AIP Conference Proceedings

RESEARCH ARTICLE | MAY 08 2023

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AIP Conference Proceedings 2706, 020077 (2023)
https://doi.org/10.1063/5.0120650

Effect of Nanocarbon on Performance Tilted Type Solar Energy Water Distillation

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Abstract. The need for clean water increases with population growth. The current condition of water is contaminated with certain substances that can endanger health when consumed. One way to overcome this problem is to treat contaminated water using solar water distillation. The advantages of using solar energy water distillation are the ease of application and environmental friendliness. The type of solar water distillation that is often used is the tilted type. The purpose of this study was to analyze the effect of nanocarbon on the performance of solar water distillation. This research was conducted in a laboratory using heating lamps to simulate solar energy with an absorber area of 0.43 m2. The types of nanocarbon used are coconut and bamboo nanocarbon. Temperature and distilled water results sensors are controlled and recorded using an Arduino microcontroller. The results were compared with the tilted type of solar energy water distillation without the addition of nanocarbon. The results of the research conducted, it shows that the type and concentration of nanocarbon affect the results of the distilled water produced. In the variation of coconut nanocarbon 1.5 grams produces clean distilled water of 0.59 liter/(m^2.hour) and the best result are found in the variation bamboo nanocarbon 1.5 grams produces clean distilled water of 0.66 liter/(m^2.hour).

INTRODUCTION

Global warming has increased the problem of water scarcity on earth; this water scarcity problem will continue as the population increases. Despite the enormous amount of water in the oceans, which cover three-quarters of the earth's surface, seawater accounts for 97% of the total water on earth as a whole, and the remaining 3% is divided into groundwater, ice, rivers, and lakes [1]. Of this water availability, only 1% of the total water on the planet is freshwater available for human consumption [2]. Water is a valuable natural resource for the survival of creatures on the earth's surface. Therefore, he quality and quantity of water available on the earth's surface are very considered for health. The availability of clean water in the world decreases in quantity and quality due to increasing population and poor water management.

The Indonesian government has set clean water standards in the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 concerning environmental health quality standards and water health requirements for sanitation hygiene, swimming pools, per aqua solutions, and public baths. According to the National Development Planning Agency (Bappenas) report, the availability of safe water for consumption in most areas of Java and Bali is currently classified as scarce to critical. Meanwhile, water availability in South Sumatra, West Nusa Tenggara, and South Sulawesi is projected to be scarce or critical in 2045. Urban communities are highly dependent on Municipal Waterworks (PDAM). Quality is not necessarily good for health because the water in urban areas is contaminated by substance pollution with chemicals, bacteria, and others. The efficient and easy way to manage contaminated water is by purifying water using a solar energy water distillation device.

3rd Borobudur International Symposium on Science and Technology 2021
AIP Conf. Proc. 2706, 020077-1–020077-6; https://doi.org/10.1063/5.0120650
Published by AIP Publishing. 978-0-7354-4447-8/$30.00

The principle of water purification is removing chemical substances or contaminants from water. The use of water distillation is to get clean water from dirty water by distillation. Solar still can be a solution for areas that lack clean water suitable for consumption. Water distillation equipment uses solar energy, which operates on the principles of evaporation and condensation. The advantages of using a solar distillation apparatus compared to other distillation systems are very significant. Solar distillation equipment has no moving parts, which requires maintenance and rugged construction [3]. Solar water distillation has an important component, namely an absorber and a cover glass. The function of the absorber is to absorb heat from the sun to evaporate the water to separate it from contaminating substances. The cover glass on the distillation apparatus functions as a medium for condensing water vapor produced by the evaporation process on the absorber, the water vapor produced is pure water and can be consumed directly.

The level of efficiency and the amount of water produced in a solar water distillation device can be influenced by various factors, including the effectiveness of the absorber in absorbing solar energy, the effectiveness of the cover glass in condensing water, the water level in the distillation tank, the amount of incoming solar energy and the temperature of the water entering the distillation apparatus [4]. Nanoparticles have several advantages, such as a large surface area to volume ratio, dimension-dependent physical properties, and lower kinetic energy. The nanoparticles are better and more stable dispersed in the essential liquid [5].

This research uses coconut and bamboo nano carbon concentration to improve the convective and conductive heat transfer characteristics. The carbon nanomaterial used has the property of storing heat so that the temperature on the absorber plate increases. The mass of water heated on the tissue layer on the surface of the absorber is expected to evaporate faster because of the influence of the high temperature of the absorber with the addition of nanocarbon. The speed of heating the water mass is expected to increase the evaporation process so that the water productivity in the distillation device becomes effective.

