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Performance analysis on inclined solar still with different new wick materials and wire mesh

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HIGHLIGHTS

- An inclined type solar still was experimentally tested with different new wick materials.
- The new materials are characterised for absorption, capillary rise, porosity, water repellence and heat transfer co-efficient.
- Wood pulp paper wick, wicking water coral fleece fabric and polystyrene sponge were chosen.
- Still with coral fleece and weir mesh–stepped absorber plate was more productive.

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ABSTRACT

In this paper the performance of an inclined type solar still was experimentally investigated using different wick materials on different absorber plate configurations. In this work, the new materials are characterised for absorption, capillary rise, porosity, water repellence and heat transfer co-efficient to select a suitable material for the solar desalination application. Different wick materials are chosen for this analysis. Based on this analysis, water coral fleece material with porosity (69.67%), absorbency (2 s), capillary rise (10 mm/h) and heat transfer coefficient (34.21 W/m^2 °C) is the most suitable wicking material for higher productive solar still. Performances of the still were compared with different wick materials (wood pulp paper wick, wicking water coral fleece fabric and polystyrene sponge) on the various absorber plate configurations (flat absorber, stepped absorber and stepped absorber with wire mesh). Maximum distillate achieved in the still was 4.28 l/day by using water coral fleece with weir mesh–stepped absorber plate.

1. Introduction

Water is essential to sustain human life and for socio-economic development. Nevertheless, there is limited access to water that meets standard limits of water quality. The quality of water can be improved through desalination. Conventional techniques for desalination are available but they require a large input of energy, mostly from fossil fuels that contribute to environmental degradation. Consequently, there is a need to use sustainable energy sources, with solar energy being one of the most promising alternatives. Desalination technology is gaining worldwide acceptance as a proven technology for fresh water production. The review of desalination history can be found in literature [1]. Desalination is the process of removing high salt content, minerals and organisms from a water source.

Desalination systems require energy for the separation of salt and water. Solar desalination systems are systems that utilize the sun energy (solar radiation) for the separation of water and salt. Classification of solar desalination varies depending on techniques and energy supply. The most common type of solar desalination system is the solar still.

A solar still is a simple device which can be used to convert saline, brackish water into drinking water. Solar still can be broadly divided into passive and active types. Passive stills are further divided into basin and inclined types. Extensive research was made to improve the productivity of these stills. In an inclined still, water flows from the top to the bottom of the absorber surface. To maintain the uniform thickness of water, a wick, which draws water through capillary effect, is used. Stills with inclined absorber surfaces are reported to have significantly higher productivity than basin type stills [2]. There are several works presented in literature, to improve the performance of an inclined wick type solar still. Ho-Ming Yeh et al. [3] studied the effects of climatic, design, and operational parameters on the productivity of the wick-type solar distillers. Minasian et al. [4] studied the performance of a new type of still formed by connecting a small conventional basin-type (installed in shadow and having an opaque cover) with a

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wick-type solar still. Badran et al. [5] studied the performance of an inverted trickle solar still. Radhwan et al. [6] studied the performance of stepped solar still with built-in latent heat thermal energy storage. Sadineni et al. [7] studied the theoretical and experimental performance of a weir-type inclined solar still. Mahdi et al. [8] studied the performance of a wick type solar still, where charcoal cloth is used as an absorber/evaporator material and for saline water transport. Sodha et al. [9] studied the performance of multiple wick solar still, where blackened jute cloth formed the liquid surface. Janarthan et al. [10] studied the effect of floating cum tilted wick type solar still with the effect of water flowing over glass cover. Anburaj et al. [11] studied the experimental performance of a new type inclined solar still with rectangular grooves and ridges in absorber plate. Tanaka et al. [12] studied the improvement of the tilted wick solar still by using a flat plate reflector.

Based on the literature review there is no work available related to the characters of wick materials used in an inclined solar still. In this context, new testing procedures are developed for analysing the important wicking characters of wick materials. Here few important wicking characters such as absorption, capillary rise, porosity, water repellence and heat transfer coefficient, are taken into account to select a suitable material for the solar desalination application [13–16]. Based on this analysis, the best wick material is chosen and used with wire mesh & stepped absorber plate to enhance the productivity of the inclined solar still.

