Desalination 422 (2017) 68–82

Contents lists available at ScienceDirect

Desalination

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

Performance analysis of modified basin type double slope multi–wick solar still

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ARTICLE INFO

Keywords:
Desalination
Instantaneous efficiency
Multi–wick passive solar still
Wick

ABSTRACT

This paper presents an outlook to enhance the productivity of a basin type double slope multi–wick solar still by introducing the wicks. The experimental data for different months are presented, and analyzed the effect of climatic and operational parameters on the performance of modified basin type double slope multi–wick solar still (MBDSMWSS). The study has been conducted at Motilal Nehru National Institute of Technology Allahabad (MNNIT Allahabad), Uttar Pradesh (U.P.), India. A significant increase in the heat input, yield, and overall thermal efficiency have been obtained. In the instantaneous efficiency equation, the yield output and the heat input to the solar still is modified as input from both the glass covers and transparent walls are considered for the modified solar still. The result shows that, the maximum yield is obtained as 9012 ml/day (4.50 l/m^2 day) for black cotton wick in comparison to 7040 ml/day (3.52 l/m^2 day) for the jute wick at 2 cm water depth in MBDSMWSS. Also, for same basin condition, the overall thermal efficiency of MBDSMWSS with the jute and black cotton wicks are 20.94% and 23.03%, respectively.

1. Introduction

Fresh water is the need of every human being and agricultural purposes but the sources of water around the world keep declining due to huge consumption and population growth. Most of the sources of fresh water are contaminated due to the inclusion of the chemicals (pesticides, fertilizers, etc.), high content of heavy metals, and high concentrations of salt in aquifers. The palatability of drinking water has been determined by catalog of tasters in relation to its Total Dissolved Solids (TDS) level as follows: excellent (< 300 mg/l); good (between 300 and 600 mg/l); fair (between 600 and 900 mg/l); poor (between 900 and 1200 mg/l); and unacceptable (> 1200 mg/l) [1]. The areas around the world, where conditions arises from lack of access to clean and germs free potable water, and grid–based electricity has been absent, there is an utterly need for facilitating such a cost effective technique, which is easy to handle, pollution free, and produces sufficient amount of potable water to fulfill the needs of society. Most of the developed and advanced techniques for water purification have rely on coal–based electricity, which causes damage to the environment and adversely affects the water quality. Thus, keeping the constraints of the present situation, a renewable energy based water purification technique is required. Solar desalination is one of such an efficient process that uses solar thermal energy for obtaining clean water from brackish water. Solar distillation is primarily a minor–scale replica of the natural hydrological cycle that originates rain, which is the elementary source of fresh water worldwide. Solar still is used as a structure for solar distillation process [2,3], which utilizes solar energy to drive thermal distillation processes. Solar desalination suitable in the areas where drinking water is either limited in supply or is present in impure form and solar energy is abundant in supply.

Arab Alchemists in 1551 [4] presented the work of distillation in the earlier stages of desalination methods. Malik et al. [5] studied the design and performance of different types of solar distillers. Sodha et al. [6] analyzed the performance and presented the design of a multi–wick solar still, in which blackened jute wick is used to form the wet surface, and oriented to absorbed the maximum solar radiation to achieve high temperature. Tiwari and Tiwari [7] shows the effect of climatic parameters like the radiation intensity of solar rays, temperature of an environment, and operational parameters like the brackish water depth on the performance of solar distillation system. Shukla and Sorayan [8] presented and validated a thermal model for a multi–wick solar distiller. In this work, a computer model had been evolved and based on modified heat transfer coefficients, validation of thermal model had been accomplished. Mahdi et al. [9] built a tilted wick–type solar still to characterize its performance. In this work, the charcoal cloth was used as a wick to absorb the saline water. Rajaseenivasan et al. [10] were

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http://dx.doi.org/10.1016/j.desal.2017.08.009
Received 4 April 2017; Received in revised form 28 June 2017; Accepted 17 August 2017
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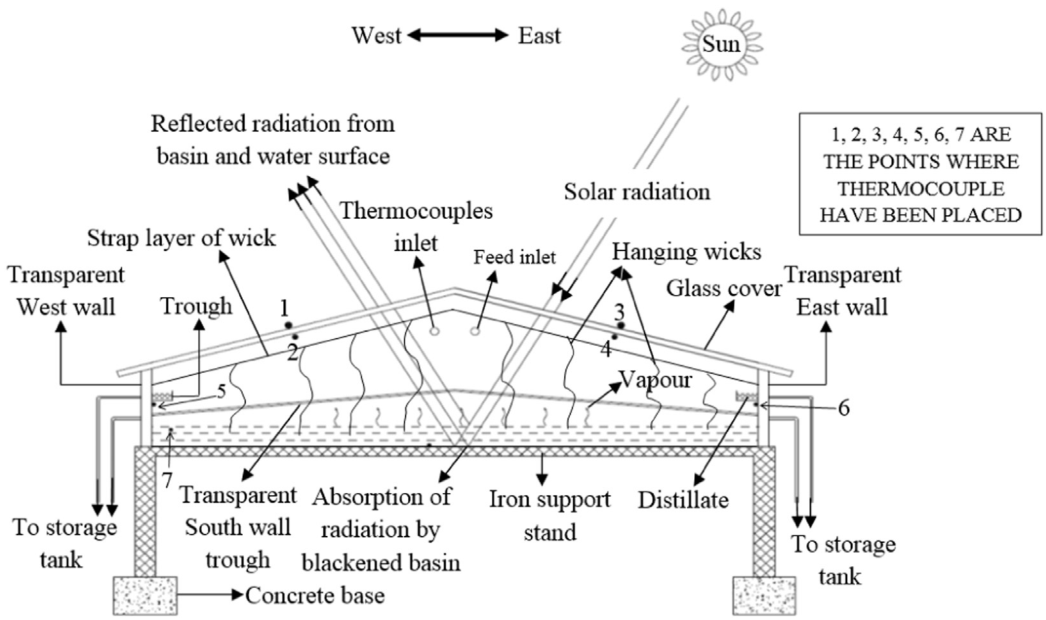

