Advancements in Solar Still Designs: A Review of Optimization Strategies and Performance Factors

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***Abstract*:** *Clean water scarcity is a pressing issue, especially in arid and remote regions where access to freshwater is limited. Desalination technologies play a crucial role in transforming brackish and saline water into potable water. Solar stills, leveraging abundant solar energy, offer a sustainable solution for water desalination in rural and isolated areas. This review paper explores various types of solar stills, focusing on their design, performance, and optimization using the Taguchi method. Specifically, it examines the effects of solar intensity and slope angle on the efficiency of double slope solar stills (DSSS) through a comprehensive literature review. Challenges in design, including enhancing heat transfer and maximizing water yield, are discussed alongside advancements in materials and modeling techniques. Factors influencing the performance of solar stills, such as glass-water temperature difference and water depth, are critically analyzed. Moreover, the paper explores desalination technologies as a viable solution to address global water shortages. By synthesizing existing research, this review aims to provide insights into the advancements and challenges in optimizing solar stills for sustainable water desalination.*

Keywords: *Desalination, solar stills, Taguchi method, double slope solar still, water scarcity, optimization*

I. INTRODUCTION

Clean water supplies are desperately needed for home, agricultural, drinking, and cleaning purposes. These days, water is scarce in desert regions and isolated places. Studies show that just 1% of the water which is available is fresh, whereas the other 20% is brackish. Approximately 79% of this water is salted [1]. The technique of desalination allows for the production of clean water using salty water. In rural and isolated locations with little traffic and little demand, solar stills are used to desalinate water. Sunlight doesn't require transportation and is easy to find, abundant, always cheap. The process of distillation occurs naturally. Water is heated by solar radiation, which then evaporates, condenses in clouds that and returns to the ground as rainfall. On a smaller scale, solar stills replicate this organic process. Desalination can be accomplished in either the direct or indirect manner using the sunlight. Indirect systems are those that combine a traditional distillation process using a solar collection system. Direct solar powered stills employ solar energy to generate distillate directly in the solar collector [2]. Review articles about several kinds of solar stills are available in the literature.

II. CHALLENGES IN SOLAR STILL DESIGN AND PERFORMANCE

Solar stills with single and double gradient collectors A double-slope sun still (DSSS) features two layers of glass that wrap around the highest point, increasing the condensation surface area for condensing of the rising water vapor under the still, while it functions similarly to single-slope solar stills (SSSS). The DSCSS has a more productive rate of fresh water with effective condensation, as shown in Figure 1 [3]

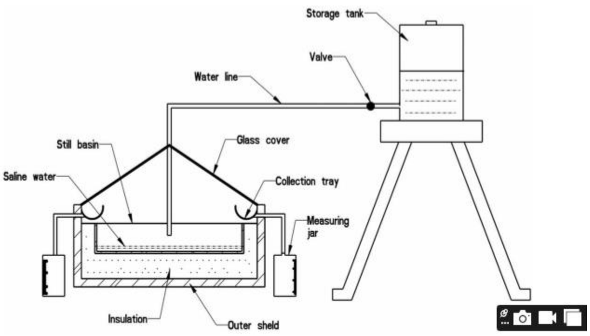

Figure 1.Double-slope collector solar still [4]

A. Single Basin Solar Still Concave Wick Solar Still

A stepped solar-still (Figure 2) was constructed to act as the water-channel basin. It was made of semi-circular in tube pieces that were welded gradually one next to another to keep a consistent gradient. An airtight (vacuum capable) jacket has been included to reduce heat losses through the solar-still's bottom. Since air is a good insulator, the jacket was sealed to stop heat loss through the network's base. The solar still is filled and emptied with water that has been treated via an input at the top and a vent at the bottom, correspondingly. In order to optimize solar radiation, the layout additionally features a variable slope that may be changed based on a suitable latitude and solar height.[5]

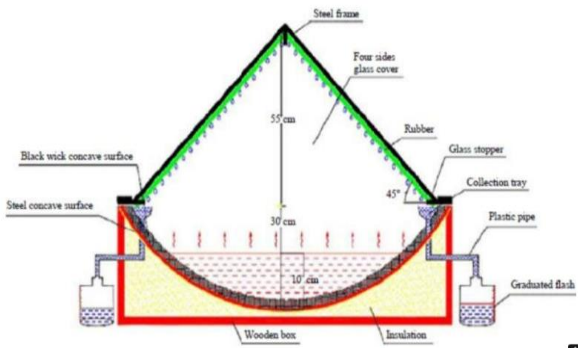

Figure 2.Schematic diagram of a concave wick solar still[6]

B. Pyramid Single Basin Solar Still

Experimentally studied a pyramid solar still under forced and natural convection. Experiments are carried out in Tafila city (Jordan) and performance of solar still with and without fan show that the reduced temperature of glass increases the condensation with larger temperature difference. The solar still yield during mid-noon on experimental day with and without fan found to be 0.4 and 0.35 kg m–2h–1, respectively and the maximum efficiency of the solar still was increased from 40-50% with fan as cooling. Hence, with the help of a solar PV assisted fan cools the surface areas of the glass for better condensation of vapor shows in figure 3.

