International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 06 June 2025
Page No: 2779 - 2790
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0410

# Improving the Productivity of a Double Slope Solar Still by Integrating a PMMA Fresnel Lens: Experimental Approach

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## Abstract
*This study investigates the performance enhancement of a Modified Double Slope Solar Still System (MDSSS) through the integration of a polymethyl methacrylate (PMMA) Fresnel lens under the climatic conditions of Chengalpattu, India. The experimental setup evaluates the impact of solar concentration on basin water temperature, glass cover temperature, freshwater yield, and system efficiencies at three different basin water depths (10 mm, 20 mm, and 30 mm). The Fresnel lens was oriented in the north–south direction with tilt angles ranging from 0° to 60° to optimize solar capture. Results show that the incorporation of the Fresnel lens significantly increases basin water temperatures (by 8–10 °C), glass cover temperatures, and cumulative freshwater yield across all tested depths, with a maximum yield of approximately 6.0 L/m² recorded at 10 mm depth. Energy and exergy analyses reveal notable efficiency improvements in the lens-assisted configuration, with energy efficiency reaching up to 87% and exergy efficiency improving by up to 8% compared to the system without the lens. These findings confirm that the use of a Fresnel lens effectively boosts solar distillation performance by enhancing thermal energy concentration, particularly in systems operating with shallow water depths. The proposed enhancement offers a viable solution for increasing freshwater production in passive solar desalination systems.*

***Keywords:*** *Solar still, basin water depth, Fresnel lens, solar radiation, water quality.*

## 1. Introduction
Although access to safe drinking water is a fundamental human right, millions of people worldwide suffer from water scarcity because of causes like population expansion, industrialization, and climate change. These elements lead to decreased water quality as well as limited access to enough water. Traditional water sources are increasingly polluted or over-exploited, creating a need for sustainable purification methods. Solar desalination, a cost-effective and environmentally friendly method for producing potable water, is particularly suitable for arid regions with sunlight, but its low productivity has hindered widespread adoption. Conventional single and double slope solar stills typically yield only 2–4 L/m²/day due to limited solar absorption, high heat losses, and low temperature gradients. Though enhancements like nanofluids, PCMs, and hybrid systems exist, they often increase complexity and cost, limiting practicality in low-income areas. Polymethyl methacrylate (PMMA), or acrylic, is preferred for Fresnel lenses due to its high optical clarity, weather resistance, and ease of molding. It is lightweight, impact-resistant, and more cost-effective than glass,

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making it well-suited for low-cost solar desalination in rural or developing regions. The study explores the use of a PMMA-based Fresnel lens as a solar concentrator in double slope solar stills, direct to increase freshwater output and thermal efficiency without complex tracking or mechanical systems, thereby improving productivity. Several studies have explored methods to enhance the productivity of solar stills using both optical and thermal approaches. Kalogirou (2005) [1] reviewed various solar thermal collectors and emphasized the potential of solar concentrators in desalination systems. For example, the integration of a compound parabolic concentrator with a concentric tubular solar still (CPC-CTSS) and a pyramid-type still increased daily water yield from 4.960 L to 7.770 L, illustrating the benefits of system augmentation [2]. The use of linear Fresnel lenses has shown to nearly triple water output and improve efficiency by 68.76%, highlighting their promise for freshwater production in remote regions [3]. Additionally, a double slope single basin solar still with internal and external modifications achieved a 171.43% increase in distillate yield, showcasing the effectiveness of combined structural enhancements [4]. Advanced surface treatments, such as femtosecond laser texturing on PMMA covers, have also improved performance by 23.1% through increased solar absorption and durability [5]Despite these advances, limited research has focused on the integration of lightweight, cost-effective PMMA Fresnel lenses specifically in double slope solar still configurations. This gap offers an opportunity to investigate their practical effectiveness in enhancing freshwater yield through simple optical concentration, particularly in rural or resource-limited settings.

