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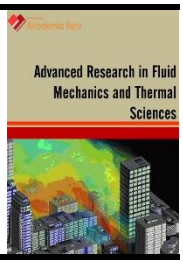

Enhancement of Fresh Water Production in Solar Still Using New Phase Change Materials

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ABSTRACT

This paper presents the method of enhancing the performance from a paired basin and four-lateral glass faces solar still with and without the latent heat thermal energy storage. For contrasting the output from solar still with and without the latent heat energy storage, the solar still is designing and installing. Experiments are conducted at East-West orientation in Karbala city at the end of October and the beginning of November. Polyvinyl pyrrolidone (PVP K-30), polyethylene glycol (PEG 6000) and carboxymethyl cellulose sodium salt (CMC), where used because of their chemical properties as latent heat energy storage. The hourly output is a little rising in the case from solar still without (LHTESS) through sunlit days. There is a raise from about 25% - 40% in freshwater output for (LHTESS) than that from solar still without (LHTESS). As well it was found that through the onward glitter time the pure water created of the solar still is increasing. A solar still for (LHTESS) is find to be increased according to the type of additive.

1. Introduction

The pure water availability was decreased rapidly by the use of water for human living purpose. The growth of industries also mainly depends on water. The world was surrounded by 70% of salt water. However, the human cannot use that salt water directly. That is why world research for an alternative method for produces pure water. There is a lot of purification process. However, some processes need external energy like electrical and thermal energy. The best way to produce water is desalination method from salt water. In solar water desalination, the production rate of water quantity depends on climate and intensity of temperature level. Thus, the request for desalinization technologies is rising. The evolution from a small size with effective desalinization units are prerequisite to instituting distinct water equipment in urban regions. That is the stimulus into research about alternate desalinization processes [1-3].

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Phase change materials ought to work as the thermal storage middle. PCM is a material with an elevated heat of fusibility which is fused and dissolves in a definite temperature, is to able from storing and liberation amount thermal energy. PCM alteration its phase via absorbing latent thermal energy through sun luminosity hours and drainage the stored thermal energy that is adequate into distillation purpose through hours sunshine [4, 5]. Through a fluffy coat from PCMs down the basin underlay from a solar still, a large amount from heat shall store in PCMs through sunshine hours instead of from extravagance at surroundings. Through freezing the PCM, the stored thermal heat energy drainage to keep basin water in temperature sufficient to manufacture pure water through the night until fluffy layers from basin water. Such reasons enhancement from still output especially through nighttime [6]. It was found that the chosen phase change materials depend accurately on the extreme temperature of brackish water. The performance enhancement was studied from the concentrator-coupled hemispherical basin solar still by means of phase change materials [7]. Because a phase change materials addition, productivity was raised. A performance from a solar still by means of three different types form PCM was presented experimentally [8]. Muhammad Saad *et al.,* presented a review paper for providing the roadmap of the potential application of hydrate technology in the field of water desalination [9]. Abbas sahi *et al.,* made an experimental work for new design of four glass faces solar still with East-West orientation in Karbala city. The daily efficiency was found to be 48% for ambient temperature of 24.9 ^{o}C [10]. Bala Abdullahi *et al.,* studied the effects of slope angle of solar collector and collection optimization which was done using ESS [11]. Aseel Hadi *et al.,* [12] and Farhan L Rashid *et al.,* [13] studied the effect of using nanoparticles on energy release and storage systems. Processes of desalination technology are either thermal utilizing both heat and electricity, or membrane which are based on electricity only [14-20]. Ahmad Tajuddin *et al.,* used inorganic salt hydrated phase-change material (PCM) based on calcium chloride hexahydrate ($CaCl_2 \cdot 6H_2O$) to characterize phase change behaviour such as the super cooling degree and phase change temperature [21]. Nor Azwadi et al. provide a comprehensive review, which summarizes recent research progress on PCM-CTES and an overview of numerical and experimental studies on the heat transfer performance of different base fluid of PCMs [22].

