Performance Study of Basin Type Solar Still with Different Concentrations of Water-Al_2O_3 Nanofluids

Farooque Azam and Naiem Akhtar

Abstract In this paper, a comparison of the performance of single basin single slope solar still with water and with water based nanofluid of Aluminium Oxide (Al_2O_3) has been made. For this, two experimental solar stills of the same basin area have been fabricated and tested for their identical thermal performance. These solar stills have been used to compare the performance with water in one solar still and water-based nanofluid in the other solar still by performing experiments at the same location and time. It is found that the solar still with water based Aluminium Oxide (Al_2O_3) nanofluid having concentrations 0.05%, 0.1%,0.15% and 0.2% enhances the output of the solar still as compared to the water by 18.54%, 22.26%, 24.37% and 20.38%, respectively, thus giving an optimum value of enhanced output at 0.15% concentration.

Keywords Solar still · Nanofluid · Aluminium oxide

Nomenclature

Ø	Latitude (Degree)
V	Volume of water (ml)
ρ	Density of nanoparticles (gm/ml)

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1 Introduction

One of the main challenge's humans will face in the near future is the availability of drinking water, which is becoming less and less available steadily while the demand is increasing. Although water covers more than two third of the earth, only about 0.014% of the world's water may be used directly for industrial and human needs [1]. Lack of access to proper drinking water is one of the significant issues for people living in dry, rural places around the world. In regions with abundant solar energy, solar stills can help with some of these issues. Solar stills are easy to fabricate, inexpensive, have low maintenance costs and offer the significant benefit of being pollution-free. Although solar stills have poor productivity, these are an environment-friendly and sustainable way to produce pure water. Extensive research is still being done on solar still with the goal of increasing their production. The performance of solar stills is being improved through several theoretical and experimental studies [2]. Recently, nanofluids have gained attention due to their remarkable thermophysical properties and significant enhancement of heat transfer coefficient [3, 4]. Sain and Kumawat [5] conducted experiments with Al_2O_3 nanoparticles in a solar still. They [5] blended the nanoparticles with black paint coated on the basin of the single slope solar still of area $1m^2$and the overall results concluded that the mixed Al_2O_3 nanoparticles in the paint improve the productivity. Elango et al. [6] compared solar still performance with water and water based nanofluid of aluminium oxide (Al_2O_3), zinc oxide (ZnO) and tin oxide (SnO_2) of different concentrations in a single basin single slope solar still and conclude that productivity enhancement is more in aluminium oxide (Al_2O_3) as compared to other nanofluids.

In this present work, the effects of different concentrations of Al_2O_3 nanofluids on the productivity of solar still has been studied experimentally. Experiments have been performed at a concentration of 0.05, 0.10, 0.15, and 0.20% by volume, and the output is compared with identical solar stills placed side by side under the same environmental circumstances. The effect of the concentration of Al_2O_3 nanofluids with the same water depth is analysed in this experimental work.

2 Experimental Setup

Two identical-sized solar stills with proper distillate collection channels, feed water supply, and drainage lines are designed and constructed. Black paint is coated on the basin surface, having an area $1m^2$. The height of the front and rear walls is 8 cm and 38 cm, respectively (Fig. 1). Both stills are made with a galvanised iron sheet that is 1 mm thick and has insulation (glass wool) that is 1 inch thick on all four sides and the bottom. The insulation is covered with a toughened glass cover that is 4 mm thick and tilted at 28° (for Aligarh, $\emptyset = 27.89°$) [7]. The arrangement of inlet and outlet drain valves simplifies flow across the basin. Silicon sealant was employed as a sealing material between the glass cover and the still's body to check the leakage

