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Experimental investigation for performance enhancement of single slope solar still using nanofluids under winter conditions

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ABSTRACT

The objective of this study was focused on carrying out design and development of a system by distillation of water which would help in purifying water from any water body sources. The current study would like to make available distilled water in an experimental setup where in nanofluid had made the use of a solar system with single slope orientation. Numerical calculations were performed on the solar stills in Bhopal City, India (23.2599° N latitude and 77.4126° E longitude) for different nanomaterial concentrations. As working of nanofluid helps absorb heat when solar radiation exist in experimentation, which facilitates of thermal energy generation in a proactive and efficient pattern. The experimental setup design is to investigate experimentally nanofluid effect particularly in the winter season in an efficient manner. In the experimental setup an aluminum sheet rectangular tank of thickness of 2 mm was used, the set tank was made leak proof using silicone gel. Plane glass sheet thickness (4 mm) was used in this experimental setup having an appropriate setting. The potable water was kept from a minimum of 5 mm to a maximum of 100 mm. The nanofluid (Al_2O_3, SiO_2, and Al_2O_3+SiO_2) to be used, is taken in an appropriate ratio with respect to the base material, while black paint is used for absorbing the heat. Experimental results impractically showed the maximum temperature of the basin which was observed to be 71.7°C when using Al_2O_3 nanofluids and the one using without nanofluids basin was 65.8°C at 14:00 PM. A maximum efficiency of 20.63% was found for use without nanofluids. In comparison, the total efficiencies of 23.14%, 30.27%, and 26.81% were obtained using SiO_2, Al_2O_3, and a blend of SiO_2+Al_2O_3 nanofluids, respectively for 0.5 cm of water depth.

Keywords: Solar still; Nanofluids; Aluminium sheet; Glass sheet; Black paint

1. Introduction

The most recent research has indicated and elaborated on the increasing the usage of renewable energy sources as a key component to start the purification of the water process. Desalination is a technique for purifying water using nanofluids, while solar energy is a highly clean and efficient mode of energy. Solar water distillation is the technique of removing salts or other impurities from freshwater using the energy of the sun. Low-capacity and independent water-providing systems can employ solar stills. Solar energy is a major source of heat for desalination, cooking, heating, and cooling process. A solar still is a tiny device that uses solar energy to transform through salty or dirty water into potable or drinkable water. Advantages of this process include low installation costs, free water production, and scanty need for trained labor. Drawbacks include low efficiency and issues with salt, scale, and rust build-up etc. The current study aims to create a small-scale, highly effective solar distillation system.

One of the fundamental demands of all earthly life is access to water. The distribution of water on Earth is such

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that just about 3% of it is fresh, while the other about 97% is too salty, dirty or else undrinkable. Only 1% of freshwater is found in rivers, ponds, and lakes; 69% of it is in the form of glaciers; 30% of it is under the earth's surface. In recent years, the majority of the world's 2.7 billion inhabitants have experienced water scarcity, and 2.4 billion have experienced illnesses including cholera, typhoid, and jaundice and other water born because of contaminated drinking water. Therefore, most of the countries today face issues with drinking water. A large number of technologies, like reverse osmosis (RO) filters, are used, but not everyone can afford them, especially in metropolitan areas where electricity costs are high. Solar stills are therefore one of the common ways to cleanse water without using power. Charles Wilson made the first solar still in 1882. Salinized water may also be used in solar stills to produce fresh water. Most of the countries with a drinking water deficit, including the metropolitan populations having no means to purchase purifiers, in the regions close to the equator may all use solar stills to purify their water. In order to absorb the most incoming solar energy possible, the bottom of the container is lined up with a black absorber material. A glass-sloping cover generally covers the container's top. The sloping cover for the solar still is selected so that it should have the ability to transfer the majority of the sun's rays to the black absorber lining. The still is constructed to catch the most solar energy possibly collected inside of it. Insulation is offered to cut down on losses. By way of keeping another container nearby to catch any new water that drips from the glass slope cover would be designed. Solar energy stills convert solar radiation into heat vis-à-vis thermal effect, which is the underlying theory behind how it is converted into heating the content therein. Two types of solar stills used are passive and active, and the efficiency and productivity of the solar stills have been discovered to be particularly advantageous in Asian and the pacific nations like India and the Asian subcontinent. India receives over 300 d of sunlight annually, and the regions that receive the most radiation are Rajasthan and Gujarat. To improve upon its performance, efforts are needed to alter the current solar still design in including, performance variables, status, and its advancements.

Dhindsa et al. [1] used CuO, Al_2O_3, Ag, Fe_2O_3, and SiC-water nanofluids to simulate single-slope solar still. Experiments were conducted to verify the model and the stills' performances were compared. It was found that daily distillate production was 12.24% for Al_2O_3-water-based nanofluid (14.22%), followed by SiC (7.61%), Ag (8.11%), Fe_2O_3 (7.63%) and CuO (10.82%). Murugan et al. [2] to examine the impact of initial tray pressure on still production. Galvanized iron sheets were used to construct a single slope, single basin solar still with a base area of 0.49 m^2 that was tested on the porch of Velammal Engineering College in Chennai India (13°09′0.08″N, 80°11′31.22″E). A reciprocating pump was used to change the solar still's initial basin pressure. Various working pressures were used to measure the freshwater production of the still, including 25, 50, 75, and 101.32 kPa (atm pressure). When compared to atmospheric pressure operation, it was found that the solar still's output rose by 67.53%, 34.49%, and 10.72%, respectively. Jahanpanah et al. [3], investigation examined the influence of lower-temperature PCM on the total output, efficiency, and basin temperature limits of a single-slope solar still. A salable salt hydrate low-temperature PCM with a melting point of 28°C and a latent heat of fusion of 225 kJ/kg was chosen as a cutting-edge method in the industry. Eltaweel et al. [4] solar energy is a desirable source of energy due to the rising energy demand and constrained supply of traditional energy sources. Solar thermal collectors with evacuated tubes are typically used in household settings, but replacing the working fluid with a nanofluid can improve heat transmission. Experimental research had shown that with an increase in concentration, the total heat loss coefficient shrank and 2 L/min was determined as the critical flow rate. As per Taamneh et al. [5] in Chennai, India, inclined solar stills (PISS) and active solar stills (AISS) were constructed and investigated. Spiral tube collector (STC) was integrated into an AISS for drinking water extraction. The PISS and AISS produced the most distilled water, at rates of 4.4 and 8.3 kg/d, respectively. The brackish water quality investigation showed that the pH value of brackish water was 8.7, while that of fresh water was 7.6. According to Parsa et al. [6] this study investigated the performance of two nanofluid-based solar stills in the metropolis of Tehran and the 4,000 m summit of Mount Tochal over four consecutive days in July 2018. Results showed that using nanofluid had a significant influence on the systems from an energy standpoint, but from an efficient and energetic standpoint, the altitude gained the highest rapid energy and exergy efficiency by 55.98% and 9.27%, respectively. Hussein et al. [7] hybrid nanofluids were created by suspending CF-MWCNTs and graphene nanoplatelets with hexagonal boron nitride in distilled water. Tween-80 was used as a surfactant and various measuring instruments were used to examine stability and thermophysical characteristics. According to the study of Sathyamurthy et al. [8] this project uses a tiered solar still to increase the amount of drinkable water available. Results show that using TiO_2 nanofluids with volume concentrations of 0.1% and 0.2%, yields of fresh water from stepped solar stills improved by 33.18% and 41.05%, respectively, while yields of fresh water from stepped stills using MgO nanofluids improved by 51.7% and 61.89%. As per Eltaweel et al. [9] economic research showed that the cost of potable water decreased from 0.029 to 0.016 $/kg. Nanofluids can be used to improve the thermal performance of solar collectors, as they possess superior thermophysical characteristics than common working fluids. Experimental research was conducted by them to determine the impact of utilizing multiwalled carbon nanotubes in a flat-plate solar collector.

