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Modeling and performance analysis of a solar desalination unit with double-glass cover cooling

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Abstract

In this study modeling and performance analysis of a single-basin solar still with the entering brine flowing between a double-glass glazing were investigated. The base area of the solar still is 1 m^2. The function of this arrangement is to lower the glass temperature and thus increase the water-to-glass temperature difference. This results in improved performance represented by a faster rate of evaporation from the basin. The performance of the still is compared with that of a conventional single-glass cover solar still under identical weather conditions. The results show that the relative performance of the stills depends on the level of insulation used. For perfectly insulated stills the conventional solar still is superior while the double glass is superior when heat loss exceeds a certain value. The hourly and daily productivities of the stills and the temperatures of the water and the glass covers were also predicted under the meteorological conditions of Muscat, Oman.

Keywords: Solar desalination; Solar still; Double-glass solar still; Modeling

1. Introduction

In many parts of the world, especially in the Middle East, desalination has become a reliable source of fresh water. The different methods used in desalination are based on thermal or membrane principles. Among the thermal methods used is solar distillation. Interest in solar distillation stems from the fact that areas of fresh water shortages have plenty of solar energy. Moreover, its low operating and maintenance costs made it

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an attractive method in areas remote from the electricity supply grid.

Different designs of solar stills have emerged. The single-effect solar still is a relatively simple device to construct and operate. However, the low productivity of the solar still triggered initiatives to look for ways to improve its productivity and efficiency. These may be classified into passive and active methods. Passive methods include the use of dye or charcoal to increase the solar absorptivity of water, applying good insulation, lowering the water depth in the basin to lower its thermal capacity, ensuring vapor tightness, and using reflective side walls [1]. Active methods include the use of solar collectors [2] or waste heat [3] to heat the basin water, the use of internal [4–6] and external [7–8] condensers or applying vacuum inside the solar still [9] to enhance the evaporation/condensation processes, and cooling the glass cover [3,10–13] to increase the temperature difference between the glass and the water in the basin and hence increase the rate of evaporation.

In a conventional solar still, the heat of vaporization received by the glass cover gets lost to the surrounding areas mainly by convection and radiation. The radiation and the convection losses are relatively small, leading to an increase in the glass temperature and reduction in the temperature difference between water in the basin and the glass. This adversely affects the rate of vaporization and hence the still productivity. The glass temperature can be reduced by cooling. This has been accomplished by flowing water film over the glass cover [3,10–12] or flowing water between a double-glass cover [2,13].

Tiwari et al. [3] investigated the effect of water flow over the glass cover of a single-basin solar still on still productivity. In their still an intermittent flow of waste hot water in the basin was maintained. They varied the inlet waste hot water temperature in the basin between 30°C to 55°C. The daily productivity increased with the increase of mass flow rate of the waste hot water and its inlet temperature, provided that it is above ambient temperature. They also concluded that the temperature of the flowing water over the glass cover remains of the same order as the ambient temperature. Although the effect of water flow over the glass cover was incorporated in their analysis, no results on this effect were reported in their paper. The effect of water flow over the glass cover of a simple (conventional) solar still was also investigated by Lawrence et al. [10]. They conducted numerical simulations that were validated using their own experiments for a typical summer day. Their results show that the efficiency of the solar still increases as the water film flow rate increases and this increase is more significant at large heat capacity of water mass in the basin. In their analysis, Lawrence et al. [10] neglected the heat capacities of the glass cover, the flowing water, the basin liner and the insulation in addition to the absorptivity of the flowing water.

Abu-Hijleh [11] and Abu-Hijleh and Mousa [12] theoretically investigated solar still performance with flowing water as a film over the cover of a single-glass cover still. In the latter study [12], evaporation from the flowing film was included in the analysis, which was neglected in the previous study by Abu-Hijleh [11]. It was reported that with the proper use of film cooling parameters, the still efficiency could be improved by as much as 20% when accounting for evaporation from the film and by 6% without considering evaporation.

According to Tiwari [1], the cooling by flowing water between a double-glass cover was investigated numerically by Prakash and Kavanthekar [13]. It was reported that significant improvement was achieved mainly at low water mass in the basin. Later, Singh and Tiwari [2] numerically compared the thermal performance of a solar still having a double-glass cover