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Effect of phase change material on concentric circular tubular solar still-Integration meets enhancement

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HIGHLIGHTS

- The present work elucidates the integration of PCM with CCTSS
- The PCM is loaded in the specially designed portion in the tubular solar still
- The results showed that the productivity of CPC-CCTSS with and without PCM were 5779 ml/m^2/day and 5330 ml/m^2/day

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ABSTRACT

In this work, a compound parabolic concentrator (CPC)-concentric circular tubular solar still (CCTSS) with phase change material (PCM) is presented. The experiment is conducted with and without PCM in the CCTSS. The PCM is loaded (450 g of paraffin wax/tube) in the specially designed circular trough of the tubular solar still. The water temperature (T_w), air temperature (T_{air}), outer cover temperature (T_{oc}) and fresh water production are measured in frequent intervals of time. The results showed that the fresh water production of CPC-CCTSS with and without PCM integration were 5779 ml/m^2/day and 5330 ml/m^2/day. Therefore, the PCM enhanced the fresh water productivity by 8%.

1. Introduction

Thermal energy storage (TES) is an environmentally friendly methodology that helps to decrease the gap between the energy supply and demand. Latent heat storage stores the heat in the phase change material (PCM). Compared with sensible heat storage, latent heat storage density is much higher. The research about PCM is popular because of this [1]. Al-Hamadani and Shukla [2] evaluated a solar still integrated with Lauric acid and Myristic acid as PCMs. The results showed that the Lauric acid integrated solar still enhanced the solar still productivity by 36%. El-Sebaii et al. [3] studied a single slope solar still with stearic acid as a PCM. The stearic acid was put in the basin liner with thickness of 0.2 cm. They concluded that distillate productivity 9.005 kg/m^2/day and daily efficiency 85.3% were obtained. The productivity equals 4.998 kg/m^2/day when used still without PCM.

Naim and Kawi [4] studied the paraffin wax with sodium chloride solution in the solar still. About 70 ml of aqueous sodium chloride solution with paraffin was placed beneath the solar still at 0.5 cm thickness. The results showed that PCM increases the productivity of the solar still significantly. Radhwan [5] conducted an experimental work in a stepped solar still with paraffin wax that acts as a PCM. The results showed that the stepped solar still with PCM has an efficiency of 57% and the productivity is 4.6 l/m^2/day.

A modified solar still using hot air injection and PCM has been experimentally studied by Kabeel et al. [6]. 17.5 g of paraffin wax was used in the basin. The results showed that the PCM integrated hot air injection modified solar still productivity is 9.36 l/m^2/day versus 4.5 l/m^2/day for convention solar still. Kabeel and Abdelgaied [7] studied solar still with paraffin wax (PCM) 17.5 g of paraffin wax was used in this study. The daily fresh water productivity was measured for solar stills with PCM as 7.54 l/m^2/day, and without PCM as 4.51 l/m^2/day. The PCM enhanced the overall productivity by 60%. Dashtban and Tabrizi [8] conducted an experiment in a weir type cascade solar still with PCM. 18 g of paraffin wax was used beneath the solar still to store the thermal energy. The results showed that the PCM enhanced the productivity by 31%. Chaichan and Kazem [9] studied a solar distiller using a concentrating solar water heater and PCM. The paraffin wax was selected as a PCM and it was placed beneath the basin liner. The results showed that proper tracking with a PCM in the distiller improved the system productivity by 307%.

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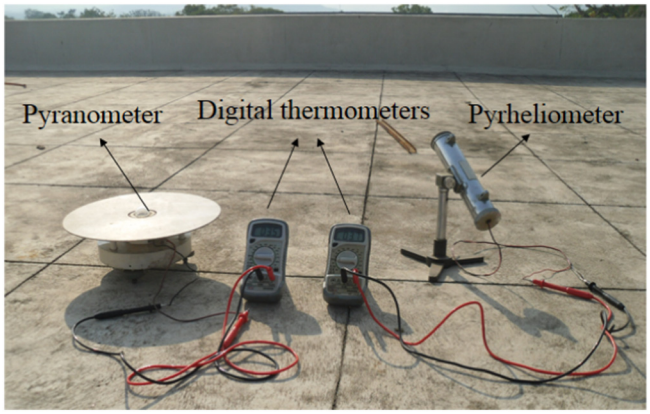

Fig. 1. Solar radiation measuring instruments.