Zakaria et al. [10] SiO_2 nanofluid coolants decreased average plate temperatures by 15%–20% compared to conventional water cooling under input flow parameters of 750–900 Reynolds number in a PEM fuel cell cooling system. Rajput et al. [11] solar thermal technology has become increasingly important due to its ability to transform solar energy into a form that can be used. This study focuses on the impact of water-based Al_2O_3 Nano fluid on the efficiency of flat-plate solar water heaters. Rahbar et al. [12] an exergy study was conducted to improve the thermodynamic performance of a double slope solar still fitted with thermoelectric heating modules. Ghaderian et al. [13], Al_2O_3 nanofluids have the highest efficiency of 57.63% for concentrations of 0.06 vol.% and mass flow rates of 60 L/h. They can be used as working fluids in ETSCs to collect heat from solar radiation and transform it into thermal energy. Ghaderian et al. [14] showed the performance of an evacuated tube solar collector (ETSC) water heater with an internal coil to determine the impact of a CuO/distilled water nanofluid. The results showed that using the nanofluid as an absorption medium increased the efficiency of ETSC by up to 14%. Kumar et al. [15] the solar stills can be used to reduce water scarcity, but their limited production is a major constraint. Experimental research was conducted to compare the performance of standard and modified stills.

According to a study carried out by Abdullah et al. [16] the famous solar desalination technology like solar stills, suffer from a lack of daily water output. In order to improve the performance of the trays solar still (TSS), an experimental investigation was carried out in this work. The rate of heat transmission between the TSS absorber and the saline water has increased. The effects of mounting reflecting mirrors on the inside of TSS were investigated. As per the study by Kabeel et al. [17] the greatest way to enhance the performance of any thermal application is to store energy as latent or sensible heat. Although desalination with renewable energy is the best way for obtaining potable water, it is not commercially viable because of its lone efficiency and output. The goal of the current study is to increase the quality of drinkable water generated by a tubular solar still employing nanomaterials in phase change material. According to Essa et al. [18] the use of nanoparticles of cuprous and aluminium oxides increased system productivity by 285.10% and 254.88%, respectively, in a modified solar still. As per research of Kabeel et al. [19] numerical studies have been conducted to assess the impacts of merging the solar still with an external condenser and employing nanofluids on the desalination system's performance. According to Abdullah et al. [20] an experimental study improved the performance of trays solar stills by increasing absorber surface area and heat transfer rates, and by utilizing corrugated absorbers to increase water output by 180%. In research of Halib et al. [21] a study examines the operational performance of three tubular solar stills, with the CTSS employing paraffin wax and graphene + paraffin wax to produce improved models. According to Abd Elaziz et al. [22] presents an ensemble random vector functional link network (EnsRVFL) to predict the yield of active solar stills using nanoparticles. It was observed that when employing Cu_2O and Al_2O_3 nanoparticles, efficiency was improved by 140% and 100%, respectively. Panchal et al.'s [23] study examines the utilization of nanoparticles to increase solar still (SS) production. MNO_2 is chosen as a nanoparticle material and mixed with black chrome paint. At 20% WC, the SS with MNO_2 nanoparticle has a payback time of 82 d compared to 98 d for SS alone. As per study of Shanmugan et al. [24] the solar still was tested in Chennai, India, with temperatures measured under transient heat flow. Flat and finned absorbers coated with 20% SiO_2 nanoparticles cost 0.0187 and 0.012 \$/L to create 1 L of water. According to Arani et al. [25] the goal of this effort was to increase the performance of the tubular solar still (TSS) by expanding its interior surface area and using jute fabric and nanocomposites. The highest CVTSS daily production was 9,000 mL/m^2/d, while the daily average thermal efficiency was 33% and 50%. As per researcher Essa et al. [26] the solar distiller has low freshwater output, so a convex dish absorber and circular stepped surface were suggested as design changes to improve its merits. According to researcher Abdullah et al. [27] solar distillers are an appropriate solution to freshwater scarcity, but their poor productivities are a problem. Two modified designs were tested with revolving wick belts and wick types.

As per Bamasag et al. [28] solar distillers are used to desalinate sea water in remote areas without access to conventional energy sources. A new design was put out to increase the productivity of the drum solar still (DSS) by including a corrugated drum solar still (CDSS), a conventional drum solar still (DSS), and a conventional solar still (CSS). According to García Marquez et al. [29] solar water distillation, PCM-based thermal energy storage materials, and nanofluids are being explored to reduce global demand for fresh drinking water. This research by Mohammed et al. [30] modified the tubular solar still (TSS) to increase its productivity by tilting the glass cylinder and using ITSS to shorten it. A convex dish absorber was replaced with a circular base and cotton wick to speed up the evaporation process. Salinized water may also be used in solar stills to produce fresh water. Countries with a drinking water deficit, metropolitan populations without the means to purchase purifiers, and regions close to the equator may all use solar stills to purify their water. As seen in Fig. 1, solar stills consist of a container filled with dirty or salty water.

According to the coined literature review limited research has been carried out on the development of a thermal model single-slope solar still having nanofluid at different weather conditions with a comparison of its effect at fixed volume concentrations of nanofluid at different variations of depth. Therefore, the main purpose of the present research is to investigate for performance enhancement of single-slope solar still using different nanofluids. Moreover, it can also help to fill the technological gap to compare the performance of solar still with the different nanoparticles and their concentration.

