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Performance study on solar still using nano disbanded phase change material (NDPCM)

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ABSTRACT

The current work examines the enactment of a traditional single sloped type of solar still in the presence of crude wax as an organic phase changing material (PCM) and a low mass of nano-zinc oxide (ZnO) particles disbanded crude wax as NDPCM in terms of daily potable water output. To accomplish this goal, three identical solar stills were planned and constructed. Among these, one was an unchanged traditional still (Normal Still), another still was combined with crude wax based PCM (CW Still), and a third still was amalgamated with NDPCM (NDPCM Still). Earlier, the NDPCM was formed by combining 1.0 percent mass of zinc oxide nanoparticles with enough quantity of crude wax. The tests were carried-out in March 2021 at 11.0168° N, 76.9558° E. The results indicated that the addition of crude wax and specifically, the NDPCM increased the output of clean water by 50.24 percent and 65.17 percent, respectively.

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1. Introduction

The lack of potable available for drinking purposes has been recognized as a severe concern on a global scale in recent years. While 70% of the surface of the planet is covered by water, just 3% of that water is drinkable. Even with sufficient freshwater resources, people can only access around 0.5 percent of it, while the remainder is stashed in the Arctic Regions as glaciers. In total available water around the globe, the seas contain about 97 percent of water, which are saline in nature [1,2]. Thus, an acceptable approach can aid in the conversion of salty water to drinkable water for human use in an appropriate manner and cost-effective way [3,4]. Energy from the sun is widely employed in modern times for a variety of purposes, including heating water and air, power and water generation, and drying of edibles [5,6,7]. Similarly, solar stills are one of the most straightforward techniques for converting saline water to clean water using solar thermal energy. Solar thermal systems, on the other hand, have a few drawbacks, including unpredictable solar radiation fluctuations caused by local weather and restricted solar energy supply [8,9,10].

Researchers have made several advancements recently to solve the aforementioned concerns with solar thermal collectors [11,12]. One such proposed option is to include phase changing substances (PCM) into the system in order to improve the system's thermal storage and stability properties [13,14]. In these instances, paraffin-based substances have become the most attractive materials due to their outstanding heat storage capabilities and low cost [15,16,17]. Additionally, it was shown that the incorporation of appropriate nanoparticles inside those substances improved the thermal stowage and stability of the basic constituents [18,19,20].

Modern research on solar stills has showed that their functionality may be significantly improved using PCM [21,22]. The operation of a tube-shaped still was investigated after uniting it with a PCM and discovered an increase in production of 8% [23]. Kabeel et al. [24] enhanced the production of the still by using a combination of PCM uniting gravel and wax. They tested the performance of the still using a plain PCM to the still and using combined PCM, and discovered that the combined PCM produced 37.55 percent additional freshwater than the plain still. Kumar et al. [25] evaluated the solar still using a nano-enhanced PCM containing sil-

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ica nanoparticles. They employed low mass of nanoparticles by carefully dispersing inside the PCM. They discovered that nanocomposite PCM increased the production of the solar powered still by 15.85% more than the still with plain PCM. Another study examined the functionality of a thermal storage integrated solar still subsequently adding it with 3 various kind of nanoparticles (TiO_2, CuO, and GO), separately, and concluded that using CuO nanoparticles significantly increased the yield of the still when comparing to certain other nanoparticles at the cheapest cost [26]. The aforementioned articles demonstrate the viability of nano-PCM, whenever a significant increase in solar still performance is desired without requiring a costly upgrade. It had become the impetus for the current work, in which the operation of the solar still was investigated using an established amalgamation of nano-PCM comprising ZnO nanoparticles with crude wax [27].

The purpose of this work was to enhance the productivity of the single slope traditional solar still by combining it with a crude wax PCM and then with a NDPCM comprising nano-ZnO particles suspended in crude wax emulsion. In present study, the drinking water yield of the still was used to determine its performance, and the fresh water output was determined through experimentation for 3 distinct combinations of solar stills.