METHOD

Experimental apparatus

The solar energy water distillation apparatus has main components, namely the absorber and the glass cover. Absorber components are generally coated with black paint, which increases the absorption of solar radiation energy. The function of the cover glass in the solar energy water distillation apparatus is as a medium for condensing water vapor. The temperature of the cover glass, which is lower than the temperature inside the distillation apparatus, can also help the process of vapor condensation. The supporting parts of the solar energy water distillation apparatus are the components of the channel pipe for the media to exit the distilled water, the frame, the peristaltic pump, the dirty water reservoir, and the container for the distilled water.

This study, using a solar energy water distillation device with a tissue absorber tilted type (Figure 1). The absorber is made of multiplex material measuring 75 cm x 58 cm with a thickness of 6 cm, and the thickness of the absorber wall is 3 cm. The absorber's surface in black paint maximizes the absorption of solar energy and is lined with bamboo tissue as a water storage medium. The outer wall of the absorber is coated with a sealant to anticipate leakage and maintain the temperature of the absorber. The absorber was covered with a transparent cover glass with a thickness of 3 mm, and the absorber was installed at an inclination of 15° with a distance between the surface of the absorber and the cover glass of 6 mm.

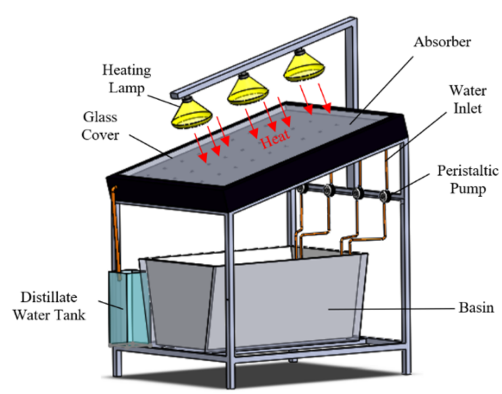


FIGURE 1. The schematic of tilted type solar energy water distillation.

The oblique type of solar energy water distillation device utilizes solar heat energy, and the incoming heat energy will be absorbed by the absorber, which is mounted obliquely and given a thin cloth on the surface of the absorber to heat the water to be distilled and cause the water to evaporate more optimally. The steam produced by heating the water in the absorber is pure water vapor, while the contaminants in the water are left in the cloth absorber. This process causes water vapor to rise to the top and come into contact with the glass, which has a lower temperature than the absorber component and causes condensation causing dew droplets to form. The glass cover component of the distillation apparatus is mounted at an angle so that the water droplets produced will fall to the gutter and then flow into the distillation reservoir. Water that has not had time to evaporate will flow through the exit pipe to the dirty water reservoir. In this study, the oblique type of solar energy water distillation apparatus was varied with the addition of the inlet below (Figure 2b). In the absorber, some holes serve as a wick. At the bottom of the absorber, there are four water inlets with a distance between channels of 15 cm and there are some parameters in solar energy water distillation used in this study (Table 1).

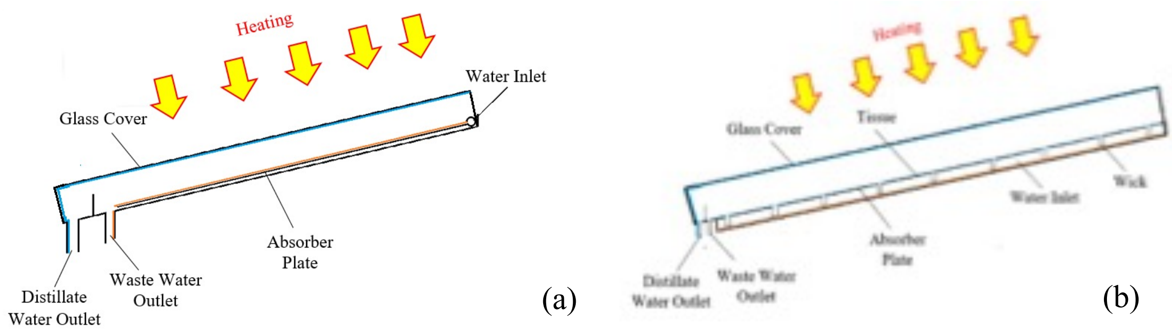


FIGURE 2. Variations of the absorber of tilted type solar energy distillation apparatus: (a) Conventional type; (b) Types of inlet variations below

