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Enhancing the solar still output using micro/nano-particles of aluminum oxide at different concentrations: An experimental study, energy, exergy and economic analysis

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Abstract

In this work, the use of micro/Nano-particles of aluminum oxide (Al_2O_3) with various concentrations in solar still has been reported. Three solar distillers has been fabricated and tested: first distiller is a Conventional Solar Still (CSS), the second distiller is a Modified Solar Still (MSS) contains micro-particles of Al_2O_3 (MSS – 0.1, 0.2 and 0.3% MP of Al_2O_3) and the third distiller is a MSS contains Nano-particles of Al_2O_3 (MSS – 0.1, 0.2 and 0.3% NP of Al_2O_3). In this experimental study, the micro/Nano-particles of the Al_2O_3 concentrations are prepared at the concentration ratio of 0.1, 0.2 and 0.3%. From the experimental outputs by adding Nano-particles of Al_2O_3 with concentrations of 0.1%, 0.2% and 0.3% in the CSS, the productivity of 4.9, 5.47 and 6.12L/m^2 has been observed. However, when using the micro-particles of Al_2O_3, the MSS productivity is equal to 4.07, 4.54 and 4.96L/m^2 for the concentrations equal to 0.1, 0.2 and 0.3%, respectively. While the maximum productivity of the CSS without micro/Nano-particles of Al_2O_3 was 3.02L/m^2. Furthermore, the daily increase in yield of 62.25, 81.12 and 102.64% are obtained when using the Nano-particles of Al_2O_3 with the concentrations of 0.1, 0.2 and 0.3% respectively, as compared to the CSS. By using the micro-particles of Al_2O_3, the daily increase reaches only 34.77, 50.33 and 64.24% for the concentration equal to 0.1%, 0.2% and 0.3%, respectively as compared to the CSS.

Introduction

Nowadays, the issue of freshwater shortages has become one of the main troubles in the world. Although three quarters of the land is enclosed with water, there is only 0.014% of water it safe to drink. It became necessary to convert salt water into distilled water [1]. Among the technologies used for saline desalination, solar based water distillation technology is best. However, the productivity of solar distillation is minimum. So, researchers used several techniques to increasing the productivity of the CSS such as using a fan [2], water to cool the outer glass [3] and sun tracking system [[4], [5], [6], [7]]. Productivity of the CSS can be

increased by adding storage materials [8]. The used storage materials include oxides like SiO_2, Al_2O_3, ZnO and TiO_2 for various types and dimensions, including millimeters, micrometers, and nanometers [9]. Nanotechnology is then very important because it is a sustainable way to increase the productivity of the CSS. Researchers and scientists have used nanofluids in various thermal applications. Gnanadason et al. [10] studied the outcome of considering carbon Nano-tubes in solar still. Compared to the CSS, experimental outputs confirmed that the daily accumulation of the CSS was improved by using carbon nano-tubes. Panitapu et al. [11] added TiO_2 nano-particles to the basin water to enhance the solar still output. Gupta et al. [12] carried out an experimental study to compare the output between the two solar stills, one of which was filled with salt water, and the second one was a CSS containing an Nano-fluid mixed with water depth equal to 5 and 10cm. The researchers confirmed that the daily accumulation presents 30% of improvement when using nanofluid at water depth equal to 5cm compared to production of CSS. Sain and Kumawat [13] conducted an experiment to augment the solar still efficiency using alumina nano-particles and the black coating of the CSS basin. It was noted that daily productivity was improved by 38% using alumina Nano-particles. Gnanadason et al. [14] modified the CSS using multi-walled carbon Nano-tubes in the still basin surface. It is confirmed that the depth of the water in a basin affects the distilled water productivity. They concluded that when using nanofluids, the evaporation rate has increased significantly. Sharshir et al. [15] published the effect of flake graphite nano-particles on the solar distiller's performance. The researchers confirmed that daily productivity was enhances by 50.28% with the use of flake graphite nanoparticles in the basin water. Gnanadason et al. [16] reported the effects of adding carbon nanoparticles to the solar still water. The researchers confirmed that the productivity and efficiency were greatly improved using carbon nanoparticles compared to CSS. In order to improve performance of the CSS, Shankar et al. [17] experimental results confirmed that Al_2O_3 Nano-particles increase the productivity of the CSS. Sharshir et al. [18] made an experimental study to increase the CSS output by using nano-fluids (copper oxide and graphite) and the glass cover cooling method. Compared to the CSS, adopting nanofluids with the glass cover cooling significantly enhances the still daily efficiency. Elango et al. [19] enhanced the CSS performance by testing different Nano-particles. Based on an analysis of the costs of their studies, the researchers concluded that the cost recovery period is much less, for the distillate filled with Nano-fluids as compared to the CSS. Prasad et al. [20] examined empirically the graphite to improve the CSS performance. The authors found that the use of silica gel filled with graphite increases the CSS efficiency by about 49%. Kabeel et al. [21] performed an experimental modification in CSS with an external condenser and using nano-particles (Al_2O_3). The results confirmed that maximum output of the CSS was 116% when using the external condenser and nanoparticles. Kabeel et al. [22] used copper oxide in the CSS and found that the efficiency of the CSS was increases by 4.16%. Kabeel et al. [23] also studied the effect of CuO nanoparticles mixed with black dye on a CSS performance. They observed that CuO nanoparticle improves the daily productivity by 25% compared to CSS. Shanmugan et al. [24] examined numerically and experimentally an enhancement of CSS performance incorporated using phase change material ($C_{18}H_{36}O_2$) and Al_2O_3 nanoparticles mixed with a black paint. The obtained results showed that the efficiency of the CSS was improved by 59.14%. Nano-particles such as Titanium dioxide [[39], [40], [41], [42], [43]], Iron oxide [19], Copper oxide [12,15,23,[39], [40], [41], [42]], Aluminum oxide [17,30,[42], [43], [44], [45], [46]], Cuprous oxide [22,30,47], Graphite [15], Silicon carbide [48], Graphene oxide [41,49], and Silicon dioxide [50] were used by different researchers. Only few research works were reported on comparing micro and nano-particles. So in this paper, the main aim is to compare the use of nanoparticle and micro particle in water desalination and to demonstrate the extent of their effectiveness in improving the yield of simple solar distillers using different concentrations of Nano/Micro-particle (Al_2O_3) equal to 0.1, 0.2 and 0.3%. Three solar distillers has been manufactured and tested: (i) the first distiller as a conventional (CSS), (ii) the second distiller with micro-particle of Al_2O_3 (MSS – 0.1, 0.2 and 0.3% MP of Al_2O_3) and (iii) the third distiller with Nano-particle of Al_2O_3 (MSS – 0.1, 0.2 and 0.3% NP of Al_2O_3). In our experimental investigation, Al_2O_3 in micro/Nano-particles concentration is equal to 0.1% in the first day. In the second and the third days, this concentration was increased to 0.2% and 0.3%,