Fig. 1. Schematic diagram of modified basin type double slope multi–wick solar still.

used the different wicks, energy storing materials, porous materials and variable depth of water in both single basin double slope and double basin double slope solar distiller to increase the yield of a double slope solar still by adding an extra basin.

Dev et al. [11–13] developed the characteristic equations (linear and non–linear) for an active and passive solar stills. In this work, the inclination angles 15°, 30°, and 45° of glass cover have been selected in winter and summer conditions both. Pal and Dev [14] studied the performance of modified basin–type double slope, and modified basin–type double slope multi–wick solar stills. Morad et al. [15] studied the performance of solar still and flat–plate solar collector solar still, which was the function of a thickness of glass cover and the brine depth in the basin. Furthermore, based on equations of external, internal heat transfers and energy balance, a thermal analysis was accomplished. Saurabh and Sudhakar [16] presented a vast review of the various designs of solar distillers used at domestic level. Prakash and Velmurugan [17] scrutinized various parameters of the solar stills, which influenced the yield. The review showed an increase in the absorber area increases the productivity. The height of the water in the basin is the main parameter for the yield of the solar still. Pal et al. [18] studied the design of modified basin–type double slope multi–wick solar still.

Manikandan et al. [19] reviewed different configurations and designs of wick type solar distillers and concluded that researchers have taken concerted efforts to make various new designs and configurations of solar distiller for higher yield. Hansen et al. [20] found that water coral fleece with heat transfer coefficient, absorbency, porosity, and capillary rise are 34.21 W/m^2 °C, 2 s, 69.67%, and 10 mm/h, respectively is best working wicking material among selected material for the higher yield of the solar still. Kaviti et al. [21] reviewed different design and configurations used to improve the productivity of inclined solar stills. Rufuss et al. [22] studied a detailed review of the various active and passive, single and multi–effect passive and active solar stills, reviewed design of the solar stills, and stated various modifications for improved overall performance and productivity. Kumar et al. [23] presented a detailed observation of the single and multi–effect type with passive and active configurations.

Al-Kharabsheh and Goswami [24] investigated a water distiller system used solar heat as a low–grade energy. Researchers presented the experimental result and theoretical analysis. In this work, the effect of various operating conditions such as depth of water body, heat source temperature, and temperature of the condenser, on the performance of the system was studied. Tiwari and Tiwari [25] investigated the effects of the inclination of a condensing cover and depth of the water on the yield and convective coefficient of heat transfer of a passive solar distiller for the climatic conditions of New Delhi, India. Deniz [26] investigated the improving of inclined solar water distiller system performance under the environmental conditions of Turkey. In this work, the system was experimented with bare, shaded bare plate, and with black cloth, shaded black cloth wick. Ayoub et al. [27] depicted a sustainable alteration in the design of a solar still in the form of a slowly swirling drum, this facilitates the creation of thin water films that evaporate hurriedly and are incessantly renewed. Kalita et al. [28] reviewed the effects of various geometric and operating parameters, and energy losses and balance were calculated using the second law of thermodynamic on the performance of a solar still. Sharshir et al. [29] reviewed the various elements affecting solar still yield like climatic conditions, design parameters, and operations. An augmentation of yield by using wicks, stepped solar still, nanoparticles, internal and external condensers, phase change materials, and internal and external reflectors have been discussed.

From the above literature review, it is found that, the multi–wick solar still is associated with following drawbacks: (i) improper supply of water into the wick; (ii) improper use of incident solar radiation; and (iii) improper collection of yield.

In this paper, a modified design of basin type double slope multi–-wick solar still is presented for its performance evaluation in the climatic conditions of Allahabad (U.P.) (Latitude 25°27′ N & Longitude 81°44′ E), India. The experiments are performed and effect of climatic parameters like solar radiation, operational parameters like feed water depth and wick material on MBDSMWSS have been studied.

2. Experimental setup and working principle

2.1. Description of experimental setup

The constructed experimental modified multi–wick solar still is installed on the rooftop of 'Heat and Mass Transfer & Solar Energy Laboratory', Mechanical Engineering Department, MNNIT Allahabad, Allahabad, U.P., India. Fig. 1 shows the schematic diagram of the modified basin type double slope multi–wick solar still.

The solar still consist of a rectangular basin of area 2 m^2 (length 2 m and width 1 m), which is made up of thickness 5 mm of Fibre

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