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# Evaluating the Impact of Absorber Geometry on Solar Still Efficiency: A Comparative Study of Square and Round Absorbers

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**Abstract** – *Solar stills have been used for many years in areas with limited access to fresh water, such as desert regions or remote locations. They are simple to construct using readily available materials and require no energy input other than sunlight. Additionally, solar stills are low-maintenance and can produce a significant amount of pure water with relatively little effort. Two solar stills are exposed to the sun, the first is a single solar still and the other is a hemispherical sender. Both stills have similar absorber. The purpose of this experiment is to compare the pure water output of the two devices. The finding shows that hemispherical solar still is more efficient than the simple solar still by 54.30 % in terms of pure water output. This suggests that the hemispherical still is better at capturing and utilizing solar energy to evaporate and condense water.*

**Keywords**: Energy solar, Solar distillation, Pure water, Absorber.

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## I. Introduction

Access to drinking water is a fundamental necessity for the health and survival of humanity. Unfortunately, many parts of the world, particularly in Africa, face significant challenges related to water scarcity and contamination. These issues complicate efforts to ensure a consistent supply of clean water. To address these challenges, effective and affordable water treatment solutions are essential. Such methods are designed to remove impurities and harmful microorganisms, ensuring that water is safe for consumption. However, traditional water treatment techniques, including filtration, chemical treatment, and disinfection, often involve complex processes, high costs, and significant energy consumption, making them less practical in resource-limited settings [1,2].

In this context, solar distillation offers a simpler and more environmentally friendly alternative. This method utilizes solar energy to evaporate and then condense water, effectively converting salty or contaminated water into clean, drinkable water. Solar stills harness the power of sunlight to purify water, providing a sustainable, cost-effective, and natural solution to water treatment challenges [3,4]. Solar stills are particularly useful in regions where access to electricity and advanced water treatment infrastructure is limited. They are not only affordable but also environmentally sustainable, as they rely on abundant solar energy for operation [5,6].

Researchers are continually exploring ways to enhance the efficiency of solar stills. One promising approach involves integrating materials with high thermal conductivity, such as metal fins, to improve heat transfer and accelerate the evaporation process, thereby increasing overall efficiency [7,8]. Another method is the use of phase change materials (PCMs), which store and release thermal energy during phase transitions, helping to maintain a stable temperature and optimize the distillation process [9,10]. Additionally, incorporating nanoparticles into the system has shown potential for further improving thermal conductivity and performance [11,12].

Further research has investigated various methods to optimize solar still efficiency. Adjustments to the thickness and angle of the glass cover can significantly impact the amount of solar energy absorbed and its efficiency [18,19]. Other studies have focused on enhancing heat transfer through the glass cover itself [20,22]. Additionally, placing refractors and mirrors near the still can direct more sunlight onto the device, further increasing its efficiency [23,24].

In terms of materials, both metallic and non-metallic substances have been evaluated for their impact on water production and purification. Zinc demonstrated a notable 54% improvement in distillation efficiency, highlighting its effectiveness [25]. In contrast, dune sand showed no improvement, with an effectiveness rate of 0% [26,27]. Aluminum increased efficiency by 33.32% [28], while iron components contributed a 23.46% improvement [29]. Sponge led to a 10% increase in efficiency [30], ethanol improved efficiency by 20% [31], palm fiber by 36%, and charcoal blocks by 8% [32,33]. Rubber, cellulose, and carbon also positively impacted performance, with rubber improving efficiency by between 15.06% and 33.13% [34], cellulose cardboard by 19.8% [35], and carbon achieving impressive improvement rates ranging from 18.18% to 79.39% [36,37].

Recent advancements from 2019 to 2023 have introduced additional passive techniques and technologies designed to further enhance the efficiency of solar stills. Innovations such as concentrators to focus sunlight, reflective mirrors to improve light absorption, evacuated tube collectors (ETCs) for more efficient heat capture, nanoparticles for better thermal properties, and various heat storage materials are being explored. These developments aim to accelerate the evaporation process by increasing the amount of heat available to the system. Current strategies focus on optimizing heat confinement using nanoparticles, improving concentrator efficiency, incorporating latent and sensible heat storage materials, and utilizing fabric-based absorbers. The challenges, limitations, and future prospects of these innovations are actively discussed in recent literature [38].