Fig. 2. Circular water storage trough with PCM.

Rajasekar and Easwaramoorthy [10] conducted experiments on a solar still integrated with nano-composite PCM. A mixture of Al_2O_3 and paraffin wax was used. The results showed that for Al_2O_3 with paraffin wax mixture (nano-composites), the system efficiency was 45%, paraffin wax alone was 40% and solar still without thermal storage was 38%. Sathyamurthy et al. [11] studied a triangular solar still with paraffin wax as a PCM. From the experimental results, the paraffin wax enhanced the productivity by 35% as compared with a conventional solar still. Also, the productivity of with and without PCM in the triangular solar stills was 5.5 l/m^2/day and 3.5 l/m^2/day, respectively.

Concentrator powered solar distillation systems play a significant role in producing de-salted water. Presently many researchers are involved in these activities to accumulate high quality de-salted water through concentrator-assisted systems [12–16].

In this work a phase change material (PCM) was loaded between the tubular absorbers. Many researchers have worked in the field of desalination with PCMs in conventional solar stills. However, no research activities on tubular solar stills with PCMs were located. The PCM has been filled inside the specially designed circular portion of five tubular arrays with 450 g each. This configuration was tested and useful conclusions are drawn here.

2. Material and methods

Fig. 1 shows the photographic view of solar radiation measuring instruments. A 2 m CCTSS was designed and fabricated. The outer and the inner circular tubes (concentric) are put with a 5 mm gap for the flowing water in order to cool the outer surface for the inner tube. Paraffin wax (melting point 58–60 °C, latent heat 226 kJ/kg, density 818 kg/m^3, thermal conductivity 0.24 W/m°C and specific heat 2.95 kJ/kg°C) is used as the PCM in this research work. Here, the circular shaped trough is used to store the saline water. The circular shaped saline water storage trough is made up of copper. Two circular shaped troughs are joined with a gap of 5 mm for loading the PCM, which is shown in Fig. 2. The PCM is loaded in a specially designed portion of the absorber which is located at the bottom of the circular water storage trough. 450 g of paraffin wax was filled between two circular shaped troughs. The absorbers for the system are modified to introduce the storage effect with the help of the PCM. A circular strip was fabricated and two small pieces from the same material were welded in the two faces (front and back sides). The optimum level of saline water is filled inside the trough using a burette and blocked the all the sides without any air gap. The CCTSS is carefully placed over the focal point of the CPC for experimentation. The thermocouples are adjusted and fixed at the appropriate places to measure the temperature of the CPC-CCTSS. The climatic

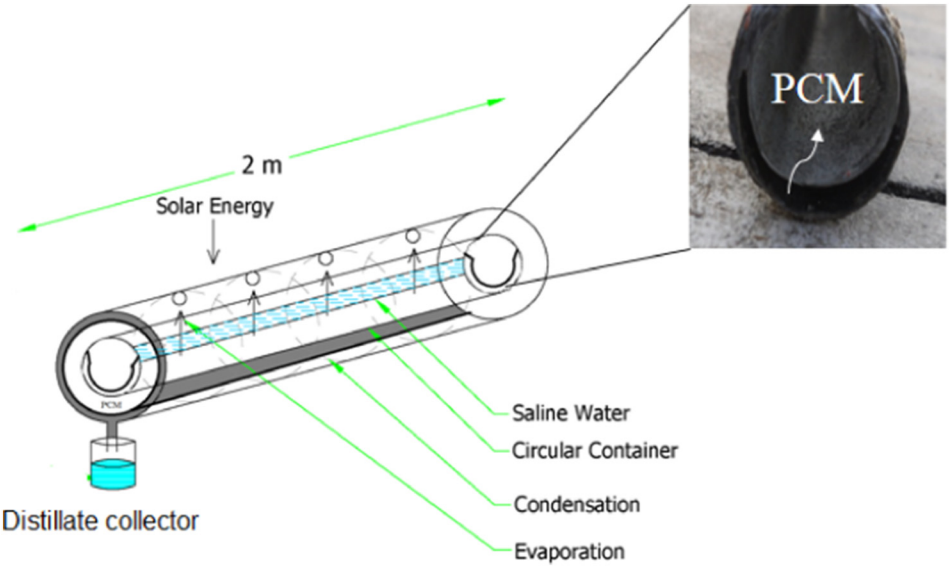

Fig. 3. View of CCTSS with PCM portion.