



Comparative study of hemispherical solar distillers iron-fins

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<https://doi.org/10.1016/j.jclepro.2021.126071> 

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Abstract

The ratio between surface area to volume is higher in spherical distillers than traditional single slope distillers. To utilize this advantage, the study measures hemispherical distillers performance. Iron fins have been employed at different lengths and spacing in absorber plate to increase absorption area and transmit heat from hot basin plate to saline water. Three configurations have been tested under same operating conditions. First, the conventional hemispherical distiller without fins representing the reference case (CHSS). Second, the modified hemispherical distiller with fins set at 5cm spacing (MHSS-IF5). Third, the modified hemispherical distiller with fins set at 7cm (MHSS-IF7). Fins diameter is constant at 1.2cm with tested length of 3, 2 and 1 cm starting from the basin absorber plate. Basin salt water is fixed at 3cm (maximum fin length) during experiments. Results prove that fin utilization is important in performance enhancement. However, fin length effect on performance depends on spacing due to shading effect in distillers. Consequently, the fins utilization improves distiller productivity up to 56.73% with best configuration of MHSS-IF7 with 2cm fin length and 7cm spacing. The fins utilization is not costly in the hemispherical distiller with positive enhancement contribution leads to minimum cost per liter of produced water.

Introduction

Water is essential for survival and is necessary for beings, plants, animals, and people. Providing fresh water has recently become a major challenge due to resources scarcity as a result of demographic growth and environmental pollution caused by industrial waste (Kabeel et al., 2018; Patel and Modi, 2020). Non-potable water (saltwater), on the other hand, is available everywhere. Yet, salt water cannot be directly used because it contains different types of salt. Distillation takes place to purify salt water and desalination is the most important process (Manokar et al., 2018; Khechekhouche et al., 2020). Distillation requires energy to heat water, which can be saved from solar energy or any cheap fuel. Solar energy is a clean/alternative source of fossil fuel, the best energy source, and is environmentally friendly for various applications such as water heating, ocean heating, and thermal energy storage (Kabeel et al., 2017, 2019a, 2019b; Katekar and

Deshmukh, 2020). Research now focuses on improving techniques of obtaining fresh water from salty water through solar distillation. Fresh water produced from traditional solar distillers ranges from 1 to 5 liters/m². Many researchers have studied techniques that aim to develop solar distillers yield through the following: suggesting solar distillers several designing methods (Kabeel and Abdelgaied, 2017a, 2019; Kumar et al., 2015; Kabeel et al., 2016, 2020a, 2020b; Omara et al., 2017; El-Maghlany et al., 2020), using energy storage materials (Khechekhouche et al., 2019; Attia et al., 2020; Kabeel and Abdelgaied, 2017b; Kabeel et al., 2019c, 2020c), and adding external solar collectors (Sampathkumar and Senthilkumar, 2012; Sathyamurthy et al., 2017; Abu-Arabi et al., 2020). Fins are one of the designing options utilized to increase traditional solar distillers daily accumulation. They are added to solar distillers basin to increase absorber area and saltwater heating rate inside the basin. Their utilization raises saltwater basin average temperature, consequently increasing solar distillers productivity. El-Sebaili et al. (2015) have studied fins height/thickness impact on solar stills productivity and daily efficiency. Rabhi et al. (2017) study have focused on simple pin fins impact on solar distiller yield. Researchers concluded that daily accumulation improved by 14.5% compared to traditional distillers. Panomwan et al. (2013) have experimentally evaluated solar still productivity with a fin plate. Results showed that incorporating a fin plate into the solar basin increased productivity. Omara et al. (2011) investigated a comparative study on corrugated stills and vertical finned solar stills. Outcomes showed that compared to traditional solar distillers, yield increased by 40% using vertical finned solar stills and by 21% when using corrugated stills. Alaian et al. (2016) have examined solar stills augmented with pin-finned wick impact on yield. They have found an enhancement in efficiency and yield, and the whole system improved by 23%. Rajaseenivasan and Srithar (2016) compared shots behavior with square/circular fins and when covering fins with wick materials. They have noted that productivity when covering fins with wick materials is much greater than that of square/circular fins. Velmurugan et al. (2008) have examined vertical fins impact on a yield of passive still. They have concluded that productivity increased by 45.5% compared to traditional distiller. Srivastava and Agrawal (2013) have examined effect of porous fins filled with old black cotton on productivity. Porous fins were partially immersed in basin, while the other part remained above surface. Results indicated that productivity increases as basin water depth decreases, which is consistent with thermal model results. El Sebaei and El-Naggar (2017) have investigated modified solar energy with square tubes filled with energy storage materials to increase productivity after sunset or when sun rays are invisible. They have noticed a significant improvement in productivity compared to traditional solar distillers. Kumar et al. (2019) have studied square pipes effect as fins on single slope distiller. Distillates productivity improvement rate with simple fins was 64%; while with energy storage inside fins, it was 95%. Kabeel et al. (2020d) have empirically examined hollow fins and paraffin wax under basin impacts on pyramid solar distillers accumulative yield.