The aim of this work is to study and evaluate the productivity of four-lateral glass faces solar distiller in Karbala-Iraqi weathers.

2. PCMs Storage Material

The PCM storage material, Polyvinyl pyrrolidone (PVP K-30), polyethylene glycol (PEG 6000) and carboxymethyl cellulose sodium salt (CMC) is used for the performance study of four-lateral glass faces solar distiller. The PCMs were diffusion at a constant thickness of 10 mm at the Aluminum fund. The PCM storage material can store a large amount from thermal energy and also boost the thermal capacity in the basin. (PVP K-30), (PEG 6000) and (CMC) is an engaging matter for thermal storage applications. Phase change materials (PCMs) are materials suitable for heat energy storage. They utilize chemical binds in storage and releasing heat. The thermal energy transfer occurs when a material changes from a solid to a liquid or from a liquid to a solid form. That is purported a change at status or phase at first these liquid-solid PCMs lead to such as traditional storage materiality: their temperature a high due to them absorb solar thermal energy. Unlike traditional thermal storage materiality, when PCMs arrive at the temperature for which they changing phase, they absorb more amounts from thermal energy without acquiring hotter. When an ambient temperature at the void about the PCM material declines, a phase change material reinforces, and liberation its latent thermal energy stored. PCMs, absorb and issue heat with maintaining almost stationary temperature. Guarantee the human repose and electronic instruments tolerance extent from 20 °C to 45 °C, the

latent thermal storage materials are so much efficient. They are likewise helpful for adjusting the day's temperature at night.

3. Experimental Work

Figure 1 and 2 show a schematic diagram and photographic views of two stainless steel basins solar still utilized into the current study. One consists a rectangle basin stainless steel which possesses an efficient area of 1.25 m2 and length of 1.250 m and width of 1m which is designed for operation, and the depth of the basin at the front and rear side is 0.1m and its uniform throughout the cross-section. The other one is a bigger basin of the length of 1.270 m, the width of 1.020 m, and an altitude of 0.110 m. The smaller basin is inserted in a bigger basin. The gap between two basins is maintained to be 10 mm by using small metal strips which are welded between two trays to hold them. This gap is provided to store PCM. The thickness of stainless-steel plate is (1.1 mm), be the top covering from glass and thickness 6 mm. The tilt angle of the cover glass is 32° and this faces the east-west orientation. The gap between two basins of stainless-steel metal is filled with 18 L of the certain mixing ratios of the Polyvinyl pyrrolidone (PVP K-30), polyethylene glycol (PEG 6000) and carboxymethyl cellulose sodium salt (CMC) with a certain weight percent. The total installation is made compact with the assist of clamps and elastic gasket. From the inlet valve to the basin, water enters and a floater is fixed inside the basin to maintain water level is constant on 6 cm. The basin was surrounded by a wooden box and it was insulated from the bottom and sides by (3 cm) thickness of insulation glass wool used to reduce a heat conduction loss. The condensed (distilled) water is at the inside glass surface and drops along the lower brim of cover. The distilled water was assembled in a flask and its measurement by graduated vessel. Thermocouples of type-K are used in the measure a temperature and which are installed at different places in a solar still such as basin water, inside surface glass cover, outside surface glass cover, ambient temperature, and vapor temperature.

