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EXPERIMENTAL ANALYSIS OF SOLAR DISTILLATION UNITS WITH DISTINCT OPERATING CONDITIONS

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ABSTRACT

Water is an essential resource for sustaining human life on Earth. Due to the limited availability of freshwater, both rural and urban communities often face challenges, including dependence on untreated wastewater, which can lead to waterborne diseases. Groundwater, though available in certain areas, is generally present in small quantities and requires proper treatment before domestic use. With the growing demand for fresh water across agricultural, industrial, and domestic sectors, there is an urgent need for effective and sustainable water purification methods. In this study, experimental investigations were conducted on a solar distillation unit designed with sloped corners, under varying conditions during April 2019. Both conventional and modified solar stills were fabricated and tested to assess their performance. The systems were operated daily from 09:00 to 17:00 over three consecutive days. The average efficiency of each design was determined at different operational stages, and notable variations in performance were observed. The results provide insights into how design modifications can enhance freshwater production efficiency in solar still systems, offering a cost-effective solution for water scarcity issues in rural and urban regions.

Keywords: Solar Still, Desalination, Waterborne Diseases, Freshwater Scarcity

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1. INTRODUTION

Saltwater contains both dissolved and suspended impurities, making it unsuitable for domestic consumption without proper treatment Chaichan and Kazem (2015). Currently, solar-based distillation is one of the most sustainable methods for producing freshwater. However, traditional solar stills often suffer from low productivity, which limits their ability to meet the growing demand for clean water, particularly in areas facing rapid population growth and urbanization NagaRaju et al. (2020),Manokar et al. (2017). To address this challenge, researchers have developed improved solar distillation units by integrating them with auxiliary systems such as separate solar collectors, forced circulation, and thermal energy storage Panchal et al. (2018), Rani et al. (2021). These enhancements help raise the water temperature, thereby increasing the evaporation rate and freshwater yield. Among various techniques, the use of phase change materials (PCMs) has shown promise for storing surplus solar thermal energy and releasing it during low-sunlight periods. In this work, paraffin wax was selected as a PCM and enclosed in aluminium containers (20 cm width × 7 cm depth) insulated with glass wool Chaichan and Kazem (2015).

The inner surfaces were painted black to maximize solar absorption, while the entire setup was placed inside a wooden box for additional insulation and ease of handling. The solar distillation process operates on the basic principles of the hydrological cycle-evaporation and condensation Bhargva and Yadav (2021), Manokar et al. (2018). Solar radiation heats the water in the basin, causing it to evaporate. The vapor condenses on the cooler glass cover, and the resulting freshwater droplets flow into collection channels. The yield of this process is influenced by multiple factors such as solar radiation intensity, water depth, thermal storage capacity, and basin surface area. Increasing the basin's surface area or incorporating heat storage media can significantly raise the water temperature, improving overall performance Panchal et al. (2018), Rani et al. (2021).

Various studies have examined the use of sponges, wicks, and other absorptive materials inside the basin to enhance heat retention and evaporation rates Kabeel and El-Agouz (2011). Experiments with sponge densities ranging from 16 to 35 kg/m^3 and thicknesses between 10 and 40 mm revealed that an optimal combination of material density and thickness improves freshwater production and thermal efficiency, while excessive thickness or density can hinder performance Abdullah et al. (2021), Salem et al. (2020). Additional research has also explored the effects of forced convection—both air and water-on condensation surfaces to enhance heat transfer and distillate yield Salem et al. (2020), Hassan et al. (2020). Despite its relatively low output compared to other desalination methods, solar distillation remains a low-cost, environmentally friendly solution for rural and remote areas where conventional purification systems are not feasible Sadaq and Mehdi (2018). Numerous low-cost modifications, such as adding heat storage materials (e.g., rocks, bricks, black sand) or using inclined wick absorbers, have been shown to significantly increase the productivity of conventional basin-type stills Kaushal et al. (2017). For instance, the inclusion of a 0.01 m layer of black sand has been reported to increase output by over 40% compared to a traditional still Deshmukh and Thombre (2017).

The present work focuses on design improvements and operating parameter optimization for solar distillation units to enhance efficiency and freshwater production, offering a sustainable solution to water scarcity in both rural and urban contexts.

2. EXPERIMENTAL SETUP AND PROCESS

Two types of solar stills-a conventional design and a modified version-were designed and tested in Jabalpur, India (latitude 23°18′ N, longitude 79°98′ E). The inclination angle of the glass cover was set to 23°, corresponding to the local latitude, to maximize solar radiation capture. The experimental evaluation compared the performance of both systems under similar climatic conditions. Based on recommendations from previous studies, the water flow rate was maintained at 0.0001 kg/s throughout the tests to ensure consistent operation and minimize unnecessary water loss. This setup allowed for accurate performance assessment, focusing on efficiency improvement in the modified still compared to the conventional unit.

