



## Research Article

# Experimental Study on Hemispherical Solar Still Performance Enhancement Using Aluminium and Galvanized Steel Floral Rings Inserts

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### PAPER INFO

#### Paper history:

Received: 08 August 2024

Revised: 12 February 2025

Accepted: 12 March 2025

#### Keywords:

Hemispherical Solar Still,  
Distillation Efficiency,  
Sensible Heat Storage,  
Galvanized Steel Inserts,  
Aluminum Inserts

### ABSTRACT

This study explores the performance enhancement of hemispherical solar stills by incorporating basin inserts made from galvanized steel and aluminum, both used as sensible heat storage materials. The aim is to compare the effects of these materials on the efficiency of the distillation process. The experimental setup maintains a consistent geometry, integrating aluminum floral ring inserts (AFRI) and galvanized steel floral ring inserts (GSFRI) to optimize heat retention and utilization. Our results demonstrate a 20% increase in distillate water production for solar stills equipped with AFRI compared to conventional designs, with an average yield of 8 kg/m<sup>2</sup>/day. The configuration using AFRI achieved an efficiency of 12.75%, highlighting the practical feasibility of this approach for sustainable water purification. Furthermore, the AFRI outperformed the GSFRI in both distillation efficiency and overall water output, emphasizing the significance of material selection in optimizing solar still performance.

<https://doi.org/10.30501/jree.2025.470255.2014>

## 1. INTRODUCTION

Global water scarcity is intensifying due to industrialization, pollution, and rapid population growth, making it essential to develop sustainable solutions. Clean water is vital for human survival, and solar energy offers a promising solution due to its simplicity, affordability, and ease of operation, despite some limitations in productivity. Solar desalination, particularly through solar stills, is an efficient method for producing potable water. In a hemispherical solar still, solar radiation heats saline water in a black-painted basin, causing evaporation (Khelifi et al., 2025). The vapor rises and condenses on the inner surface of the transparent hemispherical cover, which is cooled by ambient air or flowing water. The condensed droplets slide down the cover and are collected as fresh water. This design enhances solar absorption through its hemispherical shape, improves condensation efficiency, and reduces heat losses, thereby increasing overall water productivity. Numerous researchers have focused on enhancing the efficiency of solar stills with single and double slopes, experimenting with various basin configurations (Chekifi & Boukraa, 2023; Thakur, Agarwal, Khandelwal, & Dev, 2018). Panchal et al. (H. N. Panchal, 2015) proposed improvements to solar stills by integrating vacuum tubes and black granite pebbles. Their findings showed that distillate yield from basin materials containing calcium stones exceeded that from black granite gravel and pebbles. Omara et al. (Omara, Hamed, & Kabeel, 2011) studied the impact of finned and corrugated solar

stills, using 1.5 mm thick iron sheets, in Egyptian conditions. They revealed that corrugated and finned solar stills increased productivity by 21% and 40%, respectively, compared to conventional stills when processing 30 liters of saltwater. Abderachid and Abdenacer (Abderachid & Abdenacer, 2013) conducted a comparative analysis of a symmetrical solar still with a double effect under varying orientations. Dumka and Mishra (Dumka & Mishra, 2018a) applied Dunkle, Clark, Kumar and Tiwari, Tsilingiris, and a modified version of Spalding's mass transfer theory to assess the effectiveness of a solar still integrated with a sand bed earth surface, comparing it with a conventional single-basin, single-slope solar still. They utilized the Kumar and Tiwari model to predict yields that closely matched experimental results. Dumka and Mishra conducted a comparative performance analysis of solar stills integrated with soil versus those integrated with earth and a surrounding area coated with transparent polythene and black coal dust powder (Dumka & Mishra, 2018b). According to the review by Srithar and Rajaseenivasan (Srithar & Rajaseenivasan, 2018), numerous researchers have conducted comprehensive analyses of methods to enhance heat transfer rates in solar stills. These methods include the addition of fins, utilization of energy-storing materials, wicks, incorporation of nanoparticles, cooling with transparent covers, effects of agitation, integration of thermoelectric coolers, multi-effect solar stills, preheating with water heaters, use of photovoltaic thermal collectors, and operation with heat pumps and

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URL: [https://www.jree.ir/article\\_217259.html](https://www.jree.ir/article_217259.html)

Please cite this article as: Khelifi, R., Chekifi, T., Zoukel, A. H., Belaid, A., Guermoui, M. & Touafek, K. (2025). Experimental study on hemispherical solar still performance enhancement using aluminium and galvanized steel floral rings inserts, *Journal of Renewable Energy and Environment (JREE)*, 12(2), 68-78. <https://doi.org/10.30501/jree.2025.470255.2014>



refrigeration. Selvaraj and Natrajan ([Selvaraj & Natarajan, 2018](#)) examined various factors influencing solar still performance, such as wind speed, insulation, tilt angle, collector area, temperature difference between water and glass, and solar radiation intensity. In their study on large-scale solar desalination using a seawater aqueduct. Manokar et al. ([Manokar et al., 2018](#)) reviewed PV/T-integrated solar stills, highlighting enhanced water and energy production. Passive stills yield 2–5 kg/m<sup>2</sup> daily, while PV/T-integrated systems produce 6–12 kg/m<sup>2</sup>. They noted that higher PV temperatures reduce power output, but wind improves both PV and still efficiency, emphasizing PV/T solar stills' suitability for remote areas facing water and energy shortages. Arunkumar et al. ([Arunkumar, Wang, Rufuss, Denkenberger, & Kabeel, 2020](#)) investigated the impact of various energy storage materials, such as polyvinyl alcohol (PVA) sponges, pebbles, spherical clay balls (SCBs), and CuO nano-coated absorber plates (CuONCAPs), on the performance of single-slope solar stills (SSSS). They found that efficiencies with PVA sponges, pebbles, SCBs, and CuO NCAP were 32%, 44%, 39%, and 53%, respectively, with pebbles showing the highest efficiency. Nocturnal production was also compared. In another study, Kabeel et al. ([Kabeel, Omara, & Essa, 2014](#)) investigated the effects of suspended nanoscale solid aluminum oxide particles in the basin water of single-basin, single-slope solar stills with an external condenser. They observed that adding hot air to the basin water increased distillate yield by 108% compared to traditional solar stills ([Kabeel, Abdelgaied, & Mahgoub, 2016](#)). Velmurugan et al. ([Velmurugan, Gopalakrishnan, Raghu, & Srithar, 2008](#)) demonstrated increased distillate production in single basin, single slope solar stills by adding fins, wicks, and sponge. Furthermore, Fathy et al. ([Fathy, Hassan, & Ahmed, 2018](#)) experimentally investigated the performance of a double-slope solar still coupled with a parabolic trough collector (PTC). Solar energy is transferred via oil pipes and a finned-loop heat exchanger in the still. Tests were conducted in summer and winter for conventional solar stills, stills with fixed PTCs, and stills with tracked PTCs at 20 mm and 30 mm water depths. Results showed the solar still with tracked PTC had 28.1% higher productivity than the fixed PTC and 142.3% higher than the conventional still at 20 mm water depth in summer. Productivity was 8.53 kg/m<sup>2</sup>/day in summer and 4.03 kg/m<sup>2</sup>/day in winter with a fixed PTC. Overall, summer efficiencies were higher, with tracked PTCs achieving the best performance at lower freshwater costs. Panchal et al. ([H. Panchal, Patel, & Patel, 2018](#)) explored the use of sandstones and marbles as energy storage materials in solar stills, with dripping water used to cool the top cover. Compared to unaugmented stills, those augmented with sandstones and marble pieces showed a 30% and 14% increase in yield, respectively, while also lowering the temperature of the top cover. Abdullah et al. ([Abdullah, Essa, Bacha, & Omara, 2020](#)) experimented with tray stills, incorporating modifications such as reflectors and CuO nanoparticles in paint, as well as using paraffin wax mixed with CuO nanoparticles as a phase change material. These enhancements resulted in a 108% increase in fresh water yield and a 51.5% improvement in thermal efficiency for the tray distiller unit. Arunkumar et al. ([Arunkumar et al., 2012](#)) conducted an experimental study on a hemispherical solar still for water desalination, with and without the effect of water flowing over the cover. The cooling effect, achieved by flowing water over the top, reduced the cover's temperature and improved distillation efficiency. The study was conducted in Coimbatore, India, with observed

