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Performance analysis of single slope solar desalination setup with natural fiber

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ABSTRACT

Water scarcity across the globe is increasing day by day. Various technologies are evolving to address this issue with a viable solution. In these technologies, desalination using solar still is one of the most prominent, economic, and viable solutions. However, it has very little operating efficiency. The current research is to enhance the performance of a single slope solar desalination setup by improving the freshwater yield. In order to achieve this, a naturally available fiber, Ridge gourd is kept in the absorber basin which leads to an increase in the evaporation rate of water due to porous nature and then the productivity of the desalination setup is increased. Two solar desalination setups are designed, developed, and analyzed in the current research to compare the yield from each setup under similar testing conditions. The solar desalination setup with ridge gourd is tested to evaluate the performance improvement with respect to conventional solar desalination setup. The experiments are conducted at the terrace of the Science Block in the National Institute of Technology Puducherry, Karaikal, India (10.92°N, 79.83°E). It is observed that there is no great influence of ridge gourd on the performance of the desalination setup and hence it is insignificant to use ridge gourd fiber in the desalination for better efficiency.

Keywords: Solar; Desalination; Single slope; Ridge gourd

1. Introduction

Energy—Water nexus plays the most significant role in human life. The drinking water problem is one of the most faced problems by all the countries across the globe. It is also known that the consumption of potable water is increased because of modernization and an increase in the population. The available freshwater is less and more water is available as unusable water in the seas. The conversion of seawater to potable water is one of the viable solutions to decrease the impact of the water crisis. This process of desalination with any form of any conventional energy sources will again lead to the energy crisis. So, the desalination with renewable energy sources will be a better solution for the energy-water crisis. In the several renewable energy sources, solar energy is considered as the significant and most viable source because of its abundance and dominance over other renewable plays a significant role in the thermal and electrical conversion. [1–7]. Solar energy enters into the setup through the glass and trapped in the enclosure. Thus, it increases the water temperature which leads to evaporation. The evaporated water vapor is then condensed on the glass and the pure water is collected at the end [8–14]. Being the oldest way of desalination, solar desalination with stills is limited in extensive implementation for desalinating the seawater due to low productivity and non-continuous operation caused by the environmental changes [15,16]. Different phase change materials like paraffin wax, stearic acid, nanopowders, nanofluids, graphite flakes, Sand, Jute, etc., are used for better performance. It is proven that

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the temperatures, productivity, and efficiency are increased effectively with the use of PCM [17–26]. Based on the mentioned literature review, there are few works that have been reported using fibers like jute to enhance productivity. In this aspect, the ridge gourd (natural fiber) is introduced to investigate its effect on the performance of the single-slope solar desalination setup. The performance of the solar desalination setup is evaluated for Karaikal weather conditions from 8.30 a.m. to 6.30 p.m. to investigate the effect of ridge gourd fiber on the productivity of the desalination setup.

2. Experimental methods

2.1. Development of single slope solar desalination setup

The single slope solar desalination setup is designed, developed, and fabricated at the terrace of the NIT Puducherry, Karaikal, India (10.92°N, 79.83°E). The setup is made of waterproof plywood and the inner side of the setup is fixed with an aluminum sheet of 2 mm thickness to prevent the direct contact of wood with water which destroys the whole setup. The setup is made with an angle of 11° which is almost the latitude of the location and closed with a transparent glass of 4 mm. The absorber basin in the setup is made of copper to extract more heat as it is having the highest thermal conductivity and the dimensions of the copper basin are 100 cm × 60 cm × 5 cm with 1 mm thickness. The exterior of the setup is covered with the thermocol sheet of 2 cm thickness which acts as an insulation for any heat losses. The fabricated single slope desalination setups are shown in Fig. 1. In the experimentation, calibrated *K* type thermocouples are placed at different locations for knowing the temperature distribution. The thermocouples in both the setups are connected to the data logger (Fig. 2b) for temperature readings. The pyranometer (Fig. 2a) is used for measuring the incoming solar radiation. The calibrated collecting container (Fig. 2c) is marked with scale to measure the quantity of purified water collected.

