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Article

Enrichment of the Usage of Solar Purification of Water by Employing Hybrid Nanofluid Mixtures

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Abstract: In terms of human needs, water has traditionally been regarded as the most significant bioresource. However, there are still limitations on the quality and mobility of drinking water. Renewable energy technologies are at the forefront of research to bridge the gap between conventional fuels and renewable energy systems. Currently, the main objective is to speed up the solar water disinfection process of contaminated water when hybrid nanofluid mixtures are added. Five hybrid nanofluid mixtures containing different amounts of aluminum oxide (Al_2O_3) and Titanium oxide (TiO_2) nanoparticles were used in this study, focusing on how they affected the solar disinfection of polluted water. Five hybrid nanofluid mixtures of different volumes and volume concentrations were used for this purpose; each one was introduced into a contaminated water-contained glass container with a volume of 500 mL. Additionally, a sixth container, used exclusively for comparison, was filled with tainted water. All containers were installed next to each other and exposed to solar radiation for simultaneous measures under identical metrological conditions. During the experimental time, and after exposure to sun radiation for one, two, and three hours, samples were taken from each bottle. to gauge the toll of Total coliforms and E. coli by using the IDEXX setup. It was found that adding a hybrid nanofluid mixture of any composition speeds up the disinfection process. Additionally, it was found that the optimal concentration of the hybrid nanofluid mixture to cut down the Total Coliform was with a volume concentration of 250 mL of Al_2O_3 and 250 mL of TiO_2, while that to cut down the E. coli count was 400 mL of Al_2O_3 and 100 mL of TiO_2. Finally, it may be concluded that among all hybrid mixtures used, the hybrid nanofluid with a volume concentration of 250 mL of Al_2O_3 and 250 mL of TiO_2 is the most efficient in the solar water disinfection process.

Keywords: solar energy; water; solar disinfection; nanotechnology; contaminated water; hybrid nanofluids

Citation: Darabee, S.; Hamdan, M.; Daghari, H.; Ajib, S. Enrichment of the Usage of Solar Purification of Water by Employing Hybrid Nanofluid Mixtures. *Energies* **2022**, *15*, 5983. https://doi.org/10.3390/en15165983

Academic Editor: Simon Elias Bibri

Received: 20 July 2022
Accepted: 17 August 2022
Published: 18 August 2022

1. Introduction

The strain to offer more high-quality water to suit the demands of an ever-increasing population has intensified due to humanity's fast population growth. As a result, there is a need to find a long-term solution that would address all of the issues of removing the high levels of toxins in the water.

Chlorine is widely touted as a low-cost disinfectant, although it has been discovered to have limited value due to the alteration of water's flavor. Furthermore, improper use of chlorine compounds poses a safety risk. To avoid flavor concerns, excess chlorine must be removed. One of chlorine's drawbacks is its capacity to react with natural organic components, resulting in the formation of other halogenated compounds.

Many technologies have been developed to divert other unserviceable water into freshwater [1–3]. However, different solar water purification techniques have been proposed to construct ozone-based solar water treatment plants for Poland's geographic characteristics [4]. A solar-powered water disinfection system is an inexpensive way to develop the trait of potable water by utilizing sunlight to neutralize the influence of bacteria that cause bowel looseness. This method uses sun radiation to destroy harmful microbes, improving the quality of drinking water in the process. Disease-causing microorganisms are exposed to two aspects of sunlight: UV-B radiation and temperature [5].

Fatima et al. [6] designed and tested a drinkable, low-cost, low-maintenance solar-powered machine for disinfecting drinking water. Water from wells has been used to test the sun sterilization machine. Escherichia coli, Salmonella, and Shigella germs were fully eradicated from the water sample after a 10-min batch run. The results showed that the cleaning process in subterranean wells took only 8 min and met the World Health Organization's drinking water criteria.

Contaminated Water may be disinfected by ultraviolet (UV) portion in the solar spectrum. The incident UV together with some species such as Hydrogen peroxide (H_2O_2) or nanoparticles will produce hydroxyl radicals, which attack and kill the organic cells in the water. In this proposed research work, hybrid mixtures of nanofluids will be introduced into the contaminated water-contained containers, which will be exposed to solar radiation.

According to advances in nanoscale science and engineering, several current problems, such as water quality, can be fixed or reduced by altering nanoscale materials [7]. Nanotechnology allows for the cultivation and enhancement of existing technologies, as well as the development of new and innovative methods for purifying, manufacturing, and mining sewage water.