2. Experimental set-up and procedure

The single-slope solar still have been constructed, a basin is made by aluminium sheet thickness of 2 mm. It has low density, not-poison, high thermal conductivity, and outstanding corrosion resistance due to a self-protecting oxide layer and can be simply cast, machined, and found it is also known non-magnetic and non-sparking it is the another most

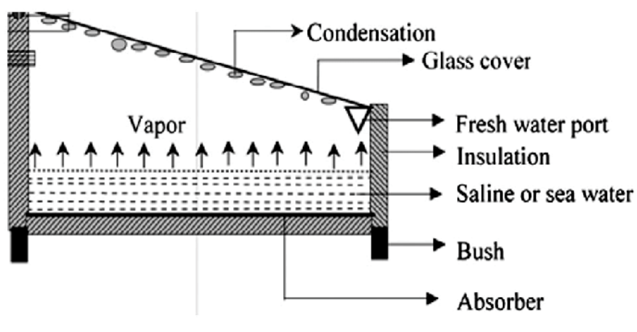

Fig. 1. Single slope solar still.

malleable metallic and the sixth most ductile and the thermal conductivity of aluminium is 237 W/m-k. Aluminium sheet used to fabricate a square tray having an evaporating area is 1 m^2. The plane glass having thickness of 4 mm used to cover the still, inclined at 23°C with the horizontal surface, which is almost equal to the latitude of the location (Bhopal) because of maximum solar energy is transferred inside the tray. On the inside of the tray was insulated with black paint to absorb the maximum solar energy. The outer side of the tray we are using thermacol and plywood was used for eliminating the loss of heat transfer from the surroundings. A silicone gel is used between the glass and structure of the still, which helps to ensure that there is no gap between the glass panes and, the whole system is insulated to the surrounding as shown in Fig. 2.

The system shown is faced towards the south, plane glass is used for condensation and transparent cover to ensure the incidence of suns radiation to enter the entire plane of the tray. To avoid some drops of distillate water falling back to the evaporator surface, a PVC semi-circular pipe is fixed to the bottom of the glass cover to collect the desalinate water and drops for collecting in the discharge tank. In addition, digital thermometers were used to measures the temperature of basin and glass surface. The surrounding temperature was observed between 27°C to 37°C. A digital Pyranometer was used to measure the direct sun radiation which varied from 717 to 1,195 W/m^2 in different weather conditions like rainy, winter and summer. The anemometer was used for measuring the wind velocity which varied from 1.0 to 2.8 m/s. The desalinate water was collected in a collection tank at an interval of every 1 h and measured with a printed scale on the container. An experimentation was performed out on Single-glass solar still using with or without nanofluid on winter session 2021 at Bhopal India. The level of water in the basin was maintained at a maximum 1.5 cm. The validation of the corresponding results obtained by the experiments were compared with the output of the fresh water without nanofluids and with nanofluids. The various instruments had been taken and located on the set-up for measurement of the required data. Finally, the freshwater output had been collected and then on the completion the program was stopped. During the experimental work following assumptions were convicted:

- Vapour leakage is negligible from the set-up.
- Heat capacity is negligible on the still.
- No temperature difference existed along the glass cover's thickness.
- The solar distiller performed in quasi-static process.
- All the components of the still was perfectly insulated including the delivery pipes.

The boundaries of both the experimental set-up and simple model were then compared with the hourly variation of freshwater output and heat transfer coefficient. After the comparisons, these models with nanofluid were found to be more efficient as compared to without nanofluids.

The hourly productivity of fresh water in (kg/h) is defined as follows:

$$P_h = \frac{h_{\text{ewg}} A_b \left(T_w - T_{\text{gi}}\right)}{L} \times 3600 \quad (1)$$

where p_h = hourly productivity, h_{ewg} = evaporative heat transfer coefficient from water surface to glass cover, A_b = basin area, T_w = temperature of water, T_{gi} = temperature of inside surface of glass cover, L = latent heat of water evaporation

So, the hourly thermal efficiency of solar still is calculated as follows:

$$\eta = \frac{p_h \times L}{A_g \times I \times 3600} \times 100\% \quad (2)$$

where η = thermal efficiency, L = latent heat of water evaporation, p_h = hourly productivity, A_g = glass cover area and I = solar radiation intensity.

3. Results and discussions

An investigation was this conducted using a single slope solar still. using different nanofluids under winter weather conditions with a depth of 0.5, 1 and 1.5 cm, the tilt angle of glass is 23°C on the base. The total distillate output obtained was more in summer because of intensity of solar radiation is more as compared to others. Data had been collected using experimentation. Calculation of all the

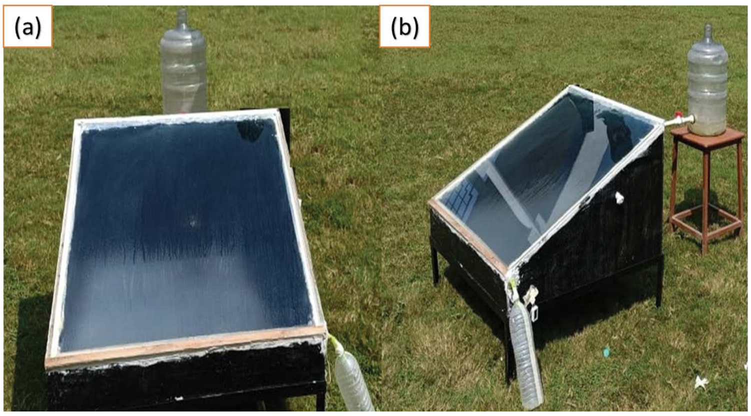

Fig. 2. Experimental setup of single slope solar still (a) and (b).

parameters for the performance prediction of the single slope solar still had been carried out. The readings were taken keeping the same radiation level at 1 h interval with and without nano fluids and its blending.

3.1. Performance analysis of Day-1 at 0.5 cm water depth (winter)

3.1.1. Effect of solar radiation at different times

In this section, variation of the solar radiation with time had been discussed. The solar radiation increases from 720 W/m^2 at 9:00 AM and it reached to maximum 1,155 W/m^2 at 12:00 PM, after that solar radiation decreased to 652 at 17:00 PM as shown in Fig. 3a.

3.1.2. Effect of wind velocity at different times

In this section, variation of wind velocity with time had been discussed. The wind velocity increases from 1.8 m/s at 9:00 AM and it reached to maximum 2.6 m/s at 14:00 PM, after that wind velocity decreased to 1.9 at 17:00 PM as shown in Fig. 3b.

3.1.3. Effect of basin temperature with or without nanofluids at different time

In this section, temperatures of basin and atmosphere with time had been discussed. The atmospheric temperature was increased from 27.3°C at 9:00 AM and reached to maximum of 36.1°C at 14:00 PM, after that atmospheric temperature decreased to 29.6°C at 17:00 PM. Basin temperature without nanofluid increases from 29.2°C at 9:00 AM and reaches the maximum 65.8°C at 14:00 PM, after that basin temperature decreases to 47.5°C at 17:00 PM. The basin temperature of SiO_2 increased from 29.1°C at 9;00 AM and it reached to maximum 67.5°C at 14;00 PM, after that basin temperature decreased to 50.2°C at 17:00 PM.

