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Performance study on single basin single slope solar still with different water nanofluids

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HIGHLIGHTS

- Water nanofluids of Al_2O_3, ZnO, Fe_2O_3 and SnO_2 were prepared and characterized.
- Performance of the stills with water and these nanofluids was studied.
- Still with nanofluids has higher production.
- The still with Aluminum Oxide (Al_2O_3) nanofluid has 29.95% higher production.

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ABSTRACT

This paper compares the performance of single basin single slope solar still with and without water nanofluid. Water nanofluids of Aluminum Oxide (Al_2O_3), Zinc Oxide (ZnO), Iron Oxide (Fe_2O_3) and Tin Oxide (SnO_2) of different concentrations were characterized for thermal and physical properties and suitable nanofluids were selected for performance testing in solar still. Two experimental stills of the same basin area have been fabricated and tested with water and different nanofluids simultaneously. The still with Aluminum Oxide (Al_2O_3) nanofluid has 29.95% higher production and the still with Zinc Oxide (ZnO) and Tin Oxide (SnO_2) nanofluids has 12.67% and 18.63% more production respectively than the still with water.

1. Introduction

Solar still is a very simple device for distilling water which utilizes the cheaply available solar energy. It is widely used to produce potable water. It is relatively cheap to construct, easy to maintain and it can be used in arid and salty areas. Usage of solar still is limited due to its low production rate. The productivity of the solar still mainly depends on evaporation rate of the water from basin and condensation rate of vapor at lower surface of the glass cover.

Various efforts were made by researchers to improve the evaporation rate of water by incorporating different techniques [1]. These techniques include adding dye [2] and charcoal pieces [3] to the basin water and using energy storing and wick materials in the basin [4–6]. Rajvanshi [2] studied the effect of various dyes on solar distillation. Black napthylamine dyes at 172.5 ppm give higher increase in production rate by 29% compared with red carmoisine and dark green dye. The effect of dyes on productivity is more on deep basin still than the shallow basin still. Zurigat and Abu-Arabi [7] used dye and reported 17% and 16% increase in productivity for the regenerative and conventional stills. The relative performance is calculated to be around 23% more for regenerative still compared with conventional one for both cases with or without dye.

Akash et al. [8] experimentally evaluated the single-basin solar still using different absorbing materials like rubber mate and charcoal to increase the absorption of the still basin. Madani and Zaki [9] investigated the yield of solar stills with porous basins. An average yield of 2.5–4 l/m^2/day was obtained when carbon powder (40–50/μm size) was used as a basin material. Patel et al. [10] enhanced the overall efficiency of conventional basin type solar still with different semiconducting oxides like Copper Oxide (CuO), Lead Oxide (PbO_2) and Manganese Dioxide (MnO_2) as photocatalyst. Studies were also conducted in the tray coated with metal sulfides like Lead Sulfide (PbS), Copper Sulfide (CuS), Bismuth Sulfide (Bi_2S_3) and Antimony Sulfide (Sb_2S_3) and dyes like malachite green, Fuschine and Alizarin Red S. Result of the studies shows oxides as the better photocatalysts than sulfides and dyes.

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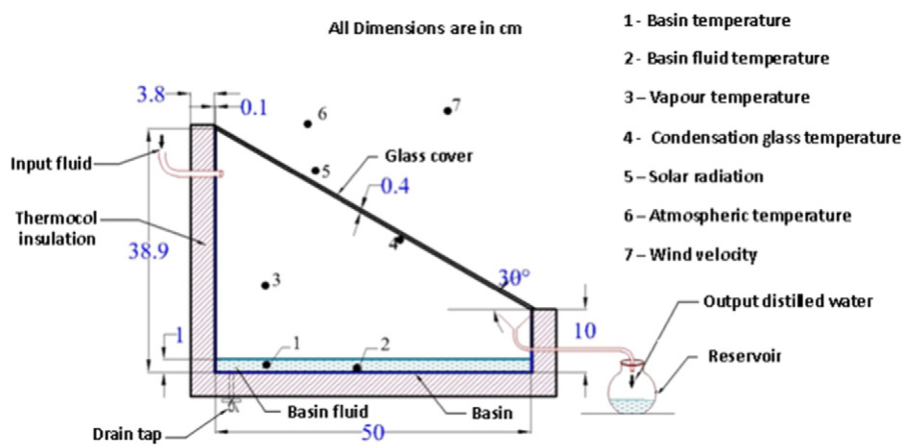

Fig. 1. Schematic diagram of single basin single slope solar still.