Nanotechnology, in particular, has the potential to create made-to-order solutions for eradicating pollution. Since water has a variety of species at sites, such as metals, biological agents, and toxins, including pathogens that are transmitted through water (such as cholera and typhoid), as well as dissolved organic and inorganic substances, this is ideal for water sterilization [8,9].

Heredia and Manuel [10] studied the idea of a resolute titanium dioxide and demonstrated a graphic marker of water sterilization. The most important outcomes were an increase in purification scale by bottle shaking, baseness under variable UV rays, and the impact of bottle size on optical stimuli water purification, as well as using a distinct indigo carmine (1.25×10^{-1} mg/disc), and dissolved organic and inorganic chemicals. The impact of nanoparticle mixes on the SWDIS process will also be investigated in this study.

Sharshir et al. [11] improved the efficiency of solar stills by altering the concentrations of graphite and copper oxide micro-flakes, basin water depths, and film cooling flow rates. According to the findings, solar still production is raised by 44.91% and 53.95%, respectively, by using CuO and graphite micro-flakes. Additionally, when the condensate along the glass cover is taken into consideration as feed water, the output yield is improved by roughly 47.80% and 57.60% using CuO and graphite particles, respectively. Finally, the stills' daily efficiencies are 46% and 49%, respectively, when using CuO and graphite micro-flakes with glass film cooling, while the daily efficiency of the traditional still is 30%.

Rajeswari et al. [12] used Citrus aurantifolia peel extract to synthesize multifunctional ZnO nanoparticles, with the peel's bioactive phytochemicals were preserved. The findings suggest that this type of nanoparticles could be effective antibacterial reagents for reducing watery infections. Additionally, the effectiveness of using ZnO nanoparticles as a water disinfectant was evaluated for water taken from Bengaluru's RR Nagar Lake and BGS Lake. The cell count per mL in RR Nagar lake water was decreased from 18,500 CFU/mL to 50 CFU/mL, while in Bengaluru's BGS lake water, it was decreased from 70,000 CFU/mL to 1 CFU/mL. A total viable count revealed that the number of microbes in the water from RR Nagar and BGS Lake had been reduced by 99.7% and 99.9%, respectively.

Recent studies claim that hybrid nanofluids maximize the efficiency of solar systems compared with other fluids, because of the synergistic impact of individual nanoparticles [13]. The properties of hybrid nanofluids have been investigated in a number of publications, most of which have reported positive findings. Hybrid nanofluids have been discovered to be of optimal properties, demonstrating their suitability for solar systems that need for the working fluid to have favorable thermal, optical, and rheological properties.

Rabbi and Sahin [14] looked into how two hybrid nanofluids can improve solar still performance. Hot water and two common nanofluids were also employed to investigate how to increase the performance of solar stills. The yield, efficiency, and exergy efficiency were 4.99 kg m^2 day, 37.76%, and 0.82%, respectively.

Having conducted an intensive literature survey, no previous work on the effect of using hybrid nanofluids on the solar water disinfection of contaminated water. In the present work, hybrid nanofluids with different compositions of Al_2O_3 and TiO_2 were used for improving the quality of water

2. Materials and Methods

In a previous study conducted by Hamdan and Darabee [15], it was shown that the ideal Al_2O_3 concentration lowers the overall counts of Coliform and E. coli by 0.06%. In addition, the ideal concentration of TiO_2 that is required to lower the overall counts of Coliform required ranges between 0.008 and 0.01%, while 0.06% of TiO_2 percentage is required to completely eradicate all E. coli.

In this study, Al_2O_3/water nanofluid with a volume concentration of 0.06% and TiO_2/water nanofluid with a volume concentration of 0.01% were mixed at a volume ratio of 0.25:1, 0.667:1, 1:1, 1.5:1, and 4:1. The composition of each mixture is indicated in Table 1.

Table 1. Hybrid nanofluid mixtures.

Mixture	Al_2O_3 Water-Based Nanofluid (mL)	TiO_2 Water-Based Nanofluid (mL)
1	0	0
2	400	100
3	200	300
4	100	400
5	250	250
6	300	200

The method used in this study to test for the total count of both Coliform and *E. coli* is that outlined in reference [15].

In this work, six glass containers were used; the first one contains only contaminated water without nanofluid, which is used as a base unit for comparison purposes, while each one of the other five containers contains one mixture of those shown in Table 1. Contaminated water was extracted from subsurface spring water gathered in the area (spring yajouz-Amman, Jordan). This water is clear (low turbidity), yet it is unfit for human consumption. It should be noted that the concentration of measured values of total Coliform and *E. coli* in this water is 2419 MPN/100 mL, and this value is used as a "baseline".

