

Solar Desalination by Using Phase Change Material (PCM)

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ABSTRACT

Estimating the growth of population and industrial development leads to demand of water resources. Water resources covered the one third of the earth, in these less than 1% is suitable for industrial and domestic uses. With rapid growth of population, industrial development leading to deforestation and declination of water. This leads to scarcity of drinking water for growth of population. To overcome the crisis an alternate solution is rain harvesting and desalination. Because of the climate change due to pollution rainfalls is decline year by year. The best solution of this crisis is the process of desalination. Direct and indirect methods are used for desalinate the sea water to the freshwater. Most of the methods like desalination, Multi stage flash distillation and reverse osmosis, are energy depended and consume electric power and fossil fuels. Demands water is more so supply should be less expensive, so solar desalination is better compared to conventional methods. The main objective of the proposed project is that by using free energy converting the saline water to the necessity water by using principle of the thermal and low-pressure vessels leads to change in latent heat and sensible heat. Possible outcome is to provide suitable combination to get better yield of drinking water from saline water. The efficiency of solar still varied for the beam radiation of 312.5 W/m^2 to 925 W/m^2 . A maximum distilled yield is 1.5 to 2.2 L/day is obtained with 0.54 m^2 area.

KEYWORDS

phase change material, energy saving, solar energy, solar desalination.

INTRODUCTION

In our solar system, the sun is only star which is situated at its center. Solar radiation from sun upholds nearly all life on earth through photosynthesis and propels the weather and earth's climate [1]. Sun's mass involves of 25% helium, 74% hydrogen, and the residue is made up of vestige quantities of heavier elements. The surface temperature of sun is about 5500 K, which gave a white appearance to the sun, due to atmospheric scattering, which exhibit yellow color. The process of generating energy in the sun is due to nuclear fusion of hydrogen to helium nuclei. The main source of energy to the earth surface is sunlight that can be harnessed through a variety of synthetic and natural processes. The photosynthesis is the most important that used by plants to apprehend the solar radiation energy and transform it to chemical form. Predominately, photosynthesis is the process of glucose synthesis from carbon dioxide, water, and sunlight, with oxygen as a dissipation product [1]. Solar-thermal plants apply different techniques to concentrate the energy of sun as a heat source [2, 3].

Solar desalination process is the use of solar energy to heat and then evaporate water and gather its condensate water in a suitable storage vessel. This process different from other ways of water purification by turn brackish or salt water into fresh drinking water. Also solar desalination unlike other forms of water purification that more energy bushy, such as simply boiling water due to its use of free energy, and reverse osmosis. The natural water cycle that the earth experiences is the largest example of solar desalination process [4]. Solar stills or solar water distillers are commonly used in distant zones where there is restricted incoming to fresh water. The main principles of solar desalination process are simply as the way nature makes rain. A solar desalination unit works on two scientific principles: evaporation and condensation phenomenon. The minerals and salts do not evaporate with the evaporated water because of their high weights compared with water. As instance, table salt does not transform into vapor until it reaches to a temperature above 1400°C . However, a specified quantity of energy is required to

raise the temperature of one kilogram of water from (0 to 100) °C, it receives five and one to half times that much to change it from water to water vapor at same temperature (100 °C). All this energy is return back when the water vapor condenses into water liquid. Most of solar stills are simple black bottomed containers filled with salt or brackish water and covered with clear plastic or glass. The black material absorbs sunlight and speeds the evaporation rate. The evaporated water is then circulated by the clear topping glass and centered on funnel. Most impurities do not evaporate and they are left in the bottom of solar still. In order to produce enough fresh water for one person in a day, solar stills need to be about six square meters in volume. To produce a large quantity of purified water, multiple solar desalination systems are needed [5]. There are many variation on the topic of the normal single-slope basin solar still and these can be one of two denominations: passive or active. Passive stills are more conventional, Active stills can obtain waste heat from different sources. A good insulator is need to reduce losses (thermal) and extend the evaporation process into the night period [6]. Researchers [7-27] used different ways for saving solar energy to be used in many applications such as solar desalination, energy saving and release, etc. The aim of this work is to find out the performance and calculate the productivity of the solar still in Babylon-Iraqi weathers.

EXPERIMENTAL PART

Components of the direct solar water desalination

Wood

It is used as insulator which does not allow the heat to pass out. Plywood, shown in fig. (1) of 15 mm thick is used for this setup.

Specifications:

- a) Density- 2400 kg/m³.
- b) Thermal conductivity- 0.0065 w/m K.