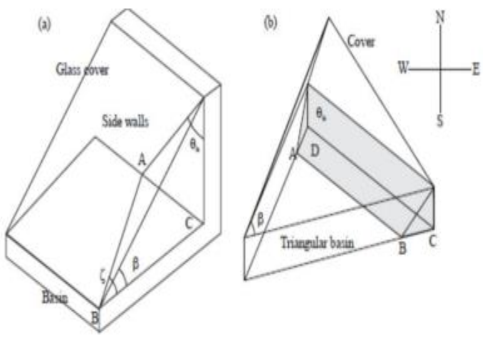

Figure 3.Schematic diagram of a triangular pyramid solar still[7]

C. stepped solar-still

The water-channel reservoir was constructed using a tiered solar-still (Figure 4) made of semi-circular pipe sections that were welded successively one next to another for maintaining a consistent gradient. An airtight (vacuum capable) jacket was additionally included to reduce the transfer of heat through the solar-still's bottom. Since air is an excellent insulator, the jacket was sealed to stop heat loss through the structure's base. The photoelectric still is filled and emptied with purified water via an input at the highest point with a drain at the bottom, correspondingly.[8]

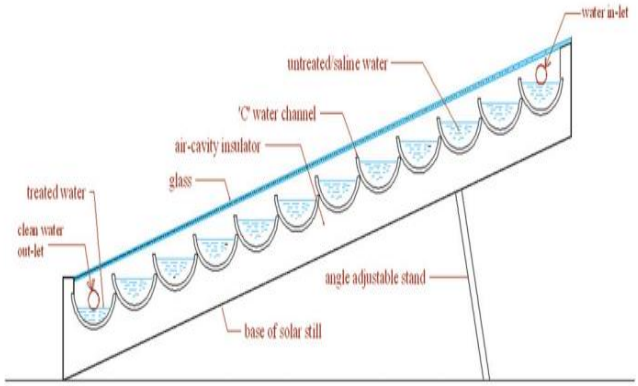

Figure 4.Stepped solar-still design.

III. TYPES OF SOLAR STILLS

Solar stills can be sub divided in to two kinds :

A. Passive solar stills: The condensation phenomenon in solar-powered systems leverages solar radiation as the primary source of heat. These systems combine both photovoltaic (PV) and thermal solar technologies to maximize efficiency. Solar radiation, in its direct and converted forms, provides ample energy to heat water or other fluids within these systems. The effectiveness of condensation largely depends on operational temperatures and vapor pressures. Lower operational temperatures enhance condensation rates by creating conditions where the vapor in the system can efficiently convert back into liquid form, thus maximizing the overall efficiency of the solar-powered setup. [9]

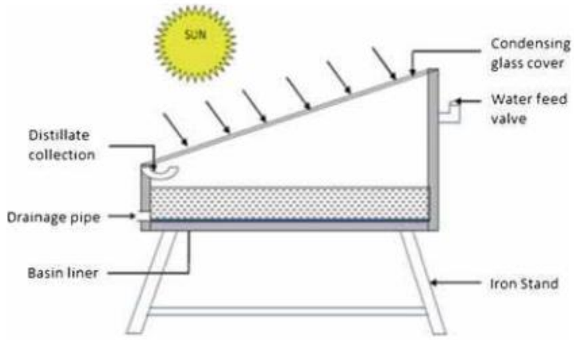

Figure 5. Schematic of a single slope passive solar still[10]

B. Active solar stills For speedier evaporated water, this type of excessive thermal power is mixed by passive solar radiation. It might be derived from a factory plant's surplus heating radiation or through solar collectors.The majority of assessments focused on photovoltaic stills, particularly on wick type, layout and construction, and improving model achievement. However, recent innovations, which include the creation of novel materials (such phase-change and nanocomposite materials)[9].

