Desalination 367 (2015) 180–185

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

# Experimental analysis of a portable solar still with evaporation and condensation chambers

Ravishankar Sathyamurthy [a,*], S.A. El-Agouz [b,*], Vijayakumar Dharmaraj [c]

[a] Department of Mechanical Engineering, Hindustan Institute of Technology and Science, P.O. Box 1, Rajiv Gandhi Salai, Kelambakkam, Chennai 603103, India
[b] Mechanical Power Engineering Department, Faculty of Engineering, Tanta University, Egypt
[c] Department of Mechanical Engineering, Veltech Multitech Dr. Rangarajan Dr. Sakunthala Engineering College, Avadi, Chennai, India

## HIGHLIGHTS

- A single slope portable solar still with phase change material was designed.
- PCM divide a single slope portable still into evaporating and condensing chambers
- The maximum efficiency of 14% of the solar still with PCM is achievable.
- After sunset, PCM acts as a heat source and more than 34% of total yield is given.
- Daily yield obtained with PCM is 52% more efficient than obtained without PCM.

## ARTICLE INFO

*Article history:*
Received 14 February 2015
Received in revised form 9 April 2015
Accepted 10 April 2015
Available online 14 April 2015

*Keywords:*
Productivity
Inbuilt condenser
Evaporation
Portable
Phase change material

## ABSTRACT

In this paper, a new model portable solar still is designed, fabricated and tested in the summer conditions of Chennai climatic condition. The phase change material is used in order to divide a single slope portable solar still into evaporating and condensing chambers. The result shows that a maximum efficiency of 14% of the solar still with phase change material is achievable. The accumulated yield and obtained with PCM is 52% more efficient than accumulated yield obtained without PCM. The still continues to produce fresh water after the sunset. More than 34% of total water production is pertaining to this time.



## 1. Introduction

Solar energy is one of the important natural resources which is used for desalination, producing thermal energy for evaporating saline water [1–4]. Solar stills are the oldest techniques used to convert saline water into fresh water. The principle operation behind the solar desalination is the greenhouse effect. Solar desalination has been classified into two subdivisions, namely; active and passive solar stills. The major advantage of passive solar still over active solar stills was that it requires an additional thermal energy enhancement like solar collectors and heat pipes for increasing the temperature of water. Solar desalination is the traditional method of getting fresh water and it is a simpler method while compared to other techniques. It consists of a transparent cover through which heat is supplied to heat up the saline or brackish water. The evaporated water reaches the cover where the water is condensed by releasing its latent heat to the surroundings. The collected water on the cover trickles due to the gravity collected in the channel as distillate. There are several methods employed to improve the productivity of the still with sensible heat storage materials like gravel, stones, concrete pipes, charcoal, wicks and mild steel scraps [5–8] and latent heat storage with phase change materials [9–13] for enhancing fresh water production. Coupling the flat plate collectors [14], reflectors [15,16], and thermo-electric [17] devices improves the efficiency of producing. On the geometry aspect using a triangular pyramid solar still [18–22], pyramid type [23,24], hemispherical cover [25], tubular solar still [26–31], hemispherical absorber [32], inverted absorber [33–37], and concave wick type [38] has a greater improvement in fresh water production. Additional improvements were achieved by separate condensers [39–44] as well as multiple-effect stills [3,45–48], and computerized sun tracking devices [49] have also been used.

With a larger area for solar still, various configurations of solar still were discussed by many researches and the productivity of solar still

* Corresponding authors.
*E-mail addresses:* raviannauniv23@gmail.com (R. Sathyamurthy), elagouz2011@yahoo.com (S.A. El-Agouz), vijiaji@gmail.com (V. Dharmaraj).