efficiencies of 34% without cooling and 42% with the cooling effect. The still featured a black-painted mild steel basin, a transparent acrylic hemispherical cover with 88% solar transmittance, and insulation using sawdust and glass wool to minimize heat loss. Basel ([Ismail, 2009](#)) designed and experimentally evaluated a simple, transportable hemispherical solar still under outdoor conditions in Dhahran. The daily distilled water output ranged from 2.8 to 5.7 L/m<sup>2</sup>/day. The still achieved a maximum daily average efficiency of 33% with a conversion ratio of nearly 50%. The study also observed that increasing the saline water depth by 50% reduced the average efficiency by 8%. These findings highlight the impact of water depth on solar still performance and the effectiveness of the hemispherical design for water distillation.

In this study, we examine how the performance of hemispherical solar stills can be enhanced by incorporating basin inserts made from two different materials: aluminum floral rings (AFRI) and galvanized steel floral rings (GSFRI). These inserts function as sensible heat storage units, absorbing solar energy during the day and retaining heat for an extended period. The stored heat is gradually released, enabling the still to continue producing water even during periods of reduced sunlight. This innovative approach not only makes the solar still more energy-efficient but also increases the amount of distilled water produced. Our experimental research aims to understand how these different insert materials affect the distillation process. We measure key factors such as the amount of distilled water produced, the system's energy efficiency, and its stability. Through this investigation, we aim to demonstrate that this integrated approach is practical and effective for water purification. We expect to see significant improvements in both the quantity and efficiency of distilled water production, particularly with the AFRI inserts. This research underscores the importance of selecting the right materials for solar stills and offers a promising solution for increasing water production in areas with water scarcity.

## 2. EXPERIMENTAL SETUP

Our experimental setup consists of three identical hemispherical solar stills, each with a diameter of 30 cm. The first still serves as the control model, featuring a standard configuration with a black-coated bottom to maximize heat absorption. The second still is enhanced with aluminum floral ring inserts (AFRI), while the third uses galvanized steel floral ring inserts (GSFRI). Each insert is approximately 5 cm in diameter and 1 cm thick, with six pieces uniformly distributed across the basin surface to ensure full coverage in both AFRI and GSFRI configurations. These inserts are strategically positioned at the base of the stills to increase the surface area for heat absorption and retention. This modification is aimed at improving the production of purified water within the solar stills (Figure 1).

To enhance the distillation process, each still is equipped with a transparent glass cover positioned above the water surface. This cover allows sunlight to heat the water while providing a surface for water vapor to condense into droplets. These droplets then flow down into a hemispherical bowl at the bottom. A 0.5 mm gap separates the black basin from the bowl, aiding in the collection of purified water droplets.

Our new experimental setup features a water container connected by 8 mm diameter tubes to three hemispherical solar stills: one conventional, one with aluminum floral rings (AFRI), and one with galvanized steel floral rings (GSFRI). The brackish water is held in a black-coated aluminum basin to

enhance heat absorption, improving distillation efficiency by increasing the water temperature. This setup mimics real-world atmospheric conditions, allowing precise observation and analysis of the distillation process. To simulate real-world conditions, we add 30 g/l of NaCl to the water input.

Tests will be conducted at our research facility in URAER, Ghardaya City, over three days from 05 to 07 July 2024, with operations running from 9 AM to 9 PM. Distillate water will be collected hourly, enabling thorough examination of water production rates and performance variations over time. A Thermocouple Data Acquisition (TDA) system, connected to a computer, will ensure precise and comprehensive data logging.

Each solar still is equipped with three sensors to monitor critical temperatures: one for the internal surface of the glass cover, one for the saline water, and another for the black basin absorber. The sensors are positioned under the same conditions to ensure uniform exposure—either all in sunlight or all in shadow—depending on the sun's movement. Weather conditions and additional data will be collected from our station at the URAER research unit in Ghardaia City.

By closely monitoring and analyzing the distillation process, we aim to gain valuable insights into the effectiveness of aluminum and galvanized steel floral rings in enhancing distillate water output and overall efficiency.