The basin temperature of Al_2O_3+SiO_2 increased from 29.1°C at 9:00 AM and it reached the maximum 69.5°C at 14:00 PM, after that basin temperature decreased to 53.3°C at 17:00 PM. The basin temperature of Al_2O_3 increased from 29.1°C at 9:00 AM and it reached the maximum 71.7°C at 14:00 PM, after that basin temperature decreased to 56.1°C at 17:00 PM. It showed that when nanofluids are use the temperatures of basin fluids was more as compared to without nanofluids. The thermal conductivity of nanofluids was higher than that of ordinary water, and they can be employed as solar absorbers.

Because it had a greater thermal conductivity than ordinary water, it can collect more solar energy and release it as thermal heat more quickly. It demonstrated that Al_2O_3, ahead of SiO_2 and water, had the maximum thermal conductivity. A 1 g concentration of Al_2O_3 nanofluid transmitted more thermal energy and heated up faster than other nanofluids as shown in Fig. 3c.

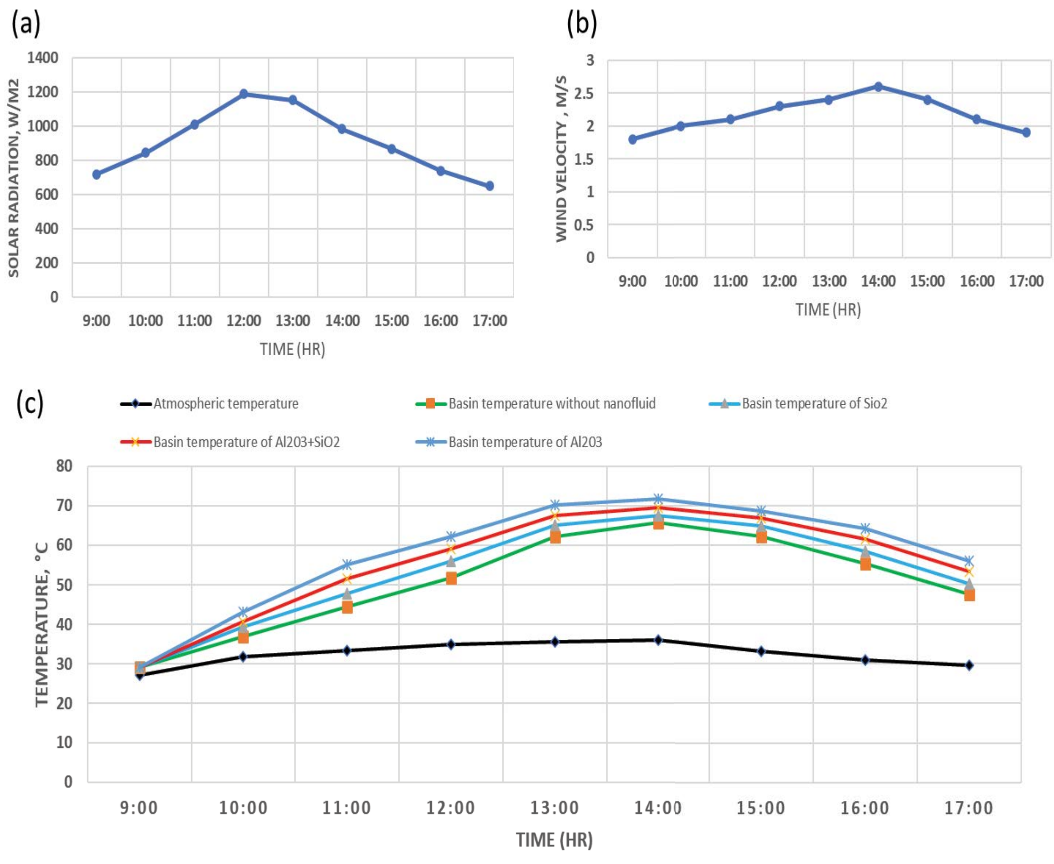

Fig. 3. (a)Variation of solar radiation at different times, (b) Variation of wind velocity at different times, and (c) Variation of basin temperatures with or without nanofluids at different times.

3.1.4. Effect of different times on hourly productivity with or without nanofluids

In this section, variation of hourly productivity with time had been discussed. The hourly productivity without nanofluid increased from 0 mL at 9:00 AM and it reached the maximum 515 mL at 14:00 PM, following that, hourly output declined to 130 mL at 17:00 PM. The hourly productivity of SiO_2 increased from 0 mL at 9:00 AM and it reached to the maximum 550 mL at 14:00 PM, following that, hourly output declined to 145 mL at 17:00 PM. The hourly productivity of Al_2O_3+SiO_2 increased from 0 mL at 9:00 AM and it reached to the maximum 610 mL at 14:00 PM, following that, hourly output declined to 175.5 mL at 17:00 PM. The Hourly productivity of Al_2O_3 increased from 0 mL at 9:00 AM and it reached to the maximum 670 mL at 14:00 PM, following that, hourly output declined to 200.3 mL at 17:00 PM.

It demonstrated that the still using Al_2O_3 nanofluid had a high output rate. Therefore, the higher the thermal conductivity, the more thermal energy the fluid contained and, as a result, the higher output productivity. Al_2O_3 produced more than SiO_2 and Al_2O_3 together, SiO_2 alone, and water as shown in Fig. 4.

3.1.5. Effect of different times on accumulated productivity with or without nanofluids

In this section, variation of accumulated productivity with time had been discussed. The accumulated Productivity without nanofluid increased from 0 mL at 9:00 AM and it reached to maximum 2,390.6 mL at 17:00 PM. The accumulated productivity of SiO_2 increased from 0 mL at 9:00 AM and it reached to maximum 2,680.9 mL at 17:00 PM. The accumulated productivity of Al_2O_3+SiO_2 increased from 0 mL at 9:00 AM and it reached to maximum 3105.8 mL at 17:00 PM. The accumulated productivity of Al_2O_3 increased from 0 mL at 9:00 AM and it reached to maximum 3,506.4 mL at 17:00 PM. The two main elements that contributed to higher Al_2O_3 production were stability and thermal conductivity as shown in Fig. 5.

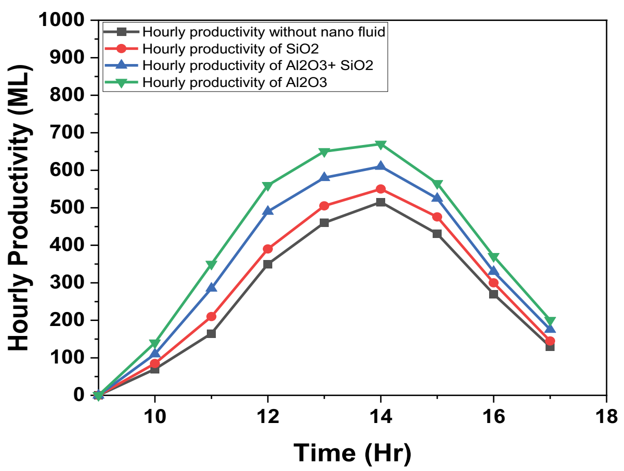

Fig. 4. Variation of different times on hourly productivity with or without nanofluids.

