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DESIGN AND DEVELOPMENT OF SOLAR DESALINATION

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Abstract - This paper presents the design, development, and experimental investigation of a conventional single-slope solar still aimed at enhancing freshwater yield with improved accuracy and efficiency. The solar still was fabricated with optimized geometric and material configurations, focusing on improved thermal performance and effective solar energy utilization. Key design enhancements include optimized basin slope, high-absorptivity coatings, and effective thermal insulation to minimize heat loss and maximize evaporation. The system was tested under real-time environmental conditions, and its performance was evaluated based on parameters such as distillate output, thermal efficiency, and productivity per unit area. The experimental results demonstrate a notable improvement in freshwater yield compared to traditional solar still designs, confirming the potential of the developed system as a cost-effective and sustainable solution for small-scale desalination in water-scarce regions. This work contributes to the ongoing efforts in sustainable water resource management through renewable energy integration.

1.INTRODUCTION

The escalating global demand for potable water, coupled with the depletion of freshwater resources, has intensified the exploration of sustainable desalination technologies. Solar desalination emerges as a promising solution, leveraging abundant solar energy to purify saline or brackish water, especially in arid and coastal regions. Among various solar desalination methods, the conventional single-slope solar still stands out due to its simplicity, cost-effectiveness, and ease of fabrication .

A single-slope solar still operates on the principle of evaporation and condensation. Saline water is placed in a blackened basin to absorb solar radiation, leading to evaporation. The vapor then condenses on the cooler inner surface of an inclined transparent cover, and the distilled water is collected in a trough. The efficiency of this system is influenced by factors such as basin material, insulation, glass cover inclination, and ambient conditions .

The fabrication process involves selecting materials with high thermal conductivity for the basin, effective insulation to minimize heat loss, and a transparent cover with optimal inclination to enhance condensation. Recent studies have explored modifications like integrating heat storage systems and varying the collector angle to improve performance .

This paper details the design and manufacturing process of a conventional single-slope solar still, aiming to enhance water yield and operational efficiency. The study also examines the impact of design parameters on the system's performance, providing insights into optimizing solar stills for practical applications.

2. Manufacturing Process of the Conventional Solar Still

The fabrication of the Conventional Solar Still (CSS) was carried out with a focus on design precision, material efficiency, and thermal performance. This section outlines the complete step-by-step methodology involved in the development of the solar still, which served as a baseline system for comparative analysis with the modified Rectangular Pyramid Solar Still (RPSS).

2.1 Design Framework

The CSS was designed as a single-slope, passive solar distillation unit with optimized geometry for effective solar capture. The absorber basin measured **100 cm × 50 cm × 7 cm**, ensuring a surface area of 0.5 m^2. The transparent glass cover was inclined based on the local latitude to maximize incident solar radiation throughout the day. Design criteria included structural durability, efficient heat retention, and ease of assembly.

2.1.1 Fabrication of the Wooden Enclosure

A robust wooden enclosure was constructed to house the absorber basin. High-quality, heat-resistant **plywood** was selected for its strength, thermal insulation properties, and ease of fabrication. The inner walls of the wooden frame were reinforced with a **2 mm thick aluminum sheet** to prevent moisture damage and improve reflectivity and insulation. The wooden body was built to tight tolerances to minimize thermal leakage and ensure a snug fit for the internal components.

2.1.2 GI Tray Preparation

A custom-fabricated **Galvanized Iron (GI) tray**, measuring **140 cm × 80 cm × 10 cm**, was used as a containment unit for the absorber basin and heat storage elements. Galvanized iron was chosen for its corrosion resistance and compatibility with high-temperature conditions. The tray was designed to accommodate a uniform 3 cm layer of thermal storage material (paraffin wax), thereby enhancing the system's thermal inertia and performance stability.

2.1.3 Construction of the Absorber Basin

The absorber basin, a critical component for converting solar energy into thermal energy, was fabricated using a **1 mm thick GI sheet**. To enhance thermal conduction, a grid of **square hollow GI fins** (dimensions: **2.2 cm × 2.2 cm × 5 cm**) was securely attached to the surface of the tray via riveting. These fins increased the effective surface area for heat transfer and improved the overall evaporation rate.

2.1.4 Application of Basin Paint and Thermal Coating

The interior of the absorber basin and the aluminum-lined surfaces of the wooden enclosure were treated with **Thurmalox 250**, a high-temperature, high-emissivity black coating capable of withstanding thermal stresses up to 649°C. This paint was selected for its ability to enhance solar absorption and thermal retention, thereby accelerating the heating process of saline water inside the basin. All coated surfaces were allowed to cure properly to ensure long-term durability and effectiveness.

Perfect! Since you're mixing **paraffin wax with carbonized (burned) wood dust** to enhance the thermal properties of the system, here's the updated **"Experimentation"** section rewritten for **paper publication**, reflecting that innovation clearly:

2.2 Objective

The primary goal was to assess the effectiveness of using a composite mixture of **paraffin wax and burned wood dust** as a cost-effective, sustainable, and high-performance heat storage material. This modification aimed to boost the evaporation process during peak sunlight hours and extend the heat supply into the evening, resulting in higher freshwater yield.