## 2. Critical Review

The experimental focus reflects a practical attempt to overcome one of the key limitations of conventional solar stills low productivity. By incorporating a PMMA Fresnel lens, the research seeks to intensify solar energy input and thus accelerate the evaporation-condensation cycle within the still. A major strength of the study lies in its experimental approach, which adds empirical value to a largely theoretical field. The integration of a Fresnel lens as a passive optical concentrator is an innovative, cost-effective solution that aligns with sustainable energy goals. However, a critical examination of the procedure reveals several methodological aspects that require improvement for greater scientific rigor and broader applicability. Many research experiments conducted outdoors under natural solar conditions, focusing on a single climatic season, reveal that solar still performance is highly sensitive to environmental variables. The Fresnel lens's effectiveness overstated by restricting trials to high-irradiance months, as it fails to account for year-round performance variability. but the Fresnel lens effectively concentrates sunlight, maintaining elevated temperatures for extended periods, resulting in consistent water evaporation, particularly during early morning and late afternoon hours, enhancing system productivity[6]. The description of operating conditions, including the static placement of the Fresnel lens and the setup geometry, raises concerns about the consistency of solar focus throughout the day reported by Kaur et al.2025 [7] The lens's focal point affected by the sun's shifting position, potentially causing periods of energy inefficiency. The optimal optical concentration may not be maintained without a dynamic tracking system or periodic manual adjustment [8]. This weakens the claim of sustained productivity improvement across daylight hours in the solar still. The use of a Fresnel lens in solar stills increases the concentration of solar radiation, raising the basin water temperature and enhancing evaporation. The depth of water in the basin plays a crucial role in how effectively this concentrated heat is utilized. Shallow water depths heat up quickly, allowing maximum benefit from the focused solar energy, leading to higher productivity. In contrast, deeper water absorbs more heat but takes longer to reach optimal temperatures, reducing efficiency. Therefore, maintaining a low to moderate basin depth is essential to maximize the effectiveness of Fresnel lens concentration in solar desalination systems. Despite the promising role of PMMA Fresnel lenses in enhancing solar still productivity, existing studies often lack comprehensive evaluation across varying climatic conditions and solar angles[9]. Most experiments are limited to high-irradiance months and static lens configurations,

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which do not reflect year-round or full-day performance. Additionally, insufficient attention is given to the effects of solar tracking and variable basin water depths on thermal efficiency and output consistency. These limitations hinder a complete understanding of the Fresnel lens's potential under real-world conditions. In this research objective is to experimentally investigate the performance enhancement of a double slope solar still integrated with a PMMA Fresnel lens by evaluating its effectiveness across different water depths and environmental conditions. It direct to assess the impact of lens orientation and solar tracking limitations on consistent energy concentration, with the goal of optimizing design parameters for sustained freshwater productivity throughout the day and across seasons.

## 3. Materials and Methods

### 3.1. Description of the Double Slope Solar Still

The experimental setup consists of a 1 m2 basin area of double slope solar still integrated with a Fresnel lens concentrator to enhance solar radiation input. The structure features a transparent glass cover on both sides, which allows for improved solar transmittance and serves as a surface for condensation. Solar radiation was absorbed by the solar still basin through the PMMA lens, and the input water temperature was preheated. A Fresnel lens is mounted above the still to concentrate sunlight directly onto the water surface, thereby increasing the temperature and promoting a higher rate of evaporation. Condensate water collecting tubes are positioned at the lower ends of the sloped glass covers to PVC semi circulate tube into the yield water containers. an open square shape of the channel attachment of the zigzag setup enhances heat absorption and facilitate uniform water distribution. A feed water path equipped with a flow control valve connects the basin to a saline water storage tank, allowing precise regulation of the water input. The entire assembly is supported on a sturdy stand that provides structural stability and elevation, assisting gravity-driven flow and improving operational accessibility.

### 3.2. Specifications of the PMMA Fresnel Lens

The Fresnel lens used in the experimental setup is made of Polymethylmethacrylate (PMMA), a material known for its high optical clarity and durability. The lens has a focal length of 250 mm and dimensions of 500 mm × 500 mm, making it suitable for concentrating solar radiation over a focused area. It exhibits a high transmittance of 92% in the visible spectrum, ensuring minimal energy loss during solar concentration. The lens is lightweight and robust, capable of withstanding environmental exposure while efficiently focusing sunlight without significant optical distortion. It is positioned parallel to the glass cover of the solar still to maximize the direct irradiation on the water surface. The aperture of the lens is monitored hourly to ensure consistent solar tracking and effective energy input throughout the day. (Figure 1)