Two studies address the low output of solar stills with different approaches. The first study improves a double slope solar still using modified absorber plates and an external copper condenser (ECC), achieving a daily efficiency of 1.7 L/m² and an overall efficiency of 17.86%. This configuration was 55.57% more cost-effective than traditional designs. The second study uses CFD simulations to test various absorbent materials and reveals that black toner significantly improves productivity and heat transfer, with a cost per liter of $0.0066. Both studies highlight the benefits of improving design and materials to increase the efficiency of solar stills [39,40].

This study is to evaluate and compare the performance of two distinct solar still designs: a conventional solar still (CSS) with a square metal absorber and a hemispherical solar still (CHSS) with a round metal absorber, both having the same absorber surface. Emphasis is placed on determining the impact of absorber shape on water purification efficiency under identical conditions. The novelty of this work lies in its comparative analysis of the shape of absorbers in solar stills, as most studies generally focus on design or material variations, but not specifically on the influence of absorber geometry absorber on performance. This research aims to provide insights into how different shapes of absorbers can affect the overall efficiency of solar distillation systems, providing valuable insights for optimizing the design of solar stills.

## II. Methodology

### *II.1. Experiment progress*

In October 2022, a research experiment was conducted at the University of El Oued in southeastern Algeria to evaluate the performance of two different types of greenhouse solar stills. The study aimed to compare the efficiency of a conventional solar still (CSS) with that of a hemispherical solar still (CHSS) under identical meteorological conditions.

The experiment involved two solar stills placed in a controlled outdoor environment to ensure they received equal exposure to sunlight. The CSS featured a traditional design with a standard rectangular shape, while the CHSS was designed with a hemispherical configuration. Both stills were equipped with the same size and type of absorbent surface to ensure a fair comparison, as shown in Figure 1.

The main objective of this experiment was to evaluate and compare the performance of these two solar still designs. By analyzing the efficiency and output of each still, the research aimed to determine which design was most effective in converting solar energy into purified water under the given conditions.