2.2. Inclusion of ridge gourd natural fiber in the absorber basin

The ridge gourd, the fruit of Luffa acutangular fiber is selected because of its porous nature, medicinal values, and its availability. It is previously used as bath sponges, but they are also used as fillers in the production of composites, materials of adsorption in water treatments, and application in sound insulation [27]. The peeled off fiber and structure of luffa is shown in Fig. 3, and the absorber basin filled with the ridge gourds fibers are shown in Fig. 4. The absorber basin is filled with water at a depth of 2.5 cm which is optimized for better yield. The complete experimental setup is shown in Fig. 5.

3. Results and discussions

The different temperatures of the desalination experiment without ridge gourd are plotted in Fig. 6 and the same temperatures with ridge gourd from the other desalination setup are plotted in Fig. 7. In Fig. 6, it is clearly seen that the water temperature is relatively high when compared with Fig. 7. This is due to the obstruction of heat by the ridge gourd fibers in the absorber basin. Because of this lower temperature, we can see the low yield in the setup containing ridge gourd fibers. The ridge gourd fibers absorbing the water and they are not capable of evaporating the water from them quickly which leads to the slower evaporation rate and hence lower productivity. The other temperatures like glass, absorber, and ambient are relatively similar in Figs. 6 and 7 that are without and with ridge gourd fibers. The

Fig. 1. Single slope solar desalination setup.

Fig. 2. (a) Pyranometer, (b) data logger, and (c) collecting container.

Fig. 3. Peeled off *Luffa acutangula* (ridge gourd) fiber.

usage of the ridge gourd showing a negative impact on the performance of the single-slope solar desalination system. The ambient temperature and glass temperatures are mainly influenced by the incoming solar radiation and hence the curves are almost similar. The absorber and the water temperatures are mainly influenced by the ridge gourd fiber in the absorber basin. It is obstructing the rise of temperatures of water and basin because it is totally spread over the water in the basin.

In Fig. 8, it is clearly observed that there is a decrease in the freshwater yield with the inclusion of ridge gourd fiber in the desalination system. It is seen that the system without fiber yielded 1,630 mL for a 0.6 m^2 absorber basin. Whereas, the desalination system with ridge gourd fiber yielded 1,600 mL for the same absorber area. In this regard, it is observed that the use of ridge gourd decreasing the yield because it is obstructing incoming solar radiation as well as it is not allowing to increase the water temperature and hence lowering the evaporation rate.

The same set of experiments was conducted on the second day to test the performance of setup with the change in solar radiation. The different temperatures of the desalination experiment without ridge gourd are plotted in Fig. 9 and the same temperatures with ridge gourd from the other desalination setup are plotted in Fig. 10. In the system without ridge gourd, it is observed that the water

Fig. 4. Absorber basin with *Luffa acutangula* (ridge gourd) fibers.

Fig. 5. Experimental Setup with ridge gourd and without ridge gourd.

temperature is high when compared with the system with ridge gourd. This is due to the obstruction of heat by the ridge gourd fibers spread over the water in the absorber basin. Because of this lower temperature, we can see the low yield in the setup containing ridge gourd fibers. As said earlier, the fibers are absorbing the water and are not capable of evaporating the water quickly which leads to a decrease in the evaporation rate and hence lower productivity at the end of the day. The ambient temperature and glass temperatures are mainly influenced by the incoming solar radiation and hence the curves are almost similar. The absorber and the water temperatures are mainly influenced by the ridge gourd fiber in the absorber basin. It is obstructing the rise of temperatures of water and basin because it is totally spread

