

RESEARCH PAPER

Improving the Thermal Performance of Solar Still Using Nanomaterials and Sprinklers

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ABSTRACT

This article investigate effect the adding three types of nanomaterials (titanium oxide, copper oxide and Nano aluminum oxide) at three concentrations (0.01, 0.05, 0.09) on the thermal performance of solar still, as these materials improve the evaporation rate. There are added to three stills designed with same dimensions and the measurements were recorded at the same time as well as to conventional solar without Nano material to compare the results. At the same time, we used sprinklers to cool of outer surface of glass and thus improve condensation rate. They work when of temperature difference between the inner and outer surfaces of glass is 3 degrees Celsius. They operate on the Arduino device and derive energy from a solar cell. The results showed that amount of potable water from solar stills enhanced with nanomaterials and sprinklers is much higher than the amount of water produced from the still from the traditional solar still.

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INTRODUCTION

Solar stills are one of most successful ways to solve the problem fresh water in remote and isolated areas, as they depend on sustainable source of energy and are cheap to manufacture. However, the low productivity and low efficiency prompted researchers to use multiple methods to improve their efficiency and increase the amount of fresh water produced. Especially since there are areas of world that experience hot weather, a severe shortage of fresh water, and high solar radiation intensity such as Saudi Arabia, South Africa, and southern Iraq [1]. However, despite the advantages of solar stills, which are low cost, easy to manufacture, and sustainable source, their production of distilled water is low. Therefore,

many studies have been conducted to improve production the solar distilled water. A study presented by Madhu et.al 2017, the evaporation rate of solar still was improved using three nanoparticles (CuO , Al_2O_3 , TiO_2) materials with concentrations ranging from 0.2-0.05. The highest productivity was achieved 4.3L [2]. Researcher Rashidi et.al (2018) presented an experimental study in which water was mixed with Nano-aluminum oxide, and results showed that the improvement rate increased by 25% [3]. In study presented by researcher Bataineh, 2020[4], in which he improved the evaporation rate using Al_2O_3 and Nano SiO_2 at depth of 0.5 cm, the improvement rate was 10% using Al_2O_3 and

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8.5% by using SiO₂. The researcher Panchal et al, conducted an experimental study to study the effect of nanomaterials on improving thermal performance of solar still, used Nano manganese oxide (MnO₂) at two different concentrations, 2% and 4.5%, after mixing it with black paint to form nano coating for coating walls of tank made of stainless steel. The improvement rate was 19.5%, [5]. An experimental and numerical analysis for researcher MahianO et.al was conducted to study the efficiency of solar distillation device using solar collectors connected in series and connected to solar distillation device, which in turn is equipped with heat exchanger. After the Nano fluid exits the

solar collectors, it enters the heat exchanger inside the solar distillation basin [6].

Researcher Shehata et al. also presented an experimental study that improved the production rate of solar still using reflectors and ultrasonic vibrations, with a study of the effect of water depth. Productivity increased by 25% at a height of 35 cm and 44% at height of 25 cm [7]. The rate of evaporation and condensation is not the only factor that affects the production of a solar still, although they are main factors, but there are other factors such as water depth. Studies have confirmed that water depth is inversely proportional to productivity, and that the best