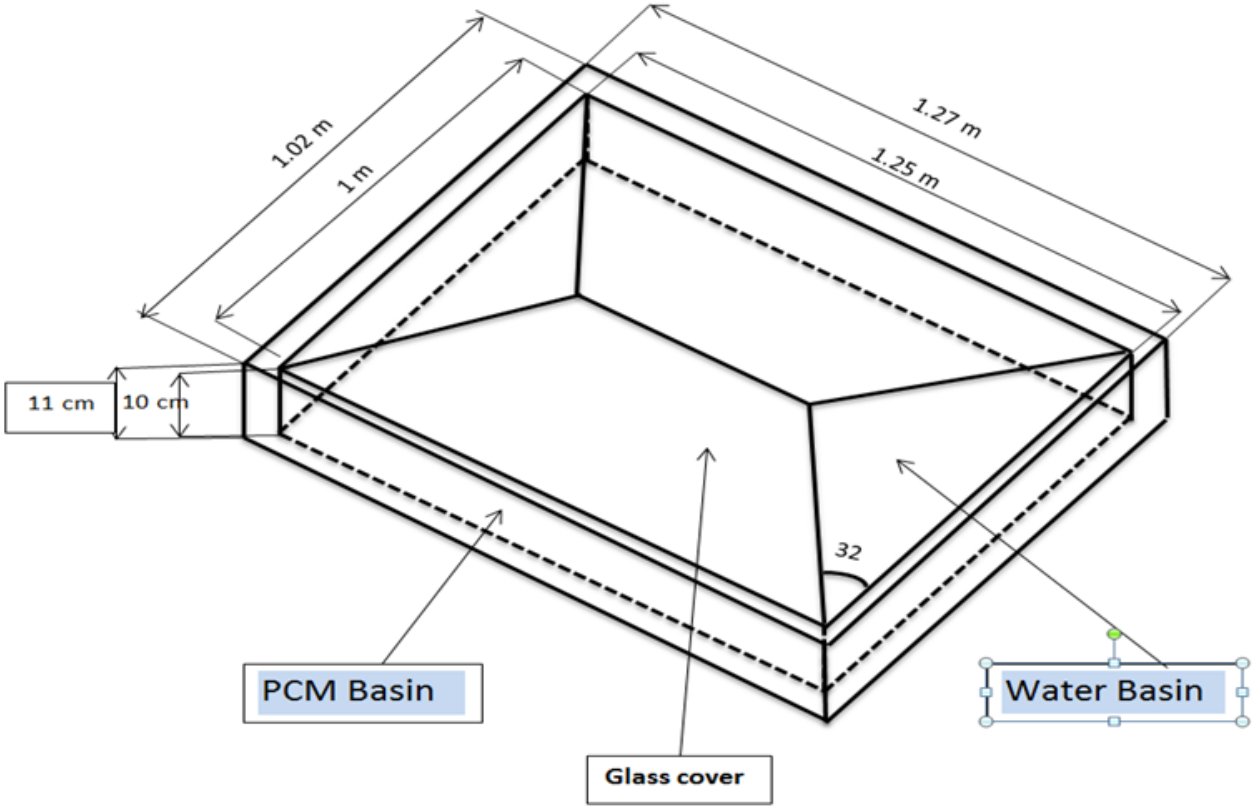

Fig. 1. A schematic diagram of the solar still

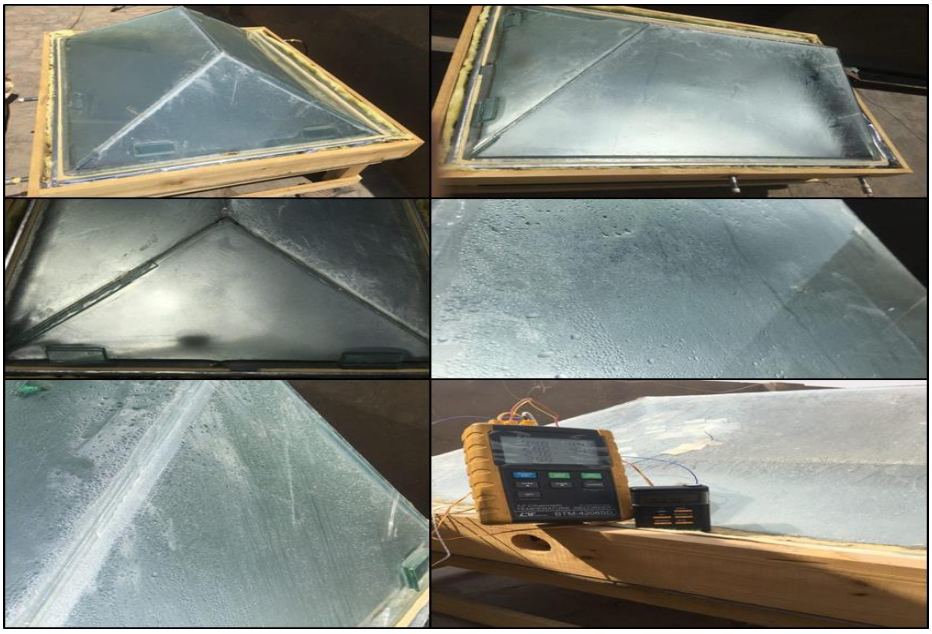

Fig. 2. Photographic views of the solar still

3.1 Principle of Solar Desalination

The solar still basin possesses a thin water stratum, a diaphanous surface glass cover on top of the water is wrapped and the basin conduit for assembling the distilled water of basin solar still. A glass covers surface transfers the rays of sun through it to saline water within the solar still or water basin is to be raised a temperature through solar radiation that passes into a glass cover surface and absorbs via the undermost the basin solar still. At the solar still, a temperature variation between a surface glass cover and water is the driving force for the freshwater production. Vapor inflow upwards of the hot surface water in basin and condensate on the inside surface glass cover. This condensate distillate water is assembled through the canal.

3.2 Measurement Devices

Solar power meter (TES- 1333) is utilized to measure the direct solar radiation, SD card data logger 12 channels, graduated vessel. The graduated vessel is utilized to measure a volume of fresh water distilled from basin solar still. Thermocouples of type-K are used to measure a temperature at inside and outside surface glass cover, ambient and vapor temperature.

4. Results and Discussion

Outdoor experiments are conducted in a single basin with and without PCM at different certain mixing ratios during 8.00 Am to 22.00 Pm hrs. In a day with the maximum intensity of solar irradiation and the temperature of water, glass, basin and ambient temperature in every one-hour time interval are measured.

Produce of the solar distillation be dependent on the happening solar radiation. The Figure 3 presents the difference in solar irradiation influx with time. It is observed to increase with time over to 1:00 Pm with utmost influx reaching into 720 W/m2. Solar radiation is increased of the morning until afternoon at 1:00 PM and then it in the tapering order.

Figure 4 and 5 indicate the difference in water temperature and basin temperature with time, respectively. Both temperatures are observed to increase and arrived at the utmost value (45°C).

