Solar Still

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solar still water distillation renewable energies

1. Introduction

The development of the world economy depends on water. It is the basic component of agriculture, industry, and infrastructure. Undoubtedly, water is one of the most needed components for life. While 70% of our planet is occupied by water, most of this water is saline. It is important to note that approximately 97% of water is found in the ocean, which is naturally salty; approximately 2% of the water is trapped in glaciers and icebergs in the arctic area; and Only 1% of water is fresh (accessible on the surface of the Earth or underground) for agricultural, animal, and human needs [1]. For instance, this very small amount of fresh water seems to be enough to maintain life and vegetation on our planet. However, we need to keep in mind that this amount of fresh water is being reduced every day due to many reasons, such as water resources pollution due to industry growth and global warming. In the meantime, the need for fresh water is growing intensely due to the growth in population density. This has led to the well-known problem of water scarcity. A widely used solution for this problem is desalination. Desalination is considered one of the major key solutions and is a sustainable and effective solution to the problem of freshwater shortages [2][3]. Desalination is defined as a process in which fresh water is the end product of saline water. In this process, thermal energy is utilized to evaporate the saline water, resulting in clean water free of salts and inorganic and organic components. One of the greatest merits of this process is that requisite thermal energy may be easily obtained from solar energy. This is why solar desalination has great potential to help overcome the water shortage problem.

2. Solar Still

Solar stills are considered an essential component of solar energy utilization for converting sea, brackish, or wastewater to fresh water. They consist of various components, such as the glass cover, water basin, absorber plate, insulation, and distillate trough channel. They can be defined as an efficient solar device for water distillation that directly uses the heat of the sun. Solar stills provide solar-powered desalination based on the concept that solar energy directly drives water evaporation. Solar stills can be used to distill, collect, and supply high-quality drinkable water essential for the daily survival of people who live in remote areas or small isolated communities [4].

Solar stills are simple, with no moving parts, are cheap to build using locally available materials, friendly to the environment with no pollution, have a low maintenance cost, and can be used in arid and salty areas, but their problem is their low water productivity and large area occupancy. Producing fresh water by utilizing a passive solar still would cost approximately $0.014 for each kilogram of water for a 30-year-lifetime system, as pointed out by Kumar and Tiwari [5]. The main idea of solar still operation and its thermodynamic model was introduced by Dunkle [6] and Lof [7], respectively. Solar stills are suitable for small-capacity and self-reliant water supply systems as they can only produce potable water by solar energy. Solar distilled water has a better taste than commercially distilled water; the main reason is that in solar distillation, the water is not subjected to a boiling process. Hence, its PH value is unaffected.

The most important solar still performance parameters are the efficiency and productivity as well as the internal heat and mass transfer coefficients. Their efficiency can be defined as the ratio of the latent heat energy of the condensed water to the total amount of solar energy incident on the still. Whereas productivity is defined as the amount of daily water output per unit area of the solar still. The temperature difference between the water in the basin and the inner surface glass cover governs the productivity rate of the stil [8]. Therefore, it mainly depends on the evaporation rate of the water from the basin and the vapor's condensation rate at the glass cover's lower surface. Generally, there are two main categories for solar stills classification, active and passive stills. For active solar stills, additional thermal energy is delivered to the basin by an external mode (such as collector/concentrator pane or waste thermal energy from chemical plants) so as to enhance the evaporation rate and hence the productivity. Moreover, the temperature differential between evaporation and condensation areas is increased in this type. While the solar still is called passive if this external mode is negligible. Therefore, the evaporation and condensation processes take place naturally. In this type, the basin water directly receives solar energy, and it is considered the sole source of energy that heats the water. So, the evaporation of the saline water leads to low productivity, which is considered the biggest disadvantage of the passive still. However, Tiwari et al. [9] concluded that passive solar stills are inexpensive sources of potable water, whereas the active ones are economical from a commercial point of view, such as in producing distilled water for retail purposes. Tiwari and Tiwari [10] classified the active solar distillation techniques as follows:

- Active solar distillation of high temperature: In this method, the hot water is fed into the basin by adding more thermal energy using solar collectors. This technique raises the temperature from 20–50 °C to 70–80 °C to achieve better evaporation. The solar still is attached with a flat plate solar collector or a parabolic concentrator, heat pipe, solar pond, and photovoltaic-thermal energy (PV/T) modules. The efficiency of the solar still working by this technique decreases with increasing solar collector area [11]. Regenerative active solar and air bubble solar stills are other high-temperature active solar distillation examples.
- Pre-heated water active solar distillation: the water basin's temperature is raised using pre-heated water. The waste hot water can be obtained from different sources such as chemical or food industries and thermal power plants. It is directly delivered to the basin or through heat exchangers. This technique can be used to increase the still productivity by about 3.2 times compared with the conventional still [12][13].
- Nocturnal active solar distillation: In this technique, the hot water is fed into the basin only one time per day. Nocturnal distillation can be defined as the working of a solar still when sunlight is unavailable. This is normally

achieved by using the daily stored solar energy through the night or by supplying waste heat which is available from different sources [14].

Solar stills employ the same processes encountered in nature for rainfall generation (i.e., evaporation and condensation). In this device, the impure water is placed in a container. The solar radiation crosses the glass cover and is then absorbed by the lower surface, which is coated with black paint. The absorbed radiation is converted directly into heat. This heat is absorbed by seawater, and partial evaporation of it takes place; the evaporated seawater is then condensed into distilled water on the internal side of the cover. After that, the drops of the distilled water begin to slide down due to gravity and are collected at the bottom of the inclined transparent cover [15]. Whereas the evaporated water leaves all the contaminants in the basin.

Solar stills consist of the following components [Ranjan and Kaushik [16]]:

- Glass cover, where the water vapor condensation takes place.
- Saline water (brine) body.
- Collector plate or basin-liner, where saline water is reserved to absorb the solar radiation.
- Base with insulation to reduce heat loss.
- Sidewalls or edges.
- Water container feed.
- Distillate output.
- Vapor leakage.
- Connecting pipes.
- Atmosphere, where the solar thermal energy interaction takes place.

The primary objective of solar stills is to maximize the distillate output. Distillate output depends on many different factors such as climate parameters (e.g., solar intensity, ambient air temperature, wind velocity, the humidity of the atmosphere, water-glass temperature difference, and sky conditions), design parameters (like the orientation of still, and tilt angle of cover.), and operating parameters (like water depth in the basin, and salinity of water) Garg and Mann [17].

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