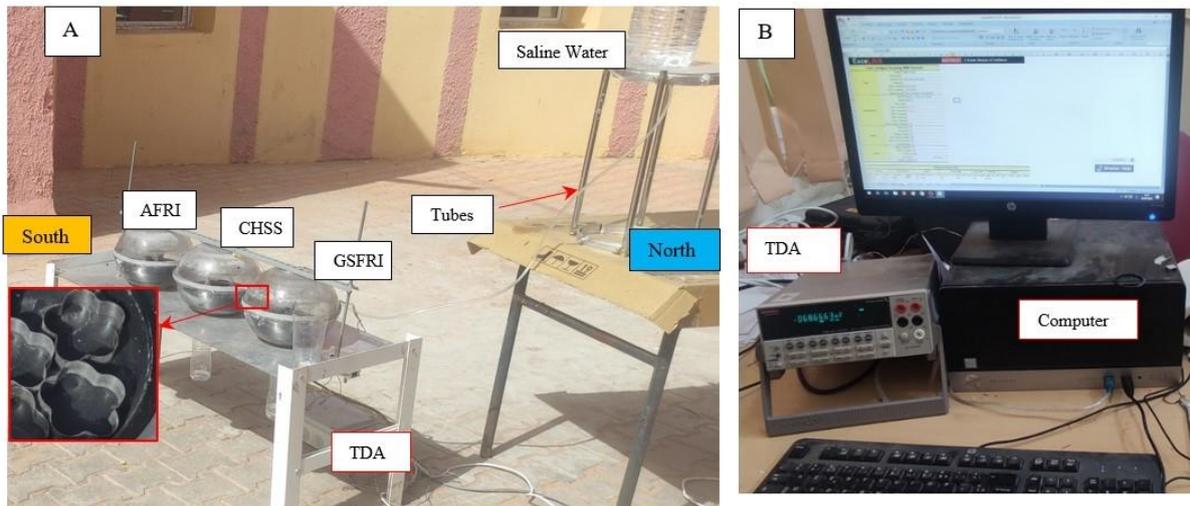
The thermal properties of galvanized steel and aluminum, as outlined in Table 1, are critical factors influencing their performance as materials for solar still components. Aluminum exhibits superior thermal conductivity compared to galvanized steel, suggesting it may be more efficient in absorbing and transferring heat energy. This characteristic is particularly relevant to our study comparing the performance of aluminum floral ring inserts (AFRI) and galvanized steel floral ring inserts (GSFRI) in enhancing solar still efficiency. While the lower melting point of aluminum compared to galvanized steel is not

directly relevant to the current application, the substantially higher thermal conductivity of aluminum positions it as a potentially more suitable material for facilitating heat transfer within the solar still system. This thermal advantage could contribute to increased water evaporation rates and, ultimately, higher distillate production. By meticulously comparing the performance of AFRI and GSFRI under identical experimental conditions, we aim to elucidate the impact of material selection on solar still efficiency. This research will provide valuable insights into optimizing solar still design for improved water production in regions with limited freshwater resources.

### 3. MEASURING INSTRUMENTS AND METHODOLOGY

#### 3.1. Instrument

Experiments were conducted on the proposed hemispherical distillers under the hot climatic conditions of Ghardaia (32.38°N, 3.78°E), Algeria, in July 2024, spanning from 08:00 a.m. to 9:00 p.m. The tests for both hemispherical distillers were carried out under identical outdoor conditions, with measurements taken at hourly intervals. Each distiller was filled with one liter of saline water at a concentration of 30 g/L, maintaining a depth of 3.0 cm throughout the experiments. K-type thermocouples, with an accuracy of  $\pm 0.1^\circ\text{C}$ , were strategically placed in both solar stills to monitor temperatures at various points, including the saline water, absorber, interior cover, and exterior cover. Additionally, ambient weather temperatures were recorded, and a solar sensor with an accuracy of  $\pm 10 \text{ W/m}^2$  was employed to measure total solar radiation. Distillation yield was quantified using a graduated cylinder with an accuracy of  $\pm 1.0 \text{ mL}$ . All measurements and data collection procedures followed rigorous hourly intervals. The measuring range, accuracy, and uncertainty of the measuring instruments are provided in Table 2.



**Figure 1.** A: The experimental setup of HSS composed of glass cover; a black painted basin, a transparent hemispherical glass cover, tubes, collection basin; CHSS: Conventional Hemispherical solar still, HSSAFRI: Hemispherical solar still with aluminum floral ring inserts (AFRI); Hemispherical solar still with Galvanized steel floral ring inserts (GSFRI) B; TDA : Thermocouple Data Acquisition and Computer used in Data analysis

**Table 1.** Thermal Properties of Galvanized Steel and Aluminum

Property	Galvanized Steel	Aluminum
Melting Temperature ( $^\circ\text{C}$ )	1425	660.3
Latent Heat of Fusion ( $\text{kJ/kg}$ )	260-270	397
Thermal Conductivity ( $\text{W/m}\cdot\text{K}$ )	50	235
Specific Heat ( $\text{kJ/kg}\cdot\text{K}$ )	0.49	0.897
Density ( $\text{kg/m}^3$ )	7850	2700

**Table 2.** Characteristics of the measuring devices used in the investigation

Instrument image	Instrument	Quantity measured	Uncertainty %	Range
	Solar-100	Solar radiation intensity	±2%	0–2000 W m <sup>-2</sup>
	THERMOCOUPLE	Temperature	±5%	0-400°C
	Thermometer DM6802	Temperature	±5%	-50 to 1300°C
	Keithley 2010 Industrial Multimeters	Temperatures	±1%	-328-2501

We provided a comprehensive description of the measuring instruments used in our experiments, detailed in Table 1. This table includes the technical specifications, ranges, and uncertainties of each instrument, offering a clear understanding of their capabilities and limitations. This information is crucial for understanding the equipment's performance, ultimately enhancing the interpretation and reliability of our experimental data. By presenting these details, we aim to offer transparency and enable other researchers to accurately assess the precision and accuracy of our measurements.

Moreover, the study relied on precise climatic data obtained from the on-site weather station at URAER Ghardaia. This data, which includes measurements of ambient temperature, wind speed, and humidity, provided essential context for our experiments. By utilizing this local climatic information, we ensured that our findings accurately reflect real-world conditions, thereby strengthening the validity and applicability of our research. Incorporating this environmental data allowed us to replicate the actual conditions under which the systems would operate, offering a more robust and credible analysis of the experimental outcomes.

### 3.2. The thermal efficiency

The thermal efficiency of a hemispherical solar still measures how effectively it converts sunlight into purified water. It indicates how well the still utilizes solar energy to produce distilled water. This efficiency is essential for evaluating the performance of the still and its ability to address water purification needs in areas with limited access to clean water sources. By understanding thermal efficiency, researchers and engineers can optimize the design and operation of hemispherical solar stills, maximizing water production while minimizing energy losses. The following formula can be used to determine thermal efficiency ( $\eta$ ), given the system area ( $A$ ), solar radiation intensity ( $I$ ), distillate amount ( $m$ ), and the latent heat of vaporization ( $h_{fg}$ ) ([Abdullah et al., 2023](#)):

$$\eta_d = \frac{\sum m \times h_{fg}}{A \times I} \times 100 \quad (1)$$

$$h_{fg} = 2501.67 - 2.389 \times T_w \quad (2)$$

The ability of a hemispherical solar still to convert sunlight into clean water is directly related to its thermal efficiency, a critical aspect of this study. This efficiency metric is essential for evaluating the performance of the still in providing clean water, particularly in areas with limited access to freshwater sources. Achieving high thermal efficiency ensures the cost-effectiveness and sustainability of these systems, making them more viable and effective solutions for addressing water scarcity issues.

