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Experimental Studyon Single Slope Solar Still using Different Nanofluids

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Abstract: In this research, a single slope solar still is employed as the primary apparatus, and a variety of nanofluids, including but not limited to metallic and non-metallic nanoparticles, are examined. The experimental setup involves the systematic comparison of the performance of the solar still using these nanofluids against a traditional base fluid. Parameters such as distillate output, evaporation rate, and overall energy efficiency are measured and analysed to quantify the impact of nanofluid integration.This experimental study investigates the enhancement of the performance of a single slope solar still through the utilization of various nanofluids. The study found that using a SiO_2, blend of SiO_2+ ZnO and ZnO nanofluids at 0.5 cm water depths yielded the highest efficiencies of 19.15%, 21.64%, and 24.11%, while single slope solar steel showed better hourly productivity and efficiency. This research aims to pave the way for the development of more efficient and sustainable solar still systems, addressing the growing demand for freshwater resources in arid regions while harnessing the potential of nanotechnology in solar energy applications.

Keywords: *Solar Still, Nanofluids, Performance, efficiency, Comparison and Enhancement.*

1. Introduction:

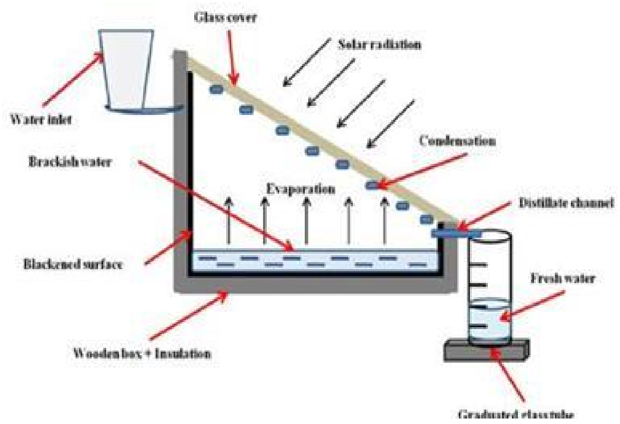

Figure-1 Single Slope Solar Still

A single slope solar still is a type of solar desalination system designed to convert saline or brackish water into freshwater through the energy of sunlight. This simple yet effective apparatus utilizes solar radiation to facilitate the evaporation and subsequent condensation of water, resulting in the collection of purified water for human consumption or other applications. as shown in Figure 1.

The design of the single slope solar still is characterized by a sloping surface, typically covered with a transparent material, which allows solar radiation to enter and initiate the evaporation process the basin type solar still mimics this natural hydrological process on a small scale. Solar distillation uses solar energy as a source of heat energy for obtaining fresh water from salty, brackish, or contaminated water.

2. Literature Review:

A literature review is a critical and systematic summary and evaluation of existing research, studies, and scholarly articles on a specific topic or research question. It serves as a foundation for understanding the current state of knowledge in a particular field of study and helps identify gaps, contradictions, and areas where further research is needed. The primary purpose of a literature review is to provide context for a research project, thesis, or academic paper by demonstrating the researchers.

Ramasamy Dhivagar et.al. (2023) In this study, a novel approach was explored to enhance the performance of a solar still by utilizing conch shell biomaterial as an energy storage medium and porous media. The conch shell biomaterial efficiently stores solar thermal energy, releasing it into saline water during low solar radiation periods. Acting as a porous absorber, the conch shells also absorb significant solar radiation, elevating water temperature. Experiments conducted in Ongole, India, revealed a 10.8% improvement in cumulative productivity compared to a conventional solar still. The novel conch shell biomaterial demonstrated superior energy and exergy efficiency, surpassing conventional systems by 10.3% and 9%, respectively. Additionally, the modified solar still exhibited enhanced CPL and CO_2 emissions mitigation by approximately 11.1% and 10.9%, respectively, emphasizing its environmental benefits.[1]

Haider Ali et. al. (2023) rising population strains fresh water resources globally. Limited access to fresh water in many regions underscores the need for affordable technologies. Solar stills, particularly single-slope ones, show promise in generating fresh water. A study presents a prototype with a maximum production of 2.88 L/day, boasting 52.42% energy efficiency and 7.04% exergeticefficiency. Further research on design modifications could enhance productivity, highlighting the potential of solar stills for freshwater production. [2]

A.S. Abdullah et. al. (2023) Global water scarcity due to industrialization and population growth prompts exploration of alternative solutions. A study compares a modified solar still (MSS) with a conventional solar still (CSS), incorporating innovations like a copper water heating coil, internal reflector, external reflectors, and Nano-phase change material (PCM-Ag). MSS variants, particularly MSS-R-EC and MSS-R-PCM, show significant improvements in productivity and thermal efficiency. Integration of external reflectors and a condenser enhances MSS performance. Economic analysis indicates cost-effective freshwater production, with MSS-R offering the most favourable outcome at 0.018 $/L [3]

