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Active single basin solar still with a sensible storage medium

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ABSTRACT

Transient mathematical models are presented for an active single basin solar still (ASS) with and without a sensible storage material under the basin liner of the still. Sand is used as a storage material due to its availability. The flowing water temperature is assumed to vary with time and space coordinates. Analytical expressions are obtained for various temperatures of the still elements as well as for the temperature of sand. The performance of the still with and without storage is investigated by computer simulation using the climatic conditions of Jeddah (lat. 21° 42′ N, long. 39° 11′ E), Saudi Arabia. Effects of mass flow rate and thickness of the flowing water for different masses of the storage material on the daylight P_{dl}, overnight P_{on} and daily productivity P_d and efficiency η_d of the still are studied. The dependence of P_d and η_d on the thickness and thermal conductivity of the basin liner material is also investigated. It is found that P_d and η_d decrease as the mass of the storage material increases, due to the increased heat capacity of the storage material. Furthermore, P_d and η_d are found to decrease with increasing thermal conductivity of the basin linear material. Therefore, it is advisable to fabricate basin liners of ASS from cheap insulating materials such as glass and mica with an optimum thickness of 3 mm. On a summer day, a value of P_d of 4.005 (kg/m^2 day) with a daily efficiency of 37.8% has been obtained using 10 kg of sand compared to 2.852 (kg/m^2 day) with a daily efficiency of 27% when the still is used without storage. The annual average of daily productivity of the still with storage is found to be 23.8% higher than that when it is used without storage.

1. Introduction

There is an urgent need for clean, pure drinking water in many countries. Often, water sources are brackish and/or containing harmful bacteria and therefore cannot be used for drinking. In addition, there are many coastal locations where sea water is abundant but potable water is not available. Pure water is also needed in some industries, hospitals and schools. Solar distillation is one of the many processes that can be used for water purification. Solar radiation can be the source of heat energy where brackish or sea water is evaporated and is then condensed as pure water.

Solar stills are broadly divided into passive and active stills. Extensive research was reported on different methods to improve the productivity of these stills [1–10]. The important parameters affecting the performance of a solar still, such as solar intensity and the mass of basin water [11] as well as wind speed [12], are also reported. Still performance was found to increase with thinner water films [11]. However, decreasing the thickness of basin water results in a decrease of overnight productivity of the still [13]. Therefore, to improve the still productivity even with thicker water layers (deep basins), a baffle plate made of mica was inserted within the basin water [14]. It has been found that the baffle plate significantly enhances the single basin solar still performance all year round [15]. Tiwari et al. [16] outlined that the passive solar distillation is a slow process for the purification of brackish water. This process can be significantly enhanced using the active mode of operation. However, the overnight productivity of conventional active solar stills (ASS) equals zero. Therefore, many attempts have been made to improve the performance of ASS by coupling these stills to flat plate collectors [17,18], shallow solar ponds [19,20], solar concentrators [21] etc. All these methods introduce additional costs and some difficulty in operation and maintenance of ASS. Another method that may be used to improve the productivity of active and passive solar stills is by using storage systems either sensible or latent heat systems. The latent heat thermal energy storage systems have many advantages over sensible heat storage systems including a large energy storage capacity per unit volume and almost constant temperature for charging and discharging [22]. Some problems may take place on using the latent heat storage materials such as corrosion and leakage. Few papers have appeared concerning the use of phase change materials as storage media in solar stills [23,24]. As far as the authors know, some of the work was reported concerning the use of sensible storage materials; such as black rubber and black gravel [25] as well as pebble, coal and sand [26], integrated with solar distillation systems in an attempt to enhance the productivity of solar stills.

This paper presents the transient performance of an active single basin solar still (ASS) integrated with a thin layer of a sensible storage material, beneath the basin liner of the still, for the purpose of fresh

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