## 4. RESULTS AND DISCUSSION

### 4.1. Weather conditions

Understanding the impact of weather on distillation processes is crucial, particularly when using solar stills to purify brackish water. Weather variables such as temperature, wind speed, and humidity play a significant role in influencing distillation efficiency and output. Temperature affects evaporation and condensation rates, wind speed influences heat transfer and vapor movement, and humidity affects vapor pressure and air saturation levels. By studying how these factors interact, we can optimize distillation systems to increase clean water production from brackish sources, helping address water scarcity issues in various regions. Now, let's take a closer look at Figure 2 to better understand these interactions.

### 4.2. Solar radiation and ambient temperature

Solar radiation and ambient temperature are crucial factors affecting the performance of a hemispherical solar still integrated with floral rings for sensible heat storage. Solar radiation serves as the primary energy source to heat the basin water, triggering evaporation. Ambient temperature, on the other hand, influences the rate of heat loss from the system and impacts its overall thermal efficiency. Thermal efficiency refers to the ratio of useful energy output (distilled water) to the total solar energy received by the still's surface over a specified period. This is a key metric for assessing solar still performance. Higher levels of solar radiation and ambient temperature boost the evaporation rate, increasing distillation

output. Understanding these variations is critical for optimizing the design and operation of the hemispherical solar still with floral rings, ensuring maximum water production efficiency.

Figure 2 offers valuable insights into the environmental conditions—solar radiation intensity and ambient temperature—during the three-day experiment (05/07, 06/07, and 07/07, 2024) testing the hemispherical solar stills with integrated floral rings. The predictable fluctuations in solar radiation intensity throughout each day underscore the importance of maximizing water evaporation during peak sunlight hours. Solar radiation intensity (Rad) peaks around noon, reaching values between 300-1000 W/m<sup>2</sup>, and significantly drops at night. The floral rings in the design absorb this daytime heat, extending the period of elevated water temperature even after the sun sets, resulting in increased water production compared to a conventional still.

Ambient temperature (T<sub>amb</sub>) follows a similar pattern, rising from around 25°C at night to over 43°C during the day. These higher daytime temperatures increase the temperature difference between the water inside the still and the surrounding air, enhancing the driving force for evaporation. The floral rings further improve this effect by trapping heat within the still, reducing heat loss. Additionally, Figure 2

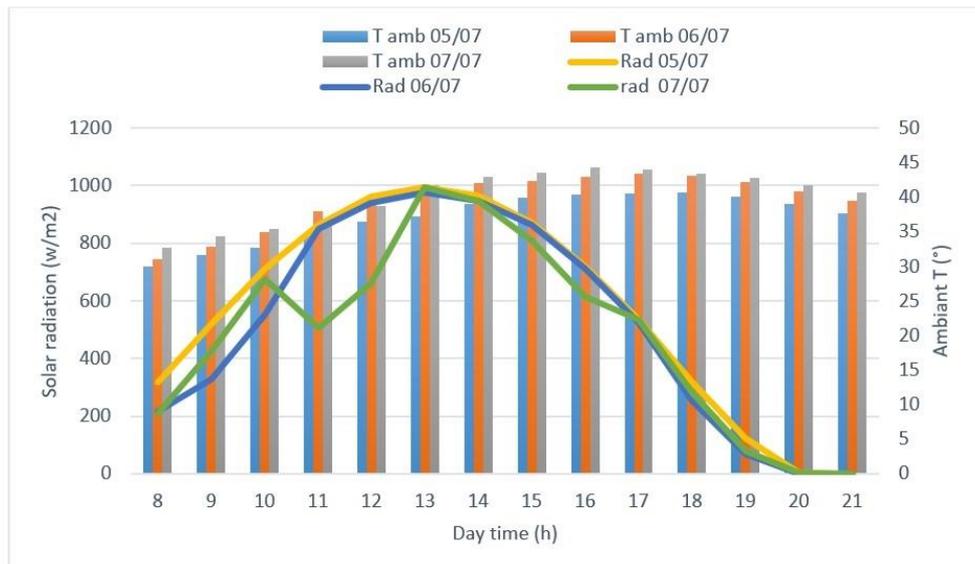
highlights the importance of heat storage and management in the solar still design. By capturing solar energy during peak sunlight hours (exceeding 800 W/m<sup>2</sup>) and gradually releasing it throughout the day and into the night, the floral rings can enhance the overall efficiency and water production of the hemispherical solar stills.

**4.3. Wind speed, Humidity ambient temperature**

Figure 2 illustrates the intricate relationship between ambient temperatures, wind speed, and humidity on July 6th and 7th, providing essential insights for optimizing solar stills in the desalination of brackish water.

Figure 3 shows the variations in wind speed, humidity, and ambient temperature over July 6th and 7th, highlighting their impact on the performance of the floral ring solar stills. Wind speeds ranged from 1.5 to 6.5 m/s, peaking between 3 PM and 4 PM, while the ambient temperature rose from 31°C to 45°C, with the highest temperatures also occurring in the late afternoon.

Relative humidity fluctuated between 8% and 25%, peaking at 8% in the morning and gradually decreasing throughout the day. These environmental factors are crucial for the solar still's efficiency.



**Figure 2.** Evolution of ambient temperatures and solar radiation intensity during three days 05/07, 06/07 and 07/07 2024



**Figure 3.** Evolution of ambient temperatures as function of wind speed and humidity during both days 06/07 and 07/07

Higher wind speeds can enhance evaporation by improving convective heat transfer but may also cause heat loss, reducing overall efficiency. Lower humidity levels, common in hotter conditions, further promote evaporation since drier air can absorb more moisture. The floral rings integrated into the solar stills are designed to capture and store heat during peak solar radiation (800–1000 W/m<sup>2</sup>), releasing it gradually throughout the day and even after sunset. This design helps mitigate the negative effects of fluctuating wind speeds and low humidity by maintaining a higher temperature difference between the water and the surrounding air, ultimately enhancing the evaporation rate and improving the distillation process.

#### 4.4. Glass cover temperature

In this subsection, we examine the relationship between sunlight intensity and the temperature of brackish water, a key factor for optimizing the performance of our hemispherical solar stills equipped with aluminum floral ring inserts (AFRI) and galvanized steel floral ring inserts (GSFRI). As sunlight intensity increases, the water inside the still absorbs more heat, causing its temperature to rise. This increase in temperature accelerates the evaporation process, turning the brackish water into steam, which is then condensed into clean water. By understanding how sunlight intensity influences water temperature, we can refine the design and operation of the AFRI and GSFRI systems to maximize their efficiency. This optimization will ultimately enhance water production, providing a sustainable source of clean water for communities facing water scarcity.