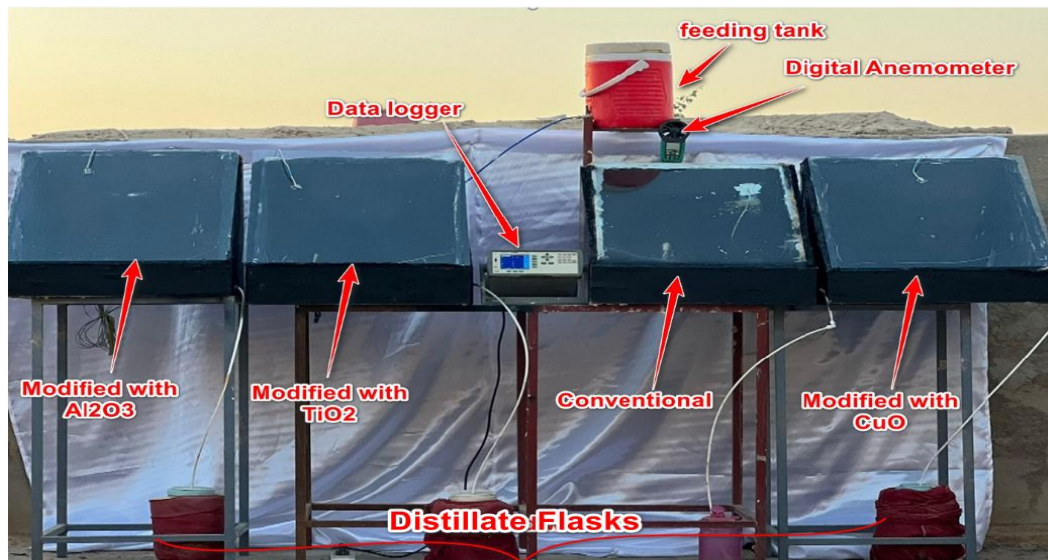


Fig. 1. Experimental setup of the conventional and the modify solar still.

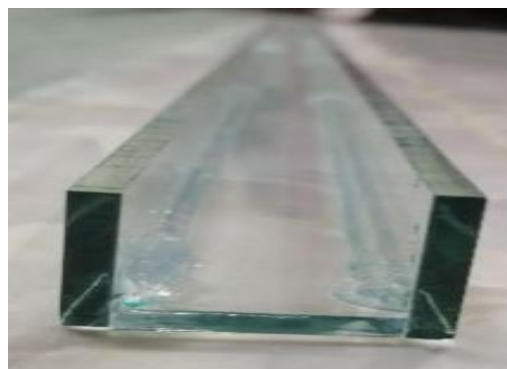


Fig. 2. Distillate water channel.

productivity is achieved at depth of 1cm and angle of inclination of 20 degrees. [8,9]. thermal insulator also has significant effect on the production rate of the solar still, as increasing the insulating efficiency increases the amount of fresh water [10]. From previous studies, we note that improving the production rate of solar still depends on improving the evaporation rate, the condensation rate, or

both. In this study, we improved the production rate to improve the evaporation rate using three types of nanomaterials: CuO, TiO₂, Al₂O₃, and each material at three different concentrations: 1%, 5%, and 9%, to know effect of the concentration of nanomaterial on productivity. At of same time, we achieved thermal balance inside the still, where the evaporation rate was improved by



Fig. 3. Water sprinklers (a) and its motors (b).

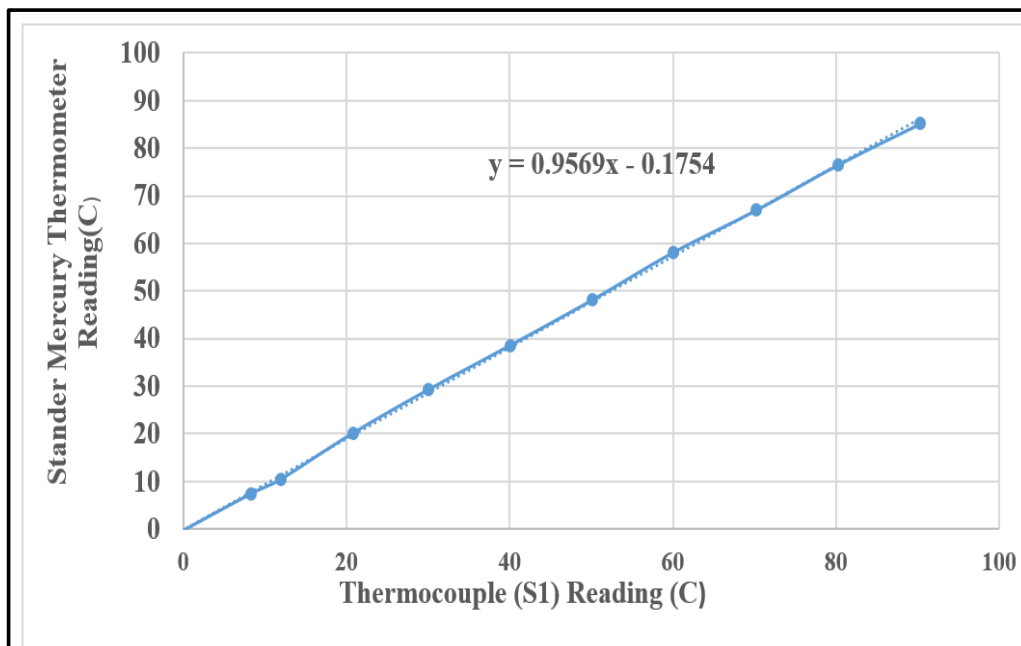


Fig. 4. Calibration of thermocouple.