respectively. The experiments were conducted in the city of El Oued, Algeria, on three consecutive days in June 2020. This work contributes to the development of solar water desalination technology in Algeria for treating non-drinking water to drinking water.

Section snippets

Aluminum oxide micro-particles preparation

The morphology of the $Al2O_3$ of oxide micro/Nano-particles were measured by scanning electron microscope as illustrated in Fig. 1 and Fig. 2 (a, b and c). The micro-particles size was about 5 μm and 100 nm thickness as presented in Fig. 3. The morphology of Al_2O_3 nano-particles is spherical, with radius equal to 3 nm.…

Aluminum oxide nano-particles preparation

Commonly, Sol-Gel process is a simple process for the nano materials synthesis. For the alumina synthesis, the modification of the sol-gel CTM (Cooperative self-assembly mechanism)…

Experimental setup

In this investigation, three CSSs were constructed to study the solar stills performance. Different concentrations of Nano/micro-particle of Al_2O_3 at concentrations of 0.1, 0.2 and 0.3% were prepared and tested. A as shown in Fig. 4, the CSS has basin area of 0.25 m^2 (500 mm × 500 mm). The higher-side wall has 140 mm height and lower-side wall has 60 mm height. The CSS was manufactured using wood with 25 mm of thickness and basin was manufactured using galvanized iron sheet. The whole basin…

Experimental procedure

The experimental test is presented in Fig. 5. The experiments were operated for a period of three days: 24, 25 and 26 June 2020 for 11 h in the city of “El Oued Algeria; located at 47° 06 ‘E and 33° 30’ N". Three CSSs were fabricated: (i) the first distiller is a conventional (CSS), (ii) the second distiller is a MSS with micro-particle of Al_2O_3 at different concentrations (MSS – 0.1, 0.2 and 0.3% MP of Al_2O_3) and (iii) the third distiller is a MSS Nano-particle of Al_2O_3 at different…

Intermittent deviation of solar intensity and various temperatures

Fig. 6 shows the intermittent deviation of solar intensity I(t), temperatures of ambient (T_a), salt water ($T_{s.w}$) and glass (T_g) for the MSS - 0.1% MP of Al_2O_3, MSS - 0.1% NP of Al_2O_3 and CSS. From graph 6, it is known that I(t) increases in the sunrise hours and reaches its maximum value of 1010 W/m^2 at 12:00 Hrs. Similarly, T_a gets its highest value of 44 °C at 13 Hrs. The daily mean value of I(t) is 759.3 W/m^2 and T_a is 38.9 °C. The intermittent deviation of T_a, $T_{s.w}$, and T_g have the curve…

Conclusions

In the present study, experimental investigation on using micro/Nano-particle of Al_2O_3 has been carried out. In order to optimize the concentration of $Al_2O_{3,}$ the solar stills was tested at the concentrations of 0.1%, 0.2% and 0.3%. From the comparative experimental study on micro/Nano-particle, the following conclusions are recorded:

- The optimum concentration rate was found as 3% weight fraction for the micro-particle of Al_2O_3 and Nano-particle of Al_2O_3….
- The increase in MSS productivity of 62.25, …

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Nomenclature

SSSS
: Single Slope Solar Still…

DS solar still
: Double Slope Solar Still…

CSS
: Conventional Solar Still…

EnE
: Energy Efficiency…

ExE
: Exergy Efficiency…

MSS – 0.1, 0.2 and 0.3% NP of Al_2O_3
: Modified Solar Still with Micro-particles 0.1, 0.2 and 0.3% of Al_2O_3…

MSS – 0.1, 0.2 and 0.3% MP of Al_2O_3
: Modified Solar Still with Nano-particles 0.1, 0.2 and 0.3% of Al_2O_3…

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Ethical approval

Not Applicable….

Consent to participate

Not Applicable….

Consent to publish

Not Applicable….

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Availability of data and materials

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Declaration of Competing Interest

The authors declare that there is no competing interest.…

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