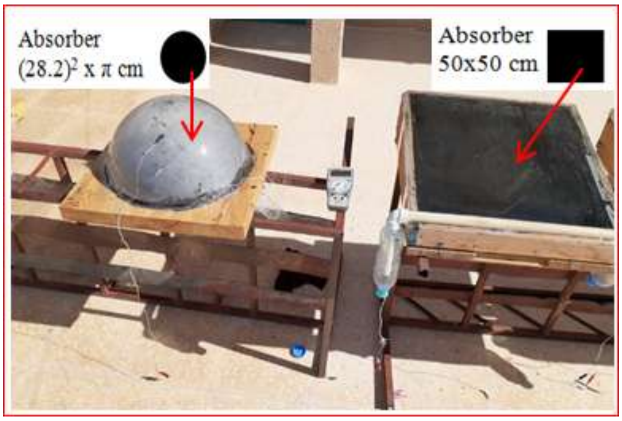


Figure 1. Solar still during the experiment

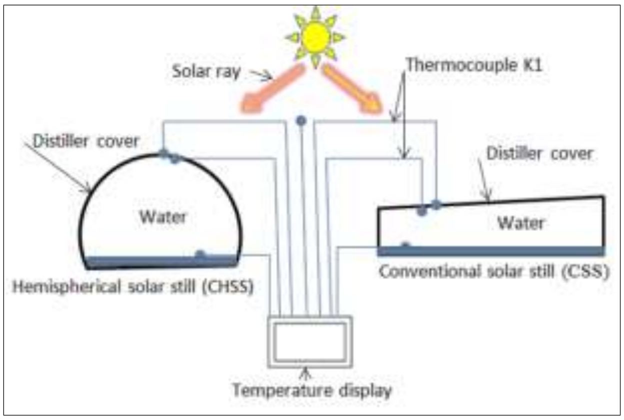


Figure 2. Explanatory scheme

### *II.2. Measurement Methods for Solar Still Performance*

A conventional solar still (CSS) uses a flat, square metal absorber plate under an inclined glass cover to absorb solar energy and heat water in a pond. This results in water evaporation, condensation on the glass cover of the cooler, and collection of distilled water. In contrast, a hemispherical solar still (CHSS) has a round, hemispherical absorber plate covered with a transparent dome. The hemispherical design improves solar energy absorption and heat distribution, improving evaporation rates and condensation efficiency. The curved shape of the dome allows for more efficient condensation and collection of distilled water, potentially increasing overall performance compared to the flat design of the conventional solar still.

In the experiment, K-type thermocouples are used to monitor various temperatures crucial for evaluating the performance of solar stills.

Figure 2 illustrates the experimental setup, showing the geometry of the two solar stills – conventional (CSS) and hemispherical (CHSS) – as well as the locations of the type K thermocouples. The diagram details the locations of the thermocouples on the glass cover, ensuring accurate data collection to evaluate temperature variations and performance. These thermocouples are strategically placed: one on the outside of the glass cover, one on the inside, one immersed in water and one to measure the ambient temperature. The location allows for comprehensive temperature data collection, which is essential for understanding heat distribution and efficiency. To measure water production, a fisherman records the amount of distilled water collected. Data is collected hourly, from 08:00h to 16:00h, ensuring continuous monitoring of temperature changes and water flow throughout the experiment.

## III. Results and discussion

### *III.1. Evolution of solar radiation and ambient temperature*

Solar radiation is indeed a critical factor that affects the performance of solar stills. The amount and intensity of solar radiation directly influence the amount of heat energy that is absorbed by the solar collector, which in turn affects the rate of water evaporation and the overall efficiency of the still. Therefore, in solar distillation experiments, it's essential to consider and control the amount of solar radiation received by the stills to accurately evaluate their performance.

Figure 3 shows the amount of solar radiation ($W/m^2$) received at a particular location over an 8-hour period. The highest amount of solar radiation is received between 12:00h - 14:00h, with a maximum value of 900 $W/m^2$. This is the time when the sun is at its highest point in the sky, and the radiation received is the most intense. The Figure 3 also shows that the maximum ambient temperature is 31°C at 14:00 h. This information can be useful in determining the optimum operating conditions for solar distillation, as the process can be affected by changes in temperature.