IV. FACTORS AFFECTING THE PERFORMANCE OF SOLAR STILL

Wind turbines use a variety of variable-speed the generator kinds. Even though permanent magnet synchronous generators (PMSGs) are utilized less frequently over double-fed induction generators (DFIGs) these days, professionals agree that PMSGs have particular benefits. PMSGs can function need a gearbox or are distinguished through their direct-drive design, reduced rotation speed, & lack of rotor current as well. Such features alleviate major investment considerations by lowering maintenance demands, improving performance, and lowering costs. However, PMSGs also have some disadvantages. They impose strict production and operational standards, requiring an adjustable emf field. Furthermore, an electric inverter must control the generator's fluctuating speed.[11]

A.Glass–water temperature difference Air weight naturally circulates more throughout the solar system when the temperature differential among the container of water and the glass cover gets larger. Enhances the transmission of heat and condensation of water in a bowl to a glass cover [12]. The technique of reduction is thought to have been propelled by the difference in temperatures amongst the water and the coating of glass. Regenerating energy stills with dual mirrors and triple bar stills may be used to increase the temperature differential amongst the glass and water cover..[13-14]

B. Free surface area and deepness of water The amount of exposed water remaining significantly impacts how quickly water evaporates under the sun. Consequently, improving the well's water-free surface area increases solar energy output. Bath water is mixed with a sponge to do this [15]. Because the thickness of the liquid in the pond is proportionate to the static output, the thickness of the water has a major effect on the basin's production [16]. It has been discovered that the substance is easier to reach at lower water levels. A dry patch will develop if certain solar depth is preserved. The effect of different sun depths is still being developed by Caliph and Hamood. The worst case scenario for the operation of shallow solar panels was reported by Porta et al. [17].

V. DESALINATION AS A SOLUTION FOR POTABLE WATER SHORTAGE PROBLEM

As technology has advanced, a wide range of commercial and industrial technologies are employed to produce potable water from saline or brackish water. These gadgets are capable of purifying any type of tainted water. As a result, they might be utilized in establishments including houses, hotels, and schools. As shown in Figure 1, the water cleaning devices are divided into three primary categories: chemical devices, thermal distillation methods (which involve phase changes), and membrane techniques (which involve single phase processes). [18]

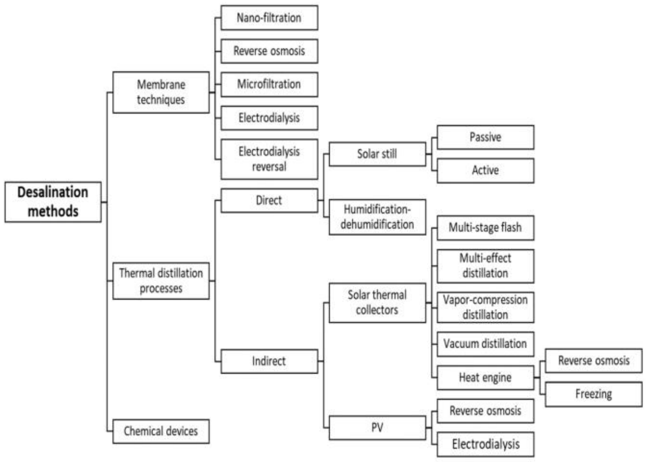

Figure 6. Classification of desalination methods.[18]

Efficiency of solar stills The performance or efficiency of solar still is defined as amount of distilled water as output to Solar energy absorbed within time interval as input [19]. It can also be defined as the ratio of latent heat energy of the condensation at inclined cover to the total amount of solar energy located on the still . The performance of the still is calculated as illustrated in

Equation 1

$\eta = \frac{M h_{fg}}{A_{st} \sum I}$: efficiency of solar still.

M: total output of the still through the day (kg/m2 /day).

h_{fg}: latent heat of evaporation of water(kJ/kg).

A_{st}: area of solar still in m2 .

$\sum I$: total amount daily solar radiation (KJ/m2 /day).[20]

VI. CONCLUSION

As the assessment comes to an end, it is clear how crucial solar stills are as a sustainable and practical solution to the problem of water scarcity in isolated and dry areas. These gadgets provide a decentralized method of producing drinkable water using brackish sources by utilizing solar energy. The studied literature emphasizes the impact of characteristics like slope angle and sun intensity in improving performance, as well as developments in solar power plant design and optimization approaches. Maximizing scalability and efficiency while lowering costs and environmental effects continues to present challenges. Subsequent investigations ought to concentrate on amalgamating novel technology and materials in order to enhance the efficacy and global usability of solar stills.

Conflict of Interest: The corresponding author, on behalf of second author, confirms that there are no conflicts of interest to disclose.

also permitted to post their work in institutional repositories, social media, or other platforms.

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