3.1.6. Effect of different time on hourly efficiency with or without nanofluids

In this section, variation of hourly efficiency with time had been discussed.

The hourly efficiency without nanofluid increased from 0% at 9:00 AM and it reached the maximum 32.77% at 14:00 PM, after that hourly productivity decreased to 12.50% at 17:00 PM. The hourly productivity of SiO_2 increased from 0% at 9:00 AM and it reached the maximum of 35% at 14:00 PM, after that hourly productivity decreased to 13.94% at 17:00 PM. The hourly productivity of Al_2O_3+SiO_2 increased from 0% at 9:00 AM and it reached the maximum of 38.82% at 14:00 PM, after that hourly productivity decreased to 16.87% at 17:00 PM. The hourly productivity of Al_2O_3 increased from 0% at 9:00 AM and it reached the maximum of 42.64% at 14:00 PM, after that the hourly productivity decreased to 19.26% at 17:00 PM as shown in Fig. 6.

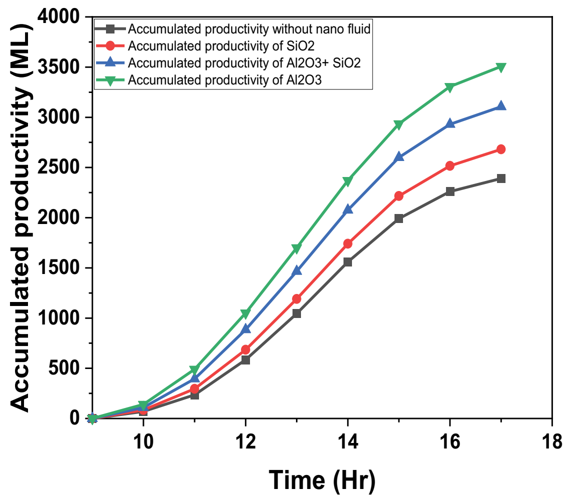

Fig. 5. Variation of different times on accumulated productivity with or without nanofluids.

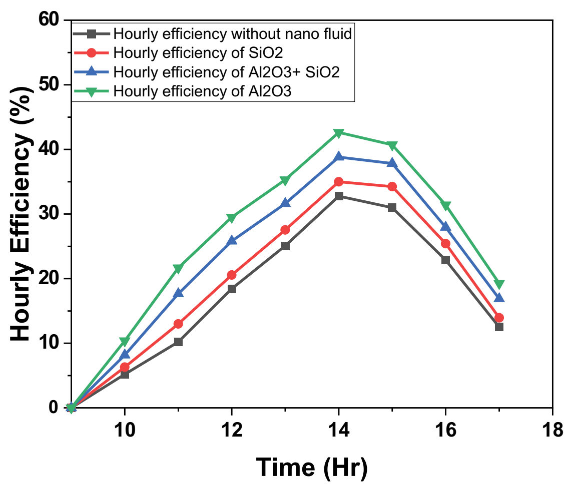

Fig. 6. Variation of different times on hourly efficiency with or without nanofluids.

3.2. Performance analysis of Day-2 at 1 cm water depth (winter)

3.2.1. Effect of solar radiation at different times

In this section, variation of solar radiation with time had been discussed. The solar radiation increased from 717 W/m^2 at 9:00 AM and it reached to maximum of 1,205 W/m^2 at 12:00 PM, after that solar radiation decreases to 650 at 17:00 PM shown in Fig. 7a.

3.2.2. Effect of wind velocity at different times

The wind velocity increased from 1.8 m/s at 9:00 AM and it reached the maximum 2.7 m/s at 14:00 PM, after that wind velocity decreased to 1.8 at 17:00 PM as shown in Fig. 7b.

3.2.3. Effect of basin temperatures with or without nanofluids at different times

In this section, variation of temperatures of basin and atmosphere with time had been discussed. The atmospheric temperature of increased from 27.5°C at 9:00 AM and it reached to maximum 36.3°C at 14:00 PM, after that atmospheric temperature decreased to 29.5°C at 17:00 PM. Basin temperature without nanofluid increased from 29.4°C at 9:00 AM and it reached the maximum 62.8°C at 14:00 PM, after that basin temperature decreased to 45.3°C at 17:00 PM.

The basin temperature of SiO_2 increases from 29.4°C at 9:00 AM and it reached the maximum 64.7°C at 14:00 PM, after that basin temperature decreased to 48.1°C at 17:00 PM. The basin temperature of Al_2O_3+SiO_2 increased from 29.4°C at 9:00 AM and it reached the maximum 67.4°C at 14:00 PM, after that basin temperature decreased to 50.8°C at 17:00 PM. The basin temperature of Al_2O_3 increased from 29.4°C at 9:00 AM and it reached to maximum 69.9°C at 14:00 PM, after that basin temperature decreased to 53.5°C at 17:00 PM as shown in Fig. 7c.

3.2.4. Effect of different times on hourly productivity with or without nanofluids

In this section, variation of hourly productivity with time with time have been discussed. The hourly productivity without nanofluid increased from 0 mL at 9:00 AM and it reached to maximum of 475 mL at 14:00 PM, after that hourly productivity decreased to 120 mL at 17:00 PM. The