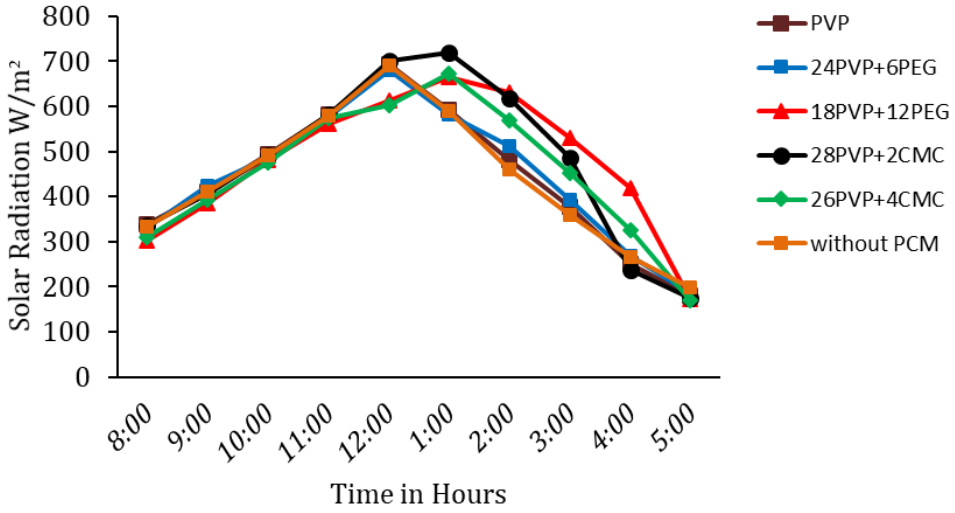

Fig. 3. Variation of solar radiation with time

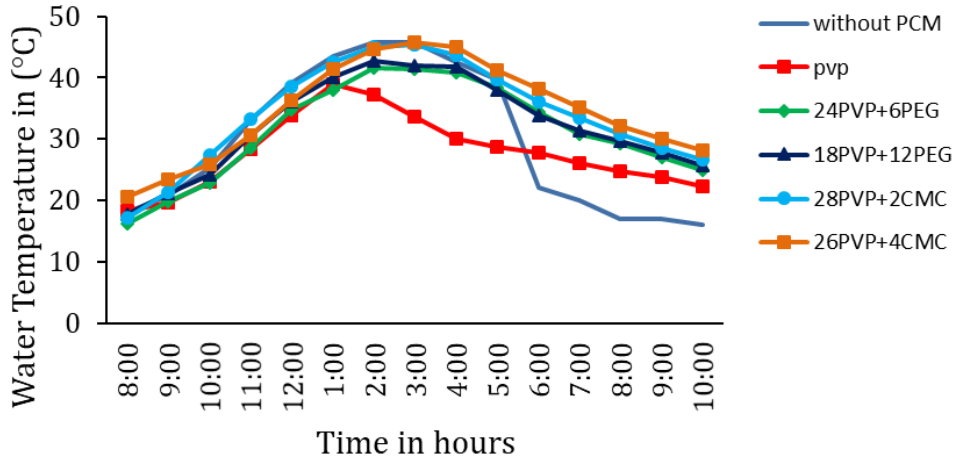

Fig. 4. Variation of water basin temperature with time

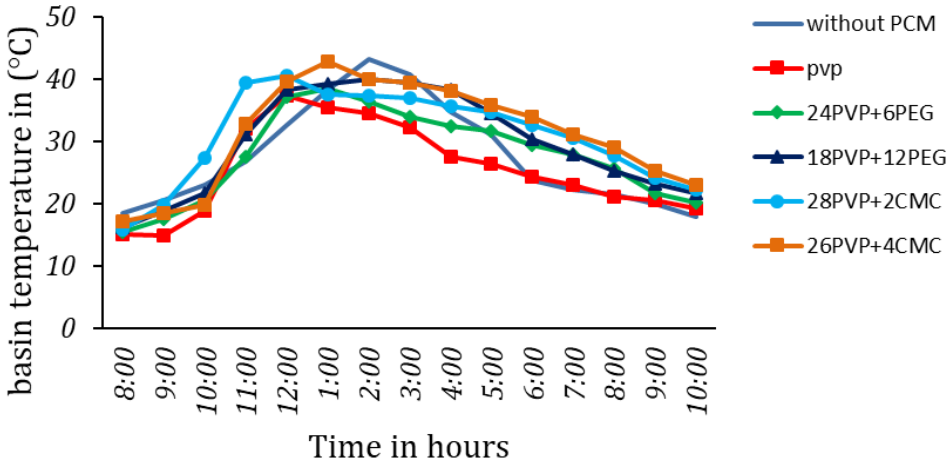

Fig. 5. Variation of basin temperature with time

Figure 6 shows water vapor temperature during the operating period of solar still. It is obvious that water vapor temperature increases with increasing solar intensity and phase change material variation, the maximum value at (1:00 to 4:00 pm). This indicates that the amount of water evaporated at this time period is the greatest value.

Figure 7 and 8 present the quotidian variation of glass inside and outside temperatures, respectively. From knowledge, it is important to have a difference in temperature between the inside and outside solar distiller to achieve the greenhouse phenomenon required to be a driving force for fresh water production. It is observed that the variation between the outside and inside glass cover temperature was (7 to 12 C°) at the peak (12:00 to 2:00 pm) due to touching of wind to the external from glass cover surface which reduces the temperature at this surface.

