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Productivity Enhancement of TSS using Various Active Techniques

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Abstract: ***Solar distillation methods have been developed since ancient times and continue to evolve with ongoing research efforts. Among recent advancements, the tubular solar still (TSS) has emerged as a promising technology; however, it remains in the developmental stage. The present study focuses on enhancing the productivity of the TSS by integrating auxiliary solar collectors to increase the rate of water evaporation and, consequently, freshwater yield. The key novelty of this work lies in the first-time experimental coupling and comparative evaluation of three different solar collectors with a TSS configuration: Case-1 (TSS + parabolic trough collector), Case-2 (TSS + evacuated tube collector), and Case-3 (TSS + compound parabolic concentrator). The performance of these modified systems was experimentally compared with that of a conventional baseline TSS. All experiments were conducted under identical outdoor conditions with the systems arranged side by side in Nagpur, India (21.135°N, 79.0033°E). The results demonstrate that the Case-3 configuration (TSS + CPC) achieved the highest enhancement, with productivity increasing by approximately 2.2 times compared to the conventional TSS. Furthermore, the economic analysis indicates that the TSS–CPC system represents the most cost-effective solution among the investigated configurations.***

Keywords: Tubular solar still, Evacuated tube collector, Parabolic trough collector, Compound parabolic collector

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I. INTRODUCTION

Distilled water is indispensable across various sectors worldwide, from scientific research and healthcare to industrial processes and household applications and potable water for human beings. Over centuries, water distillation technology has undergone significant evolution, advancing from ancient civilizations' rudimentary methods to modern, more efficient techniques spurred by the Industrial Revolution [1]. Since then, numerous advancements have been made in distillation techniques, with a focus on improving reliability, reducing the cost of distillation, enhancing durability, and scaling up the system [2]. Recent decades have seen a notable shift towards sustainability, marked by the incorporation of renewable energy technologies like solar and geothermal power into distillation processes, aligning with global climate change mitigation efforts. Solar water distillation, utilizing evaporation and condensation principles, offers a sustainable solution for water purification. Traditional solar stills, typically made of glass or plastic, capture sunlight to heat water, causing it to evaporate, with the vapor condensing and collecting as purified water while leaving contaminants behind [3]. Various solar distillation techniques developed so far mostly include single slope, double slope solar stills, external condensation [4], additional thermal collectors, use of different heat storage materials, different glass covers [5], etc.

The present study experimentally evaluates the performance of a tubular solar still (TSS) under field conditions. The novelty of this work lies in the first-time coupling and comparative assessment of three different solar collectors—parabolic trough collector (PTC), evacuated tube collector (ETC), and compound parabolic collector (CPC)—with a TSS. All collectors are designed to operate without tracking, ensuring a cost-effective and low-maintenance system. The performance of these modified configurations is compared side by side with a conventional TSS, with productivity, distillate cost, energy efficiency, and exergy efficiency analyzed for all cases.

II.METHODOLOGY

The experiment was designed with the hypothesis that preheating the water in the basin of the tubular solar still (TSS) using additional solar collectors would improve its performance by enhancing the evaporation rate and, consequently, the productivity of the TSS.

Three different types of solar thermal collectors were affixed to the TSS to assess the impact of each collector on its productivity, comparing their performance to that of the TSS without any additional heat source. The experiments were conducted in Nagpur, India (Latitude 21.135°N, Longitude 79.0033°E,), during March 2023 as shown in Fig. 1.