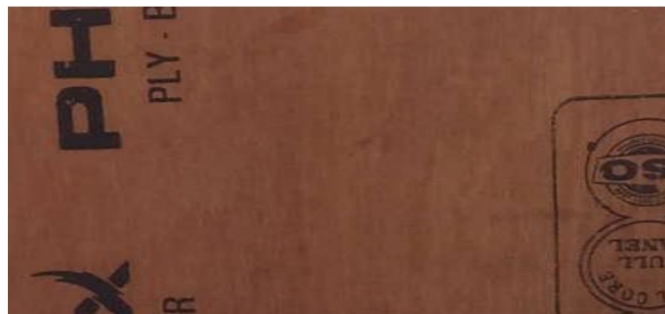


Figure 1. Plywood used in the experiment

Stainless steel

It placed above the wood and water is fed on top of this sheet, shown in fig. (2). Absorbing more amount of heat and transfer it into water can be done by stainless steel.

Sheet of 3mm thick is used for our system.

Specifications:

- a) Density- 8 gm/cm³.
- b) Latent heat of fusion is 25300 J/kg C). Thermal conductivity- 16.2 w/m K.



Figure 2. Stainless steel sheet

Glass

The main purpose of using glass is that it condenses the water vapor. This glass is tilted to an angle so that maximum solar radiation can pass through it.

Specifications:

- a) Thickness - 4mm.
- b) Transmittivity-89%.
- c) Density-2500 kg/m³.

Glass wool

The insulator material is made of glass fibers putted by a binder into a texture. The small pockets were used to trap air, and these small pockets results in high thermal insulation.

Specifications:

- a) Density- 10-100 kg/m³.
- b) Thermal conductivity- 0.04 w/m K.

Black rubber

Black Silicone Rubber Sheet 0.1-3mm thick high temperature resistance to prevent water vapor leakage.

Thermocouple is a means used to measure temperature. These thermocouples involves of two wire legs made from several materials.

Specifications:

- a) Temperature range from -270 °C to 1260 °C
- b) Material: positive leg is involved of 10% chromium, 90% nickel, and a negative leg is involved of 1% silicon, 2% manganese, 2% aluminum, and 95% nickel. These thermocouples had voltage output (-6.4 to 54.9) mV and sensitivity of (41µV/°C) over maximum temperature range.

Phase Change Material (PCM)

The physical behavior of these material involves change in the phase from liquid to solid, and from solid to liquid, which are used for storing and releasing heat. In these materials, energy is stored for use at another time when disappeared the energy source. In this work, the Polyethylene Glycol (PEG 6000) is used, which is showed in fig. (3).



Figure 3. Polyethylene Glycol (PEG 6000)

Paint

Using black paint to absorb heat. The coating Rust-oleum painter 97% The coating black to high absorber.

Specifications:

- a) high absorber
- b) water prove
- c) fast drying

Experimental Work

Figures (4) and (5) present the schematic and photographic view of the experimental set up, respectively. The basin of solar still has an active area of 4050 cm^2 , made of stainless steel sheets with 3 mm thick, length of 90 cm, and width of 45 cm. The basin of solar still is insulated from the PCM basin to avoid the effect of PCMs on the water productivity, and to avoid the mixing of water in the basin of solar desalination with PCMs. PCM of 4.5 kg is filled the gap between the two basins. The upper part of solar still is made of 4 mm transparent glass located with angle of 34.56° . To insulate the solar still basin from the bottom and four sides, it is required to use glass wool of 5 cm thickness and then it has been placed in a wooden box to increase the insulation and reduce the energy loss. Along the lower section of solar still glass cove, a channel is placed along to direct the produced fresh water, and then send it to an outer graduated vessel. There is a floater at the bottom of the solar still basin, used to preserve the water level at constant height of 3 cm. Thermocouples of k-type are used in measuring temperature and are located at different locations in the solar desalination unit.

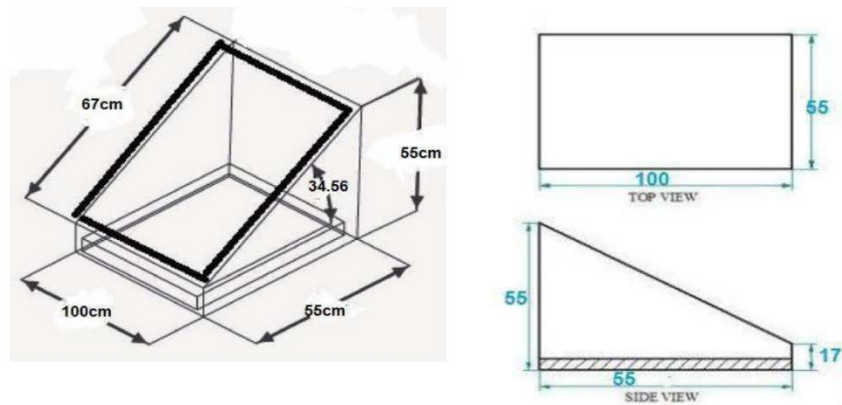


Figure 4. The schematic diagram of solar still



Figure 5. The photographic diagram Solar Still System

RESULTS AND DISCUSSION

Desalination without PCM

Experimental analysis has been made to study the effect of solar radiation, and phase change material on the system performance. The variation of water temperature in the system for a different interval of time as shown in the figure (6). The temperature of water in the system is high at noon where higher solar radiation is obtained.