The Enzyme Substrate Test is employed in this study, which hydrolyzable substrates for the simultaneous detection of coliform bacteria and *E. coli* enzymes using the IDEXX system. A complete description of this test together with the followed procedure to test for the presence of both total Coliform and E. coli is outlined in reference [15].

3. Results and Discussion

Figure 1 represents the hourly solar isolation radiation and ambient temperature during an experimental day. As indicated, the incident solar radiation increases from 328 W/m^2 in the morning to a peak value of 650 W/m^2 at noon, beyond which it decreases in the late afternoon to 470 W/m^2. Similarly, the hourly temperature increases from 14 °C in the morning to a maximum value of 27 °C, then decreases to 20 °C later in the afternoon.

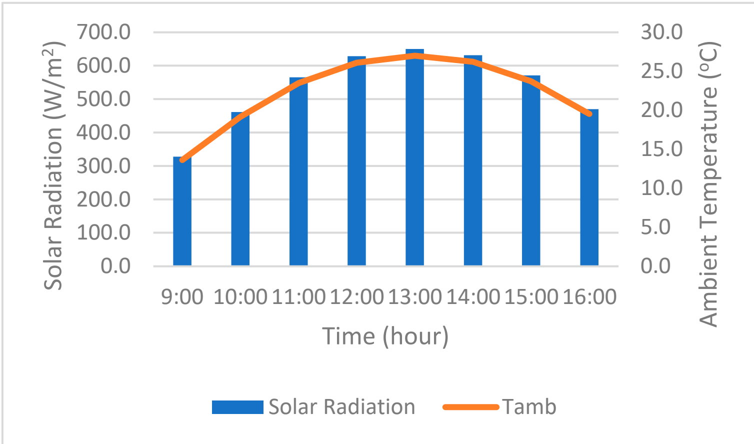

Figure 1. Hourly solar radiation and ambient temperature.

Figure 2 shows the variation in temperature of the mixtures with time. As indicated in this figure, at 11:20, all mixtures are at the same temperature of 24 °C beyond this time temperature of mixtures, which increases with time due to the increase in the incident solar radiation. The temperature of the contaminated-hybrid nanofluid mixture remains constant at any time, with their maximum temperature reaching 40 °C at 13:30. It may be noted that contaminated water remains at a lower temperature than those of the contaminated-hybrid nanofluid mixtures, which is because the nanoparticles in the mixture tend to increase the thermal capacity of the fluid and hence the temperature increases. Note that both hourly solar radiation and ambient temperature shown in the figure were obtained from the GRWS100 weather station, which is located at The University of Jordan.

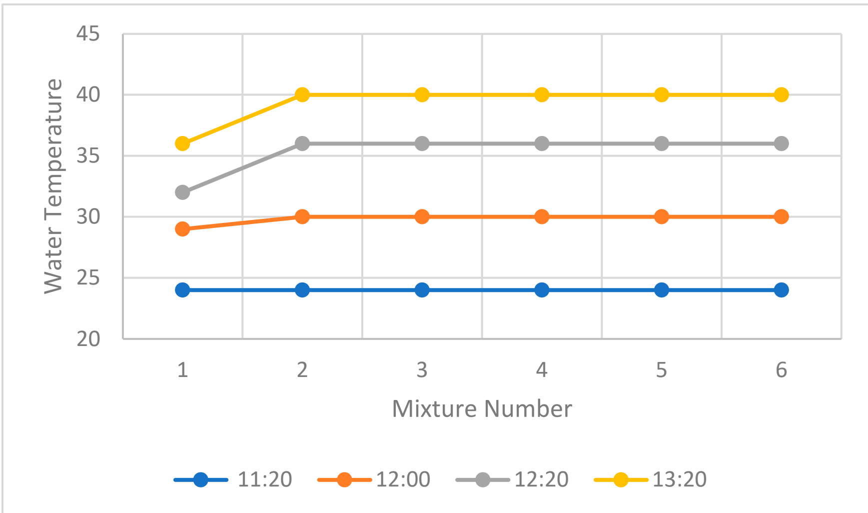

Figure 2. Variation of contaminated water hybrid nanofluid mixtures with time.