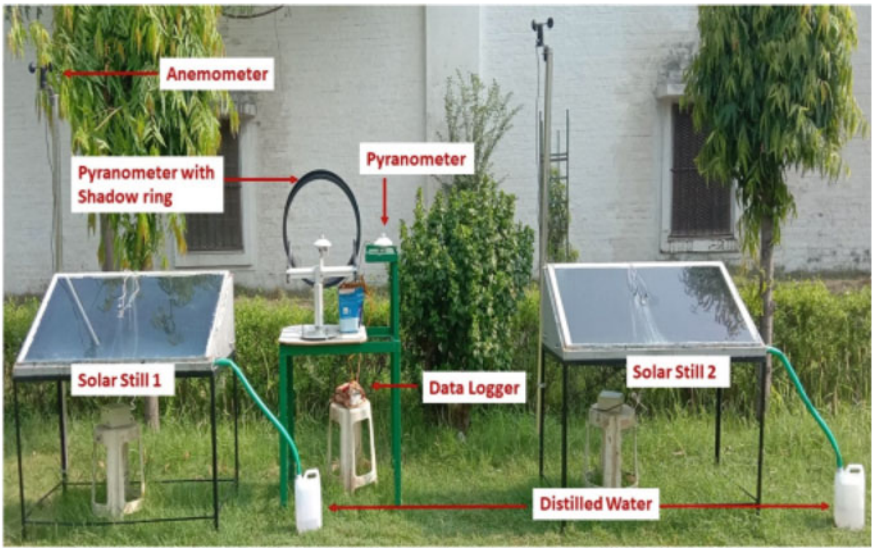

Fig. 1 Actual view of experimental setup

of vapour. It was also ensured that there is no leakage of water from the solar stills by pouring water in the basin. The setup is well-equipped with temperature measurement instruments at various positions. A k-type thermocouple with a digital display is mounted with a setup to measure and record basin temperature, water temperature, vapour temperature, glass interior temperature, and glass outside temperature at regular intervals of 5 min. Ambient temperature, wet bulb temperature, and relative humidity are also measured. Kipp and Zonen Pyranometer (CMP-11) with data logger is used to measure and records solar radiation data. The hourly distillate from both stills was estimated using a beaker with a capacity of (0–1000) ml. Both stills are kept on an obstruction-free roof, facing south.

3 Preparation of Nanofluids

The nanoparticles of Aluminium Oxide (Al_2O_3)have been selected because of their good thermal conductivity and low cost [6, 8]. Aluminium Oxide (Al_2O_3) is less expensive when compared to other nanoparticles used to produce nanofluids. Even though some nanoparticles have great thermal conductivity, their exorbitant cost prevents their usage. As a result, the chosen nanoparticles are more affordable and have better thermal conductivity [9]. Average primary particle size of the Aluminium Oxide nanoparticles is 13 nm, specific surface area is 100 ± 15 m^2/g and density is approximately 50 g/l.

The preparation of nanofluids is a critical step in using nanoparticles to boost the thermal conductivity of fluids. Since nanoparticles are hydrophobic, prone to conglomeration, and settle quickly, a surfactant such as sodium dodecyl benzene sulphonate (SDBS) is used to retain the suspension stable and even. The preparation of nanofluids is a critical step in using nanoparticles to increase the thermal conductivity of fluids [10]. In the present work, water based nanofluids ofAl_2O_3(Al_2O_3-water) with four different concentrations are prepared. The known weight of dry nanoparticles of Al_2O_3, is mixed into distilled water. The weight of the nanoparticles for the desired volume concentrations (0.05, 0.1, 0.15 and 0.2%), calculated using Eq. (1).The prepared samples were stirred for 20 min with a magnetic stirrer and ultrasonicated for 1 h with an ultrasonicator. Mass of the nanoparticle is calculated by the following expressions.

$$\text{nanoparticles(gm)} = \frac{\%\text{Conc}}{100} \times \text{V} \times \rho \tag{1}$$

4 Experimental Procedure

Tests were carried out in both the solar stills on the 4th, 5th, 6th, and 7th of July 2022, with one of the stills containing water and the other containing water nanofluid. Before conducting the present experimental work, a series of experiments was conducted on both the solar stillss to verify their identity on thermal performance so that a good comparison could be possible. After verification, the present experimental work was started using 10 L nanofluids in one solar still and 10 L distilled water in another solar still. Various instruments used to measure different parameters are listed in Table 1. The tests were carried out at Aligarh Muslim University's (AMU) Solar Energy Laboratory, Mechanical Engineering Department (27.89°N, 78.08°E).

Table 1 Details of the instruments used in the experimental setup

Instrument	Accuracy	Range	% error
Kipp and zonen pyranometer (CMP-11)	±1 W/m^2	0–4000 W/m^2	0.25
Anemometer (QS-FS01)	±0.1 m/s	0.1–30 m/s	5.00
K-type thermocouples	±0.1 °C	0–1260 °C	0.20
Borosil measuring jar	±5 mL	500 mL	5.00

5 Results and Discussion

Solar radiation, ambient temperature, wind speed, basin water temperature, and the glass temperature of stills were all measured with different concentrations of nanofluids as shown in Figs. 2, 3, 4 and 5. It can be seen from these figures that the temperature profiles and solar radiation intensity exhibit the same behaviour. Its value is at its highest around the noon and is at its lowest in the morning and afternoon. Additionally, the temperature profile follows the same pattern as that of the solar radiation. The performance of the solar still is described in terms of distillate output per hour for each of the four cases (four different concentration of Al_2O_3) as shown in Fig. 6a–d. Table 2 shows the enhancement in distillation output due to the use of nanofluids during day as well as night hours.