Based on the abovementioned deliberations, hemispherical distillers are characterized by having large receiving/condensing surface area compared to traditional single-slope distillers. According to previous studies, fins are utilized to increase absorber area and saltwater basin heating rate. Their number and length enhances heat transfer rate (positive effect), but the shading effect as penalty impact on the performance is also increases This point has not yet been experimentally tested. The present study aims to achieve highest performance in hemispherical distillers. Thus, iron fins have been installed in basins to take advantage of large receiving/condensing surface area in order to improve distillate water production rate throughout working days. Research aim can be summarized in the following:

- Hemispherical distillers performance enhancement through fins utilization in experimental work.
- Optimization between fin numbers/length and spacing for maximum productivity production.
- Creating cheaper and simpler distiller designs.

Accordingly, two different hemispherical distiller designs are implemented. Distance between fins is 5 cm (MHSS-IF5) in the first design and 7 cm in the second (MHSS-IF7). Three different iron fins heights are examined to determine which is best (1 cm, 2 cm, and 3 cm) in both designs (MHSS-IF5 and MHSS-IF7). Both results are compared to the traditional hemispherical distiller (CHSS) to figure out iron fins best distribution and height, which helps achieve highest performance.

Section snippets

Experimental setup

The current experimental study aims to achieve highest performance in hemispherical distillers. To achieve this goal, iron fins are installed in hemispherical distiller basin to increase absorption surface area and achieve maximum possible utilization of large receiving/condensing surface area characterizing hemispherical distillers. The study investigates iron fins optimum distribution/height to reduce shadow effect. To identify of iron fins distribution influence on hemispherical distillers...

Results and discussion

Since there are three fins lengths for tests, weather conditions are measured for three consecutive days and recorded for each length. The recorded data includes solar intensity and ambient temperature as shown in Fig.3. Recorded values from 8 a.m. to 6 p.m. are approximately the same with maximum and minimum ambient temperatures of 30–48°C respectively, and maximum and minimum solar intensity of 18–1006 W/m² respectively. The total daily solar energy (area under the curve) is approximately...

Conclusion

The ratio between large surface area and solar distiller volume is studied. Performance is enhanced through extending surface using fins. Three arrangements are tested in the same ambient and under the same solar intensity time variation as follows: conventional case without fins (CHSS), modified hemispherical distiller with fins set at 5 cm spacing (MHSS-IF5), and modified hemispherical distiller with fins set at 7 cm spacing (MHSS-IF5). Fins diameter is constant at 1.2 cm with tested length...

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper....

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...They concluded that the daily production was enhanced by 24.8%. Attia et al. (2021a) conducted the optimal configuration of the iron fins that achieve the highest distillate yield of hemispherical distillers. They found that the utilization of iron fins with 2 cm height and 7 cm spacing distance improved the yield of the distiller by 56.73%...

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...Therefore, Researchers have investigated improving designs to reduce the construction cost like hemispherical [7], pyramid [8], tubular [9], single slope [10], inclined wick [11], double slope [12], stepped [13] SS using external heating source (PV/T collector) [14], concentrator [15], aluminum foil sheet as absorber cover [16], internal and external reflectors [17-19] to improve the performance of SS. Research also been directed towards improving productivity of solar distillates and efficiency by add absorbents materials (energy storage materials) such as: dye [20], sand grains [21,22], sandbags [23], phosphate bed [24], phosphate bags [25], charcoal [26], aluminum balls [27], trays metal [28], fins [29], sponge [30], gravel [31], phase change materials (PCM) [32-34] and nanofluids [35-39]. Balachandran et al. [40] performed a study on a SS with eggshells as an energy storage medium, the used eggshells were placed in the basin of the SS...

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