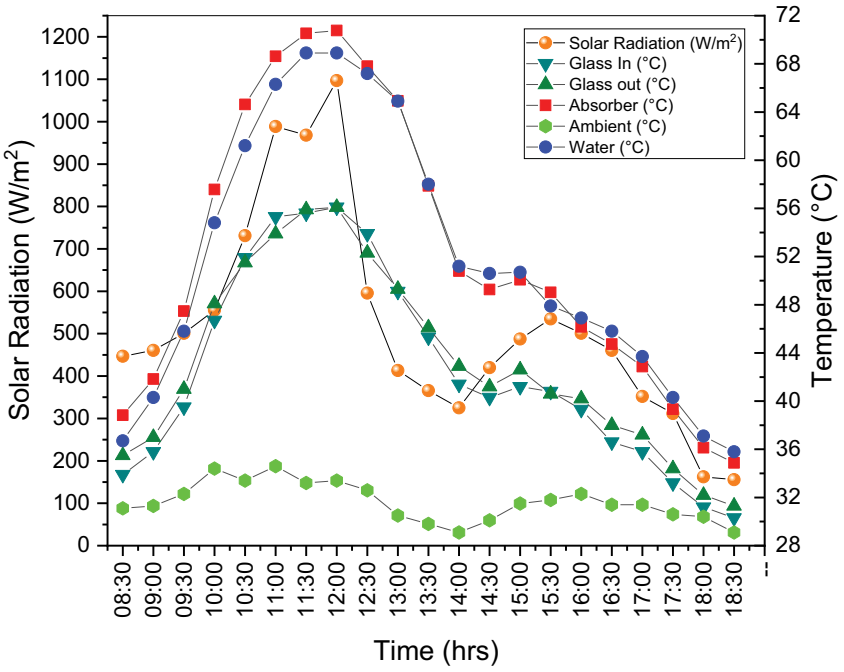

Fig. 6. Variation of solar radiation and different temperatures with respect to time and without ridge gourd.

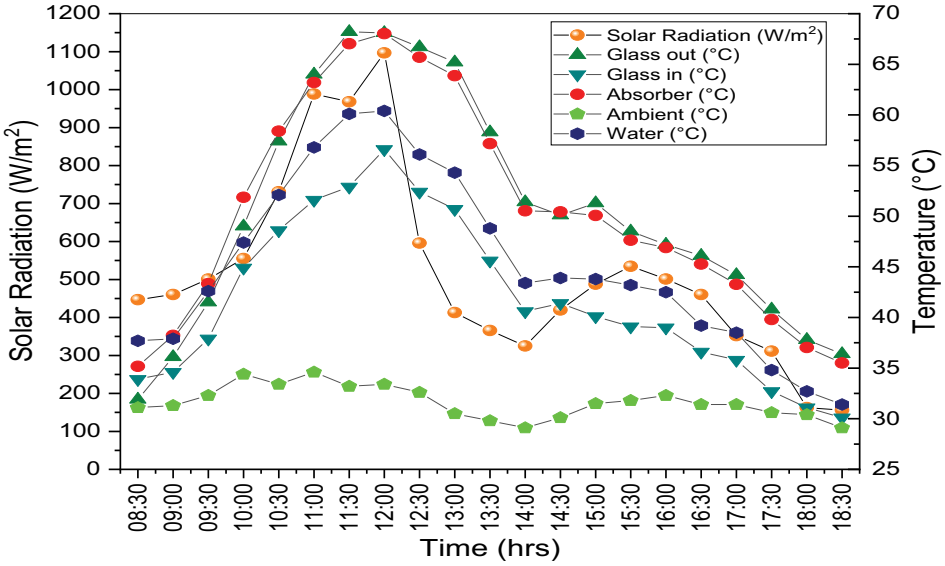

Fig. 7. Variation of solar radiation and different temperatures with respect to time and with ridge gourd.

over the water in the basin. Thus, the usage of the ridge gourd showing a negative impact on the performance of the single-slope solar desalination system.

In Fig. 11, it is clearly observed that there is a decrease in the freshwater yield with the inclusion of ridge gourd fiber in the desalination system. It is seen that the system without fiber yielded 1,550 mL for a 0.6 m^2 absorber basin on day 2. Whereas, the desalination system with ridge gourd fiber yielded 1,500 mL for the same absorber area on the same day. In this regard, it is observed that the use of ridge gourd decreasing the yield because it is obstructing incoming solar radiation as well as it is not allowing to increase the water temperature and hence lowering the evaporation rate.