2.2.1Preparation of Thermal Storage Material

Fresh wood waste was sun-dried and then burned at low flame until fully carbonized. The resulting black powder was finely ground and sieved to achieve uniform particle size. **100 grams of this carbonized wood dust** was then thoroughly mixed with **10 kg of melted paraffin wax** to form a homogeneous thermal storage composite. This mixture was poured into the **GI tray** and allowed to solidify before use in the experimental setup.

2.2.2 Experimental Setup

The solar still was constructed with a layered configuration:

- The **bottom tray (140 cm × 80 cm × 10 cm)** was filled with the prepared **wax-wood composite** to act as the **latent heat storage bed**.
- A **metal absorber basin (100 cm × 50 cm × 7 cm)** was placed on top, into which a **2 cm layer of seawater** was added.
- The system was enclosed in a **thermally insulated wooden box**, with interior surfaces painted black using **Thurmalox 250** high-emissivity coating.
- A **transparent inclined glass cover** was fixed above the setup to allow solar radiation to enter and to facilitate condensation.

2.3 Methodology

1. The solar still was exposed to direct sunlight from **8:00 AM to 9:00 PM** over two days.
2. As the solar radiation increased, the **paraffin wax and wood dust composite** began to absorb and store heat.

2.3.1 Instrumentation and Measurement

To ensure the accuracy and precision of the data collected during the **solar desalination experiment** using a conventional solar still, several specialized instruments were employed. These instruments enabled continuous monitoring of key parameters, such as temperature, wind speed, and solar radiation, which are critical for assessing the performance of the system.

2.3.2 Thermocouples

Thermocouples were strategically installed at various locations within the **conventional solar still** to measure temperature fluctuations. These included sensors placed in the **thermal storage bed**, **water in the absorber basin**, and the **ambient environment**. The thermocouples provided real-time, high-accuracy temperature data, recorded at **30-minute intervals**, which was essential for analyzing the heat absorption, transfer, and dissipation processes in the system.

2.3.3 Anemometer

An **anemometer** was used to measure **wind speed** at the experimental site, as wind speed influences the rate of heat dissipation and the condensation efficiency within the solar still. Wind speed data was recorded at regular intervals of **30 minutes**, which was vital for correlating the wind conditions with the performance of the solar desalination process.

2.3.4 Solar Power Meter

A **solar power meter** was employed to measure the **solar radiation intensity** incident on the surface of the solar still. This measurement allowed for quantification of the amount of solar energy available for the **evaporation process**. The solar radiation readings were recorded continuously throughout the experimental period, from **8:00 AM to 9:00 PM**, providing insights into the fluctuations of solar intensity throughout the day.

2.3.5 Data Logging and Analysis

The data from the thermocouples, anemometer, and solar power meter were continuously logged into a **data acquisition system**. This system enabled real-time monitoring of the experimental conditions and facilitated detailed post-experiment analysis. The data collected was critical for evaluating the thermal efficiency, heat retention characteristics, and overall performance of the **conventional solar still** for solar desalination, providing a benchmark for comparison with the modified system using paraffin wax and carbonized wood dust.

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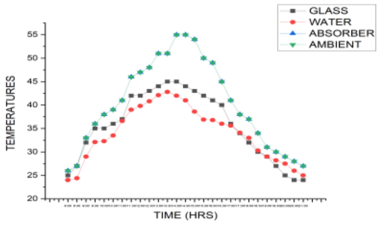
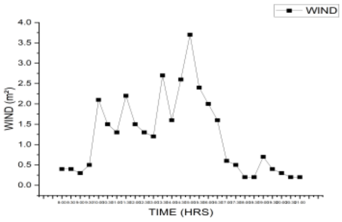
BIOGRAPHIES

TEMPERATURE CHANGES FOR CSS





WIND AND RADIATION CHANGES

3.CONCLUSION

The **solar desalination process** using the **conventional solar still method** presents a promising approach for sustainable freshwater production, especially in regions with limited access to clean water. This study demonstrates that the **efficiency of water production** can be significantly improved through optimized design and material integration. By utilizing conventional solar stills, the process leverages natural solar energy to evaporate seawater and condense it into clean, potable water.

Although solar stills are typically low in efficiency due to heat losses and evaporation limitations, this research shows that **modifying the system** with an enhanced **thermal storage medium** (such as paraffin wax blended with carbonized wood dust) can **prolong heat retention** and improve the evaporation rate. This results in a **faster freshwater production** rate, reducing the overall desalination time, especially during off-peak sunlight hours.

Through precise control and monitoring of parameters like temperature, solar radiation, and wind speed, it was found that the **time required for freshwater production** could be **shortened** by optimizing heat retention and improving the thermal efficiency of the conventional solar still. This **innovation** could be crucial for improving the **sustainability and cost-effectiveness** of solar desalination systems, especially in areas where energy costs and freshwater scarcity are significant concerns.

Further advancements could involve integrating advanced materials and refining the system's design to further reduce desalination time, enhance water quality, and **increase the overall yield**. With these improvements, the conventional solar still method holds great potential for addressing global water shortages in an environmentally sustainable manner.

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