Ewelina Radomska et. al. (2023) This study investigates the impact of phase-change materials (PCM) on passive solar stills (SS) for water desalination. Experiments using two paraffin waxes and varying PCM mass show a strong dependence on operating conditions. Theoretical analysis reveals that productivity decreases with increasing PCM-to-water mass ratio under uniform initial temperatures. However, if the PCM serves as a thermal insulator in non-insulated SS, a 1.1% productivity increase occurs, with an optimal PCM-to-water mass ratio. The most significant productivity boost, up to 47.1%, is achieved by heating the PCM externally and inserting it into the SS as water temperature decreases. This study addresses the knowledge gap in understanding PCM's varying impact on SS productivity.[4]J. Singh et.al. (2022)

A conventional single-slope solar still is enhanced by coupling it with a novel nanofluid-based volumetric absorption solar collector (NBVASC). The nanofluid, derived from functionalized carbon soot nanoparticles in used engine oil, boosts solar energy absorption. In experiments conducted from May to July 2020, coupling the NBVASC led to significant improvements-75.3% in distillate productivity, 66.9% in thermal efficiency, and 33.9% in night distillate. Notably, the solar still coupled with NBVASC outperformed a surface absorption-based collector, showcasing the advantages of volumetric absorption. This study marks a significant advancement in efficient solar-driven desalination for remote underdeveloped areas.[5]Dindsha et.al. (2022) investigated the efficiency of CuO, Al_2O_3, Ag, Fe_2O_3, and SiC-water nanofluids in a passive single-slope solar still, with 0.02m water depth as optimal. Experimental validation showed a 12.24% total deviation, with Al_2O_3 nanofluid exhibiting the highest daily production increase (14.22%) among tested nanofluids.[6]

Hafs et.al. (2020) This paper focuses on improving the thermal performance of a solar desalination system. By incorporating fins in the basin liner and utilizing Cu_2O nanoparticles in the base fluid, the objective is to boost fresh water productivity. The study, conducted in Rabat (latitude 34°00′47″ N), employs a 3D mathematical model in COMSOL Multiphysics 5.2a. Results indicate a 20% daily productivity increase with the finned basin liner using nanofluid (Brackish water/Cu_2O) and a 12.6% increase with the finned basin liner using the base fluid, compared to a conventional solar still.[7]**Dheeraj Kumar et al. (2020)** aimed to enhance solar still productivity through preheating saline water using external methods. Their study utilized a conventional single-slope solar still with an integrated flat plate collector. Optimal efficiency was achieved with a 3 cm water depth, resulting in 1.59 l/day and 57.07% thermal efficiency, emphasizing the impact of basin water depth on heat transfer coefficients.[8]

P. Thamizharasu et.al. (2020**)** An experimental study enhanced a stepped solar box cooker (SSBC) using SiO_2/TiO_2nanoparticles in varying ratios (5% to 25%) for bar plate coating. Coating the bar plate with SiO_2/TiO_2nanoparticles increased solar radiation absorption and inner moist air temperature, enhancing the system's thermal performance. Using 15% SiO_2/TiO_2 nanolayers improved overall thermal efficiency by 31.42%. Compared to single nanolayers (SiO_2, TiO_2), SSBC with SiO_2/TiO_2 nanolayers achieved performance increases of approximately 31.77%, 37.69%, 49.21%, 36.99%, and 34.66% with 5%, 10%, 15%, 20%, and 25% ratios respectively.[9]

Objective of Research Work:

The following objectives are as under.

- Increasing the efficiency
- Compare Nanofluids performance
- Determine optimal water depth

3. Experimental Setup:

Experiments were conducted at the University Institute of Technology, RGPV, Bhopal location (23.26°N. 77.41°E). The experiments were performed in Nov 2022 and carried out 9:00 to 17:00 PM. The direct and diffuse solar radiations as well as reflected radiation are transmitted through the glass cover and absorbed by the black painted steps. The absorbed solar radiation heats up the water and evaporates. The evaporative water come in contact with glass cover and gets condensed.

Figure-2 Experimental Setup

This condensed water slides toward the glass inclination and collected through the collecting channel. Nanofluids are highly thermally conductive nanoparticles containing fluids. They have been used as a pond fluid to increase the performance of the solar still. Single slope single basin solar still was fabricated using 2 mm Aluminium sheet by keeping

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the height of the lower vertical side at 100 cm for a 23° inclination of the window glass cover, the required height of the other vertical side was 38.9 cm.