http://dx.doi.org/10.1016/j.desal.2015.04.012
0011-9164/

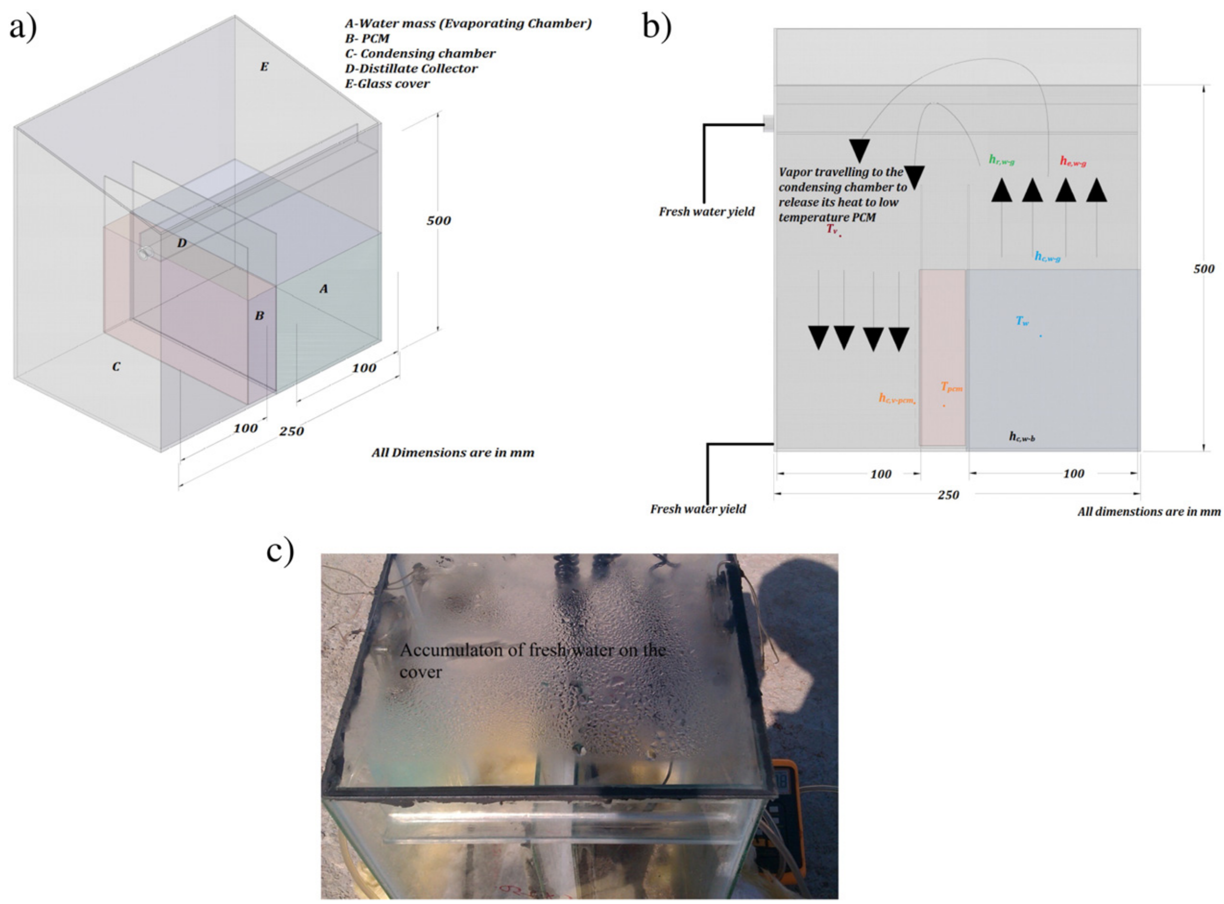


**Fig. 1.** a. Schematic diagram of a modified solar still. b. Cross sectional view and principle mechanism of the solar still. c. Accumulation water droplets on the glass cover of the solar still.

was still lower and, only a few researches were carried out in portable solar still. This paper presents the new model solar still with phase change material in between the evaporating and condensing chambers.

## 2. Experimentation

Fig. 1a and b shows the schematic diagram of a modified solar still and principle mechanism of the solar still. It consists of an evaporating chamber (A), phase change material (B) and condensing chamber (C). Phase change material (B) is kept in between the evaporating and condensing chambers for heat recovery from solar intensity as well as from the latent heat rejected by the vapor during condensation in chamber C. Table 1 shows the thermo-physical properties of paraffin wax as phase change material. The height of saline water maintained in the solar still is 60 mm. The evaporated water from the chamber (A) condenses in the slope glass cover (E), while the vapor releases its latent heat during condensation. Through the distillate collector the water condensed in the slope of the cover trickles down to the collector. The vapor thus formed during the evaporation process also travels to the other end of the evaporating chamber i.e., to the condensing chamber. During this process, the vapor rejects its heat to the PCM due to the higher temperature of water vapor. Experiments are conducted in a hot and humid climate of Chennai outdoor conditions. Fig. 1b shows accumulation of water droplets on the glass cover of the solar still.

**Table 1**
Thermo-physical properties of paraffin wax.

| Property | Value |
|---|---|
| Melting temperature (°C) | 40–60 |
| Specific heat of solid/liquid (kJ/kg °C) | 2.95/2.51 |
| Density of solid/liquid (kg/m$^3$) | 818/760 |
| Thermal conductivity of solid/liquid (W/m °C) | 0.24/0.24 |
| Heat of fusion (kJ/kg) | 226 |

The temperature values of the glass cover and water are measured by using high precision RTD sensors (PT-100) with a range of 0 to 100 °C with an accuracy of ±0.1 °C. The solar radiation is measured by using SP Lite2 Silicon Pyranometer with a range of 0 to 2000 W/m$^2$ with an accuracy of ±0.05 W/m$^2$. The wind velocity of the air is measured by using YOUNG Model 81000 Ultrasonic Anemometer with a range of 0 to 40 m/s with an accuracy of ±0.05 m/s. The desalinated water is measured by using a graduate tank with a range of 0 to 2000 ml with an accuracy of ±0.05 ml.

Using the mathematical correlation partial pressure, convective and evaporative heat transfer coefficient [45] in the solar still is determined as follows:

$$h_{c,w-g} = 0.884\left[\left(T_w - T_g\right) + \frac{\left(P_w - P_g\right)(T_w + 273.15)}{268,900 - P_w}\right] \quad (1)$$

$$h_{e,w-g} = 0.01627 h_{e,w-g}\left[\frac{\left(P_w - P_g\right)}{\left(T_w - T_g\right)}\right]. \quad (2)$$

The partial pressure developed in the solar still is given by [50],

$$P_w = e^{\left(25.317 - \frac{5144}{T_w + 273.15}\right)} \quad (3)$$