Thermal characteristics of the basin water greatly affect the performance of the still. The nanofluids are fluids containing nanoparticles of size 1 to 100 nm which possess high performance in heat transfer (nanometer-sized particles of metals, oxides, carbides, nitrides, or nanotubes). They possess good thermal characteristics and these are used as working fluids to improve the performance of the thermal system [11]. Omid Mahian et al. [12] reviewed the possible utilization of different nanofluids in solar energy areas for different applications. In solar still, the water nanofluid improves the thermal transport and evaporation property. Kabeel et al. [13] conducted experiments on solar still integrated with external condenser and observed that, the still production increased by 116% when water Aluminum Oxide nanofluid was used.

In this work, two single basin single slope solar stills were fabricated and the experiments were conducted to compare the performance with and without nanofluids in the same location and radiation conditions simultaneously. Water nanofluids of different metals with different concentrations were produced, characterized for its thermal and physical properties and used in the still to study the performance.

2. Experimentation

2.1. Solar still

The salinity of normal water is <100 ppm. But, the water available in Kovilpatti through bore well is too salty whose salinity is 1070 ppm and hence, they cannot be used for drinking purpose. In order to reduce the salinity and make them potable, solar desalination technology was applied. Nanofluids are highly thermal conductive nanoparticles containing fluids. They have been used as the basin fluid to improve the performance of the solar still. Single slope single basin solar still was fabricated using 0.01 m GI sheet by keeping the height of the lower vertical side at 0.1 m. For a 30° inclination of the window glass cover, the required height of the other vertical side was 0.389 m. The absorber area of basin stills was 0.5 m × 0.5 m (0.25 m^2). The schematic diagram of single slope still is shown in Fig. 1. The inner side of the basin was painted black to maximize the absorption of solar radiation. The bottom and sides of the basin were well insulated with a thermocol layer of 0.038 m thickness. An ordinary clear window with a glass thickness of 0.004 m was used as the top cover of the solar still and was inclined at an angle of 30°.

The total experimental setup was arranged in a way to face the south direction to receive the maximum solar radiation. A silicon rubber sealant was used as the seal between the glass cover and the body of the still to prevent leakage of the evaporated vapor. The distillate water condensed from the glass cover was collected in a distillation trough fitted on the lower side of the solar still. An inlet pipe was provided to supply nanofluids and drain tubes were provided to recover the unevaporated nanofluids for further use. Plastic tubes were used to discharge the distilled water. Fig. 2 shows the clear view of the single slope single basin solar still.

Fig. 2. Experimental view of the still.

2.2. Preparation of nanofluids

In this work, various nanoparticles like Aluminum Oxide (Al_2O_3), Zinc Oxide (ZnO), Iron Oxide (Fe_2O_3) and Tin Oxide (SnO_2) have been

Table 1
Thermal conductivity and cost of certain nanopowders.

Sl. no	Nanopowders	Thermal conductivity (W/m° K)	Quantity	Cost (Rs)
1	Aluminum Oxide (Al_2O_3)	40	25 g	2000
2	Zinc Oxide (ZnO)	29	100 g	1500
3	Tin Oxide (SnO_2)	36	25 g	1500
4	Iron Oxide (Fe_2O_3)	7	25 g	1750
5	Gold nanopowder (Au)	315	1 g	35,029
6	Titanium Dioxide (TiO_2)	8.5	100 g	12,859
7	Copper Oxide (CuO)	76	5 g	3111
8	Carbon nanotubes	3000–6000	250 mg	19,521
9	Zirconium (IV) Oxide (ZrO_2)	2	100 ml	10,611
10	Silicon nitride (Si_3N_4)	29–30	25 g	11,434
11	Boron nitride (BN)	30–33	50 g	4911
12	Aluminum nitride (AlN)	140–180	50 g	5193
13	Diamond nanopowder (C)	900	1 g	8755
14	Silver nanopowder (Ag)	424	5 g	12,917