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Factors influencing the performance and productivity of solar stills - A review

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ABSTRACT

Water scarcity is a major threat for future as the fresh water resources are being exploited and polluted rapidly by mankind. Hence, converting the brackish, saline water in to pure water is one of the viable solutions to overcome the demand for water. Desalination using solar still is simple among various techniques available for removal of salinity. The limitation being its productivity, researchers have consistently attempted to improve the performance of solar stills. This article reviews various factors that influence the performance of the solar still like solar radiation intensity, temperature difference, collector area, basin water depth, insulation, angle of inclination, thickness of glass cover plate, wind velocity and a few methods for improving the quantity of distillate produced. Such a review would benefit the knowledge society for further research and development of a solar still to make it an economically viable option.

1. Introduction

Water is an elixir of life. Water covers approximately three fourth of Earth's surface. About 97% is salty seawater and 2% is frozen in glaciers and polar ice caps. Thus, the remaining 1% of the world's water supply is a precious commodity which is necessary for our survival [1]. The shortage of clean water for livelihood in many parts of the world is an important problem and requires immediate attention. The demand of fresh water is becoming an increasingly important issue across the world. In arid regions, potable water is very scarce and the establishment of a human habitat in these areas strongly depends on how such water can be made available. The importance of supplying potable water can hardly be over stressed [2]. Solar water desalination is one of the processes that can be used for purification of saline water.

Solar still is the simplest solar desalination device. The solar stills may have single slope or double slope as shown in Figs. 1 and 2. The solar still at its lower part consists of basin which is insulated with insulating material to reduce the thermal losses to the surroundings. The basin consists of absorber plate, coated with black paint to maximize absorption of the incident solar radiation on the basin. An inlet is provided to feed the saline water to the basin. Transparent condensing covers are located on the top of the still. An outlet is provided to collect the distilled water from the gutter or collection channel.

The productivity of the conventional solar still is very low. Thus to augment the productivity of the solar still, several research works are being carried out [3]. The performance and productivity depends upon many parameters like solar radiation intensity, temperature difference between the cover plate and water, collector or absorber plate area, depth of water, insulation, angle of inclination, thickness of cover plate, and wind velocity. In order to enhance the performance and productivity, solar still can be further improved.

The solar stills are broadly classified into two types namely, active and passive solar stills. Passive solar stills evaporate the basin water directly through sun and active solar still uses some external setup like solar collectors to feed an extra thermal energy for faster evaporation. Design modifications of passive solar stills include wick type stills, spherical solar still, etc. Active solar still includes solar still integrated with solar heater, solar still integrated with solar concentrators, waste heat recovery or pre-heated water active solar still, regenerative active solar still and solar still with heat exchanger.

A floating wick type solar still was designed by Janarthanan [4] and he has shown an increase in productivity of 16% to 50% when compared with conventional solar still.

A spherical type solar still was experimented by Dhiman [5]. In this solar still, a blackened metallic plate was horizontally placed in the center and it is covered by spherical glass cover. The experimental results have shown 30% increase in efficiency when compared to that of the conventional solar still.

Badran had done an experiment using double slope solar still coupled with feed tank, constant head tank and a flat plate collector (FPC).

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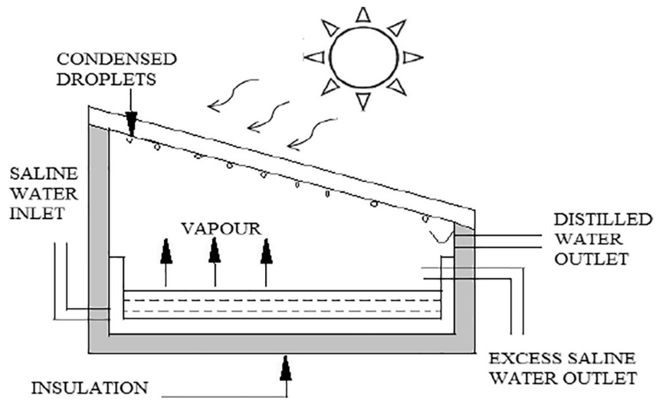

Fig. 1. Single slope solar still.

Hot saline water is fed into the system on a sunny day and it was reported that the flat plate collector coupled solar still yields 2.3 l/m^2 whereas the solar still without coupling yields 1.5 l/m^2 [6].