TABLE 1. Design Parameters for the absorber solar still setup

Parameters		Dimension
Length of absorber	:	750 mm
Width of absorber	:	580 mm
Height of absorber	:	60 mm
Inclination angles	:	15°
Length of the glass cover	:	840 mm
Width of the glass cover	:	640 mm
The thickness of the glass cover	:	3 mm

Data Retrieval System

Before retrieving the data, the sensor is checked and monitored with the Arduinno Microcontroller. Data were taken on the study included:

1. Cover glass temperature, T_c (°C)
2. Absorber temperature, T_a (°C)
3. Volume of distillation water, m (liter)
4. Length of data retrieval time, t (seconds)
5. Amount of light energy coming, G (watt/m^2)

Data Analysis

Performance efficiency on solar energy water distillation equipment can be interpreted as comparing the amount of energy used in the water evaporation process with the amount of solar energy that comes during the heating time [6]. The energy used to carry out the process of evaporation of water on the absorber component is quap, while the energy that produces losses in the distillation apparatus is qkonv and qrad. The losses in question are the energy that moves from the water that is accommodated in the absorber component to the inner glass surface by convection or radiation. The distillation efficiency can be formulated as follows:

$$\eta = \frac{m\, h_{fg}}{A_C . \int_0^t G\, dt} \qquad (1)$$

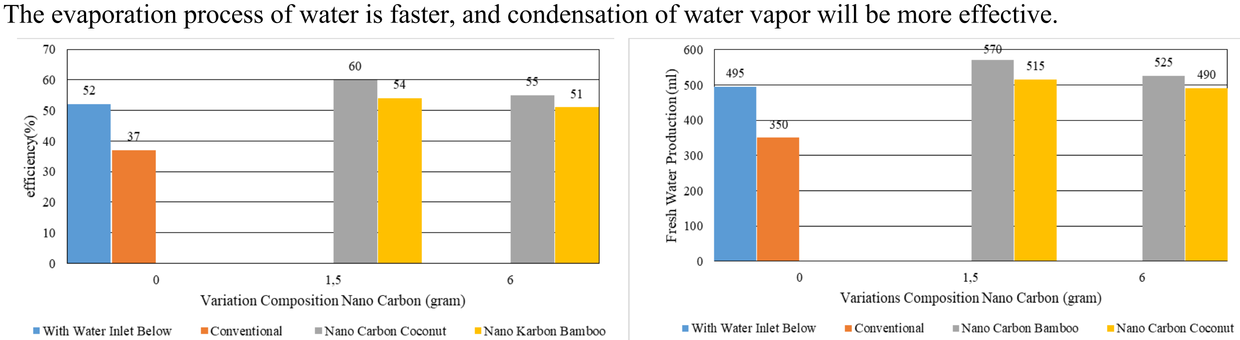
η is efficiency (%), m is the result of water from the distillation process (kg), h_{fg} is the heat of vaporization of water (kJ/kg), Ac is the area of absorber (m^2), G is the heating lamp emitted (W/m^2), and dt is the heating time (seconds).

RESULT AND DISCUSSION

Operation Data

The experiment was carried out at the Mechanical Engineering Laboratory, Sanata Dharma University, Yogyakarta, using infrared lamps as a solar energy simulator with an absorber area of 0.43 m^2. The absorber temperature, glass temperature, tub water temperature, wastewater temperature, light energy intensity, and the amount of distilled water produced were monitored and recorded during the experiment by the Arduino microcontroller system. The main objective of this experiment is to compare the performance of a conventional distillation apparatus with a downward-flow inclined type distillation apparatus using variations in the addition of coconut charcoal and bamboo charcoal nanocarbon concentrations in terms of efficiency, distilled water productivity, absorber temperature, and glass temperature. The results of this study are presented using a graph, and the system performance (efficiency) is compared to the productivity of the distilled water produced.

