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Performance enhancement of a single basin solar still with flow of water from an air cooler on the cover

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HIGHLIGHTS

• Solar still output enhances by flowing water from an air cooler over glass cover.
• The largest increase in annual distillate output is for climate of Jodhpur (56.5%).
• The least increase in annual distillate is for climate of Chennai (41.3%).
• Cost of additional distillate output with two stills is *Rs 0.60/l* for Jodhpur climate.

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ABSTRACT

The annual performance of a conventional solar still, with water from the tank of an air cooler, flowing over the cover, has been computed for four different climatic zones in Indian plains. It is seen that the annual yield can be increased between 41.3% and 56.5%. The increase in annual efficiency is between 7.4% and 9.9%. Increase in yield is the largest for hot and dry climate of Jodhpur and the least for warm and humid climate of Chennai. Moreover the distillate output increases slightly with increase in mass flow rate and tends to saturate around 0.075 kg/s. These figures are indicative of the viability of the concept. Cost of additional water produced by flow of water from the desert cooler over the cover with two solar stills working together is between Rs. 0.60/l for hot and dry climate to Rs. 0.78/l for warm and humid climate. (U.S.D. 1.00 = Rs. 62.50)

1. Introduction

Use of solar still to produce fresh water from brackish or sea water is an important method of utilizing solar energy to produce fresh water. However the use of solar stills has been limited due to low production per unit area; over the years attempts have been made to enhance the production rate and efficiency of solar stills. The main focus has been to increase the temperature difference between the water in the basin and the glass cover as this enhances the mass transfer between the water in the basin and glass cover and thereby increases the production of water in the solar still. This can be achieved either by increasing the temperature of water in the basin by active or passive methods [1,2] or by decreasing the temperature of glass cover or a combination of both. One of the methods of reducing the temperature of glass cover is by continuous flow of water over the glass cover (Fig. 1) as was investigated by Tiwari and Rao [3]; they analyzed the transient performance of the solar still with water flow over the glass cover. It was seen that the daily distillate output got doubled by lowering the temperature of the glass cover by continuous flow of water over it at uniform velocity. Tiwari and Maduri [4] incorporated the flow of waste hot water in the basin along with water flow over the glass cover and obtained the increase in distillate output, commensurate with the increase in inlet water temperature in the basin. Lawrence et al. [5] validated their model by incorporating the effects of water flow over the cover and heat capacity of water mass in the basin. They found an increase of 7 and 10% in efficiency of solar still due to water flow over the glass cover in the cases with and without black dye present in the basin of the solar still; moreover there is no change in efficiency of solar still at a flow rate of 1.5 m/s. Abu-Hijleh [6] theoretically investigated the effectiveness of film cooling under different operating characteristics; his results indicated that the proper use of the film cooling parameters can increase the still efficiency by 6% but poor combination can reduce still efficiency. Abu-Hijleh and Mousa [7] extended the earlier work and included the evaporation effect of water film flowing over the glass cover; they obtained a 20% increase in the still efficiency.

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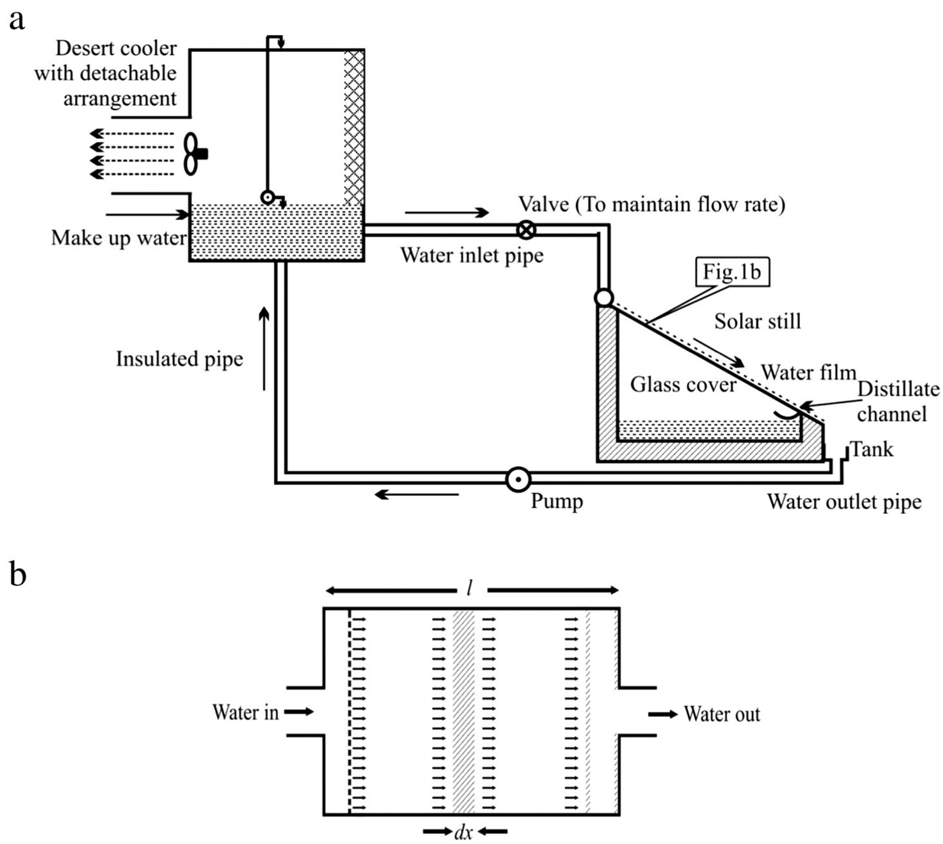