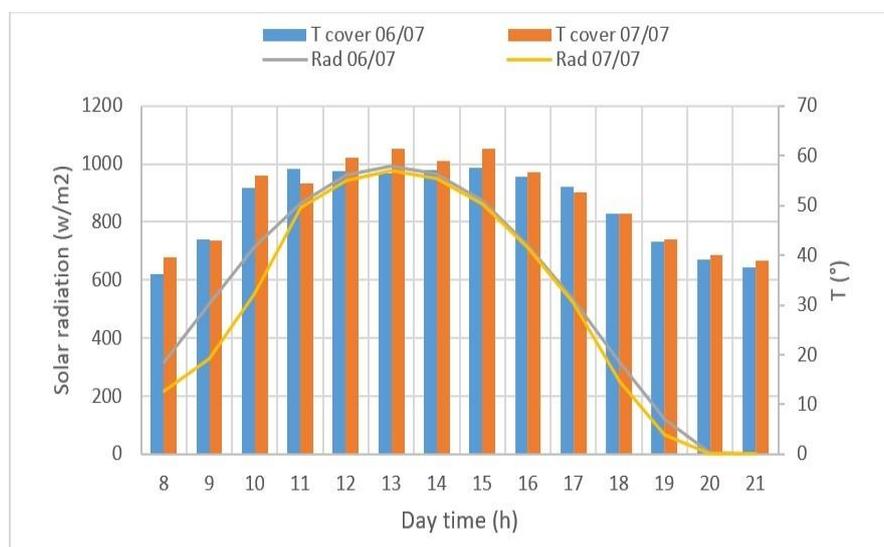
Figure 4 illustrates the performance of the galvanized steel floral ring inserts (GSFRI) in hemispherical solar stills, highlighting the relationship between solar radiation intensity and surface cover temperature. The data clearly shows a strong correlation between solar radiation intensity (ranging from 200 to 900 W/m<sup>2</sup>) and the surface temperature of the GSFRI inserts. As solar radiation peaks between 2 PM and 3 PM, the surface temperature of the GSFRI rises from 35°C to 65°C, demonstrating its capacity to efficiently absorb and retain heat. Even as sunlight diminishes later in the day, the GSFRI continues to maintain a significant amount of heat, with surface temperatures cooling to 38°C by 9 PM. This ability to store heat after peak sunlight hours is crucial for enhancing the evaporation process and maintaining a consistent temperature

differential, which can lead to higher distillation rates. To further verify these findings, a comparative analysis of water production data alongside the surface cover temperatures (shown in Figure 5) is essential. Such an analysis will provide a clearer picture of whether the elevated temperatures of the floral ring inserts directly contribute to higher evaporation rates and increased overall efficiency, thus solidifying the floral ring design's role in optimizing solar still performance in real-world conditions.

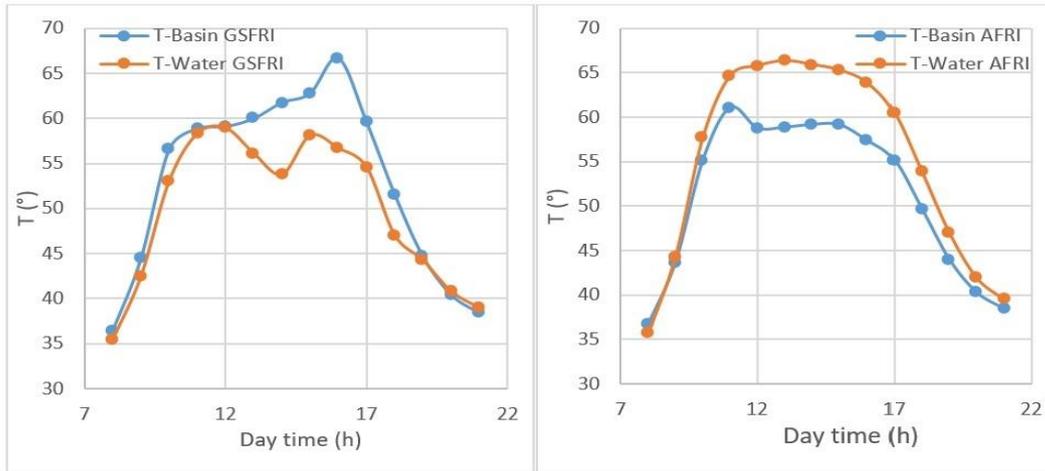
#### 4.5. Basin and brackish water temperature evolution

In this subsection, we explore the interplay between basin surface temperatures, humidity, and wind speed. By examining how these environmental factors interact, we gain essential insights into the thermal dynamics of our experimental setup. Basin surface temperatures are influenced by both ambient humidity and wind speed, which play critical roles in the heat transfer processes within the solar still. Humidity affects the rate of evaporation by influencing the air's moisture content, while wind speed impacts convective heat transfer and can either enhance or diminish the cooling effect on the surface. A thorough understanding of these interactions is crucial for optimizing the performance of our distillation apparatus. By leveraging these environmental conditions, we aim to enhance the efficiency and water production yield of our solar stills. This comprehensive analysis will provide a clearer picture of how to optimize the system's design and operation for improved performance in real-world settings.

Figure 5 provides a comprehensive view of how basin temperature and brackish water temperature evolve throughout the day on 06/07. This analysis highlights the impact of different conditions on the thermal performance of solar stills with aluminum floral ring inserts (AFRI) and galvanized steel floral ring inserts (GSFRI). The figure shows that both AFRI and GSFRI stills exhibit a clear daily temperature cycle, with temperatures rising during sunlight hours and decreasing in the evening. Throughout the day, the AFRI stills consistently maintain higher basin temperatures compared to the GSFRI stills. For example, around 16:00, the temperature in the basin of the GSFRI still reaches approximately 66°C, while the AFRI stills achieve a similar peak temperature of 66°C at the same time.



**Figure 4.** Evolution of surface cover temperature in the hemispherical solar still with galvanized steel floral ring inserts (GSFRI) as a function of solar radiation intensity on July 5<sup>th</sup> and 6<sup>th</sup>



**Figure 5.** Basin temperature and brackish water evolution as function day time during 06/07

The higher temperatures in the AFRI stills can be attributed to aluminum's superior thermal conductivity and heat retention properties. Aluminum's efficient heat absorption allows it to capture and retain more heat during peak sunlight hours, resulting in sustained higher temperatures in the basin. In contrast, the GSFRI stills, made from galvanized steel, exhibit lower thermal conductivity, leading to less effective heat transfer and retention. This results in relatively lower basin temperatures and less efficient heat management. The figure also reflects how changes in environmental conditions, such as humidity and wind speed, affect the thermal dynamics of the stills. Lower humidity levels can enhance evaporation rates, benefiting both AFRI and GSFRI stills. However, higher wind speeds may increase convective heat loss, potentially impacting the performance of both types of stills. On the other hand, Figure 4 provides a detailed depiction of this relationship, showcasing how different levels of irradiance affect the temperature of the water within our solar stills. This analysis is pivotal for understanding how efficiently our solar stills convert solar energy into thermal energy, thereby influencing overall water production. By examining these temperature fluctuations, we aim to optimize the design and operation of our system to maximize its effectiveness in brackish water distillation.