2. Materials and methods

2.1. Phase changing materials (PCM)

The crude wax was acquired domestically from a local provider. A total of ten kilogram of crude wax was purchased. Sigma Aldrich supplied the ZnO nanoparticles (30 nm mean size). Due to the fact that the obtained crude wax was in the shape of pellets, they were heated to remove any entrapped gases and to obtain them in a homogeneous form. The NDPCM was made by disbanding 1.0 mass fraction of zinc oxide (ZnO) nanoparticles in molten crude wax using a magnetic stirrer [28]. The synthesized NDPCM was then sonicated for 150 mins to guarantee a greater degree of nano-ZnO dispersion in crude wax [29,30], as illustrated in Fig. 1.

The latent heat content, melting and freezing temperatures had observed experimentally using differential scanning calorimetry (DSC) and further, heat conductance was measured with the thermal properties analyzer (KD2 Pro) for both crude wax and NDPCM as instructed by Kumar et al. [30,31]. Table 1 summarizes the obtained thermal physiognomies of the crude wax and NDPCM. It would be obvious that the ZnO nanoparticles enhanced the thermal conductivity of the crude wax to 0.23 W/m°C, which is 27.78% greater than that of the plain crude wax.

Fig. 1. Sonication of NDPCM in ultrasonicator.

Table 1
Thermal characteristics of crude wax and NDPCM.

Description	Crude wax	NDPCM
Melting Point (°C)	62	61.4
Freezing Point (°C)	58	58.7
Latent Heat (kJ/kg)	145	138
Specific Heat (kJ/kg°C)	2.10	2.08
Thermal Conductivity (W/m°C)	0.18	0.23

2.2. Experimental set-up

For the trials, three numbers of individual single slope solar stills with similar dimensions were constructed. A chamber was created beneath the basin of two solar stills to accommodate the crude wax/NDPCM. The traditional solar still, the still with crude wax and the still with NDPCM were named labelled as Normal Still, CW Still and NDPCM Still, respectively. A 5 kg of crude wax was used to fill the CW Still, and a 5 kg of NDPCM was used to fill the NDPCM Still. Throughout the test, each still was loaded with the eight litres of water. All solar stills were positioned in close vicinity to one another, facing south. The diagrammatic representation of the still is presented in Fig. 2.

During the investigation, the still's top glass cover was angled at 11°toward the south, while the other sides were protected with the thermal insulating materials. Instantaneous solar irradiance had obtained with a solar meter, and temperatures such as the top covering glass temperature, the still water temperature, and the surrounding air temperature were measured with thermocouples with a resolution of 0.5 °C. Table 2 details the important parameters of stills.

3. Results and discussion

The studies had accompanied on the 3 kinds of solar powered stills named as Normal Still, CW Still and NDPCM Still, as described previously, all of which were exposed to real solar irradiance on the same day. The experiments were conducted in March 2021 at 11.0168° N and 76.9558° E, in hot and sunny weather conditions. The radiation from the sun and ambient temperature variations throughout the course of the trial day are portrayed in Fig. 3.

The tests instigated at 8 am and settled at 6 pm on the days of the assessment. Three trials were undertaken on average to confirm the accuracy and repeatability of the results. Explicitly, the data arrived on the 11th, 14th, and 16th of March found to be comparable, and the data for the 14th March 2021 were critically analyzed in this study. 705 W/m^2 and 30 °C, respectively, were observed as the mean irradiance and air temperature. Throughout the experiment, the upper cover glass temperature of all stills was recorded and is shown in Fig. 4. The highest temperature was

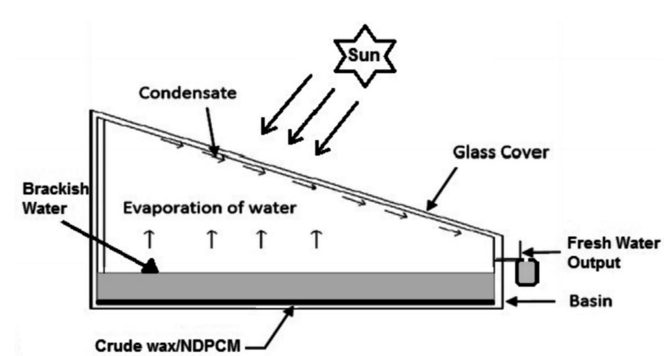

Fig. 2. Diagrammatic representation of experimented solar stills.