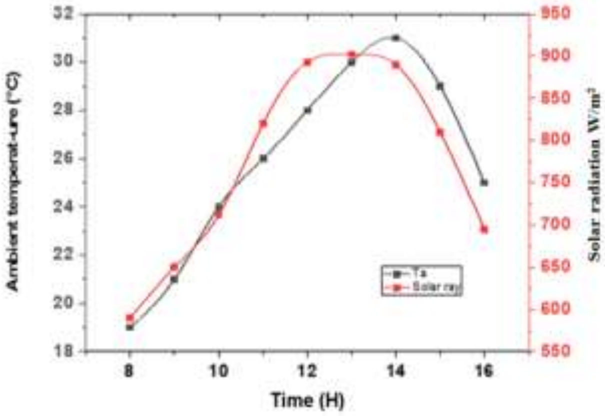


Figure 3. Variation of solar radiation and ambient temperature

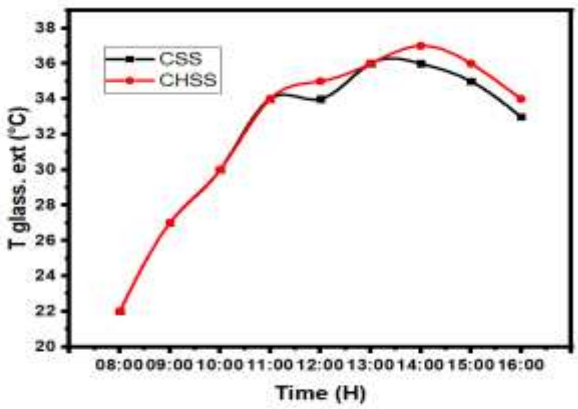


Figure 5. Variation of external glass covers temperature

### 3.2. Glass covers internal and external temperature

Figures 4 and 5 illustrate the temperature variation on the inner and outer sides of the glass cover over time for the conventional solar still (CSS) and the hemispherical solar still (CHSS). Notably, the inner side of the glass cover consistently exhibits higher temperatures than the outer side. This temperature difference is mainly due to the presence of hot steam inside the still, which heats the inner surface of the glass. The maximum temperatures recorded on the inner surface of the glass cover for the CSS and CHSS are 38°C and 39°C, respectively. These temperatures reflect the intense thermal interaction between the hot steam and the glass, a crucial aspect of solar still operation.

In contrast, the outer surface of the glass, which is exposed to the ambient environment, exhibits slightly lower maximum temperatures of 36°C for the CSS and 37°C for the CHSS. This temperature gradient between the inner and outer surfaces of the glass results in heat loss to the environment.

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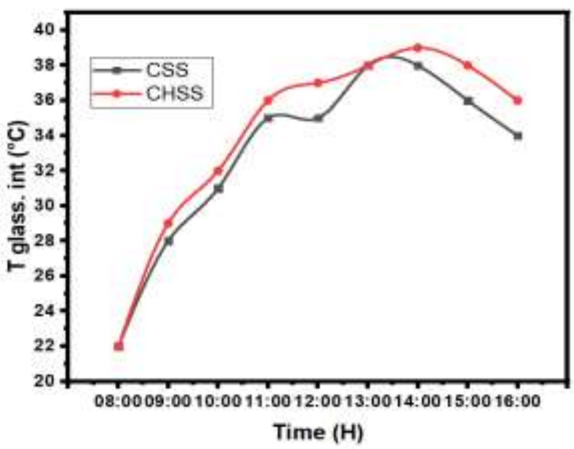


Figure 4. Variation of internal glass cover temperature

### III.2. Water temperature evolution

The water temperature is a key factor in the performance of a solar still. As the temperature of the water increases, it induces the process of evaporation, which is necessary for the production of pure water in a solar still. An increase in water temperature results in an increase in evaporation rate, which ultimately leads to a higher yield of pure water. Therefore, maintaining an optimal water temperature is crucial for ensuring the efficient and effective operation of a solar still.

Figure 6 illustrates the variation of water temperature over time in two solar stills, namely the CHSS and CSS. It is apparent from the graph that there is a significant difference between the two systems, with the CHSS consistently displaying higher water temperatures than the CSS throughout the experiment. The difference in maximum temperatures between the two stills is most notable during the period between 14:00h and 16:00h. Specifically, the CSS records a maximum temperature of 45°C, while the CHSS records a higher maximum temperature of 48°C.

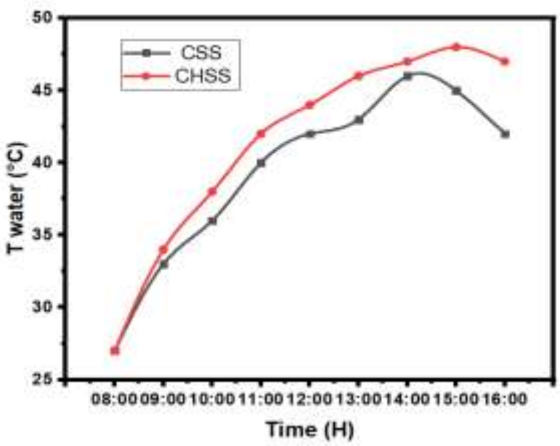


Figure 6. Variation of water temperature

### *III.3. Accumulation and Hourly output of pure water*

The data presented in Figure 6 displays the collection of distilled water using two different types of stills, namely the CHSS and CSS. The measurements were conducted over a period of 8 hours on a sunny day. Results showed that the CHSS still outperformed the CSS still, with a consistently higher yield of pure water. Specifically, the CHSS still produced an output of 755 ml, whereas the CSS still produced only 410 ml. The observed difference in pure water output between the two types of stills, as shown in Figure 7, is indeed significant. With an output of 755 ml compared to 410 ml for the CSS still, the CHSS still clearly outperforms the CSS still in terms of water collection. This finding suggests that the hemispherical solar still may be a better option than the conventional still, at least in terms of pure water yield.