Figure 3 (a). Shows the comparison of the efficiency of the distillation apparatus at various concentrations of nanocarbon. The graph shows the efficiency in the variation of the 1.5 gram nanocarbon concentration of 60% on bamboo charcoal and 54% on coconut charcoal or 15% and 4% higher than the variation efficiency without nanocarbon. The 6 gram nano carbon concentration variation is 55% in bamboo charcoal or 6% higher than the variation without nanocarbon. The efficiency of the variation of the nanocarbon concentration of 6 grams of coconut charcoal is 2% lower than the efficiency of the variation without nanocarbon, and this is because, at the time of data collection, the upper tissue layer was dry due to an ineffective water capillary process so that the evaporation process of water was not optimal. The lowest efficiency of 37% was obtained by conventional distillation apparatus. The results of the efficiency of the distillation apparatus are proportional to the productivity of the distilled water produced. The addition of nanocarbon to the absorber shows an increase in efficiency because nanocarbon is a heat storage material. Increasing the temperature of the absorber component can accelerate the evaporation rate of water in the tissue layer so that the water condensation process is more effective. Figure 3 (b) compares the productivity of distilled water with variations in the addition of nanocarbon concentrations. The highest productivity of distilled water was on the variation of nanocarbon of bamboo charcoal of 570 ml and variation of nanocarbon of coconut charcoal of 525 ml. The lowest productivity of distilled water is 350 ml in a conventional distillation apparatus. The high productivity of distilled water produced is due to less water in the absorber tissue layer and nanocarbon in the absorber tissue layer. The evaporation process of water is faster, and condensation of water vapor will be more effective.



(a) (b)

FIGURE 3. (a) Efficiency of solar still at variations in nanocarbon concentrations. (b) Distillation results at variations in nanocarbon concentrations.

Figure 4. Shows the comparison of the temperature difference (ΔT) with time. The graph shows that each time increment (ΔT) continues to increase. This increase in temperature difference is based on the radiation energy absorbed by the absorber and glass every time (minutes). At the 10th minute, all data were in adverse T condition because the absorber temperature (Ta) was still below the glass temperature (Tc). From the 20th minute to the 40th minute, the variation of 1.5 gram bamboo charcoal experienced a faster temperature increase which was shown by a curved graph upwards. This temperature increase was the effect of the addition of nanocarbon bamboo charcoal which could absorb heat better. Up to minute-120, the increase (ΔT) in the variation of 1.5 gram bamboo charcoal continued to increase and outperformed other variations with a final result of 8.62°C. While the variation data without adding nanocarbon at 10 to 20 minutes experienced a delay in increasing (ΔT), this was due to the absorber not absorbing heat energy optimally increasing constantly and was the lowest (ΔT) result. The magnitude of the temperature difference (ΔT) affects the productivity of distilled water. When (ΔT) is higher, the water vapor will quickly release energy into the glass. So that water vapor will be easier to condense on the inside of the glass, and the productivity of the resulting distilled water is more outstanding. This temperature difference (ΔT) is a requirement for forming the condensation process and the formation of water droplets on the inner glass surface. From the 20th minute to the 120th minute, the variation data without the addition of nanocarbon showed (ΔT)

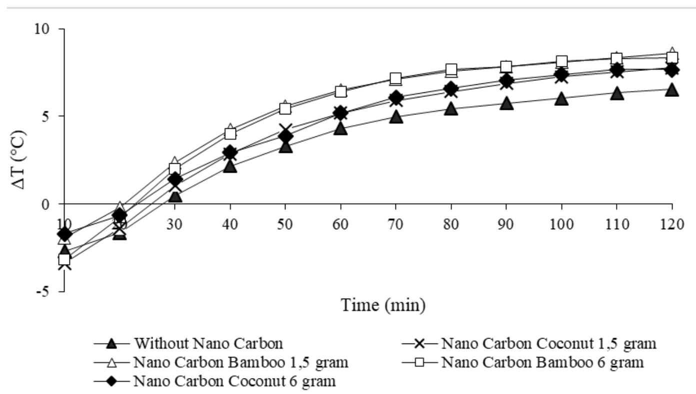


FIGURE 4. Temperature difference (ΔT) in variations in nanocarbon concentrations.

CONCLUSION

Based on the results of research that has been carried out regarding the effect of adding nano carbon concentration on the performance of the tilted type solar energy distillation apparatus, the following conclusions are obtained:

- The addition of nanocarbon on the absorber tissue layer affects the productivity of distilled water in the distillation apparatus. With the addition of nanocarbon, the absorber can absorb heat energy more optimally so that the evaporation process of water mass is faster than without the addition of nanocarbon.
- By applying the addition of nanocarbon concentration to the performance of the tilted type of solar energy distillation apparatus with variations in the inlet below, significantly affects the productivity of distilled water. The best research results on variations in nanocarbon concentration of bamboo charcoal 6 grams with a distillation result of 0.66 liter/(m^2**.**hour) with a distillation efficiency of 60%.

ACKNOWLEDGMENTS

The authors thank to the Directorate General of Higher Education for the financial support in the form of Sanata Dharma University year 2021-2022.

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