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Advanced designs of solar desalination systems: A review

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ABSTRACT

Solar still is an ideal source of fresh water for both domestic and agricultural aspects. It is one of the most important viable applications of solar energy. The simplest and most proven type of solar stills is the single basin type, but its thermal performance is limited. Many research papers were presented where different methods were performed to improve the productivity of single basin solar stills. In this paper, a review of different designs of solar stills was presented particularly the double, triple and multi-effect solar stills, vertical stills, tubular type solar stills, finned and corrugated stills, and stepped type solar stills. A detailed cost analysis for different configurations was presented. The various parameters affecting the performance of the considered designs of solar stills were outlined. The daily productivity of the double basin solar still is on the average 36% higher than that of the single basin still. The inverted absorber triple basin solar still gives a substantially higher yield than double and single basin inverted absorber solar stills. An optimum area of the vertical still absorber was found to be 3.5 m^2. From the results obtained for the tubular solar still it was concluded that with cooling air flow, the production increased by about 32.8%, and with cooling water flow, it further increased by about 59% more than the system without cooling. A maximum increase in productivity of about 98% was achieved for stepped solar stills when fins, sponge and pebbles were used. The maximum productivity of stepped solar still was obtained with tray depth and width of 5 and 120 mm, which is about 57.3% higher than that of the conventional still.

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1. Introduction

Fresh water is essential in domestic life and is used in agriculture as well as industry. The consumption of fresh water is increasing all over the world, mainly due to the population explosion and the rapid industrial growth. The need for fresh water is increasing, but most of the available water is naturally brackish or impure, not suitable for drinking and requires treatment. In the existing water purification and desalination methods, for mass production, electrical energy or fossil fuels are used. The usage of either fossil fuel or electrical energy derived from fossil fuel increases the atmospheric pollution and global warming. In addition, fossil fuels are slowly declining with time because of the rapid consumption used in technology development. Solar energy is the best alternative heating energy source. It is inexhaustible, clean and available in almost all parts of the world. The use of solar energy is however more economical than the use of fossil fuels in remote areas having low population densities, low rainfall and abundant available solar energy. Solar distillation is one of the important methods of utilizing the solar energy for the supply of potable water to small communities where the natural supply of fresh water is inadequate or of poor quality, and where sunshine is abundant. Solar stills can easily provide enough water for family drinking and cooking needs. Solar still is the oldest device used for treating saline or impure water to provide drinking water to small, isolated communities. In remote and arid locations where the conventional energy sources are costly and scarce, the demand for fresh water can be met by using solar stills. In locations where there is plenty of solar energy and where sources of brackish water are available, supplies of small amounts of fresh water can be produced at reasonable cost by solar stills. The first known use of stills dates back to 1551 when it was used by Arab alchemists. Other scientists and naturalists used stills over the coming centuries [1]. The first "conventional" solar still plant was built in 1872 by a Swedish engineer Charles Wilson in the mining community of Las Salinas in what is now northern Chile [2]. The basic principles of solar water distillation are simple, yet effective, as distillation replicates the way nature purifies water. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapor rises and condenses on the glass surface for collection. This process removes impurities such as salts and heavy metals, as well as destroys microbiological organisms. The end result is water cleaner than the purest rainwater. But water is usually contaminated with chemical impurities and harmful organisms. The distilled water from the present solar stills does not acquire the "flat" taste of commercially distilled water since the water is not boiled (which lowers pH) because of the natural evaporation which is the rainwater process. Therefore, it is recommended to add small amounts of minerals or salts to the distilled water, since the minerals found in water may be healthy. Lost minerals can also be replaced by trickling the distilled water through a bed of marble chips [1]. Solar still can be easily fabricated using locally available materials and are easy to operate and maintain [3]. The productivity of fresh water by solar distillation depends drastically on the intensity of solar radiation and the sunshine time interval during the day [1]. Some researchers indicated that some parameters such as water mass [4], black dye [5], wind speed, insulation thickness [6] and installing booster mirrors [7] have an effect on the output of the solar stills.

The single-basin solar still is the simplest type of solar distillation systems. It is simple in construction, operation and maintenance. One of the main drawbacks of this design is the low yield, which is depending on season, the region and the intensity of solar radiation [8]. Many researchers tried to develop and enhance the thermal performance of solar stills. In this work; double, triple and multi-effect solar still, vertical stills, tubular type stills, finned and corrugated stills and stepped type solar stills and their modifications were reviewed.

2. Double-effect basin type solar stills

The productivity of solar stills can be improved by re-utilizing the latent heat of condensation of water vapor released at the lower surface of the still cover in heating a thin layer of water positioned at the upper surface of the cover. When we fix another condensation surface at the top of the still, the still termed as the double-basin solar still (DBSS). The main advantage of this type is that the latent heat of water vapor condensing at the lower surface of the lower glass cover is utilized in heating the upper layer of water, rather than being wasted to the atmosphere. The concept of the DBSS was suggested by Malik et al. [9]. Many papers were

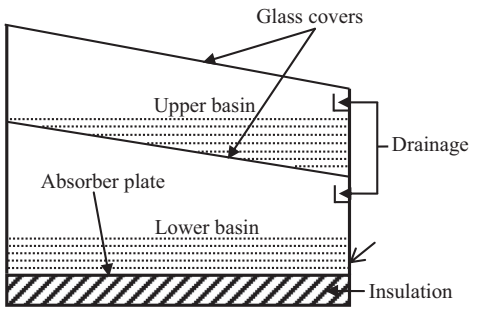

Fig. 1. Single slope double basin solar still [10].

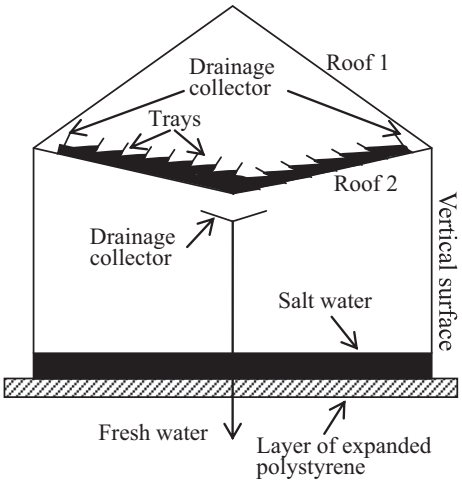

Fig. 2. Double basin plastic solar still [24].