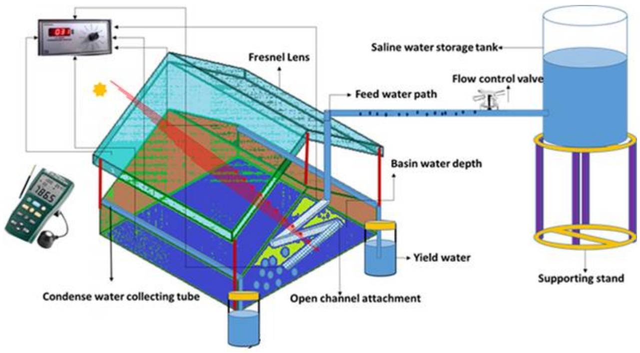


**Figure 1 Schematic Diagram Modified Double Slope Solar Still with PMMA Lens Attachment Setup**

### 3.3. Construction Materials

The construction of the solar still involves carefully selected materials to ensure optimal performance and durability. The glass cover is made of 4 mm thick tempered glass, chosen for its high solar transmittance and strength under thermal stress. The basin, which holds the saline water, is constructed from galvanized iron and painted black to enhance solar heat absorption. The frame structure is also made of galvanized iron, providing both mechanical strength and resistance to corrosion. To reduce thermal losses, plywood insulation is placed beneath the basin. Silicone rubber sealant is used at joints to ensure the system is airtight and to prevent vapor leakage during operation. For water transport, a combination of PVC pipes and GI channels is used, selected for their chemical resistance, durability, and

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cost-effectiveness.

### 3.4.Instrumentation

A PMMA Fresnel lens was used as the primary optical concentrator to focus sunlight onto the basin area of the solar still, thereby increasing the temperature and evaporation rate. A pyranometer was installed at an optimal angle near the still to measure solar irradiance. Thermocouples (Type K) were used to record the temperatures of the basin water, glass cover, inner chamber air, and ambient conditions at regular intervals. A digital temperature data indicator was connected to the thermocouples for real-time temperature acquisition and monitoring. The system's productivity was evaluated using graduated measuring cylinders or calibrated vessels at distillate collection points on both slopes to quantify daily freshwater output. Additionally, anemometers were used to record wind speed, which could affect heat loss, and humidity sensors were occasionally deployed to monitor ambient relative humidity. The combination of these instruments ensured accurate performance evaluation of the modified solar still under varying environmental conditions.

### 3.5. Experimental Procedure

The Experiment was conducted under real-time outdoor conditions to evaluate the performance improvement due to solar concentration. The setup was installed in an open area receiving unobstructed sunlight at SRM Institute of Science and Technology, Kattankulathur-603203, Chengalpattu in India with experiments carried out during the summer months of June 2024 to ensure high solar intensity. Daily experiments were conducted from 9:00 AM to 5:00 PM to capture the full range of solar radiation throughout the day. Under operating conditions, the solar still was initially filled with a fixed volume of saline water in the basin, typically around 1cm basin water depth with a known salinity level. A PMMA Fresnel lens was positioned above the still at an optimal focal distance to concentrate sunlight onto the water surface, increasing the thermal input. The tilt angle of the solar still and the Fresnel lens was aligned with the local latitude to maximize solar gain. The system was allowed to operate naturally, relying on solar energy alone without any auxiliary heating. Throughout the experiment, several variables were measured. These include such as basin water, inner surface of the glass cover, ambient air, and focused spot from the Fresnel lens, measured using K-type thermocouples connected to a digital data indicator. Daily distillate output (Liters) collected from both slopes of the still using graduated measuring cylinders. These measurements were taken at regular intervals, typically every 30 minutes, to study the system's thermal performance and freshwater yield. Comparative tests were also performed with and without the Fresnel lens to isolate its impact on productivity. The Fig.2 illustrates an experimental setup of solar stills designed to study the effect of varying basin water depths on the distillation process. Three different basin water depths 10 mm, 20 mm, and 30 mm are tested across separate solar still units. Each unit features a triangular transparent cover designed to promote solar heating and facilitate condensation on the inner surface. The stills are arranged side by side, and the changes in condensation behaviour are clearly visible with respect to the water depth in the basin. As the basin water depth increases, differences in the formation and distribution of condensed water droplets can be observed on the transparent surface, suggesting a variation in thermal response and evaporation-condensation dynamics. The images at the bottom of the figure highlight specific features such as condensation areas, aperture positions for vapor movement, and flare effects on the transparent surface. This experimental comparison helps in understanding how basin water depth influences the efficiency and productivity of solar water distillation systems. (Figure 2)