Figure 6 provides an in-depth look at how humidity and wind impact the basin and brackish water temperatures within our solar stills equipped with Aluminum Floral Ring Inserts (AFRI) and Galvanized Steel Floral Ring Inserts (GSFRI) on July 7th. The temperature of the water follows a distinct daily cycle, reaching a peak of around 69°C at approximately 2 PM and decreasing during the evening. This pattern is indicative of the solar radiation's influence on water heating. A significant observation is the inverse relationship between humidity and water temperature. As humidity levels drop, the water temperature rises, suggesting that lower humidity, which means less moisture in the air, results in a reduced cooling effect, allowing the water to retain more heat. This effect is more pronounced in the AFRI setup due to aluminum's superior thermal conductivity and heat retention capabilities compared to galvanized steel. Wind speed remains relatively constant, varying between 5 and 10 m/s throughout the day. The impact of wind speed on temperature is less clear from the data; however, wind can enhance evaporation by increasing convective heat transfer, albeit at the risk of also increasing heat loss from the system.

#### 4.6. Effect of floral insert

In this subsection, we explore the impact of different floral ring inserts on the temperature dynamics within hemispherical solar stills. By comparing the performance of Galvanized Steel Floral Ring Inserts (GSFRI), Aluminum Floral Ring Inserts (AFRI), and Conventional Hemispherical Solar Stills (CHSS), we aim to understand how material properties influence heat absorption, retention, and overall thermal efficiency. This analysis is crucial for optimizing solar still designs to enhance water production, particularly in regions where clean water access is limited. Figure 8 illustrates the evolution of brackish water and basin surface temperatures, providing key insights into the effectiveness of these inserts.

Figure 7 provides a comprehensive comparative analysis of temperature evolution for brackish water and basin surfaces in solar stills equipped with Galvanized Steel Floral Ring Inserts (GSFRI), Aluminum Floral Ring Inserts (AFRI), and a Conventional Hemispherical Solar Still (CHSS) on July 7th. In panel A, the brackish water temperature peaks around 69°C for both GSFRI and AFRI, while CHSS reaches around 66°C. Throughout the day, AFRI consistently maintains higher or equal water temperatures compared to GSFRI and CHSS, attributable to aluminum's superior thermal conductivity and heat retention properties. This advantage facilitates more effective heat transfer and prolonged retention, leading to higher water temperatures. In panel B, the basin surface temperature follows a similar trend, peaking at approximately 66°C for AFRI, 64°C for CHSS, and 60°C for GSFRI.

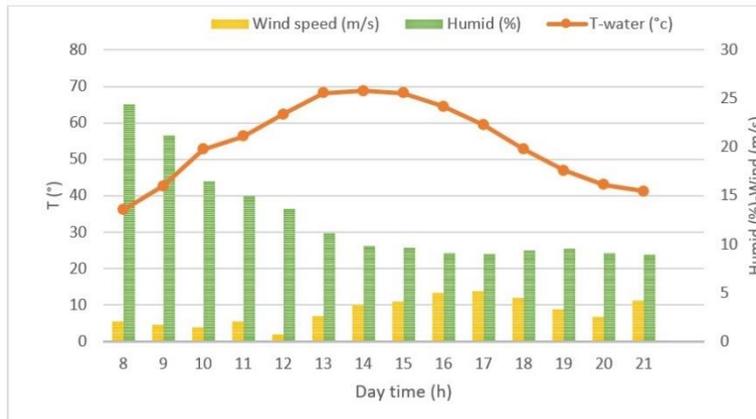
The consistently higher basin temperatures in AFRI stills highlight aluminum's efficacy in absorbing and retaining heat during peak sunlight hours. This sustained higher temperature in the basin not only enhances the evaporation process but also suggests more efficient overall thermal management within the AFRI stills. The performance difference is further accentuated by the fact that the AFRI stills exhibit higher temperatures despite the varying thermal properties of the materials used in the inserts. The superior performance of AFRI indicates a potential for increased water production compared to GSFRI and CHSS. This analysis underscores the importance of material selection in floral ring inserts for optimizing the efficiency of solar stills, with aluminum floral rings proving to be significantly more effective in enhancing thermal performance and, consequently, water purification efficiency. The results suggest that adopting aluminum floral rings in solar

still designs could be a promising approach to maximize water production, especially in regions facing water scarcity.

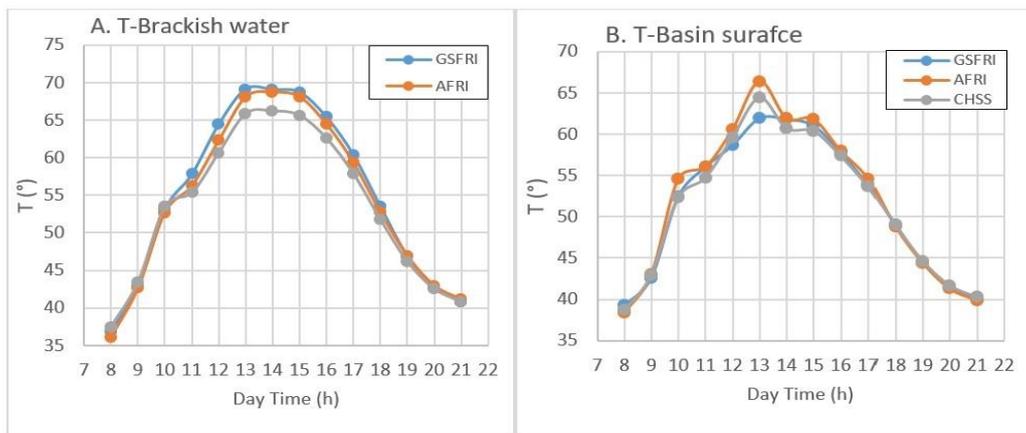
**4.7. Distillate analysis**

In this subsection, 4.5 "Distillate Analysis," we assess the effectiveness of different solar still configurations in optimizing water production. The focus is on comparing the volume of distillate collected at 9 PM over three consecutive days for solar stills equipped with aluminum floral rings (AFRI), galvanized steel rings (GSFRI), and conventional designs (CHSS). This analysis aims to uncover the potential benefits of floral ring inserts and their impact on enhancing the performance of solar stills.