Table 2
Description of the experimented solar still.

S. No.	Items	Material and dimensions
1.	Collector of stills	Black coated aluminium sheet
2.	Bottom area	7500 cm^2
3.	Dimensions of the basin	100 cm × 75 cm
5.	Cover glass	5 mm thick borosilicte glass
6.	Material of side and bottom of the stills	High grade GI sheet
7.	Height of the stills	52 cm at North & 14 cm at South
8.	Top glass angle	11° towards South

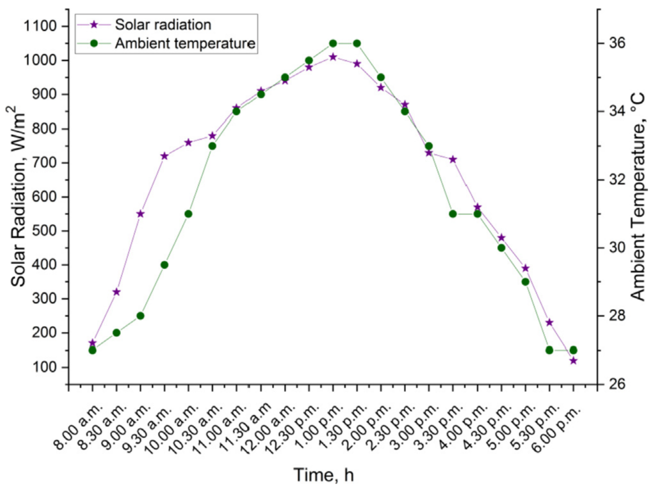

Fig. 3. Instantaneous solar insolation and temperature of surrounding during the testing day.

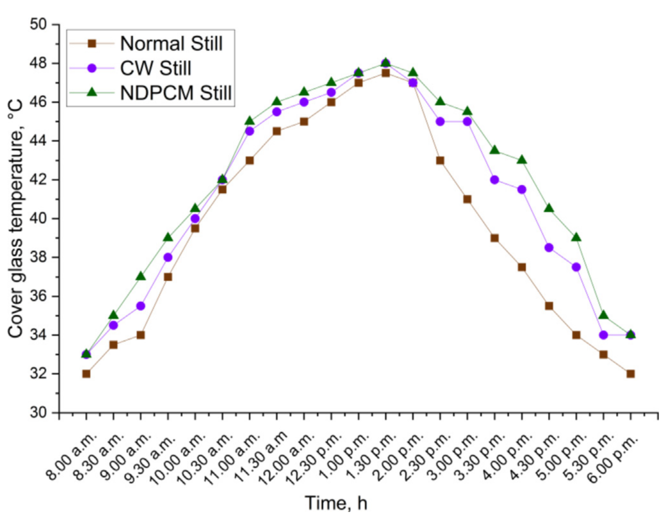

Fig. 4. Cover glass temperature during the testing day.

observed at midday, and the shift was proportionate to the amount of solar energy measured. The peak temperature of the cover glass was nearly same for all stills. Fig. 5 illustrates the fluctuation in the temperature of the basin still water in the various stills during the trial day. The temperature rise was to be nearly identical for the three experimented stills until noon. However, crude wax and NDPCM performed admirably by sustaining the requisite water temperature for an extended length of time, allowing the stills comprising crude wax and NDPCM to operate more productively.

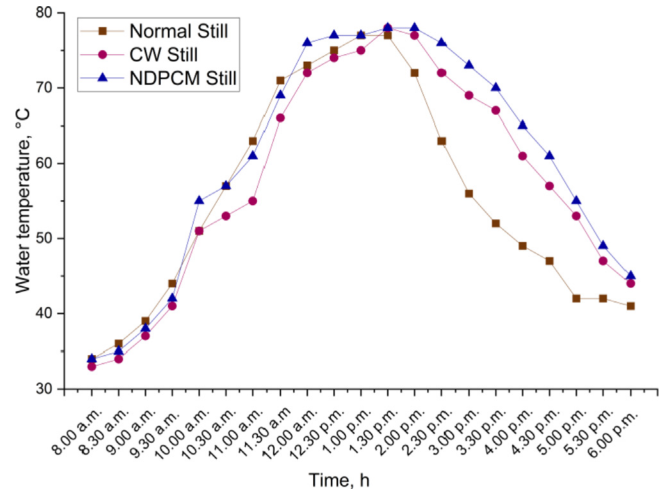

Fig. 5. Water temperature in still basin during the testing day.