Fig. 1. a: Schematic representation of a solar still coupled to a desert cooler. b: Over side view of the flowing water over the glass cover.

Dhiman and Tiwari [8] presented an analytical model of a multiwick type solar still with water flowing over the glass cover and obtained 10% increase in distillate output. Janarthanan et al. [9] experimentally validated the model of a tilted wick type solar still with water flowing over the glass cover and concluded that the optimum flow rate of water flowing over the glass cover is 1.5 m/s. Ahmed and Alfaylakawi [10] experimentally evaluated the effect of wind speed and the use of water sprinklers to cool the temperature of glass cover of the solar still; an increase in production rate by 15.7% and 31.8% was obtained, using water sprinklers at intervals of 20 min and 10 min respectively. Badran [11] applied water sprinkler and asphalt basin liner in a single slope solar still and observed experimentally a 51% increase in still productivity.

In the earlier analyses with water flow over the glass cover to reduce the temperature of glass cover, the initial temperature of water flowing over the glass cover is assumed to be either the ambient temperature or a temperature significantly higher than the wet bulb temperature. In the present communication the authors have presented an analytical model of a conventional solar still with provision of flowing cooled water (at wet bulb temperature) from the tank of an air cooler. Water is collected in a tank placed below solar still and circulated back to the air cooler (Fig. 1a). Air cooler also known as evaporative or desert cooler, is used to cool air. Cooling of air is accomplished by flow of air induced by a fan in a direction normal to the vertical porous pad through which water flows from top to bottom; this water collects in a tank at the bottom of the pad and is pumped up to the top. Evaporation of water results in cooling of air as well as water. Cooled air is utilized for space conditioning whereas the coolness stored in tank water is not utilized; one can use this coolness stored in tank water to cool extraneous objects (cover of stills) moreover it is seen that utilization of coolness of water in the tank does not appreciably affect the temperature of air [16]. Present paper explores one such possibility in which cooled water from the tank of the desert cooler is distributed through a common pipe and circulated uniformly over the glass cover of a solar still (Fig. 1a) or an array of solar stills depending on the size of the cooler and its height above the solar still. In the present analysis the authors have considered two stills working together; mass flow rate of water flowing over the glass cover can be adjusted by a valve provided with an inlet pipe; water falling from the cover of the still is collected in a tank provided at the bottom of still and circulated back to the air cooler. Authors have suggested two different strategies for summer and other months of the year. During summer months when cooling of air is required the air cooler and solar still works simultaneously and the steady state temperature of water in the cooler tank becomes nearly equal to wet bulb temperature of the ambient air [12–16]. In other months where cooling of air is not required and the cooler is not running the tank of the cooler is kept open to the atmosphere (in shade) for day and night, and the temperature of water in the open tank is nearly equal to the wet bulb temperature of air. As the steady state temperature of water in the tank of the air cooler is very nearly equal to wet bulb temperature of ambient air for both the strategies, the temperature of the glass cover should be lower than that in the case of using inlet water at ambient temperature, and consequently the rate of condensation of water over the glass cover should increase; moreover the recirculated water from the still to the air cooler does not appreciably affect the performance of the air cooler [16]. The presence of a water film forms an intermediate layer of refractive index 1.33 between the air of refractive index 1.0 and glass with refractive index 1.5; this reduces the intensity of the incident light which gets reflected and increases the transmission of solar radiation into the still. In the present paper the authors have numerically computed and compared the annual