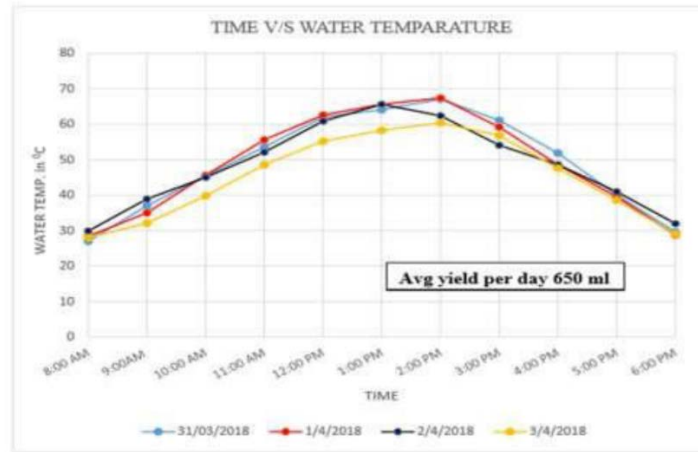


Figure 6. Variation in glass temperature in hourly basis for different time intervals

As the intensity of solar radiation increases, yield also increases. From the figure (7), we can see that from noon 12 to 2 pm there is more yield because the intensity of solar radiation is more at that time. Radiation in the evening is less compared to noon and hence the yield will be less.

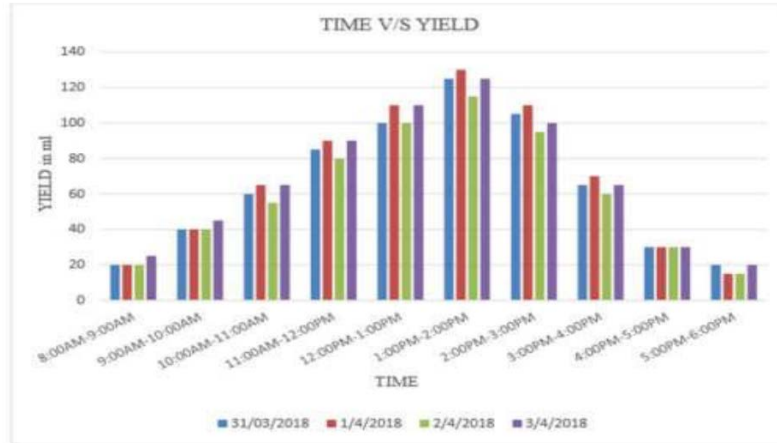


Figure 7. Variation in distillate yield for different interval of time

Solar radiations fall on the water by passing through the glass. The glass transmits the radiation and by doing that it absorbs some heat and the temperature of glass increases. From figure (8) we can observe the temperature of the glass for a different interval of time. The temperature of the glass is similar to that of water temperature.

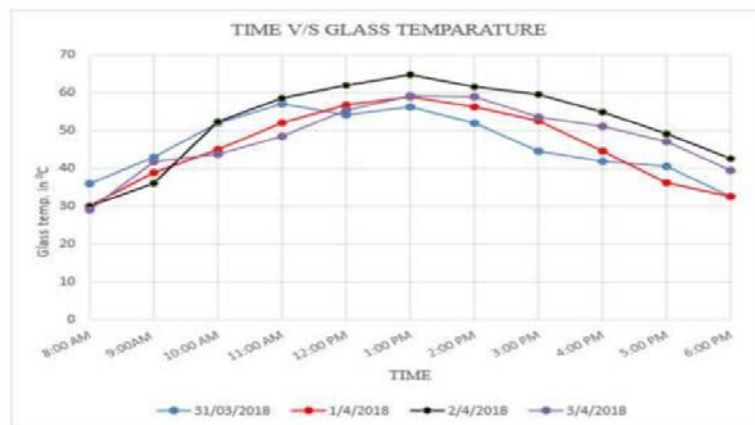


Figure 8. Variation in glass temperature for different days of experiment

Desalination with PCM

Desalination with phase change material increases the yield. As we can see from the figure (9), at the night we can get some yield. Implementing PCM reduces the water temperature compared to desalination without PCM. The overall output will be more compared to desalination without PCM.