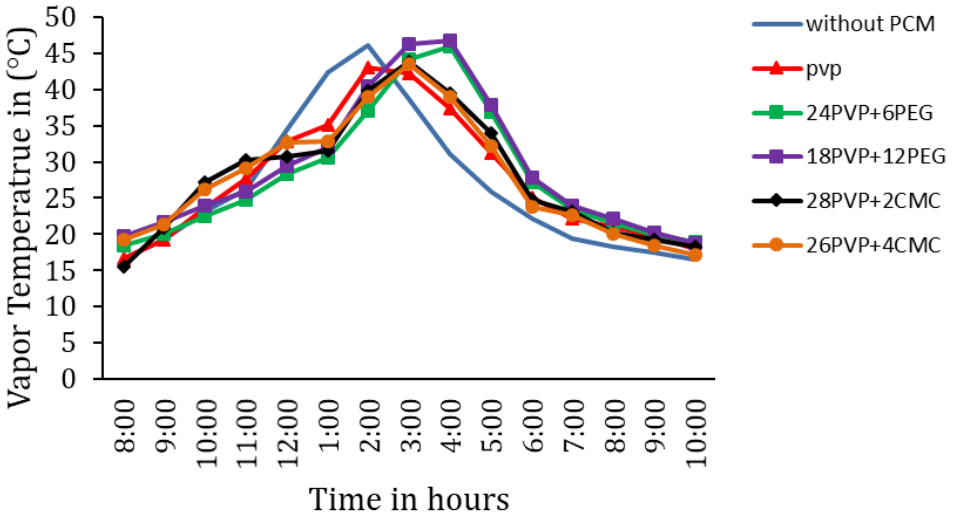

Fig. 6. Variation of vapor temperature with time

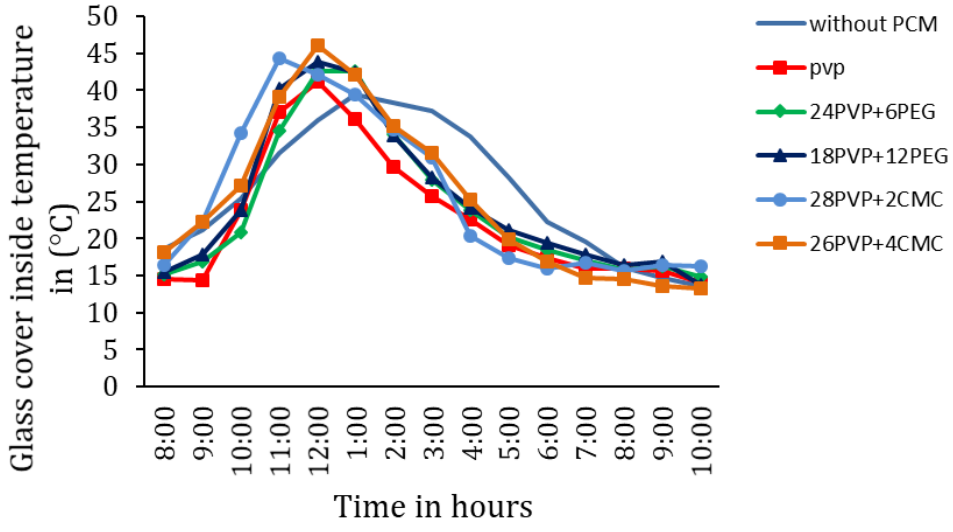

Fig. 7. Variation of glass cover inside temperature with time

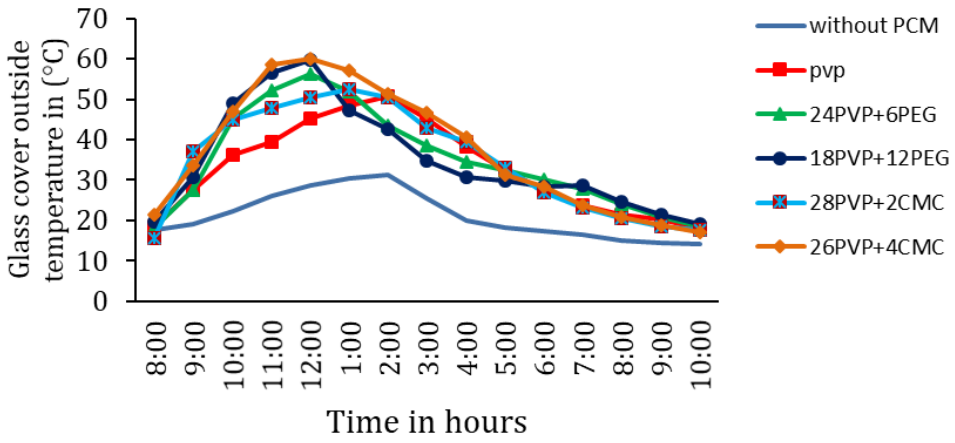

Fig. 8. Variation of glass cover outside temperature with time

Figure 9 shows phase change materials temperature during the operating period of solar still. It is obvious that phase change materials temperature increases with increasing solar intensity the maximum at (2:00 to 3:00 pm). The PCM temperature was increased with increasing CMC concentration and the largest value occur with (26 gm of PVP and 4 gm of CMC).

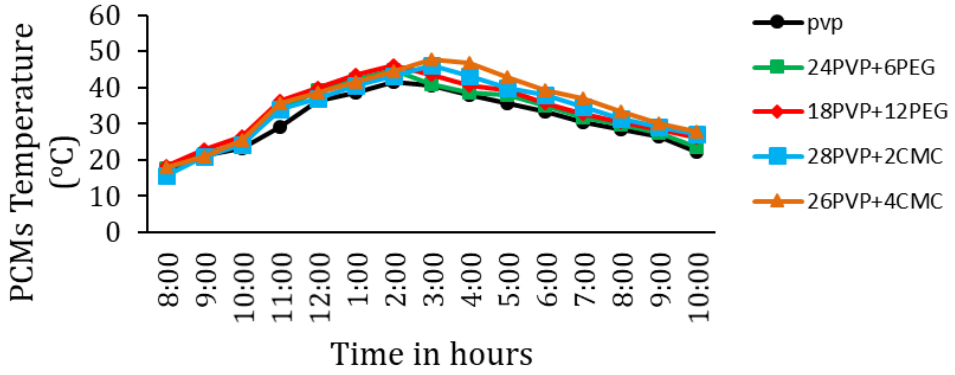

Fig. 9. Variation of PCMs temperature with time

Figure 10 presents the difference of the daily solar still distillate output with time into a solar still without PCMs and solar still when used different PCMs. It can be observed that over the full range from the insolation day time, a distillate output from the solar still for PCM is greater than that for solar still without PCMs.

A distillate output from the solar still with PCM is increased by about 20% to 110%. This is because when using PCM the system working time will increase from 3 to 5 hrs. Moreover, PCM increases the thermal resistance for losing heat.

Figure 11 presents the relation between the hourly overall thermal efficiency and the tested time. The systems efficiency associate with PCMs type used in test and solar intensity. It arrived at its top value at 5 PM. Next, this hour PCM distillers showed topmost efficiencies particularly with (PVP+CMC). With regard to this distiller, an average extreme efficiency realized was 28.2 % for the tested period.