Experimental and theoretical study of a single slope solar still coupled with parabolic trough and a heat exchanger has been attempted by Zeinab and Ashraf. They have reported an 18% increase in distillate output for the active solar still when compared to a conventional passive solar still [7].

Tiwari and Sinha conducted experiments using regenerative solar still and inferred that passive regenerative solar still was better than active regenerative solar still. The efficiency of passive regenerative solar still was 50%, whereas, the same for an active regenerative solar still was 40% [8].

Kumar and Tiwari conducted experiments on hybrid photovoltaic thermal active solar still and stated that the productivity was 3.5 times more than that of the passive solar still [9].

A better understanding of various parameters that influences the productivity and performance of a solar still is necessary to make it more viable for small scale domestic applications through suitable design modifications. Such parameters and other methods are reviewed in this article.

2. Parameters influencing the productivity and performance of solar still

The solar still productivity and performance depends on the parameters like solar radiation intensity [10], temperature difference between the cover plate and water [11]–[13], basin water depth [14,15], glass cover plate inclination [11–15] and its thickness [10,16], wind velocity [17].

The parameters such as solar radiation intensity and wind velocity are uncontrolled as they are metrological parameters. Other parameters including collector area, basin water depth and insulation, etc. are controllable and shall be managed effectively for improving the productivity.

Among these parameters the most influential parameters are solar radiation intensity, collector area, basin water depth and the temperature difference between glass cover plate and water.

2.1. Solar radiation intensity

Omar et al. [18] performed an experimental and theoretical analysis on a single slope solar still based on solar radiation intensity. They concluded that the productivity and efficiency of the solar still improves with increase in intensity. In particular, the maximum efficiency is obtained at early afternoon since the solar radiation intensity is high during this period. Emad A. Almuhanna [19] has also inferred that the rate of distillate production increases as the intensity of solar radiation increases.

2.2. Temperature difference of glass cover plate and water

By using electrical resistance heater in the double slope solar still Kalidasa Murugavel et al. [20] analysed variation in productivity at different temperatures. They have concluded that the when the temperature difference between the water and glass cover plate is high, more the distillate is produced.

Ahmed et al. [21] also performed an experimental analysis on double slope solar still by using a water heater in the base of solar still for artificially increasing the temperature of water and concluded that the productivity is enhanced to 370% due to the increase in temperature difference.

2.3. Collector area and selective surface coating

Velmurugan et al. [22] inferred that an increase in collector area results in more productivity. As the evaporation rate of the water in the solar still is directly proportional to the exposure area, the productivity of the solar still increases with increase in free surface area of water in the basin [23].

Solar collectors are coated with flat or matte black paints for higher absorption of solar radiation. A selective surface coating of basin tray shall result in increased productivity due to its high absorptivity and less emissivity. Furthermore, such a coating prevents corrosion of basin material due to salinity of the water fed. Madhukeshwara et al. reported that black chrome coating on solar collectors has a higher thermal efficiency when compared to matte black and sol-chrome coatings [24].

2.4. Basin water depth

The basin water depth has significant effect on productivity of the solar still. Several researchers have inferred that the depth of water is inversely proportional to the productivity of solar still [25–27].

Suneja S and Tiwari [28] analysed the effect of water depth and concluded that the decrease in water depth increases the productivity of

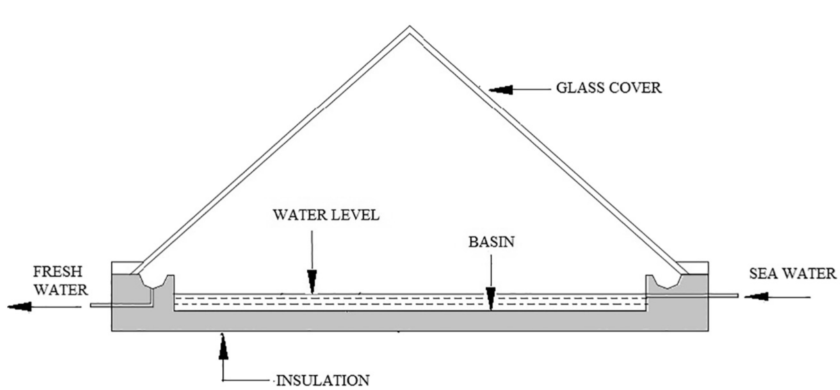

Fig. 2. Double slope solar still.