Figure 8 illustrates the hourly variations in production of two types of solar stills – CHSS (Hemispherical Solar Still) and CSS (Conventional Solar Still) – throughout the experimental period. The data reveals a clear difference in performance between the two distillers. CHSS has consistently demonstrated superior performance, producing significantly higher hourly outputs than CSS. For example, at the peak hour of 2:00 p.m., the CHSS reached a maximum flow of 140 ml, while the CSS reached a maximum of only 75 ml. This marked difference highlights the increased efficiency of CHSS in converting solar energy into distilled water. The higher and sustained efficiency of the CHSS throughout the experiment highlights its effectiveness in maximizing water production compared to the conventional design.

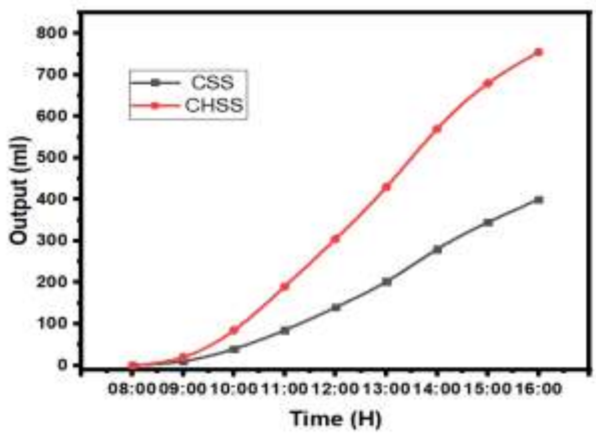


Figure 7. Variation of accumulation output

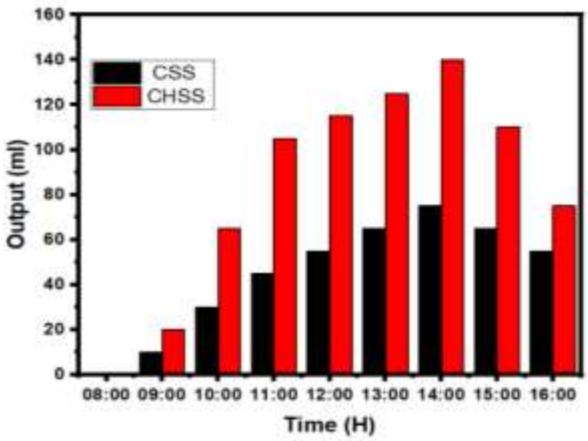


Figure 8. Hourly variation of output

## IV. Conclusion

The study focuses on the comparison of the performance of two types of solar stills, the conventional CSS still and the hemispherical CHSS still. We discussed the importance of parameters such as water temperature, temperature gradient, and internal and external temperatures of the glass cover, and their impact on the efficiency of water production in a still solar.

The data presented in the study that:

- The water temperature and the temperature gradient of the CHSS still are always higher than that of the CSS.
- The output of CHSS is 755 ml while it is 410 ml for CSS this means an improvement of 54.30 %.

Based on the results, the CHSS still is more efficient in producing pure water than the CSS still. However, building a CHSS distiller can be more difficult than building a CSS distiller that uses components readily available in markets around the world. It is important to consider both the efficiency and feasibility of construction when choosing a distiller for a particular application. While the CHSS distiller may be more efficient, it may not be the best choice if it is difficult to construct or requires specialized materials that are not easily obtainable. On the other hand, a distiller that uses readily available components may be easier to construct but may not be as efficient as a more specialized design. Ultimately, the choice of distiller will depend on the specific needs and constraints of the application.

## Declaration

- The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.
- The authors declare that this article has not been published before and is not in the process of being published in any other journal.
- The authors confirmed that the paper was free of plagiarism.

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