It is concluded from experimental results thatAl_2O_3 nanoparticles used with water as the base fluid increase solar still productivity. Additionally, it served as a heat-storage medium, released energy into the water, and improved production at night. It

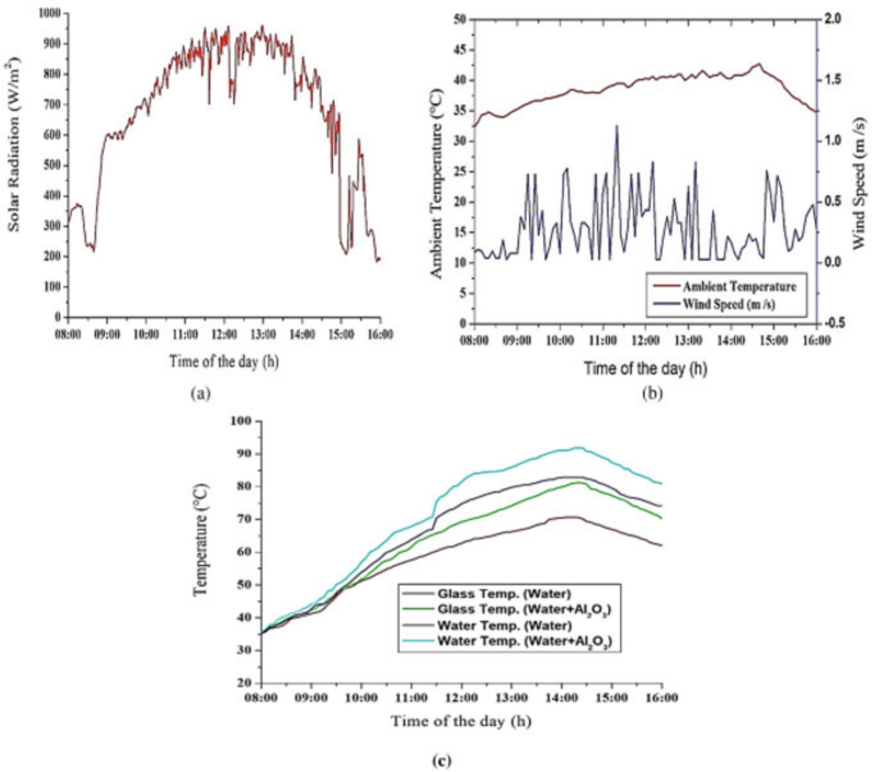

Fig. 2 Variation of (a)solar radiation (b) ambient temperature and wind speed (c) temperatures of solar still for the 0.05% concentration of Al_2O_3on 4th July 2022