From the above results, it is very clear that the usage of ridge gourd in the desalination setups giving a negative impact on the performance instead of increasing the evaporation rate, unlike jute cloths. In this aspect, the energy efficiencies of the setups are evaluated and it shows that there is a decrease in efficiency when the ridge gourd is used as shown in Fig. 12. However, the decreased percentage is almost negligible when compared to the system without ridge gourd. But, the ridge gourd fiber is not so effective in increasing

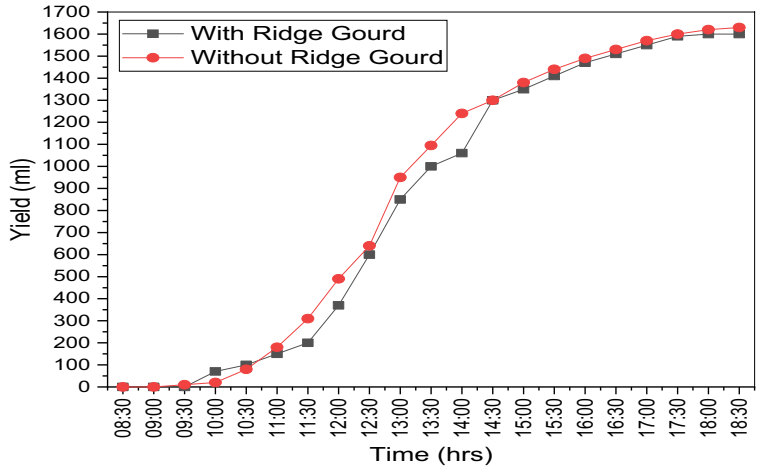

Fig. 8. Variation of distillate yield with respect to time in the desalination setup with and without the inclusion of ridge gourd fiber.

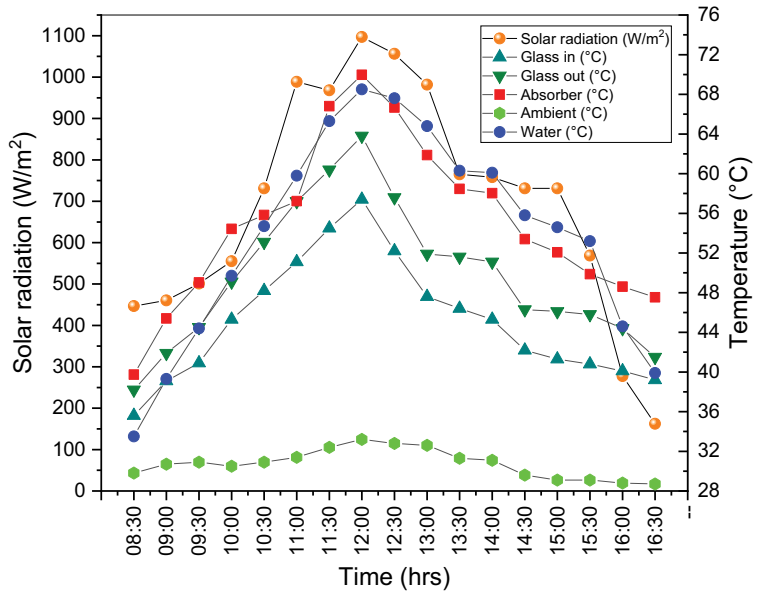

Fig. 9. Variation of solar radiation and different temperatures with respect to time and without ridge gourd.