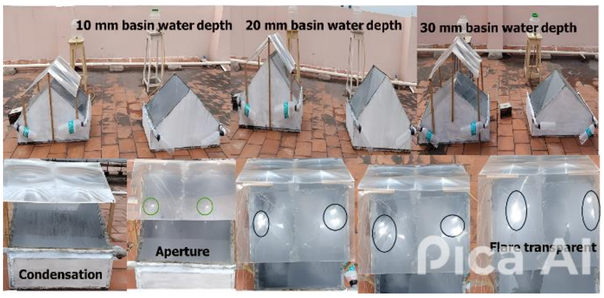


**Figure 2 Experimental Diagram of Basin Water Depth on Condensation Performance in Solar Still**

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### 3.6.Theoretical Estimation

Theoretical framework helps predict the performance of the solar still under varying operating conditions such as basin water depth, solar intensity, and ambient temperature, allowing for performance optimization and design improvements. The thermal efficiency is calculated by the following relation in the solar still [10].

$$h_{c,w-g_i} = 0.88\left[\left(T_w - T_{g_i}\right) + \frac{(P_w-P_g)(T_w+273)}{2.68\times10^5-P_w}\right]^{0.333} \quad (1)$$

Natural convection heat transfer is caused by the temperature differential between the basin water and the inner glass cover of the solar still. The rate of convective heat transfer Qc, w-gi, heat transfer coefficient between the water and inner glass cover surface are expressed as the following formula,

Q_(c,w-g_i )=h_(c,w-g_i )×(T_w-T_(g_i ) )(2)

The convective heat transfer coefficient between a glass and a water surface can be calculated using the following term [11]

h_(c,w-g_i )=0.88 [(T_w-T_(g_i ) )+(P_w-P_g )(T_w+273)/(2.68×〖10〗^5-P_w )]^0.333 (3)

P_(w ) and P_g are calculated from the equation (4)and (5)

P_w=e(25.32-5144/((T_w+273) )) (4)

P_g=e(25.32-5144/((T_g+273) )) (5)

qe = 0.0162hc, w-gi (Pw-Pgi¬) (6)

qe = he (Tw-Tgi) (7)

he = 0.0162 hc, w-gi $\left(\left(\frac{(Pw-Pg)}{(Tw-Tg)}\right)\right)$/((Tw-Tg)) from (6) and (7) (8)

The distillate water output calculates per square area by following relation

mevap = q_e/h_fg 3600 or = (h_e (T_w-T_gi))/h_fg 3600 kg/m2h (9)

Latent heat of vaporization for ≤ 70oC. Corresponding equation is provided by (Fernandex and Chargoy, 1990)

h_fg =2.4935 ×106 [1-9.5×10-4T_w +1.32×10-7T_w^2-4.79×10-9T_w^3] J/kg (10)

The exergy input is calculated by the following step in the passive solar still [12] 〖Ex〗 _in=A_lens.I.(1-T_atm/T_sun ) (11)

The exergy output is estimated by the following relation in the passive solar still

〖Ex〗 _out=m_evap.[h_fg-T_a.Δs] (12)

The entropy change is calculated during the evaporation process inside the solar still[13].

ΔS=c_p.ln(T_w/T_atm )-h_fg/T_w (13)

Instantaneous efficiency is calculated by the following equation[14]

η=(Y_h×L)/(I×3600)×100% (14)

Overall efficiency is estimated by the following terms [14]

η_o=(Y_d×L)/(∑_1^(d.w.h)I×3600)×100% (15)

The exergy efficiency is calculated by the following equation [15]

η_ex = 〖Ex〗 _out/ 〖Ex〗 _in (16)

## 4. Results and Discussion

This experiment was conducted under the environmental conditions of Chengalpattu, India, to evaluate the performance of a double-slope solar still integrated with a Fresnel lens. The study assessed the concentration effect of the Fresnel lens at three different basin water depths, both with and without the lens attachment. The lens was oriented along the north-south direction, and its aperture was monitored hourly. The system was tilted from 0° to 60° relative to the horizontal, from the south toward the north. The following sections provide detailed explanations of the environmental parameters, as well as the basin water and glass cover temperatures measured with and without the Fresnel lens. The energy and exergy analyses were estimated and compared. Fig.3 shows the variation in atmospheric temperature, wind velocity, and solar radiation throughout the day on June 17, 2024. The solar radiation curve (blue line) exhibits a typical diurnal pattern, peaking at around 13:00 h with a maximum intensity of approximately 1080 W/m², corresponding closely with the highest atmospheric temperature of about 39 °C. These conditions are ideal for efficient solar still operation, as elevated solar radiation and ambient temperature increase the basin water temperature and evaporation rate. The wind velocity (red line), ranging between 2.5 and 6 m/s, demonstrates moderate fluctuations throughout the day, with slightly higher speeds