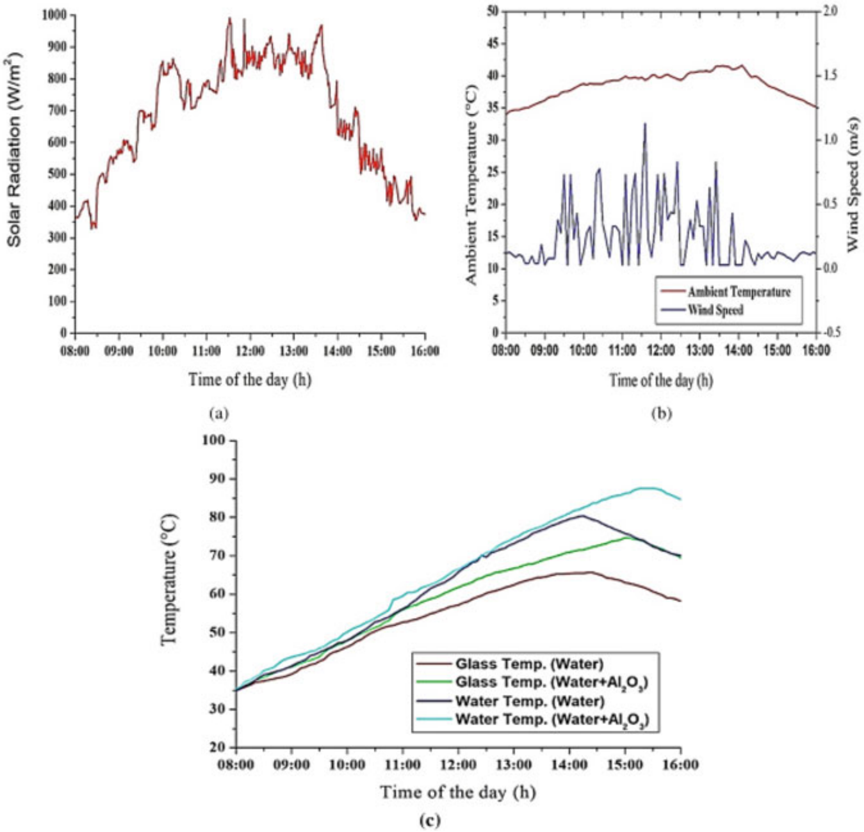

Fig. 3 Variation of **a** solar radiation **b** ambient temperature and wind speed **c** temperatures of solar still for the 0.1% concentration of Al_2O_3on 5th July 2022

has been discovered that, up to a certain point, the concentration of Al_2O_3 nanoparticles enhances the yield of distilled water before it starts to decline as shown in Table 2 The total output of the solar still (distilled water) is increased by 18.54%, 22.26%, 24.37%, and 20.38%, respectively, when using water-based Aluminium Oxide (Al_2O_3) nanofluid at concentrations of 0.05, 0.1, 0.15, and 0.2%. The same enhancement is 18.77, 22.76, 25.57, 23.79% during day hours (08:00 AM–04: 00 PM) and 18.24, 21.63, 22.77, 15.52% during night hours 04:00 PM–07: 00 AM). Result also shows that solar radiation has strong influence on distillation output, more the solar flux more will be the distillation.

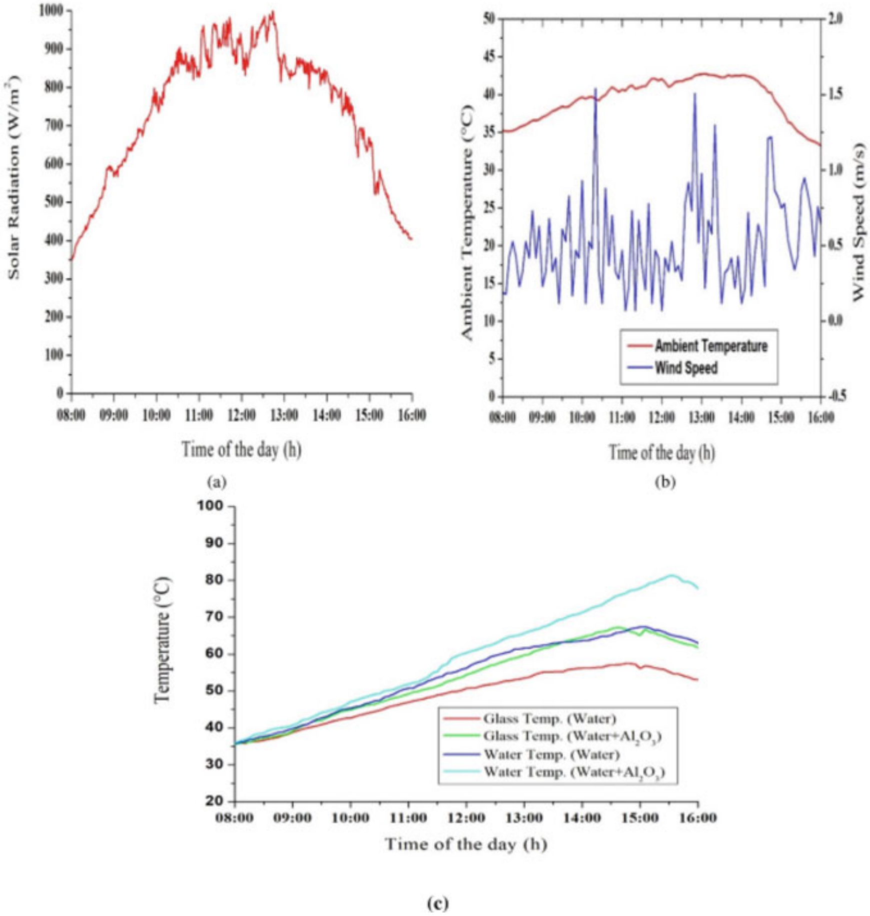

Fig. 4 Variation of **a** solar radiation **b** ambient temperature and wind speed **c** temperatures of solar still for the 0.15% concentration of Al_2O_3on 6th July 2022