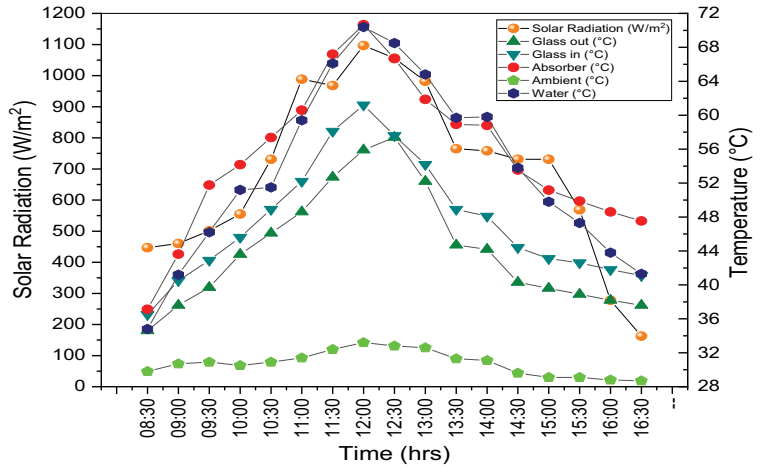

Fig. 10. Variation of solar radiation and different temperatures with respect to time and with ridge gourd.

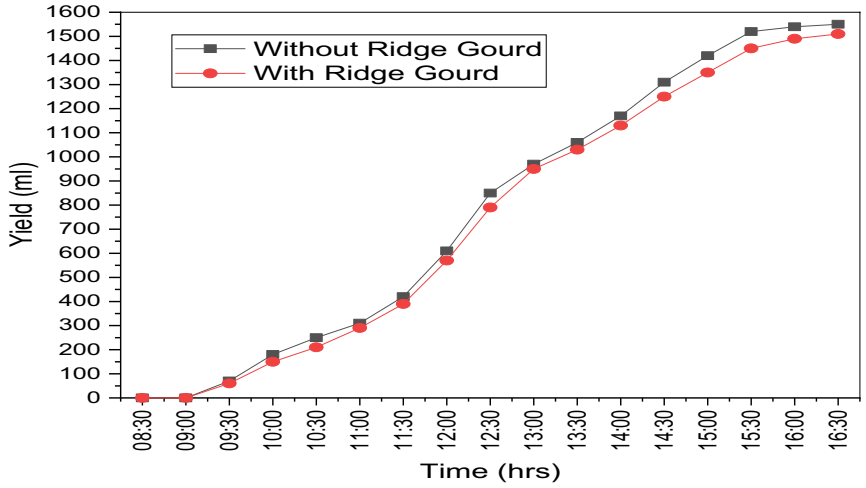

Fig. 11. Variation of distillate yield with respect to time in the desalination setup with and without the inclusion of ridge gourd fiber.

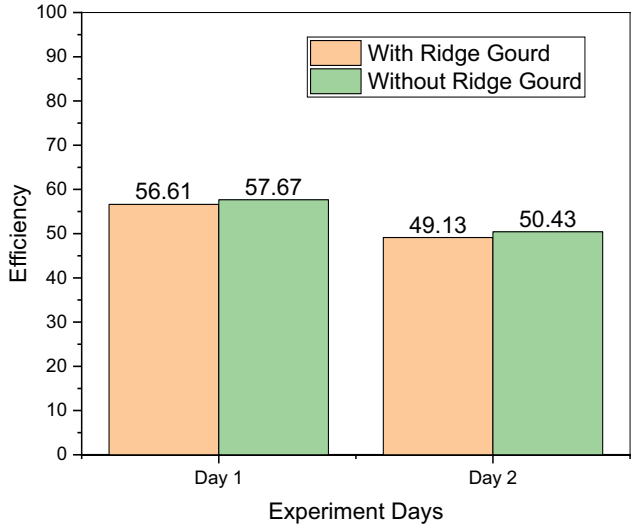

Fig. 12. Comparison of energy efficiencies for both configurations.

the yield and hence it is strictly recommended that the ridge gourd fiber should be not be used in the single slope solar desalination setups for better yield rate.

4. Conclusions

The current research primarily focussed on the usage of the ridge gourd natural fiber in the single slope solar desalination system for its better productivity. In this aspect, two single slope solar desalination setups with copper absorber basins of each 0.6 m^2 basin area are fabricated and evaluated for performance analysis. The results of the comparative study on the single slope solar desalination setup with and without ridge gourd fiber strongly oppose the use of ridge gourd fiber for further research in the path of enhancing the productivity in single slope solar desalination setups due to no significant impacts on the performance of the desalination setups.

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