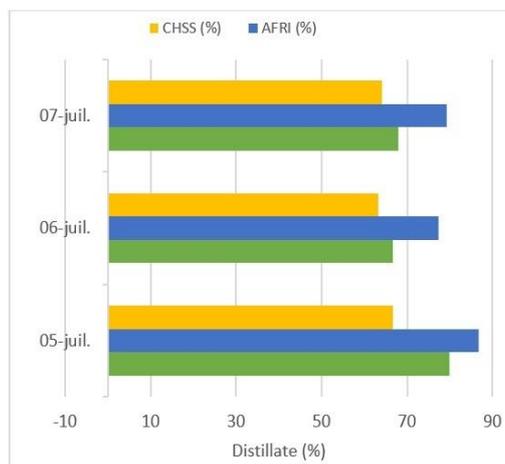
Figure 8 highlights the potential benefits of floral ring inserts in solar stills by depicting the volume of distillate collected at 9 PM over three days (July 5th-7th) for three configurations: AFRI (aluminum floral rings, blue bars), GSFRI (galvanized steel rings, green bars), and CHSS (conventional still, red bars). AFRI consistently yielded the highest distillate volume, peaking at approximately 87% on July 5th, followed by GSFRI, and then CHSS. This pattern suggests that floral ring inserts, particularly those made of aluminum, may enhance water production due to their superior heat absorption and retention properties.



**Figure 6.** Brackish water temperature evolution as a function of humidity and wind during the day time in 07/07 for hemispherical solar still with AFRI



**Figure 7. A.** Brackish water temperature evolution during the day time in 07/07 for GSFRI, AFRI and CHSS. **B.** Basin surface temperature evolution during the day time in 07/07 for GSFRI, AFRI and CHSS



**Figure 8.** The distillate collected at 21 PM for three days (05, 06 and 07/07) for all of AFRI GSFRI and CHSS.

Aluminum, known for its high thermal conductivity, appears to facilitate more efficient heating and evaporation processes within the solar still, thereby increasing the volume of distilled water. However, it is important to note that the data represents only a single collection time each day and does not account for external factors like weather variations across the days. Variations in sunlight intensity, ambient temperature, wind speed, and humidity can significantly impact the efficiency of solar stills and the distillate yield. To ensure a thorough and accurate evaluation, it is essential to conduct a comprehensive analysis of total daily distillate production rather than relying on a single time point. This broader analysis would provide a more complete picture of the performance of each configuration under varying environmental conditions. Additionally, the inclusion of detailed weather data is crucial for interpreting the results accurately. By correlating distillate volumes with specific weather parameters, we can better understand how different climatic conditions affect the performance of each solar still configuration. This will help determine whether the superior performance of AFRI is consistent across a range of weather conditions or if it is particularly effective under certain circumstances.

#### 4.8. Distillation efficiency

In this subsection, we evaluate the performance of various solar still configurations to determine their effectiveness in water distillation. The focus is on comparing the thermal efficiency of three setups: hemispherical solar stills with aluminum floral ring inserts (AFRI), galvanized steel floral ring inserts (GSFRI), and conventional designs (CHSS). By analyzing data collected on June 7th and July 7th, we measure and compare the percentage of thermal efficiency achieved by each configuration. This evaluation aims to uncover how different materials influence distillation efficiency, providing valuable insights into optimizing solar still design for improved water production.

Figure 9 provides a detailed comparison of the thermal efficiency among three hemispherical solar still configurations: AFRI (aluminum floral ring inserts), GSFRI (galvanized steel floral ring inserts), and CHSS (conventional). Data collected on June 7th and July 7th reveal notable differences in performance. On June 7th, the AFRI configuration achieved a thermal efficiency of 11.57%, compared to 10.02% for GSFRI and

9.49% for CHSS. On July 7th, AFRI's efficiency increased to 12.75%, while GSFRI reached 10.93%, and CHSS was at 10.30%. These results consistently demonstrate the superior performance of the AFRI configuration. The improved efficiency of the AFRI setup is likely due to aluminum's exceptional thermal properties, including high thermal conductivity and efficient heat transfer and storage. Aluminum's ability to quickly conduct and retain heat contributes to higher water evaporation rates, thereby enhancing the overall thermal efficiency of the AFRI still. In contrast, the GSFRI configuration, which uses galvanized steel, also performs better than the CHSS but with less pronounced thermal benefits. Galvanized steel, while an improvement over conventional materials, does not match the efficiency of aluminum in terms of heat transfer and retention.

#### 4.9. Comparison with previous studies

This subsection examines the differences between our hemispherical solar still and the designs explored in earlier research. By analyzing the effects of various additives and modifications on daily water output and efficiency gains, we aim to place our findings within the broader context of solar distillation research (Table 3). This comparison highlights the progress achieved in our current work and identifies potential directions for future optimization. The table below summarizes key findings from several studies on solar still designs, including modifications like wicks, internal reflectors, and external condensers, as well as additives such as nanoparticles. For each design, the daily water output, expressed in kilograms per square meter per day ( $\text{kg}/\text{m}^2\text{-day}$ ), and the percentage increase in efficiency compared to a baseline design are provided.

Table 3 provides a comprehensive overview of how different modifications and additives impact the productivity of various solar still designs. For single-slope solar distillers, the addition of nanofluids significantly enhances performance. Specifically, a 0.1 wt%  $\text{Al}_2\text{O}_3$  nanofluid achieved the highest productivity rate of  $0.935 \text{ kg}/\text{m}^2\text{-day}$ , translating to a 29.95% improvement, while other nanofluids like  $\text{SnO}_2$  and  $\text{ZnO}$  yielded lower increases.

In tubular solar stills, incorporating wicks and a V-corrugated basin led to a productivity rate of  $6.01 \text{ kg}/\text{m}^2\text{-day}$ , showing a notable 6.01% improvement over standard designs.