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observed in the morning and late afternoon. While higher wind speeds can enhance heat loss from the glass surface, moderate velocities promote effective condensation by cooling the glass cover, thereby supporting the distillation process. The combination of strong solar radiation, high atmospheric temperatures, and moderate wind velocity created favourable conditions for the MDSSS, contributing to the enhanced thermal performance and freshwater yield observed in the system on this day. (Figure 3)

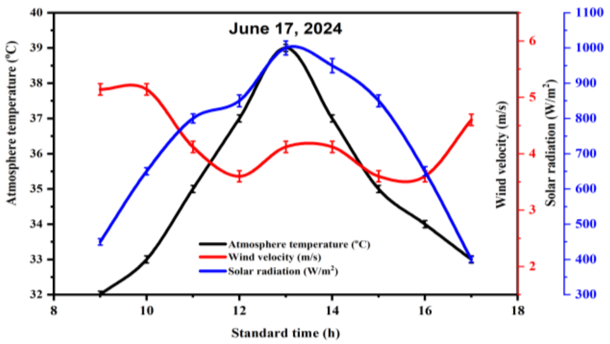


**Figure 3 Comparison of the Outdoor Operating Parameters (Atmosphere, Wind and Solar Radiation)**

### 4.1.Impact of Fresnel Lens Concentration on the Basin Water Temperature at Different Water Depth of Solar Still

Fresnel lenses in solar stills enhance basin water temperature and evaporation rates by concentrating solar energy onto the water surface. This effect is particularly beneficial across varying water depths, including deeper levels, due to the ability of focused solar radiation to penetrate more effectively. In this study, three different basin water depths (10 mm, 20 mm, and 30 mm) were considered using three separate setups. A channel attachment was employed in each case to guide the feedwater flow and maintain the desired shallow water depth consistently. The effectiveness of the Fresnel lens in increasing water temperature and promoting evaporation becomes evident across all depths, with notable improvements even at greater depths. Fig.4 presents a comparative analysis of basin water temperature in a Modified Double Slope Solar Still System (MDSSS) with and without the use of a PMMA Fresnel lens. The results show a significant temperature increase with the lens across all depths due to its solar concentration capability. The highest temperature recorded was approximately 91 °C at a 10 mm depth around 13:00 h, compared to 82 °C without the lens. Similar improvements of 8–10 °C were observed for the 20 mm and 30 mm depths. The thermal response was most pronounced at shallower depths due to their lower thermal mass, enabling quicker and higher temperature rise. Overall, integrating a PMMA Fresnel lens improves the thermal performance of the solar still, thereby potentially enhancing both the evaporation rate and freshwater output. (Figure 4)

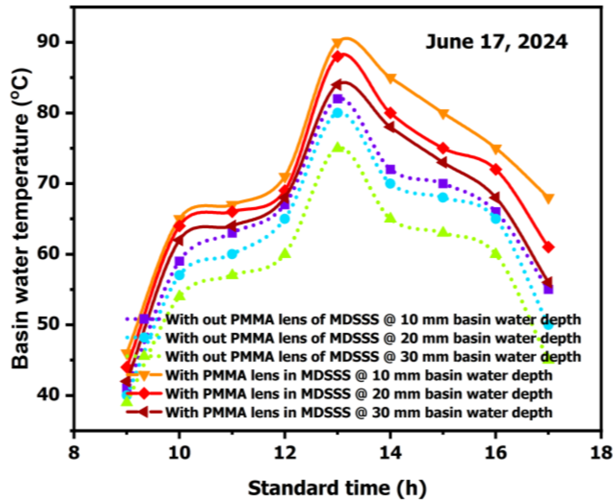


**Figure 4 Comparison of Basin Water Temperature in MDSSS with and Without a Fresnel Lens**

### 4.2.Impact of Fresnel Lens Concentration on the Glass Cover Temperature at Different Water Depth of Solar Still

Fresnel lenses in solar stills increase glass cover temperatures, enhancing evaporation and productivity by heating water, leading to greater condensation and distillation. Fig.5 illustrates the variation in glass cover bottom temperature of the Modified Double Slope Solar Still System (MDSSS) with and without the use of a PMMA Fresnel lens at basin water depths of 10 mm, 20 mm, and 30 mm on June 17, 2024. The results show that the glass cover temperature closely follows the trend of the basin water temperature, peaking around 13:00 h. With the Fresnel lens, higher glass cover temperatures were