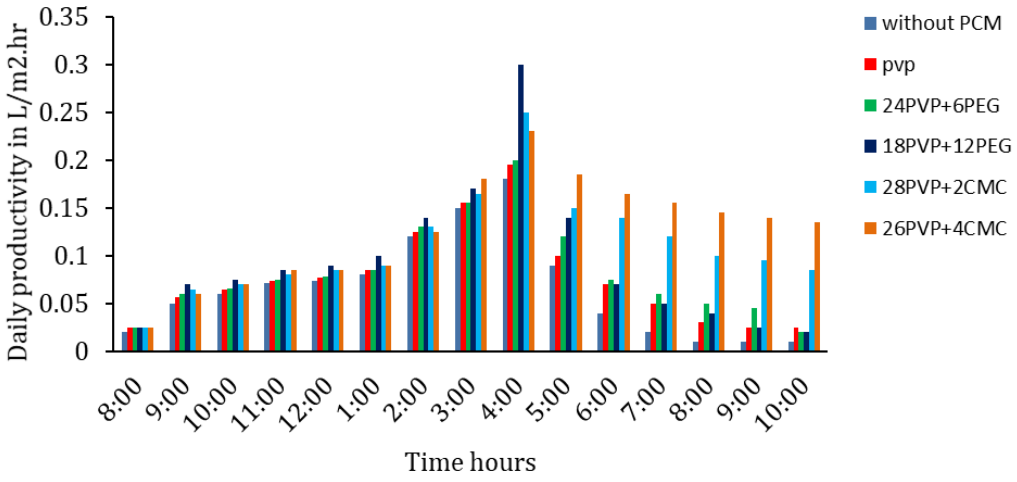

Fig. 10. Variation of daily productivity with time

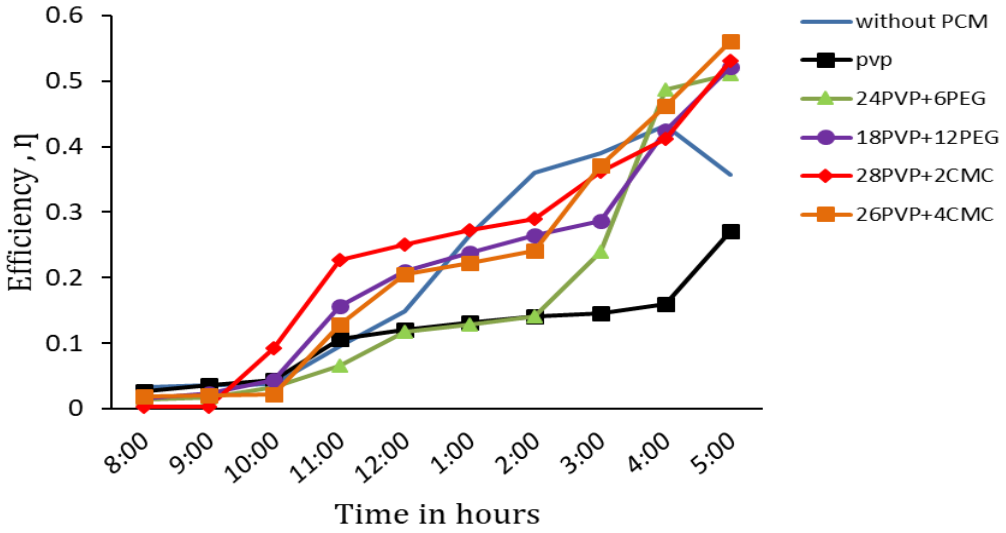

Fig. 11. Variation of the overall thermal efficiency with time

5. Conclusions

In the current study was the focus has been on designing and building of effective solar distillation system. Produced pure water by means of a solar still with its accessibility would be one from the better solutions to equipping pure water together with no technical equipment. In the current study experimental, mixing of Polyvinyl pyrrolidone (PVP K-30) and carboxymethyl cellulose sodium salt (CMC) in water could economize the best yield when compared with that from Polyvinyl pyrrolidone (PVP K-30) only or Polyvinyl pyrrolidone (PVP K-30) and polyethylene glycol (PEG 6000) utilize as Phase Change Materials. Maybe it's because higher heat storage and melting point temperature are higher than that of polyethylene glycol (PEG 6000).

i. It has been proved that the output from the solar still can be greatly enhanced via the utilize of phase change materials. The distillate output from the solar still with PCM is increased by about 20 to 110%.
ii. Using PCM increases the system working time by 3 to 5 hrs.
iii. PCM properties are a very important factor to enhance still productivity.
iv. PCM decrease the total heat lost from the still.

v. In the present study, mixing carboxymethyl cellulose sodium salt (CMC) with Polyvinyl pyrrolidone (PVP K-30) is consider the best PCMs at which maximum solar still productivity has been obtained and maximum heat storage period in the test.

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