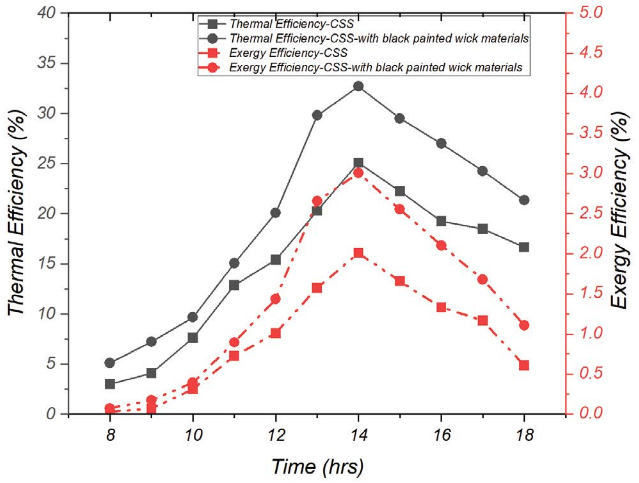


Fig. 7. Hourly variation of energy and exergy efficiency of the CSS, CSS with black-painted wick materials.

Hourly variations of energy and exergy efficiency of the CSS, CSS with black-painted wick materials are shown in Fig. 7. From Fig. 7 it is clear that both energy and exergy efficiency rose during the morning (8:00 to 14:00) and reached the maximum at 14:00 and after 14:00 it decreased. The maximum energy efficiency for the CSS and CSS with black-painted wick materials is 25.06% and 32.71%, respectively. The maximum energy efficiency difference between the CSS with black-painted wick materials and CSS is 9.53%. The diurnal energy efficiency of the CSS, CSS with black-painted wick materials is 14.99% and 20.16%, respectively. The diurnal energy efficiency of the CSS with black-painted wick

Table 1
Evaluations of present work with related studies

S. No.	Authors name	Experiment name	Yield (kg/m^2)	Location
1.	Omara et al. [11]	CSS WSS DLSW	0.9920 1.948 4.148	Egypt
2.	Tuly et al. [13]	CSS Modified SS	2.46 3.07	Bangladesh
3.	Pal et al. [16]	MMWBDSSS Cumulative experimental and theoretical production yield	3.52 4.05	Allahabad Uttar Pradesh
4.	Essa et al. [5]	CWPSS CPSS	7.900 3.550	Saudi Arabia
5.	Abdullah et al. [17]	RWSS with reflectors	10	Saudi Arabia
6.	Essa et al. [6]	LC-RWSS L-RWSS	9.600 8.200	Al-Kharj, KSA
7.	Younes et al. [18]	FWSS HBWSS CRWSS CSS CRWSS with PCM	3.850 4.250 4.400 2.200 5.2	Al-Kharj, KSA
8.	Ahmed et al. [19]	ISS with black cotton fabric	3.21	Ha'il City, Saudi Arabia
9.	Essa et al. [20]	TSS CVTSS integration of jute cloth and nanocomposites	4.200 9.000	Saudi Arabia
10.	Omara et al. [21]	CSS CRSS double layer wick material and reflectors	2.5 5.0	Egypt
11.	Younes et al. [22]	CRWSS-PCM HBWSS-PCM CSS	5.4 5.6 2.2	Al-Kharj, KSA
12.	Haddad et al. [23]	VRW SS CSS	7.17 6.25	M'sila City, Algeria
13.	Abdullah et al. [24]	CSS CTSS CTSS with heaters CTSS with PCM CTSS with heaters and PCM	2.2 4.1 5.5 4.9 6.2	Al-Kharj, KSA
14.	Sharshir et al. [25]	Average production of IWSS with copper basin with a copper chip wick pad IWSS with aluminum basin with an aluminum chip pad IWSS with steel basin with a steel chip pad IWSS with copper basin with double layer wick IWSS with aluminum basin with double layer wick IWSS with steel basin with double-layer wick	 6.3 5.13 5.28 6.34 5.13 4.12	Kafrelsheikh City, Egypt
15.	Lawrence et al. [26]	Single-slope wick-type SS from the stem extract Single-slope wick-type SS from Leaf extract	5.8 5.75	India
16.	Present study	CSS with black-painted wick	2.86	India

materials is 34.46% higher than the diurnal energy efficiency of the CSS.

Exergy efficiency also rose during the morning (8:00 to 14:00) and reached a maximum value of 2.01% and 3.01% for the CSS, and CSS with black-painted wick materials, respectively. The diurnal exergy efficiency of the CSS and the CSS with black-painted wick materials is 0.95% and 1.46%, respectively. The maximum exergy efficiency difference between the CSS with black-painted wick materials and CSS is 1.08%. Using black-painted wick materials in the CSS has increased the energy and exergy efficiency by about 17% and 24%, respectively as compared to the CSS. Using black-painted wick materials has increased the thermal and exergy efficiency by about 34.5% and 53.25% of the energy and exergy efficiency of the CSS. The efficiencies of the CSS and CC with black-painted wick materials is directly depends on the yield. The hourly efficiencies of CSS with black-painted wick materials is always higher than the CSS. The reason for higher efficiency is black-painted wick materials produced higher yield as compared to the CSS.

4. Evaluations of present work with related studies

The productivity was enhanced by 114% using WSS and yield was enhanced by 215% by using DLSWSS [11]. The inclusion of a solar pond with floating wicks increased the yield of the CSS by 53.5% [12]. The yield of conventional, modified, and finned SS was 2.46, 3.07, and 2.70 L/m^2, respectively which had a maximum efficiency of 39.74% with condenser and 30% without condenser (Tuly et al. [13]). The maximum output of 10 L/m^2 was reported by Abdullah et al. [17] using RWSS with reflectors and the minimum output of 1,172.03 kg was reported by Pal et al. [16] using MBSSMWSS. The present study produced 2.04 and 2.86 kg of yield using CSS and CSS with black-painted wick materials, respectively. Table 1 listed the evaluations of the present work with related studies.

5. Conclusion

The black-painted wick materials were used as solar intensity absorbing material in the CSS. Experimentally performance of CSS was studied and energy and exergy efficiencies are calculated; the key results are enumerated as follows:

- Higher temperature difference between basin water and glass was obtained by using black-painted wick materials.
- The maximum daily yield of 2.86 kg was obtained by using black-painted wick materials.
- Using black-painted wick materials has produced a 0.82 kg higher yield than the yield produced from the CSS.
- Using black-painted wick materials in the CSS, improves the daily yield by 40.4% and the night-time yield by 110% as compared to the CSS.
- The diurnal energy and exergy efficiency of the CSS and CSS with black-painted wick materials is 14.99%, 0.95%, 20.16%, and 1.46%, respectively.
- The use of black-painted wick materials has improved the energy and exergy efficiency by about 34.5% and 53.25% higher than the energy and exergy efficiency of the CSS.

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