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recorded, reaching a maximum of approximately 88 °C at a 10 mm water depth, compared to about 78 °C without the lens under the same conditions. Similar enhancements of 8–10 °C were observed at the other depths as well. This increase is attributed to the intensified solar radiation focused by the Fresnel lens, which not only raises the water temperature but also boosts the vapor generation rate. The vapor condensing on the inner surface of the cooler glass cover releases latent heat, thereby raising its temperature. Notably, even at higher water depths, the lens maintained a substantial thermal advantage. Overall, the elevated glass cover temperatures in the lens-assisted MDSSS confirm improved evaporation–condensation dynamics, leading to potentially greater freshwater yield. (Figure 5)

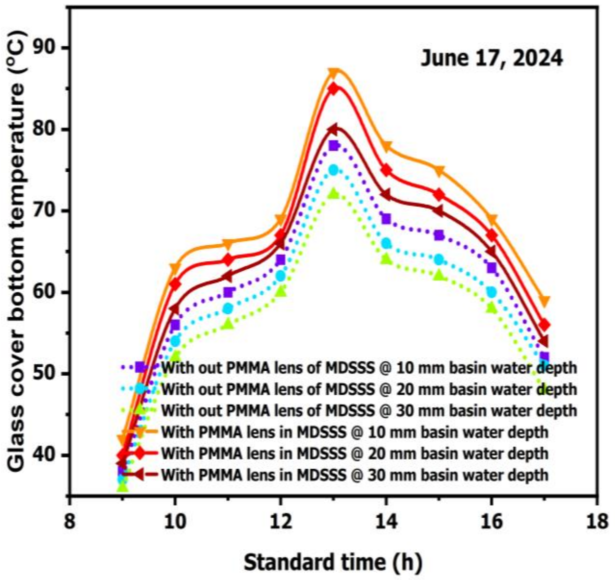


**Figure 5 Comparison of Glass Cover Temperature in MDSSS with and Without a Fresnel Lens**

### 4.3. Impact of Fresnel Lens Concentration on the Cumulative Water Yield at different Basin Water Depth of the Solar Still

Fresnel lenses in solar stills increase glass cover temperatures, enhancing evaporation and productivity by heating water, leading to greater condensation and distillation. Fig. 6 depicts the cumulative freshwater yield of the Modified Double Slope Solar Still System (MDSSS) with and without the integration of a PMMA Fresnel lens across three basin water depths (10 mm, 20 mm, and 30 mm) on June 17, 2024. The data clearly demonstrate that the use of the Fresnel lens improves the yield throughout the day. This improvement is attributed to the enhanced thermal performance provided by the concentrated solar radiation, which increases basin water and glass cover temperatures accelerating evaporation and condensation processes. The highest cumulative yield was recorded in the setup with the Fresnel lens at a 10 mm water depth, reaching approximately 6.0 L/m² by 17:00 h, compared to about 3.1 L/m² without the lens under the same condition. Similar trends were observed for the 20 mm and 30 mm depths, with lens-assisted systems consistently outperforming their non-lens counterparts. The lower water depth also showed a faster rate of yield accumulation due to quicker heating and higher evaporation rates. Overall, the incorporation of the Fresnel lens notably boosts the productivity of the MDSSS, confirming its effectiveness in improving desalination performance through solar concentration. (Figure 6)

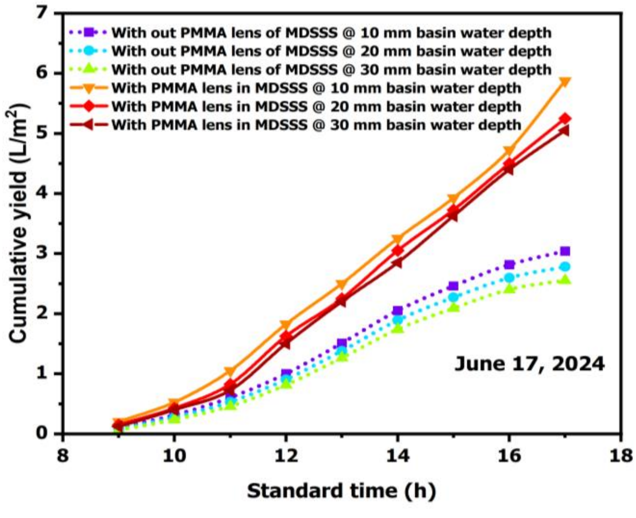


**Figure 6 Comparison of Cumulative Yield in MDSSS with and Without a Fresnel Lens**

### 4.4. Impact of Fresnel Lens Concentration on the Energy and Exergy Analysis at 10 mm Basin Water Depth

The concentration of the Fresnel lens significantly influences the energy and exergy analysis by