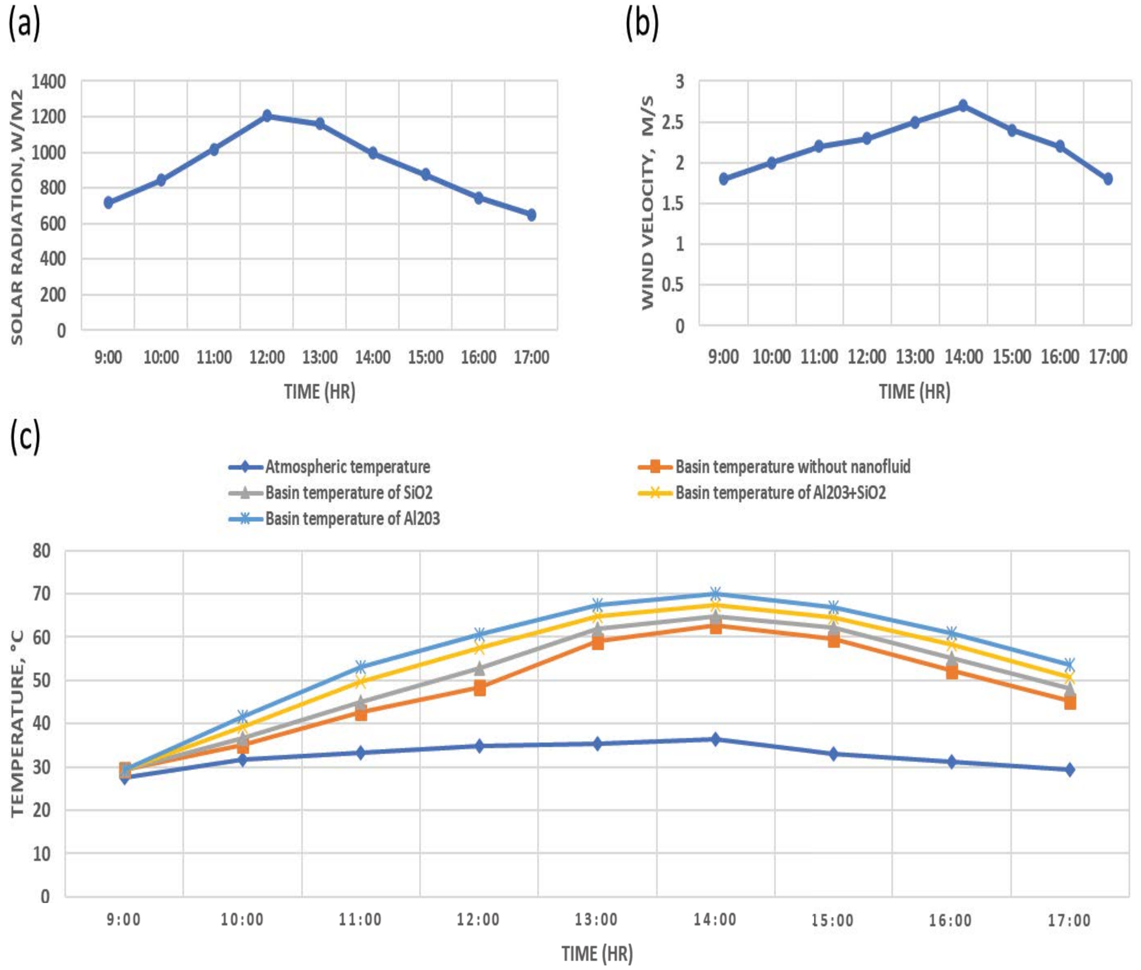

Fig. 7. (a) Variation of solar radiation at different times, (b) Variation of wind velocity at different times, and (c) Variation of basin temperatures with or without nanofluids at different times.

hourly productivity of SiO_2 increased from 0 mL at 9:00 AM and it reached the maximum of 5515 mL at 14:00 PM, after that hourly productivity decreased to 135 mL at 17:00 PM. The hourly productivity of Al_2O_3+SiO_2 increases from 0 mL at 9:00 AM and it reaches the maximum of 585 mL at 14:00 PM, after that hourly productivity decreases to 160.5 mL at 17:00 PM. The hourly productivity of Al_2O_3 increases from 0 mL at 9:00 AM and it reaches the maximum of 640 mL at 14:00 PM, after that hourly productivity decreased to 180.7 mL at 17:00 PM as shown in Fig. 8.

3.2.5. Effect of different times on accumulated productivity with or without nanofluids

In this section, variation of accumulated productivity with time have been discussed. The accumulated Productivity without nanofluid increased from 0 mL at 9:00 AM and it reached the maximum of 2212.6 mL at 17:00 PM. The accumulated productivity of SiO_2 increased from 0 mL at 9:00 AM and it reached the maximum of 2480.3 mL at 17:00 PM. The accumulated productivity of Al_2O_3+SiO_2 increased from 0 mL at 9:00 AM and it reaches the maximum of 2915.5 mL at 14:00 PM. The accumulated productivity of Al_2O_3 increased from 0 mL at 9:00 AM and it reaches the maximum of 3311.1 mL at 14:00 PM as shown in Fig. 9.

3.2.6. Effect of different times on hourly efficiency with or without nanofluids

In this section, variation of hourly efficiency with time have been discussed.

The hourly efficiency without nanofluid increased from 0% at 9:00 AM and it reached the maximum of 29.95% at 14:00 PM, after that hourly efficiency decreased to 11.57% at 17:00 PM. The hourly efficiency of SiO_2 increased from 0% at 9:00 AM and it reaches the maximum of 32.48% at 14:00 PM, after that hourly efficiency decreased to 13.02% at 17:00 PM. The hourly efficiency of Al_2O_3+SiO_2 increased from 0% at 9:00 AM and it reached to maximum of 36.89% at 14:00 PM, after that hourly efficiency decreased to 15.48% at 17:00 PM. The hourly efficiency of Al_2O_3 increased from 0% at 9:00 AM and it reached to a maximum of 40.36% at 14:00 PM, after that the hourly efficiency decreased to 17.42% at 17:00 PM as shown in Fig. 10.

3.3. Performance analysis of Day-3 at 1.5 cm water depth (winter)

3.3.1. Effect of solar radiation at different times

In this section variation of radiation at different times had been discussed.

The Solar radiation increased from 721 W/m^2 at 9:00 AM and it reached to maximum of 1195 W/m^2 at 12:00 PM, after that solar radiation decreased to 655 at 17:00 PM as shown in Fig. 11a.

3.3.2. Effect of wind velocity at different times

In this section, variation of wind velocity at different times had been discussed. The wind velocity increased

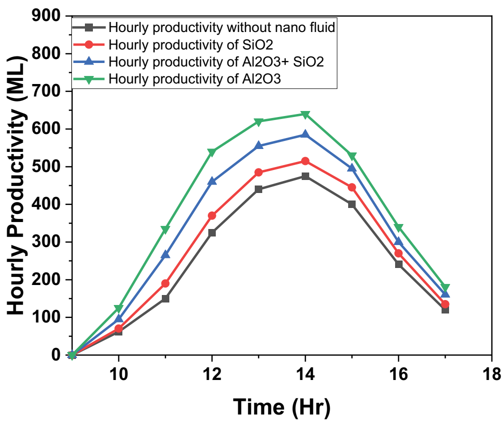

Fig. 8. Variation of different times on hourly productivity with or without nanofluid.

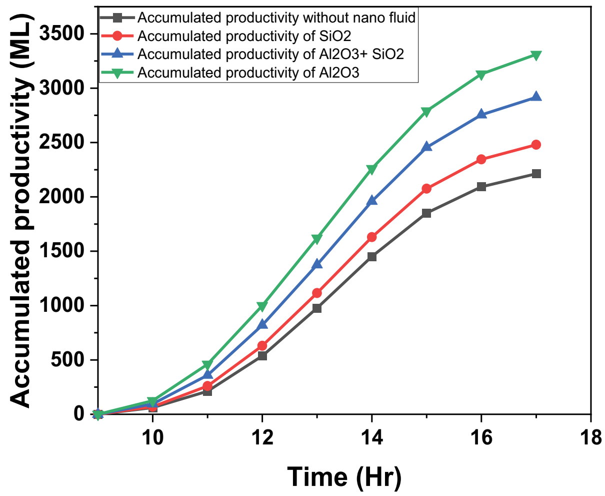

Fig. 9. Variation of different times on accumulated productivity with or without nanofluid.