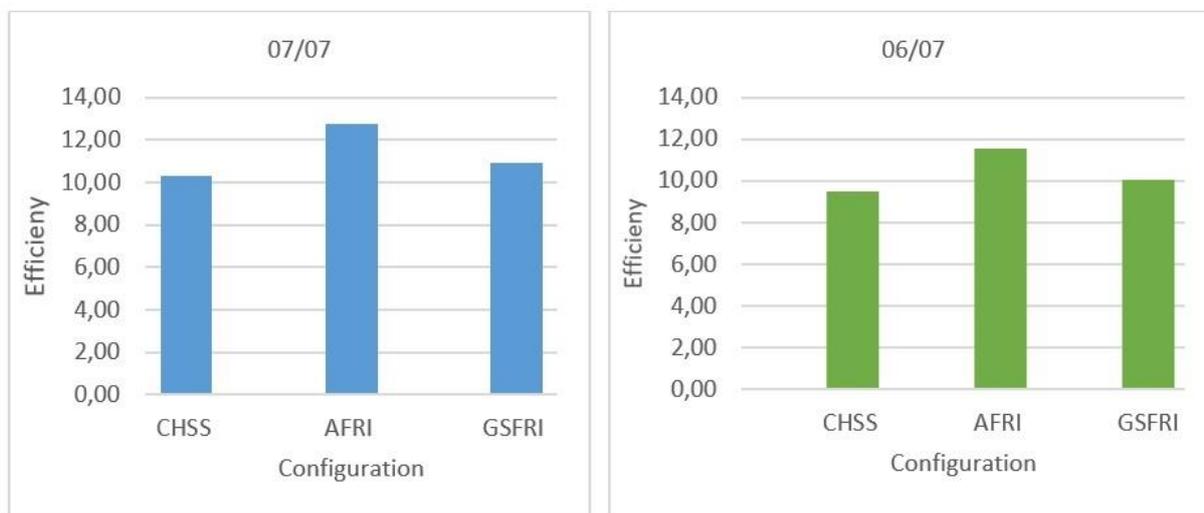


Figure 9. Thermal efficiency of three configurations in two days 06/07 and 07/07

**Table 3.** Comparison of our work and previous studies on solar still designs, modifications, additives, productivity, and rate of increase.

Design of SS	Ref.	Modification/Additives	Daily Productivity (Kg/m <sup>2</sup> )	Rate increase (%)
Single slope solar distiller	Elango et al. ( <a href="#">Elango, Kannan, &amp; Murugavel, 2015</a> )	-0.1 wt% SnO <sub>2</sub> NF	0.805	18.62
		-0.1 wt% Al <sub>2</sub> O <sub>3</sub> NF	0.935	29.95
		-0.1 wt% ZnO NF	0.750	12.67
Tubular solar still	Kabeel et al. ( <a href="#">Kabeel, Harby, Abdelgaied, &amp; Eisa, 2021</a> )	Wicks and v-corrugated basin	6.01	6.010
Trays solar distiller	Abdullah et al. ( <a href="#">Abdullah et al., 2020</a> )	-Internal reflectors	3.45	57.00
		-Reflectors +CuO nano black paint	4.10	70.70
		-Reflectors +CuO nano black paint+CuO nano mixed PCM	5.00	108.0
Single slope solar distiller	Johnstone Madhlopa ( <a href="#">Madhlopa &amp; Johnstone, 2009</a> )	External condenser	6.08	62.01
Tubular solar still	Elshamy and El-said ( <a href="#">Elshamy &amp; El-Said, 2018</a> )	Hemi-circular v-corrugated basin	4.30	26.47
Hemispherical solar distiller	Present work	Hemispherical solar stills with floral rings inserts (AFRI and GSFRI)	28 AFRI	20
			26 GSFRI	13.33

Tray solar distillers demonstrated impressive gains with modifications: internal reflectors resulted in a productivity of 3.45 kg/m<sup>2</sup>/day and a 57.00% increase; adding reflectors combined with CuO nano black paint raised the productivity to 4.10 kg/m<sup>2</sup>/day and a 70.70% increase. The most substantial boost was achieved with reflectors, CuO nano black paint, and CuO nano mixed PCM, reaching 5.00 kg/m<sup>2</sup>/day and a 108.0% improvement. Single-slope solar stills with an external condenser achieved a productivity rate of 6.08 kg/m<sup>2</sup>/day and a 62.01% increase, demonstrating significant enhancement. For tubular solar stills with a hemi-circular V-corrugated basin, productivity reached 4.30 kg/m<sup>2</sup>/day, with a 26.47% increase. The present work on hemispherical solar stills with floral ring inserts (AFRI and GSFRI) reveals the highest productivity rates, with AFRI achieving 28 kg/m<sup>2</sup>/day and a 20% increase, and GSFRI achieving 26 kg/m<sup>2</sup>/day with a 13.33% increase. These results underscore the effectiveness of advanced materials and designs, particularly the floral ring inserts, in significantly improving the efficiency and productivity of solar stills.

## 5. Conclusion

In conclusion, our study demonstrates the significant potential of incorporating floral ring inserts into hemispherical solar stills for enhancing water distillation processes. Through rigorous experimentation and detailed analysis, we identified key improvements in distillation performance due to the use of aluminum (AFRI) and galvanized steel (GSFRI) floral ring inserts. These inserts effectively enhance heat retention and distribution, leading to notable increases in water production rates and system efficiency. Our key findings include:

- The use of floral ring inserts, particularly aluminum, significantly improves heat retention and distribution, thereby enhancing the overall efficiency of the distillation process.
- Hemispherical solar stills with AFRI achieved a daily productivity rate of 28 kg/m<sup>2</sup>-day, while GSFRI reached 26 kg/m<sup>2</sup>-day, representing increases of 20% and 13.33%, respectively.
- The system's efficiency was quantified at 19.05%, underscoring the practical feasibility and effectiveness of the integrated approach.
- Comparative analysis reveals the superior performance of the floral ring insert designs over

conventional models, highlighting their potential for widespread adoption in water-scarce regions.

These findings emphasize the promise of advanced solar still technologies in addressing global water scarcity challenges and underscore the importance of continued research and development. By leveraging innovative materials and renewable energy sources, we can enhance the sustainability and efficiency of water purification processes, ultimately ensuring access to clean and safe water for communities worldwide.

## Future works

To further optimize and enhance the performance of the hemispherical solar still (HSS) prototype with aluminum floral ring inserts (AFRI) and galvanized steel floral ring inserts (GSFRI), several research directions can be pursued:

- Conduct an exergy efficiency analysis to evaluate the quality and usability of the energy harnessed and converted by both AFRI and GSFRI configurations, providing a deeper understanding of their performance.
- Investigate the impact of varying quantities and configurations of floral ring inserts (both aluminum and galvanized steel) on heat retention and overall distillation efficiency to identify the optimal setup.
- Explore methods to increase the condensation rate, such as employing external cooling mechanisms or materials with high thermal conductivity, to further boost water yield from both AFRI and GSFRI systems.
- Study the potential integration of the HSS with other renewable energy sources, such as photovoltaic panels or wind turbines, to enhance overall energy utilization and improve the sustainability of the distillation process with AFRI and GSFRI configurations.

## Acknowledgements

We extend our heartfelt gratitude to all those who contributed their time, expertise, and support to make this work possible.

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