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affecting the amount of solar energy captured and converted. Although larger concentration ratios produce more energy, they can raise temperatures, which could have an impact on energy efficiency because of increasing irreversibility. The Fig.7 illustrates the relationship between basin water temperature and the energy and exergy efficiencies of a solar distillation system at a constant water depth of 10 mm, comparing configurations with and without a Fresnel lens. As the basin water temperature increases, both energy and exergy efficiencies show a rising trend in all cases. The presence of a Fresnel lens enhances performance, particularly at higher temperatures. For energy efficiency, the system with the Fresnel lens consistently outperforms the one without it. At approximately 45°C, the energy efficiency is around 0.30 without the lens and about 0.41 with the lens. This gap widens slightly with increasing temperature, reaching about 0.87 and 0.83, respectively, at 90°C. This improvement can be attributed to the Fresnel lens's ability to concentrate solar radiation, thereby increasing the basin water temperature and evaporation rate. Exergy efficiency, which accounts for the quality of energy conversion, is notably lower than energy efficiency but follows a similar upward trend. The system with the Fresnel lens starts at around 0.04 at 45°C and reaches nearly 0.27 at 90°C, while the system without the lens increases from approximately 0.03 to 0.25 over the same temperature range. Although the difference is smaller compared to energy efficiency, the Fresnel lens still provides a clear performance advantage, indicating better utilization of the available thermal energy.Overall, the results demonstrate that incorporating a Fresnel lens enhances both the quantity and quality of energy conversion in solar distillation systems. The improvements are more pronounced at higher temperatures, emphasizing the role of thermal concentration in boosting system efficiency. This highlights the potential of optical enhancement techniques such as Fresnel lenses to improve the performance of solar thermal applications, especially in systems operating with shallow water depths. Table 1 show the study results of energy and exergy efficiency compared to other published work (Figure 6)

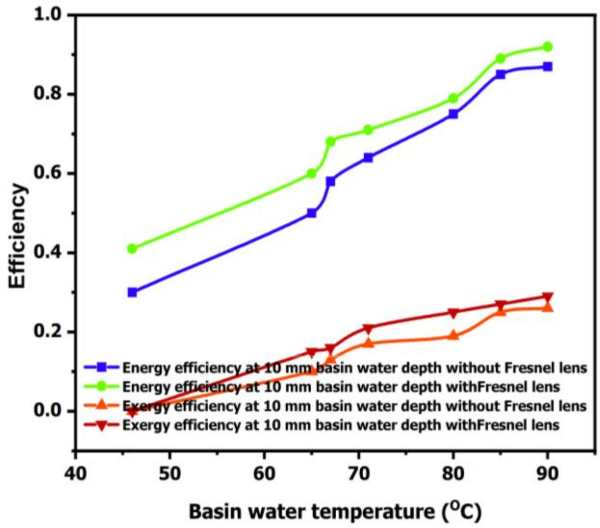


**Figure 7 Comparison of Energy and Exergy Efficiency at 10 mm Basin Water Depth with and Without Fresnel Lens**

## Conclusion

The experimental investigation conducted under the environmental conditions of Chengalpattu, India, demonstrates that integrating a Fresnel lens into a Modified Double Slope Solar Still System (MDSSS) significantly enhances its thermal and productive performance. The use of the Fresnel lens, oriented in the north–south direction and operated at various tilt angles, was effective across multiple basin water depths (10 mm, 20 mm, and 30 mm). (Table 1) It was observed that the focused solar radiation from the lens led to a notable increase in both basin water and glass cover temperatures, with maximum improvements recorded at the shallowest water depth of 10 mm. The highest basin water temperature achieved was 91°C with the Fresnel lens, compared to 82°C without it, and similar temperature gains of 8–10°C were observed at other depths. These thermal enhancements translated into improved freshwater yield. The cumulative water output reached approximately 6.0 L/m² by 17:00 h at 10 mm depth with the Fresnel lens, nearly double the 3.1 L/m² achieved without the lens. Furthermore, energy and exergy analyses at 10 mm depth confirmed that the