2. Characterization of wicking materials

From the literature review [13–16], it is clear that, among all the wicking characters of the material, porosity, water absorbency, water repellence, capillary rise and heat transfer coefficient are significant and important characters of an efficient wick material. Wicking properties of the material may be determined by the following procedures. The characterization of different wick materials were carried out at South India Textile Research Association, Coimbatore, Tamil Nadu, India.

2.1. Porosity

Porosity is a measure of the void (i.e., "empty") spaces in a material, and is a fraction of the volume of voids over the total volume, as a percentage between 0 and 100%. The porosity follows straight forwardly by its proper definition [17].

$$Ø = V_p/V_b \times 100.$$

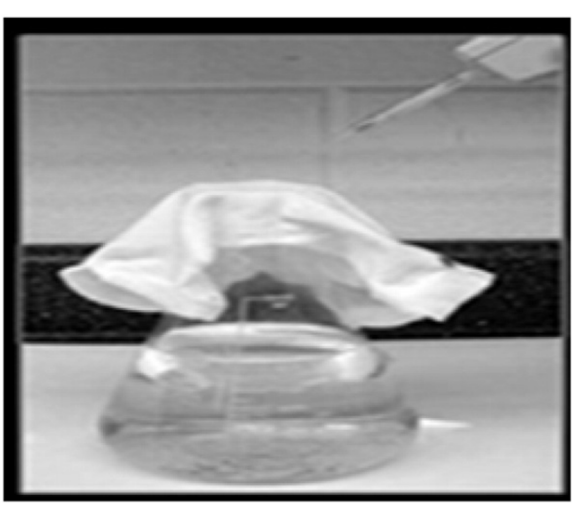

Fig. 1. Test method for water absorbency.

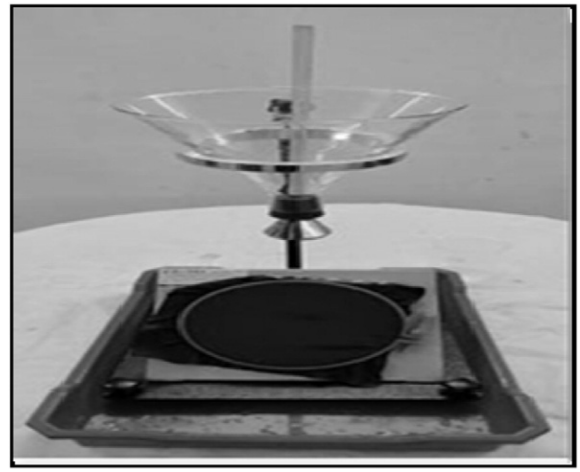

Fig. 2. Water repellent tester.

2.1.1. Bulk volume (V_b)

Bulk volume may be determined by linear measurement value (dimension of materials)

$$V_b = l \times b \times t.$$

2.1.2. Pore volume (V_p)

Pore volume may be determined by the fluid saturation method (material immersed in water)

$$W_{wtr} = W_{sat} – W_{dry}$$
$$V_p = W_{wtr}/\rho_{wtr}.$$

2.2. Heat transfer co-efficient

The evaporation of water within the still is dependent on the evaporative heat transfer coefficient, which is a function of heat transfer coefficient between the wet wick absorber surface and the glass cover. The heat transfer coefficient depends upon the difference between the absorber temperature and glass cover temperature and the difference in partial pressure of water vapour between the wick absorber and the glass cover.

The heat transfer between the wet wick absorber and the glass cover can be given as,

$$h = q/\Delta T \left(W/m^{2\circ}C\right)$$
$$\Delta T = Tg – Ta.$$

Table 1
Wicking characteristics of different wick materials.

Wick materials	Wicking characters				
	Porosity %	Absorbency (seconds)	Repellent	Capillary rise (mm/h)	Heat transfer coefficient (W/m^2 °C)
Cotton	28.5	1	0	120	36.0
Wool	27	150	0	110	45.8
Nylon	14.5	1	0	160	28.0
Waste cotton	28.23	10	0	90	41.04
Jute cloth	16.7	128	0	10	15.4
Coir mate	34.26	2	0	60	18.2
Charcoal cloth	16.2	2	0	180	58.4
Wood pulp paper	17	2	0	65	37.3
Polystyrene sponge	52.06	300	0	0	29.05
Water coral fleece	69.67	2	0	10	34.21