the nuclear materials, and the condensation rate was improved by using sprinklers that cooled the outer glass surface. These sprinklers work with the Arduino system, as detailed later.

MATERIALS AND METHODS

As shown in Fig. 1, four solar stills were manufactured, one the which was a conventional one without any improvements and was used for comparison. Three stills had their inner surfaces coated with Nano coatings at three different concentrations, which are 1%, 5%, and 9%, for three types of nanomaterials, (CuO, AL₂O₃, TiO₂) respectively.

The system was installed in city of Najaf from 8:00 am to 12:00 am. The three solar stills were made with equal areas and the same materials, as area of each one was only 50 cm square. The inner basin was made of high-quality aluminum, which is available in local markets. It was placed inside a wooden frame and space was filled with

foam to increase thermal insulation and achieve the highest possible level of global warming inside the basin. Arrange the glass cover above the solar still. The glass, which is angled at 32 degrees according to the latitude and attitude of Najaf, has an average transmissivity of 0.88. In order to secure the glass onto the solar still and avoid vapour leakage, clamps and silicon were also used. as seen in Fig. 2, and a glass distillation tube is located underneath the lid.

To achieve a balance between improving condensation and evaporation, sprinklers were placed on top of still that operate on Arduino system as shown in Fig. 3. These sprinklers operate whenever of temperature difference between the inner glass and the outer glass is 3 °C.

Error analysis

The efficiency the system is dependent on plenty of experimentally observed characteristics. The factors used to measure the efficiency of stills

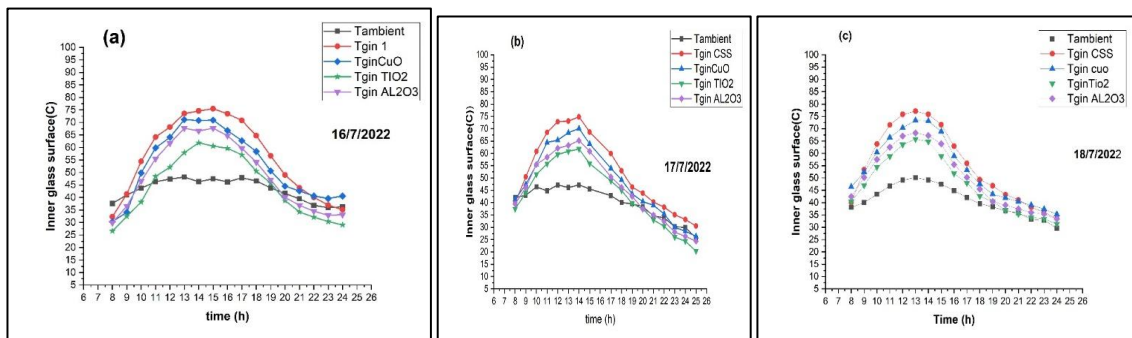


Fig. 5. Inner glass temperatures distribution for CSS and MSS with Water sprinklers and (CuO, TiO₂ and AL₂O₃) nanomaterials at concentration (a) 1%, (b) 5%, (c) 9%.