Figure 3 shows the relation between total Coliform counts in contaminated water with time before and after adding the different compositions of water and hybrid nanofluids mixtures. As indicated in this figure, the counts vary with times of exposure to solar radiation. As may be noticed, the total counts decrease with time; this decrease is from 1987 to 1119 after one hour. However, the counts further decrease upon adding hybrid nanofluids to the contaminated water. This decrease is maximum when mixture 5 is used (250 mL of TiO_2 and 250 mL of Al_2O_3) with a total count of 345. This count further decreases after two hours of solar exposure to a minimum value of 435 within the base unit (only contaminated water) and to 144 within the contaminated water containing mixture 2

(250 mL of Al_2O_3 and 250 mL TiO_2). Finally, the variation of the total count remains almost constant after three hours of exposure.

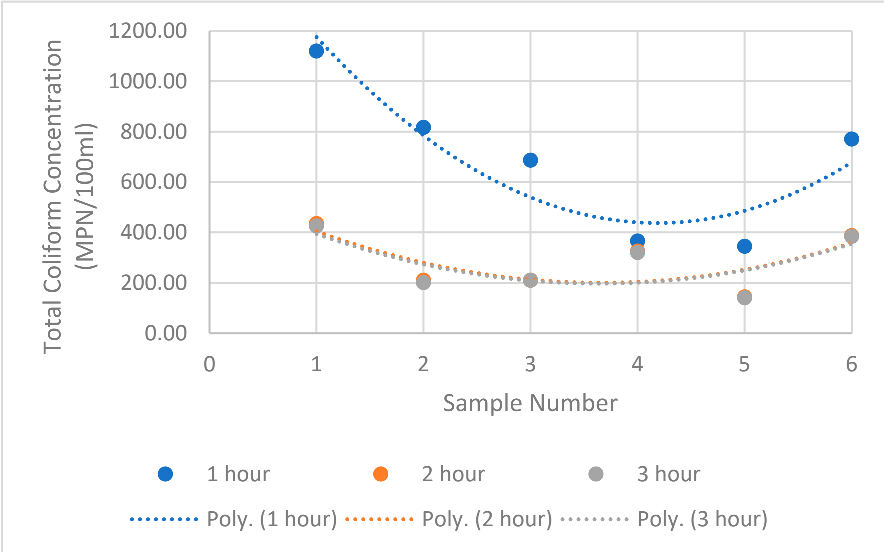

Figure 3. Variation of total Coliform count with time with different hybrid mixtures.

Figure 4 shows the variation of *E. coli* counts in the contaminated water hybrid nanofluids mixtures over time. As indicated in this figure, and similar to the trend of total Coliform, the counts of *E. coli* decrease with time, due to the increase in the exposure time to direct solar radiation. The concentration of *E. coli* counts in the polluted water after one hour of exposure time to solar radiation is 86, which was achieved upon the addition of nanofluids mixture number 2 (composition of 250 mL Al_2O_3 and 250 TiO_2 (Sample 5)). However, this count after three hours was 30, which was obtained when sample 2 is used. This count of E. coli remains almost the same after two and three hours of exposure.

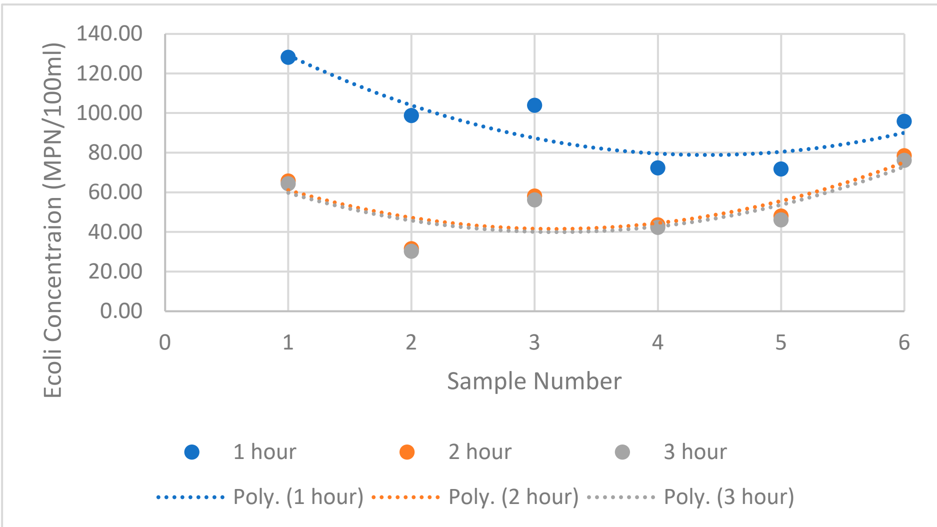

Figure 4. Variation of *E. coli* count with time with different hybrid mixtures.