2.1. CONVENTIONAL SOLAR STILL

Each solar still was constructed with a basin measuring 1 × 1 m^2. The rear wall height was 527 mm, while the front wall measured 100 mm. The structure was fabricated from 1 mm thick galvanized iron sheets. The top section of each still was fitted with a 4 mm thick transparent glass cover, allowing maximum solar radiation to enter while maintaining the internal temperature.

2.2. MODIFIED SOLAR STILL

The solar still has a basin area of 1 × 1 m^2, with the rear wall measuring 527 mm in height and the front wall 100 mm. The basin is fabricated from 2 mm thick galvanized iron sheets, chosen for their durability and resistance to corrosion in saline environments. The bottom and side walls are insulated with a 20 mm layer of glass wool to minimize conductive heat loss to the atmosphere, while an 18 mm thick plywood base provides structural support and additional thermal resistance. The top is sealed with a 4 mm thick transparent glass cover, which allows maximum solar radiation penetration while preventing vapor escape.

Figure 1

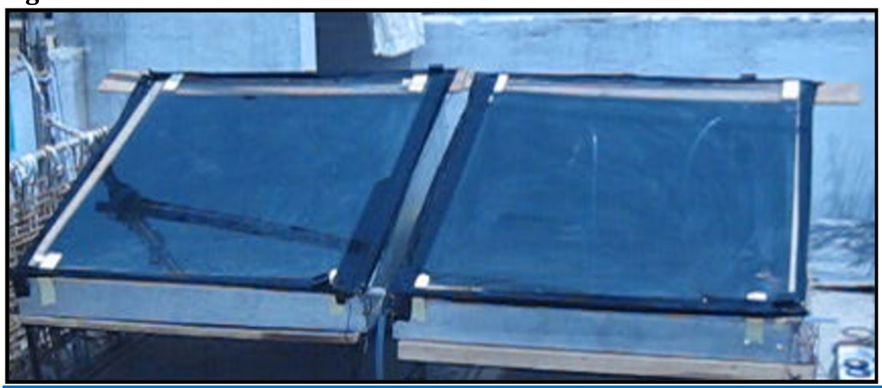

Figure 1 Experimental Setup

3. RESULTS AND DISCUSSION

3.1. ANALYSIS

Figure 2 present the conventional solar still, constructed with hard plywood of 15 mm thickness. Figure 3 illustrate the modified solar still, which incorporates hard plywood of 30 mm thickness along with 20 mm thick glass wool insulation. The experimental data for both configurations were recorded on 15 April 2019.

Figure 2

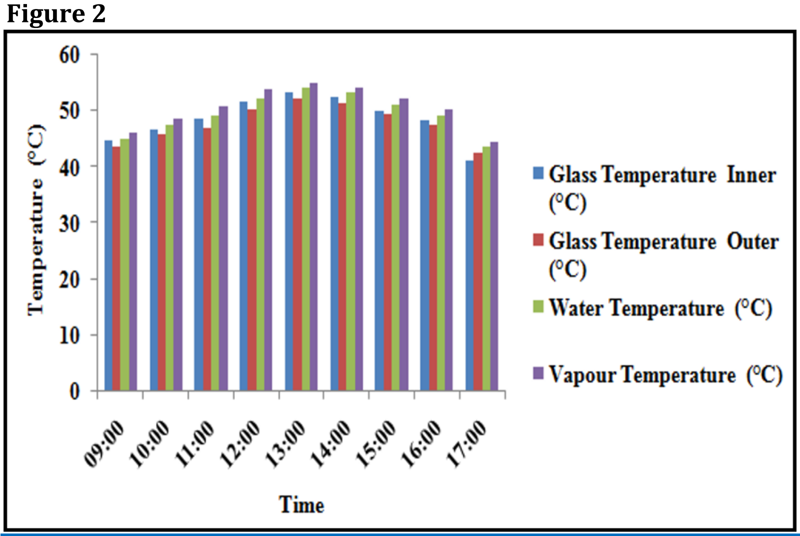

Figure 2 Conventional Solar Still with Hard Plywood Thickness of 15 mm.