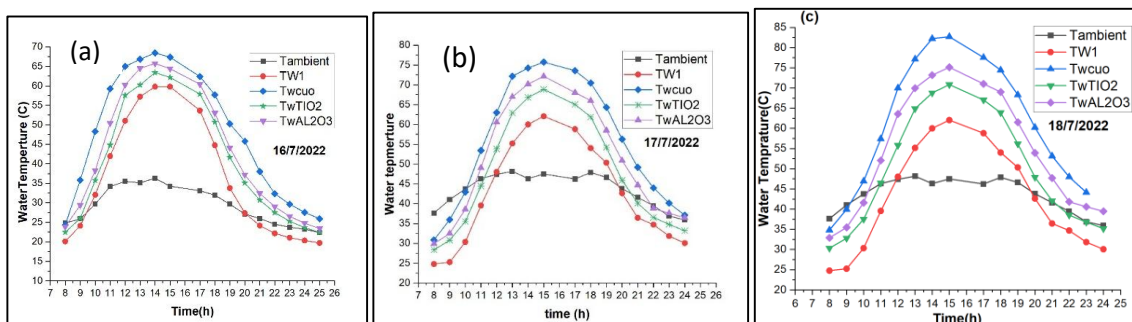


Fig. 6. Water temperatures distribution for CSS and MSS with Water sprinklers and (CuO, TiO₂ and AL₂O₃) nanomaterials at concentration (a) 1%, (b) 5%, (c) 9%.

include brine, glass cover, ambient temperatures, wind speed, total incident sun irradiation, and freshwater quantity. With a precision of ± 0.5 K, all temperatures were recorded using calibrated K-type thermocouples (Fig. 4).

RESULTS AND DISCUSSION

Nanomaterials enhance the absorption of solar radiation by water, thus increasing the water temperature, which means improving the evaporation rate. Recent years have seen an increase in the viability of nano-particles. Improving

efficiency may be achieved by minimising losses via the use of appropriate insulation and coating [11], [12].

We notice from the Figs. 5 and 6 that there is a clear drop in the internal glass temperatures of the solar stills improved by using sprinklers. We note that the internal glass temperature of the conventional solar stills is higher than the internal glass temperatures of the modified solar stills with which we used water sprinklers. This indicates that the rate of condensation in the solar distillers improved with water sprinklers is better than