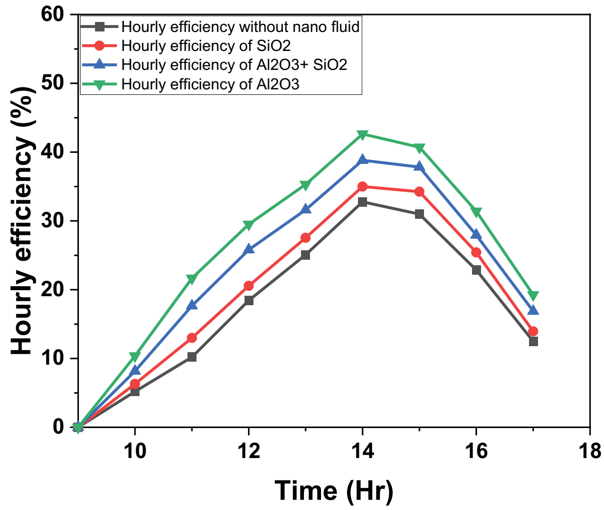

Fig. 10. Variation of different times on hourly efficiency with or without nanofluids.

from 1.5 m/s at 9:00 AM and it reached to maximum 2.8 m/s at 14:00 PM, after that the wind velocity decreased to 1.8 at 17:00 PM as shown in Fig. 11b.

3.3.3. Effect of basin temperatures with or without nanofluids at different times

In this section, variation of temperatures of basin and atmosphere with time had been discussed.

The atmospheric temperature of increased from 27.4°C at 9:00 AM and it reached the maximum of 37.1°C at 14:00 PM, after that the temperature decreased to 29.6°C at 17:00 PM. Basin temperature without nanofluid increased from 29.3°C at 9:00 AM and it reached the maximum of 60.2°C at 14:00 PM, after that basin temperature decreased to 44.1°C at 17:00 PM. The basin temperature of SiO_2 increased from 29.3°C at 9:00 AM and it reached the maximum 63°C at 14:00 PM, after that basin temperature decreased to 46.4°C at 17:00 PM. The basin temperature of Al_2O_3+SiO_2 increased from 29.3°C at 9:00 AM and it reached the maximum of 65.3°C at 14:00 PM, after that the basin temperature decreased to 49°C at 17:00 PM. The basin temperature of Al_2O_3 increased from 29.3 at 9:00 AM and it reached the maximum of 67.8°C at 14:00 PM, after that the basin temperature decreased to 51.3°C at 17:00 PM as shown in Fig. 11c.

3.3.4. Effect of different times on hourly productivity with or without nanofluids

In this section, variation of hourly productivity with time had been discussed. The hourly productivity without nanofluid increased from 0 mL at 9:00 AM and it reached the maximum of 445 mL at 14:00 PM, after that hourly productivity decreased to 105 mL at 17:00 PM. The hourly productivity of SiO_2 increased from 0 mL at 9:00 AM and it reached the maximum 490 mL at 14:00 PM, after that the hourly productivity decreased to 115 mL at 17:00 PM. The hourly productivity of Al_2O_3+SiO_2 increased from 0 mL at 9:00 AM and it reached the maximum of 550 mL at 14:00 PM, after that hourly productivity decreased to 150 mL at 17:00 PM.

The hourly productivity of Al_2O_3 increased from 0 mL at 9:00 AM and it reached the maximum of 600.5 mL at 14:00 PM, after that the hourly productivity decreased to 170 mL at 17:00 PM as shown in Fig. 12.

3.3.5. Effect of different times on accumulated productivity with or without nanofluids

In this section, variation of accumulated productivity with time had been discussed.

The accumulated productivity without nanofluid increased from 0 mL at 9:00 AM and it reaches the maximum

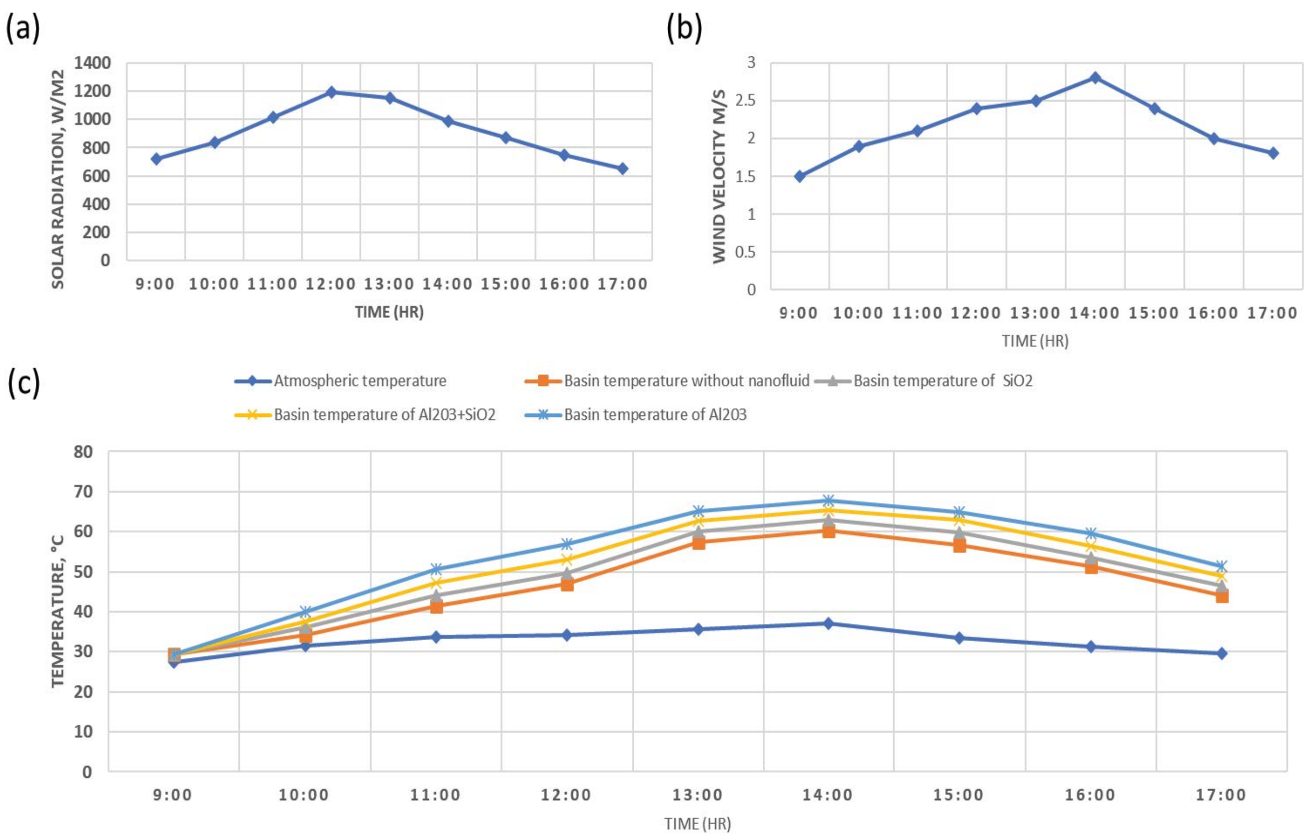

Fig. 11. (a) Variation of solar radiation at different times, (b) Variation of wind velocity at different times, and (c) Variation of different basin temperatures with or without nanofluid at different times.