Figure 3

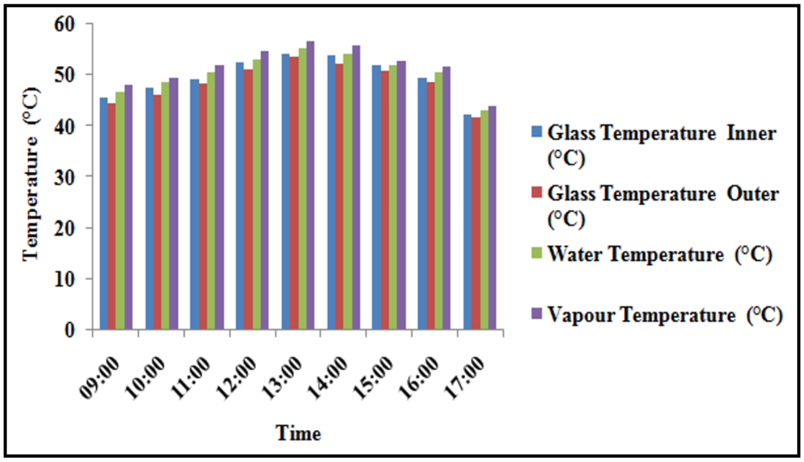

Figure 3 Modified Solar Still with Hard Plywood Thickness of 30 Mm and Glass Wool Thickness of 20 Mm.

4. CONCLUSIONS

- This study compared the performance of a conventional solar still (CSS) and a modified solar still (MSS) under different configurations to determine the most effective design for practical use.
- The average efficiency of the CSS was recorded as: 38.70% with 15 mm hard plywood.
- The average efficiency of the MSS was recorded as: 41.00% with 30 mm hard plywood and 20 mm glass wool insulation.
- The difference in average efficiency between the CSS and MSS was observed as 2.30%.

Overall, the modified solar still demonstrated superior performance compared to the conventional design.

REFERENCES

Abdullah, A. S., et al. (2021). Experimental Investigation of a New Design of Drum Solar Still with Reflectors Under Different Conditions. Case Studies in Thermal Engineering, 24, 100850. https://doi.org/10.1016/j.csite.2021.100850

Bhargva, M., & Yadav, A. (2021). Factors Affecting the Performance of a Solar Still and Productivity Enhancement Methods: A review. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-15983-z

Chaichan, M. T., & Kazem, H. A. (2015). Water Solar Distiller Productivity Enhancement Using Concentrating Solar Water Heater and Phase Change Material (PCM). Case Studies in Thermal Engineering, 5, 151–159. https://doi.org/10.1016/j.csite.2015.03.009

Deshmukh, H. S., & Thombre, S. B. (2017). Solar Distillation with Single Basin Solar Still Using Sensible Heat Storage Materials. Desalination, 410, 91–98. https://doi.org/10.1016/j.desal.2017.01.030

Hassan, H., et al. (2020). Energy, Exergy, Environmental, and Economic Analysis of Natural and Forced Cooling of Solar Still with Porous Media. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-020-09995-4

Kabeel, A. E., & El-Agouz, S. A. (2011). Review of Researches and Developments on Solar Stills. Desalination, 276, 1–12. https://doi.org/10.1016/j.desal.2011.03.042

Kaushal, A. K., Mittal, M. K., & Gangacharyulu, D. (2017). An Experimental Study of Floating Wick Basin Type Vertical Multiple Effect Diffusion Solar Still with Waste heat Recovery. Desalination, 414, 35–45. https://doi.org/10.1016/j.desal.2017.03.033

Manokar, M., et al. (2017). Different Parameter and Technique Affecting the Rate of Evaporation on Active Solar Still: A Review. Heat and Mass Transfer. Springer-Verlag GmbH Germany.

Manokar, M., et al. (2018). Different Parameters Affecting the Condensation Rate on an Active Solar Still: A Review. Wiley Online Library.

NagaRaju, V., et al. (2020). Experimental Analysis of a Solar Still with and Without Phase Change Material Under Climatic Conditions of Vijayawada, India. International Journal of Scientific & Technology Research, 9(2).

Panchal, H., et al. (2018). The Requirement of Various Methods to Improve Distillate Output of Solar Still: A Review. International Journal of Ambient Energy. https://doi.org/10.1080/01430750.2018.1542630

Rani, A., et al. (2021). Experimental Investigation on Thermal Behavior of Hybrid Single Slope Solar Still. Journal of Thermal Engineering, 7(3), 677–689. https://doi.org/10.18186/thermal.889191

Sadaq, S. I., & Mehdi, S. N. (2018). Experimental Analysis of Solar Distillation Unit with Various Slope Angles. International Journal of Advanced Technology and Engineering Exploration, 5(44). https://doi.org/10.19101/IJATEE.2018.543014

Salem, M. R., et al. (2020). Performance Enhancement of a Solar Still Distillation Unit: A Field Investigation. Solar Energy, 202, 326–341. https://doi.org/10.1016/j.solener.2020.03.098