6 Testing of Water Quality

The pH and total dissolved solids (TDS) of the generated water as determined by the the solar still were used to assess its quality. Samples of the distillate and feed water were both examined at the Environmental Engineering Laboratory, Department of Civil Engineering, A.M.U., Aligarh (India). Water distilled from different concentrations of nanofluids, 0.05%,0.1%,0.15% and 0.2% of $Al_2O_3$are samples 1,2,3 and 4 respectively, and their properties are shown in Table 3.

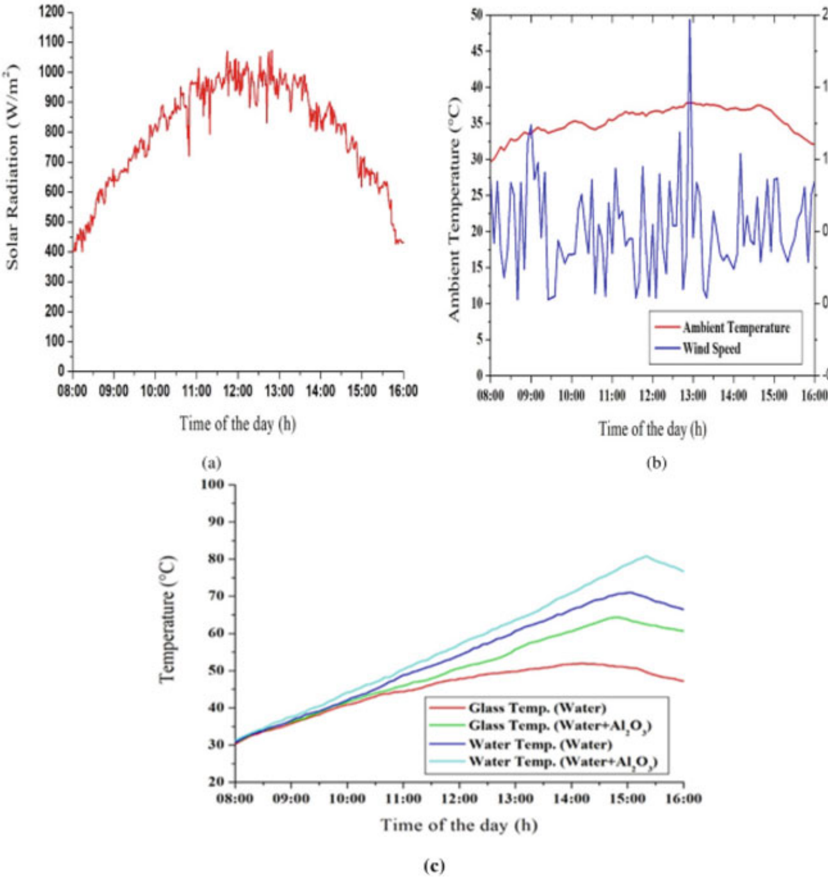

Fig. 5 Variation of **a** solar radiation **b** ambient temperature and wind speed **c** temperatures of solar still for the 0.2% concentration of Al_2O_3on 7th July 2022

7 Conclusions

- Al_2O_3 nanoparticles with water as a base fluid enhance the yielding of solar still. It also worked as a heat storage material, releasing energy into water and increasing output during the night.
- Temperature of basin fluid and glass cover are observed to be more with nanofluids as compared to the conventional one.
- Solar still with water based Aluminium Oxide (Al_2O_3) nanofluid having concentrations of 0.05%, 0.1%, 0.15% and 0.2% increase the total distilled water output of the solar still (distilled water) by 18.54%, 22.26%, 24.37% and 20.38%, respectively whereas same enhancement is 18.77%, 22.76%, 25.57%, 23.79% during