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**Table 1** Comparison Energy and Exergy Efficiency with Past Publication Results

| Source | Solar Concentration Method | Max. Basin Water Temp. (°C) | Freshwater Yield (L/m²/day) | Energy Efficiency | Exergy Efficiency | Remarks |
|---|---|---|---|---|---|---|
| **Present Study** | PMMA Fresnel Lens | 91 (at 10 mm depth) | 6.0 | 0.87 | 0.27 | Highest performance due to optimal focusing, shallow depth, and clear sky. |
| [1] | Fresnel Lens | ~84 | ~4.2 | 0.70 | 0.18 | Effective lens use, lower yield compared to present study. |
| [6] | Fresnel lens | ~86 | 4.28 | - | 0.25 | It utilizes a Fresnel lens and thermal storage for day-night operation. |
| [16] | Concentrator Disc | 98.2 | 7.3 | 0.21 | 0.03 | The ASS achieves 21.71% higher thermal efficiency and improved exergy efficiency through optimization of the concentrator disc diameter, enhancing water yield and temperature. |
| [17] | Glass | 45.42 | - | - | 0.009-0.05 | The exergy and efficiency of a system increase with higher solar intensity and water temperature, while the exergy of evaporation decreases with higher ambient temperature. |

Fresnel lens improved both the amount and quality of energy utilized by the system. The energy efficiency increased from 0.30 to 0.87, and exergy efficiency rose from 0.03 to 0.27 as basin water temperature increased. These results clearly demonstrate that optical concentration using Fresnel lenses enhances the solar still's evaporation and condensation dynamics, thereby significantly improving its overall performance. Therefore, incorporating a Fresnel lens in solar desalination systems presents a viable and efficient strategy to boost freshwater production, particularly in regions with high solar irradiance and limited freshwater resources.

## Acknowledgements

The authors gratefully acknowledge the support provided by the Department of Mechanical Engineering at SRM institute of science and technology for facilitating the experimental setup and data collection essential to this study. Special thanks are extended to the technical staff for their assistance in assembling and maintaining the solar still system throughout the testing period. The authors wish to thank the local weather monitoring station in Chengalpattu, India, for providing accurate environmental data. Finally, sincere appreciation is given to all contributors whose insights and feedback have enriched the quality and outcomes of this research.

## Recommendations for Future Work

Incorporation of Thermal Energy Storage (TES):
Future studies can explore the integration of phase change materials (PCMs) or sensible heat storage to retain excess thermal energy during peak hours and extend water production during evening or cloudy periods.

## Automated Solar Tracking System

Implementing an automatic tracking mechanism for the Fresnel lens could enhance solar concentration efficiency throughout the day, leading to even higher basin temperatures and freshwater yield.

## Nomenclature

**Table 2** Nomenclature

| Symbol | Description | Units |
|---|---|---|
| $A_{lens}$ | Aperture area of the Fresnel lens | m² |
| $c_p$ | Specific heat capacity of water | J/kg·K |
| $Ex_{in}$ | Input exergy | J |
| $Ex_{out}$ | Output exergy | J |
| $h_{c,\ w-g}$ | Convective heat transfer coefficient between water and glass | W/m²·K |
| $h_e$ | Evaporative heat transfer coefficient | W/m²·K |
| $h_{fg}$ | Latent heat of vaporization | J/kg |
| I | Incident solar radiation intensity | W/m² |
| $m_{evap}$ | Mass of evaporated/distilled water | kg |
| $P_g$ | Saturated vapor pressure at glass temperature | Pa |
| $P_w$ | Saturated vapor pressure at water temperature | Pa |
| $q_e$ | Evaporative heat flux | W/m² |
| $Q_{c,\ w-gi}$ | Convective heat transfer rate between water and inner glass | W |
| t | Time duration | s |
| $T_{atm}$ | Ambient temperature | K |
| $T_{gi}$ | Inner glass cover temperature | K |
| $T_{sun}$ | Sun temperature | K |
| $T_w$ | Basin water temperature | K |
| $Y_h$ | Hourly distillate output | kg/m²·h |

| | | |
|---|---|---|
| $Y_d$ | Daily distillate output | kg/m²·day |
| $\eta_{th}$ | Thermal efficiency of the solar still | – |
| $\eta$ | Instantaneous distillation efficiency | % |
| $\eta_{ex}$ | Exergy efficiency | – |
| $\eta_o$ | Overall distillation efficiency | % |
| $\Delta S$ | Entropy changes during phase change | J/kg·K |
| d.w.h | Daily working hours | h |

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