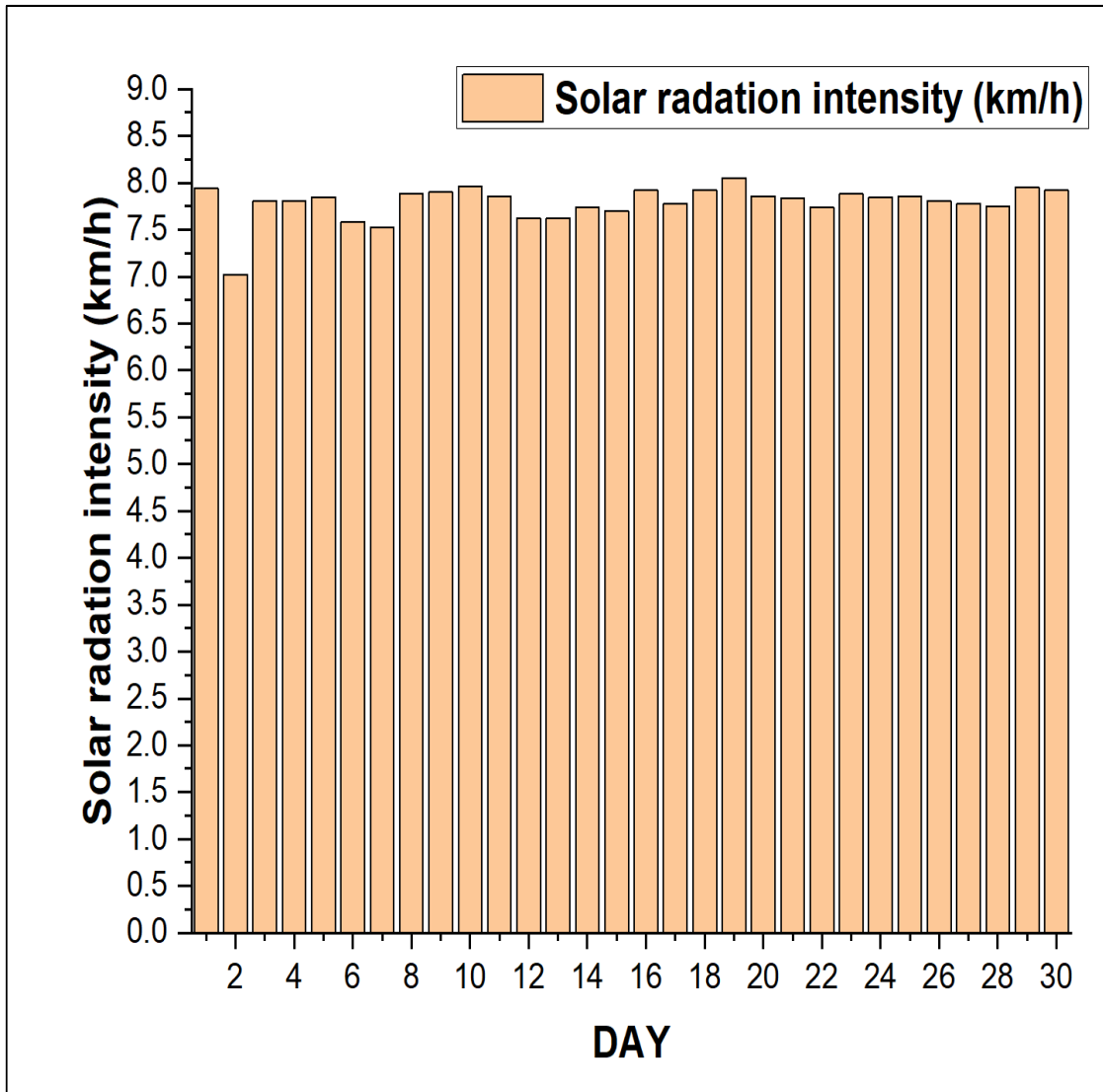


Fig. 7. Solar radiation intensity at July in Najaf city.

the rate of condensation in the traditional solar distillers.

At the same time, we improved the rate of condensation using water sprinklers, we used nanomaterials to improve the rate of evaporation by three different materials, each material with three different concentrations, as showed Figs. 3 and 4 the water temperature of solar still with contain nano material great than water temperature of conventional solar still Although cooled the outer surface of the glass is by water sprinklers, As shown in the figure, the nano-copper oxide achieved the highest water temperature due to the high conductivity of copper [13], Aluminum also achieved higher results than nanoscale titanium oxide, because the heat capacity of aluminum is higher than titanium [14], which helps keep the basin water high as long time as possible.

Also, adjusting the work of the sprinklers that cool of outer surface of glass using the Arduino device helps maintain high temperatures inside the solar distiller. Improving the rate of condensation and evaporation at the same time maintains temperatures balance inside the solar still. Solar radiation values are likely based on NASA's website for the days the system is operating [15]. As shown in Fig. 7.

CONCLUSION

This study experimentally investigated the enhancement of solar still productivity through the combined use of nanomaterial coatings and an automated glasscooling system. Three types of nanomaterials (CuO, Al₂O₃, and TiO₂) were applied at different concentrations (1%, 5%, and 9%) to improve the evaporation process, while an Arduinocontrolled sprinkler system was implemented to enhance condensation by cooling the outer surface of the glass cover. The experimental results demonstrated that integrating nanomaterials with controlled cooling significantly improves the thermal performance of solar stills. Nanoparticles increased the absorption of solar radiation within the basin, which raised the water temperature and consequently enhanced the evaporation rate compared with the conventional solar still. Among the tested materials, CuO exhibited the highest water temperatures due to its superior thermal conductivity, followed by Al₂O₃ and TiO₂. At the same time, the sprinkler system effectively reduced the glass surface temperature,

creating a greater temperature difference between the basin water and the condensing surface. This temperature gradient improved the condensation rate and contributed to higher freshwater yield. The Arduinobased control ensured that cooling occurred only when the temperature difference reached a defined threshold, helping maintain thermal balance inside the still and preventing excessive heat loss. Overall, the combined approach of nanomaterial enhancement and controlled glass cooling proved to be an effective method for improving both evaporation and condensation processes simultaneously. The results indicate that such hybrid modifications can significantly enhance solar still efficiency and productivity, making solar desalination more practical for regions suffering from water scarcity and high solar radiation, such as southern Iraq and other arid areas. Future studies may focus on optimizing nanoparticle concentration, longterm stability of nanocoatings, and scaling the system for larger desalination applications.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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