Specifically, as compared to the other two kinds of stills, the solar still containing NDPCM (NDPCM Still) retained the maximum water temperature till dusk.

The accumulative extraction of potable water from the various solar stills is shown in Fig. 6. It's worth noting that all three stills performed similarly until midday. From midday to the completion of the trials, the production of the stills carrying crude wax and NDPCM increased. Particularly, the still comprising NDPCM generated the most water in comparison to the other two kinds of solar stills.

Daily fresh water output was determined to be 4220 ml, 6340 ml, and 6970 ml, respectively, using Normal Still, CW Still, NDPCM still. Daily productivity was determined to increase by 50.24 percent and 65.17 percent, respectively, when stills incorporating crude wax and NDPCM were used instead of traditional solar stills. The results demonstrated that NDPCM, an unambiguously paraffinic compound with a 1.0 mass percentage of ZnO nanoparticles, would be a superior candidate for increasing the solar still's productivity. The NDPCM Stills better performance can be attributed to the crude wax's increased thermal conductivity with addition of nano-ZnO.

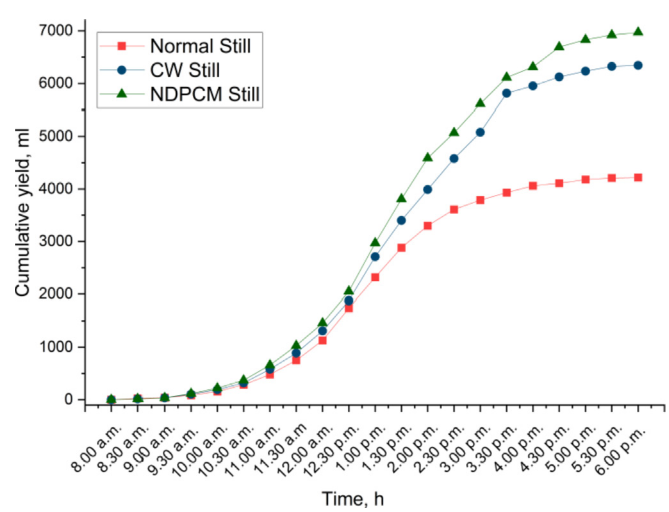

Fig. 6. Cumulative yield of the solar stills during the testing day.

4. Conclusions

Initially, the NDPCM was primed by scattering 1.0 mass of ZnO nanoparticles inside crude wax. It is noted that the ZnO nanoparticles improved the thermal conductivity of the crude wax to 0.23 W/m°C, which is 27.78% upper than the plain crude wax. For the experimental work, three single slope type solar stills with identical dimensions were manufactured. Among these, one still was unaltered (Normal Still), the second one was assembled with crude wax (CW Still) and the third still was assimilated with NDPCM (NDPCM Still). The trials were conducted concurrently with the 3 solar stills. The outcomes indicated that the still containing NDPCM generated 65.17 percent more drinkable water than the traditional still, followed by CW Still, which produced 50.24 percent more water. As a result, it is proposed that the PCM comprising crude wax and a low mass percentage of ZnO nanoparticles be used to efficiently and inexpensively improve the performance of solar stills.

CRediT authorship contribution statement

P. Manoj Kumar: Supervision, Validation, Writing – original draft. **Prashant Chauhan:** Conceptualization, Writing – review & editing. **Amit Kumar Sharma:** Data curation, Writing – review & editing. **Moti Lal Rinawa:** Methodology, Writing – review & editing. **A.J. Rahul:** Investigation, Writing – review & editing. **M. Srinivas:** Writing – review & editing. **A. Tamilarasan:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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