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Design and performance of a transportable hemispherical solar still

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A R T I C L E I N F O

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A B S T R A C T

A simple transportable hemispherical solar still was designed and fabricated, and its performance was experimentally evaluated under outdoors of Dhahran climatic conditions. It was found that over the hours of experimental testing through daytime, the daily distilled water output from the still ranged from 2.8 to 5.7 l/m^2 day. The daily average efficiency of the still reached as high as 33% with a corresponding conversion ratio near 50%. It was also found that the average efficiency of the still decreased by 8% when the saline water depth increased by 50%.

1. Introduction

A solar still (also known as solar distiller) is a device by which distilled or potable water can be produced from saline water, such as seawater or brackish water. Solar stills are normally used to provide a small scale of potable water needed in remote isolated locations, where there is plenty of solar energy and sources of saline water are available, or in emergency conditions when other sources of energy are not available [1]. Potable water can be produced at reasonable cost by solar stills which are relatively economical to build and simple to operate and maintain [2,3]. Solar distillation is a technology with a very long history. The first known application of solar stills was in 1872 when a still at Las Salinas on the northern deserts of Chile started its three decades of operation to supply a mining community with drinking water [4]. Most stills built and studied since then have been based on the same principles, though many variations in geometry, materials, methods of construction, and operation have been incorporated [4]. A review of various designs of solar stills was made by Malik et al. [5]. A conventional basin-type still is simply an airtight basin that contains a shallow layer of saline water, a sloped top cover of a transparent material (usually glass) to solar radiation, and side metal frame walls. The basin-type stills have been much studied and their behavior is well understood [4]. The cost of building and operating a conventional still is relatively low compared to those involving sophisticated designs. However, the conventional or standard basin-type solar still [5–8] proven to have a low thermal efficiency with low daily distillate productivity [9,10]. For example, Tayeb [11] found that the efficiency ranged from approximately 15 to 22% while Samee et al. [12] reported a typical efficiency of basin-type stills of 25%. Cappelletti [1] reported that a conventional solar still typically produces between approximately 5 l/m^2 day (on a bright sunny summer day) and 2 l/m^2 day (on a winter day). Moreover, Al-Hinai et al. [13] performed a parametric study on a conventional double-sloped single-basin solar still under climatic conditions of Sultanate of Oman at the Gulf region. They reported that under optimum design conditions, the still tends to give an average annual solar yield of approximately 4 l/m^2 day. The efficiency and yield of the conventional solar still depend on different factors: the design and functionality of the still, location, weather conditions, etc. [1,5]. Their low thermal efficiency is due to the considerable shadow caused by the walls of the basin that tend to decrease the absorption of solar radiation that could have been used for water distillation process. In order to improve the performance of conventional solar stills, several other designs have been developed, such as the double-basin type [14], multi-basin [15,16], inverted trickle [17], multi-effect [18,19], regenerative [20], with reflectors [21], spherical [6], triangular [22] and pyramid type solar still [23,24]. Kalogirou [25] presented an excellent review on various types of passive and active solar stills. Among these types are the single-slope with passive condenser, double condensing chamber solar still, vertical solar still, and conical solar still. In this paper, a new simple design of a transportable

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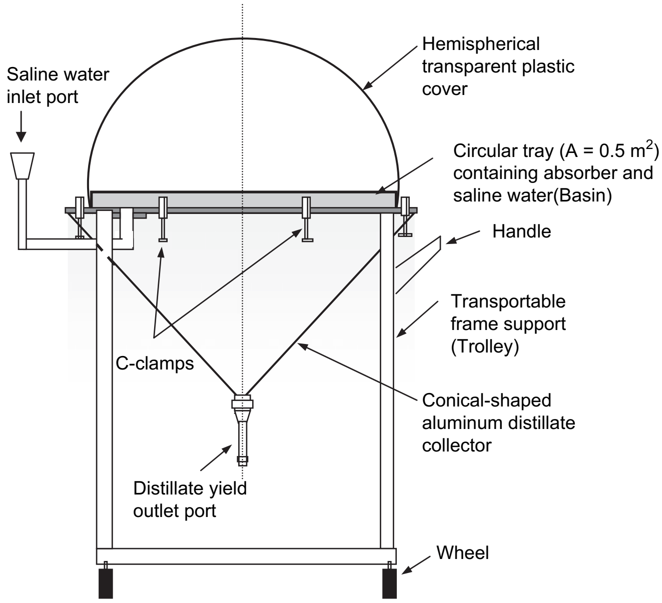

Fig. 1. Schematic diagram of the new transportable hemispherical solar still (drawn not to scale).

hemispherical type solar still is presented and its steady-state performance under Dhahran climatic conditions is evaluated.

2. Test site meteorological environment

The new semi-spherical solar still was tested under Dhahran (26°32′N, 50°13′E) climatic conditions in a typical summer month. Dhahran city is located just north of the Tropic of Cancer on the eastern coastal region of Saudi Arabia and is nearly 10 km inland from the Arabian Gulf Coast [26]. Dhahran is situated in a desert environment, although it is in the vicinity of the coast. Dhahran is characterized by two distinct seasons: a very hot season (May–October) and a cold season (November–April) [26]. The hot months are typically characterized by high solar insolation [27] with monthly mean temperatures reach close to 37 °C and in cooler months the mean temperatures drop to approximately 17 °C [26]. The relative humidity exhibits a large diurnal cycle on the order of 60% round the year. The monthly average wind speeds for Dhahran range from 4.1 to 6.4 m/s [26].

3. Design of the solar still

A schematic diagram of the new hemispherical (dome-shaped) solar still is shown in Fig. 1 and photographs of the fabricated still are shown in Fig. 2. The still mainly consists of the circular basin (tray) and absorber plate carrying the saline water, the hemispherical cover, the conical-shaped distillate collector, the distillate output plastic container, and the mobile support structure (trolley), as shown in Figs. 1 and 2. The basin of the still (tray) and absorber plate, and the collector were all fabricated using aluminum. The basin contains the absorber aluminum plate which has a surface area of 0.5 m^2 and a thickness of 4 mm. A hole with diameter of approximately 25.4 mm was drilled into the tray to provide accessibility of saline water into the basin during initial filling and the bottom section of basin was insulated to reduce thermal losses to the surroundings. The absorber was coated with black paint to maximize absorption of the incident solar radiation on the basin. The hemispherical cover, located on the top of the solar still unit, was made of a transparent plastic with absorptivity and transmissivity equal to 0.9 and 0.8, respectively. The transportable support structure was made of galvanized steel and coated with green paint. For sealing purpose, an approximately 6.5 mm thick rubber ring gasket was used and placed between the cover and the collector support structure where they were tightened and held in place using C-type clamps placed at equal distances around the periphery of the still as shown in Fig. 1. The distillate output from the still was frequently collected using a plastic container placed under the nozzle outlet part of the conically shaped collector. Copper–Constantantan thermocouples were installed and used to measure the temperature of the water in the basin at several locations to ensure uniform temperature throughout the basin, and the temperatures of the inside cover and ambient.

4. Experimental procedure

Experimental measurements were performed to evaluate the performance of the solar still under the outdoors of Dhahran climatic conditions. Before the commencement of each test the basin was filled with saline water using the inlet port, as shown in Fig. 1, and the hemispherical cover was cleaned from dust. The

Fig. 2. Photographs of the fabricated hemispherical solar still.