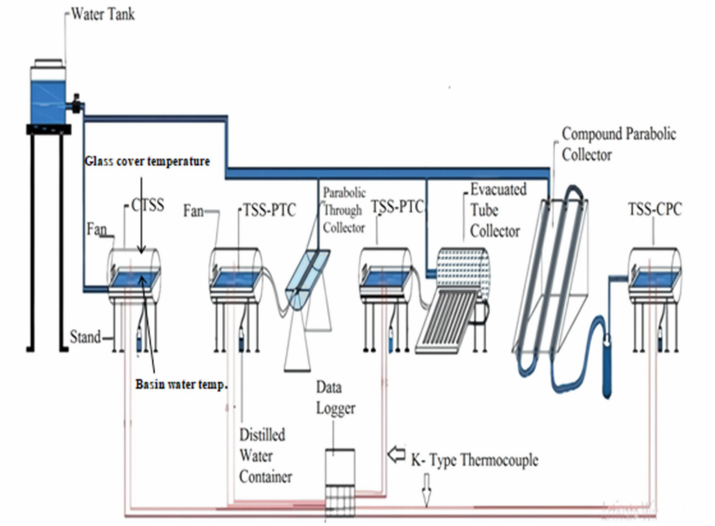

Fig. 1 Schematic representation of experimental setup

III.RESULT AND DISCUSSION

In March 2023, the experimental measures were carried out, and data collecting took place from 10:00 AM to 5:00 PM. During the studies, both solar intensity and ambient temperature increased throughout the experiments, peaking at 1:00 PM, followed by a subsequent decline. In April, the average solar intensity was 811 W/m^2, and the peak was 1008 W/m^2.During testing, the highest ambient temperature was 42°C.In this section, we investigate the effects of incorporating an evacuated tube collector (ETC), Parabolic trough collector (PTC), and compound parabolic collector (CPC) on the productivity and efficiency of the TSS. The productivity of TSS is affected by various parameters including ambient temperature, wind speed, solar radiation, and design setup of TSS. Figure 2 below illustrates the variations in vapor (Tv), basin water (Tb), glass cover (Tg), ambient temperature (Ta), and solar irradiance (I) over time for the conventional tubular solar still (CTSS).

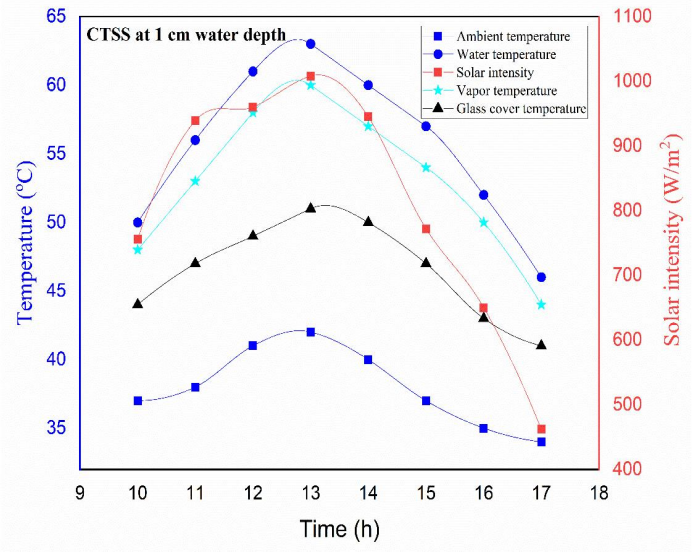

Fig. 2 Variation of the temperatures and solar radiation with time

CTSS, TSS-PTC, TSS-ETC, and TSS-CPC daily freshwater productivity are shown in Figure 3. The maximum yield for CTSS, TSS-ETC, TSS-PTC, and TSS-CPC is about 4.3, 6.9, 8, and 9.1 L/m^2, respectively..

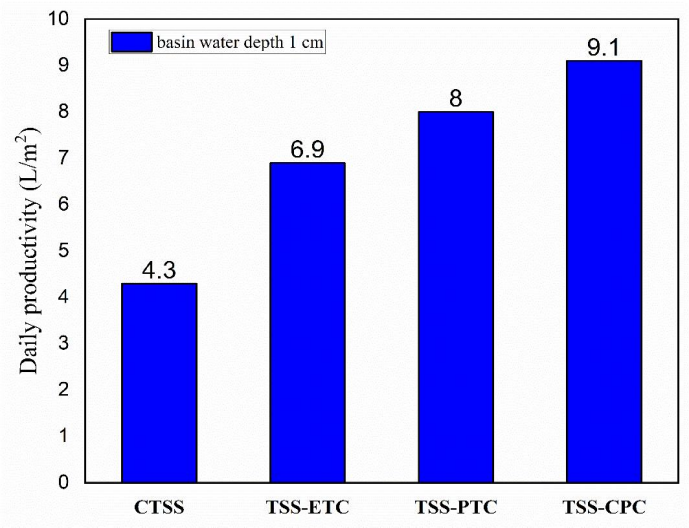

Fig. 3 Daily productivity of CTSS, TSS-PTC, TSS-ETC, and TSS-CPC

IV.CONCLUSION

The current research focuses on enhancing the performance of tubular solar stills (TSS) by integrating supplementary solar thermal collectors to improve evaporation rates and, consequently, the productivity of these solar stills. Three distinct solar collectors viz; Parabolic trough collector, Evacuated tube collector, and Compound parabolic collector denoted as Case-1 (TSS+PTC), Case-2 (TSS+ETC), and Case-3 (TSS+CPC) respectively, were attached to the TSS for additional heat input. And their performance was compared against a baseline TSS without such modifications.

Conflict of interest

The authors affirm that there are no competing interests associated with this publication, and no funding has been provided for this work.

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