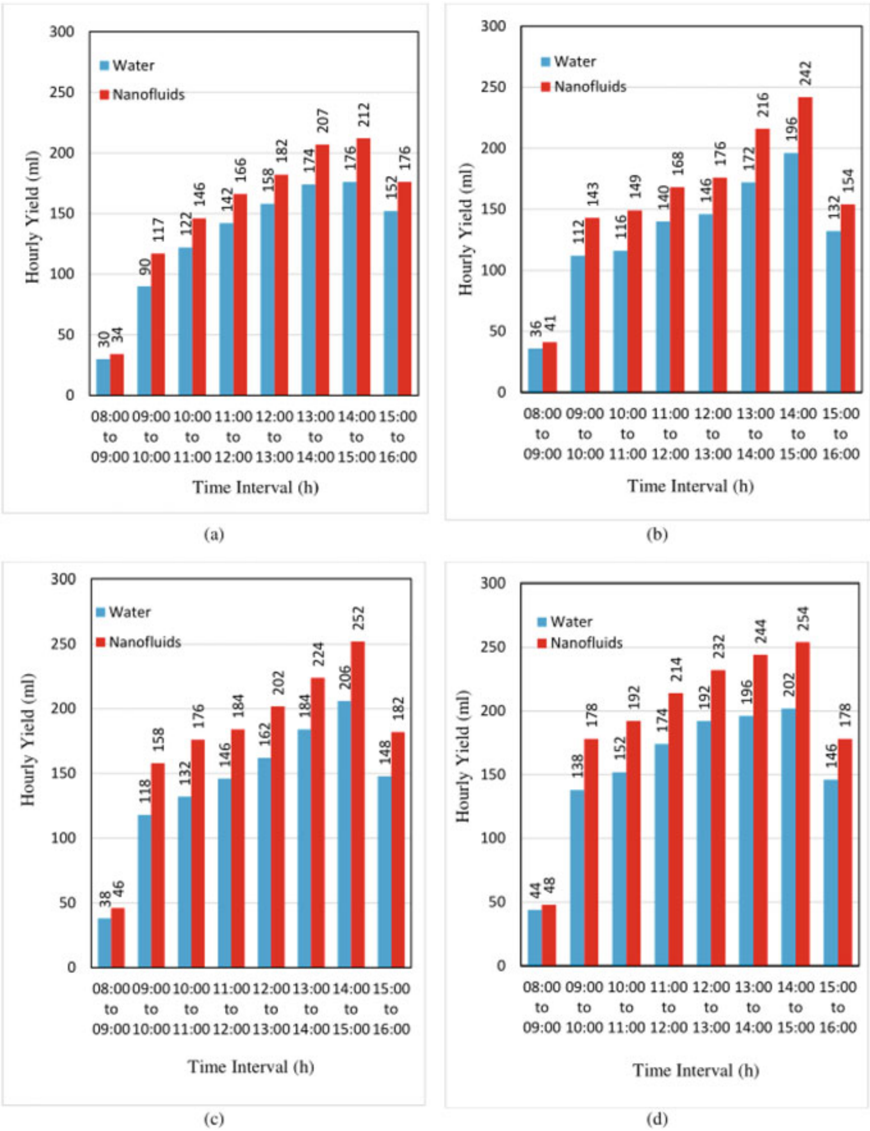

Fig. 6 Comparison in variation of distillate output with time for nanofluids with concentration **a** 0.05% **b** 0.1% **c** 0.15% **d** 0.2%

day hours (08:00 AM–04: 00 PM) and 18.24%, 21.63%, 22.77%, 15.52% during night hours 04:00 PM–07: 00 AM).

- It is found that yielding of distilled water increases with the concentration of Al_2O_3 nanoparticles upto a certain limit and then decreases.

Table 2. Yielding (water distilled) during day and night hours with different concentrations of nanofluids

S. no	Conc. of Al_2O_3 (%)	Yielding (ml) in day hours (08:00 AM to 04: 00 PM)			Yielding (ml) in night hours (04:00 PM to 07: 00 AM)			Total yielding (ml) in day hours (08:00 AM to 07: 00 AM)		
		Water	Water + Al_2O_3	% increment	Water	Water + Al_2O_3	% increment	Water	Water + Al_2O_3	% increment
1	0.05	1044	1240	18.77	822	972	18.24	1866	2212	18.54
2	0.10	1050	1289	22.76	832	1012	21.63	1882	2301	22.26
3	0.15	1134	1424	25.57	852	1046	22.77	1986	2470	24.37
4	0.20	1244	1540	23.79	876	1012	15.52	2120	2552	20.38

Table 3 Quality of distilled water

Property	Sample 1	Sample 2	Sample 3	Sample 4
pH	7.36	7.15	7.91	7.13
TDS (mg/L)	10.18	5.25	7.75	7.27

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