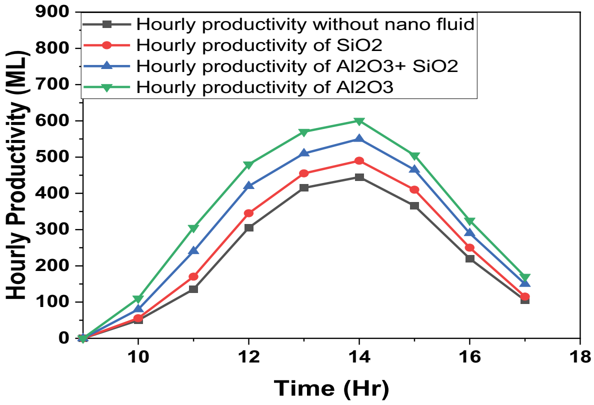

Fig. 12. Variation of different times on hourly productivity with or without nanofluids.

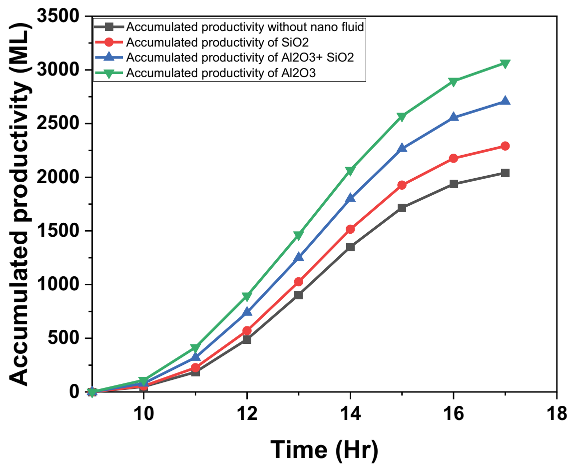

Fig. 13. Variation of different times on accumulated productivity with or without nanofluids.

of 2041.3 mL at 17:00 PM. The accumulated productivity of SiO_2 increased from 0 mL at 9:00 AM and it reached the maximum of 2,290.8 mL at 17:00 PM. The accumulated productivity of Al_2O_3+SiO_2 increased from 0 mL at 9:00 AM and it reached the maximum of 2705.5 mL at 17:00 PM. The accumulated productivity of Al_2O_3 increased from 0 mL at 9:00 AM and it reached the maximum of 3,065.5 mL at 17:00 PM as shown in Fig. 13.

3.3.6. Effect of different times on hourly efficiency with or without nanofluids

In this section, variation of hourly efficiency with time had been discussed. The hourly efficiency without nanofluid increased from 0% at 9:00 AM and it reached the maximum 28.18% at 14:00 PM, after that the hourly efficiency decreased to 10.05% at 17:00 PM. The hourly efficiency of SiO_2 increased from 0% at 9:00 AM and it reached the maximum 31.03% at 14:00 PM, after that hourly efficiency decreased to 11% at 17:00 PM. The hourly efficiency of Al_2O_3+SiO_2 increased from 0% at 9:00 AM and it reached the maximum of 34.83% at 14:00 PM, after that the hourly efficiency decreased to 14.35% at 17:00 PM. The hourly

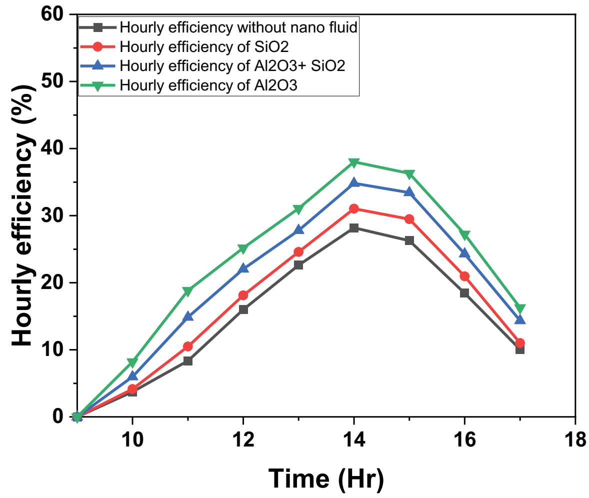

Fig. 14. Variation of different times on hourly efficiency with or without nanofluid.

efficiency of Al_2O_3 increased from 0% at 9:00 AM and it reached the maximum of 38.02% at 14:00 PM, after that the hourly efficiency decreased to 16.27% at 17:00 PM as shown in Fig. 14.

4. Conclusions

- The maximum temperature of the basin was observed to be 71.7°C when using Al_2O_3 nanofluids and that of using without nanofluids basin was 65.8°C at 14:00 PM. The higher temperature in using Al_2O_3 gives higher productivity.
- The maximum hourly productivity was observed to be 515, 550, 610, and 670 mL for without nanofluids, SiO_2 Nanofluids, a blend of SiO_2+Al_2O_3 nanofluids, and Al_2O_3 nanofluids, respectively at 14:00 PM.
- The highest observed cumulative productivity was 2,390.6; 2,680.9; 3,105.8 and 3,506.4 mL for without nanofluids, SiO_2 Nanofluids, a blend of SiO_2+Al_2O_3 nanofluids and Al_2O_3 nanofluids, respectively till the end of the experiment at 17:00 PM, that is, for 8 h.
- The use of nanofluids for maximum condensation rate, maintained a higher temperature differential within the chamber, accelerated heat transmission, and cut down on water's preheating time.
- The maximum efficiency of 20.63% was found for using without nanofluids. In comparison, the maximum efficiencies of 23.14%, 26.81%, and 30.27% were obtained when using SiO_2, a blend of SiO_2+Al_2O_3 and Al_2O_3 nanofluids, respectively at 0.5 cm of water depth.
- The primary characteristic of nanofluids in the performance of the still was its greater ability to absorb solar energy than water.
- To summarize the sole objective of the paper is in making a sincere effort to contribute its mettle in providing drinkable water for the habitat in distressed geographical areas as also make pathways for environment friendly outcomes conversing towards the net zero carbon emission approach at global label which would be a paradigm shift for humankind.

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