The absorber area of basin stills was 0.5 m × 1 m. The schematic diagram of single slope still is shown in Fig.2. The inner side of the basin was painted black to maximize the absorption of solar radiation. The bottom and sides of the basin were well insulated with a thermocol layer of 1cm thickness. The outer structure is made from plywood of 1.8 cm thickness. An ordinary transparent window with a glass of 0.04 cm thickness was used as the top cover of the solar still. As shown in Figure-2.

4/ Result and Discussion:

Data has been collected using experimentation. Calculations of all the parameters for the performance prediction of the single slope solar still have been carried out.

Performance Analysis of 0.5 cm Water Depth:

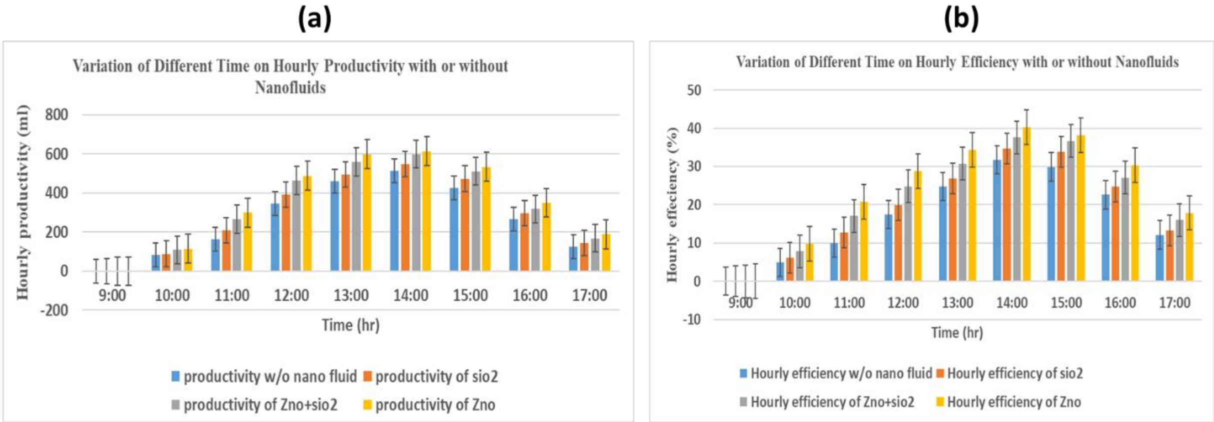

Figure-3 (a) Hourly productivity and, (b) Efficiency with or without Nanofluids

Performance Analysis of 1 cm Water Depth:

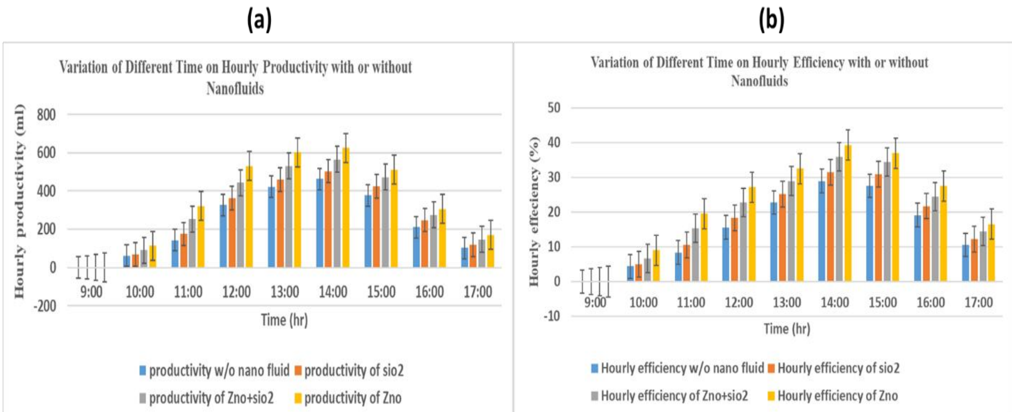

Figure-4 (a) Hourly productivity and, (b) Efficiency with or without Nanofluids

5 Conclusion:

- At 2:00 PM, the maximum hourly production was observed to be 511 mL, followed by 546 ml, 597 mL, 624 mL, and then SiO2 nanofluids, a blend of SiO2+ZnO nanofluids, and ZnO nanofluids.
- while utilising SiO_2, a blend of SiO_2+ ZnO, and ZnO nanofluids, respectively, at a depth of water 0.5 cm, the greatest efficiencies of 19.15%, 21.64%, and 24.11% are obtained.
- while utilising SiO_2, a blend of SiO_2+ ZnO, and ZnO nanofluids, respectively, at a depth of water 1 cm, the greatest efficiencies of 17.98%, 20.51%, and 22.98% are obtained.
- The hourly productivity and efficiency of single slope solar steel shown better results in 0.5 cm depth of water.

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