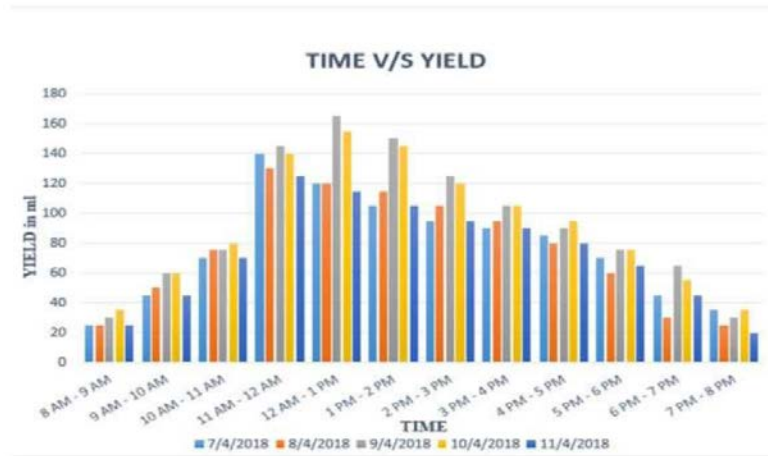


Figure 9. Yield of distilled water with respect to time

Water the temperature during day time is less in this system compared to desalination without PCM. Figure (10) shows the variation in water temperature with time. As we can see from the graph, the temperature of the water during night time is more compared to other systems because of PCM.

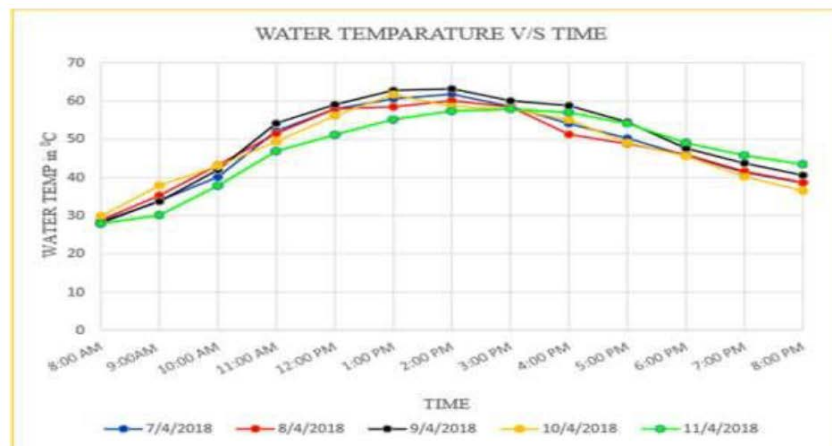


Figure 10. Variation in water temperature

The figure 11 shows the variation in PCM temperature concerning time. The PCM temperature will be similar to that of room temperature initially and gradually temperature of PCM increases by absorbing the heat. Due to latent heat, the phase change takes place from solid to liquid and vice-versa. From the graph, we can see that the temperature of PCM decreases after 5 pm, because it liberates the heat absorbed into the water.

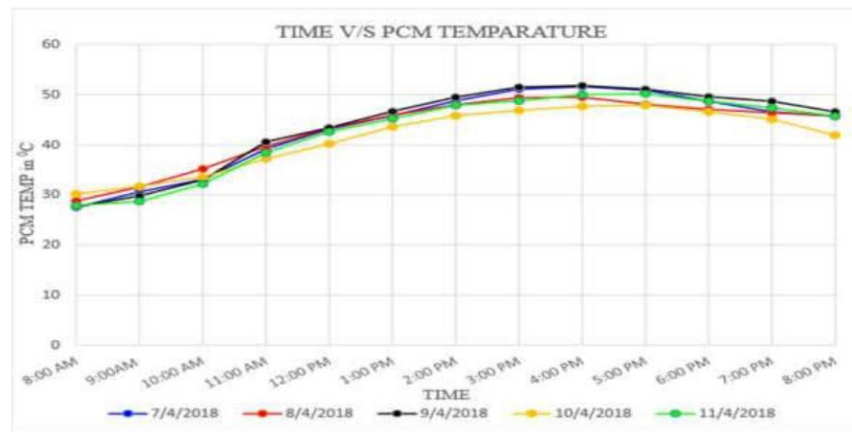


Figure 11. Variation of glass temperature with time

CONCLUSION

The present paper studied the possibility of using free energy converting the saline water to the necessity water by using principle of the thermal and low pressure vessels. Possible outcome is to provide suitable combination to get better yield of drinking water from saline water, the following conclusions can be obtained:

- The water extracted from the saline water is distilled and is not portable water. So to get portable water, we have to add some minerals.
- The water level inside the chamber also affects freshwater production. As the water level decreases, yield increases.
- If the mass of PCM increases, then the absorption of heat by PCM will be more which reduces the yield.
- Glass thickness also affects freshwater production. If the glass used is of less thickness, then the output will be more.

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