Figure 5 represents the count of both Total Coliform and *E. coli* counts after two hours of exposure to solar radiation. As shown, mixture 5 has the highest ability to minimize the count of the total Coliform, while 2 has the highest ability to minimize the count of *E. coli*. Although sample 2 gave the best results to reduce the *E. coli* count after two hours, it may be concluded that sample 5 may be used to reduce both Total Coliform and *E. coli* at the same, since the difference in the *E. coli* count between sample 2 and 5 is 17 only.

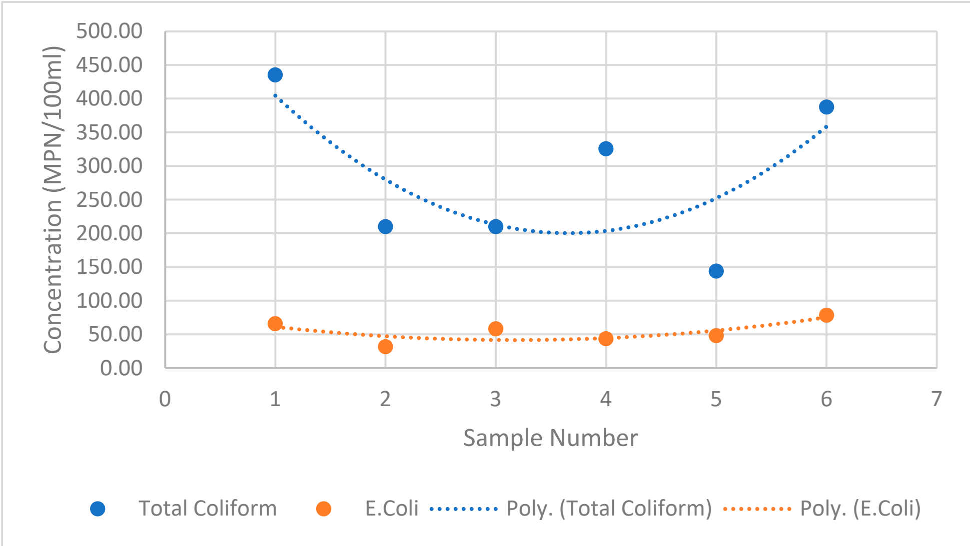

Figure 5. Variation of *E. coli* and Total Coliform counts with time with a different hybrid mixture.

4. Uncertainty Analysis

The aforementioned trials were conducted several times under identical conditions. In this analysis, the Most Probable Number (MPN) approach was used to conduct the uncertainty analysis [16]. Table 2 displays the Mean of each sample, the lower and upper limits for the 95% Confidence limits, and the 95% Confidence limits for the measured MPN value.

Table 2. Uncertainty test.

Measured MPN	95% Confidence		Mean	(Mean-Measured)/Mean × 100%
	Lower Limit	Upper Limit		
2419.6	1630.4	4716.1	3173.25	0.237501
1553.1	1016.2	2353.1	1684.65	0.078087
770.1	549	1094	821.5	0.062568
387.3	245.9	567	406.45	0.047115
98.7	72.3	133.7	103	0.041748

Based on the aforementioned data shown in this table, the combination uncertainty for the IDEXX Unit is 26.53%, which is in agreement with the random uncertainty described in [17].

5. Conclusions

The effect of hybrid nanomixtures on the solar disinfection process of contaminated water has been investigated in this study. Five different compositions of water-based Al_2O_3 and TiO_2 were used in this study, with each mixture introduced into a glass container. From this work, the following may be concluded:

1. In general, adding nanoparticles to contaminated water has a favorable effect on the disinfection process of polluted water and speeds up the process by lowering the concentration of Total Coliforms and *E. coli* present.
2. The optimal Al_2O_3 and TiO_2 combination composition to cut down the total Coliform count was found to be that of sample 5 (250 Al_2O_3—250 TiO_2).
3. The optimal Al_2O3 and TiO_2 combination composition to cut down the *E. coli* count was found to be that of sample 2 (400 Al_2O_3—100 TiO_2).

4. In general, it was found that the optimal Al_2O_3 and TiO_2 combination composition to cut down the total Coliform and *E. coli* count was found to be that of sample 5 (250 Al_2O_3—250 TiO_2).

Author Contributions: Conceptualization, S.A.; Data curation, H.D.; Formal analysis, M.H.; Investigation, M.H. and S.D.; Methodology, S.D.; Project administration, M.H.; Visualization, S.D.; Writing—original draft, H.D.; Writing—review & editing, S.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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