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INFLUENCE OF NANO Al_2O_3 TO IMPROVE THE YIELD OF DOUBLE SLOPE SOLAR STILL

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Abstract

Purpose: The supply of pure fresh water is becoming a rising issue is many areas of the world. Clean water being a basic requirement is still unavailable to a large number of people. The fast development and growth in population and agriculture has helped to increase the need of clean water. The solar distillation is one of the most cost efficient ways to accomplish this.

Methodology: When water evaporates from the basin of the still, it leaves the various impurities behind resulting in clean palatable water. Solar stills have a comparatively low yield but can be used to provide safe water options to rural areas of the world. To increase the yield of the solar still nano Al2O3 fluid is used, which is prepared using a dispersant of Sodium Dodecyl Benzene Sulphonate (SDBS). The still is a double slope basin type solar still with black paint coating on the inside and external reflecting mirrors, to enhance the yield.

Main Findings: This project compares the efficiency and output of double slope solar still with and without the nanofluid. The single basin double slope solar still was fabricated using low cost durable materials and the 0.01 vol. % Al2O3 water based nanofluid was prepared. The results showed a positive outcome of a 15% increase in the rate of distillate collected with the use of nanofluids. The payback period was calculated to be less than 2 weeks without nanofluid and one week with the use of nanofluid.

Implications: The present study is useful for obtaining pure drinking water at remote locations in Sultanate of Oman where solar energy is abundance.

Novelty of Study: Nanofluids are used to enhance the distillation rate when compared to the conventional solar stills.

Keywords: Double slope, Solar still, Nanofluids, Distillate, Solar energy, SDBS, Al2O3

INTRODUCTION

The world today is facing a large scarcity of pure water. Large parts of the world face a lack of accessible clean water. There are various methods of water purification such as flash, multi-effect and membrane distillation. The energy requirements for the process can be provided from sources such as fossil fuels or renewable resources. Solar distillation has proved to be an efficient way to purify sea water to serve the constantly increasing needs of the world. Solar stills are convenient, cheap and environmentally friendly which serves as an advantage whereas the low output is its disadvantage for commercial value.

Solar stills distill water using the heat provided by the sun to evaporate the water which then condenses on the walls of the still, drips down and is collected. This process aids in the removal of impurities present in the water and micro-organisms and obtaining pure water. With the major depletion in fossil fuels and non-renewable energy, the need to shift energy sources to natural sources is ever increasing.

In a nation like the Sultanate of Oman, where there is 300+ days of sunlight, the potential from solar energy is very high and viable. The use of solar stills could help reduce the scarcity of water in different areas and utilize the solar energy to its potential. The use of solar stills proves efficient in multiple aspects such as low energy consumptions and a comparatively higher output. It is also very convenient and is a cost effective way of fulfilling the water needs of interior areas that are going through water stress conditions. The addition of nanofluid enhances the yield of the still which will in turn help commercialize solar stills worldwide.

The attempt is to increase the yield and thus provide to the needs of water in different areas. The thermal conductivity of the water is increased by the suspension of nanofluid and the physical modifications to the solar still. The model is environmentally friendly and simple to construct.

The solar stills can be used worldwide due to its simple nature, cost efficiency and convenience. The modified stills serve a larger purpose as they have a higher output which can fulfill a higher requirement.

LITERATURE REVIEW

Experimental investigation of single basin double slope solar still was performed by Rajamanickam and Reghupathy 2013. The experiments were conducted in India using a double slope solar still with cover tilt angles ranging from 11° to 70°. The optimum tilt angle was found to be 20° during the month of February. The still productivity was also compared with conventional single slope solar still of the same size and the effect of orientations like east-west and north-south on productivity. After fixing the orientation, effect of water depth was studied. The results show that distillate output decreased linearly with increasing water depth in the still. The effects of cooling water flow over the cover plate were studied. Flow rates in the range of 100ml/min to 1800 ml/min were considered and an optimum flow rate for production was found to be 250ml/min. The maximum distillate output of 3.98 L/Day/m2 was obtained with minimum depth of 10mm of water in the basin and at an optimum flow of water flowing over the cover plate. The percentage increase in water production with cooling arrangement was 30.5%in comparison with double slope solar still without cooling. The economic analysis depicted a payback period of 288 days.

Effect of nano fluids on solar thermal energy applications had been reviewed by Suresh, S. 2015.The sun is a nature source of renewable energy. Solar energy consumption is very important in the backdrop of global warming and decrease of carbon dioxide secretion. Solar energy has been explored through solar thermal exploitation, photovoltaic power invention, and so on. Solar thermal consumption is the most accepted utilization surrounded by them. In conservative solar thermal collectors, plates or tubes coated with a layer of selectively absorbing material are used to take up solar energy, and then energy is carried away by working fluids in the form of warm. This type of collector exhibits several shortcomings, such as restrictions on incident flux density and relatively high heat losses. The shortage of fossil fuels and environmental considerations motivated the researchers to use alternative energy source such as solar energy. Therefore, it is essential to improve the effectiveness and recital of the solar thermal systems. In addition, some reported works on the applications of nanofluids in thermal energy storage, solar cells, and solar stills are reviewed. Dispersing outline amounts of nanoparticles into common base-fluids has a significant impact on the optical as well as thermo-physical properties of the base-fluid. Enhancement of the solar irradiance assimilation capacity leads to a higher heat convey rate resulting in more capable heat transmit. Nanofluids are suspension of nanoparticles in base fluids, a new challenge for thermal sciences provided by nanotechnology. Nanofluids have unique features different from conventional solid-liquid mixtures in which mm or µm sized particles of metals and non-metals are dispersed. Due to their excellent characteristics, nanofluids find wide applications in enhancing heat transfer. The aim of this appraisal manuscript is the study of the nanofluids in solar Energy applications. In order to overcome these drawbacks, direct solar absorption collector has been used for solar thermal exploitation.

Fresh water demand for the whole world is increasing day by day due to increase in population, increase in demand from agriculture as well as industries sector. Performance of a modified solar still with internal reflectors is provided by Harimohan, S. and Rajeev, V., 2016. The distillate obtained from the modified still was at 3.00 PM which is 25 ml and considerably higher than the 3ml obtained at the same time from a conventional still which is only 3ml. Maximum temperature obtained from the modified still is 32ºC at 3.30 PM.

Purification of water supplies becomes very important nowadays as the earth's water reserves gets polluted by toxic chemicals. Modelling of water purification system from saline water to drinking water using solar energy is performed by Alpesh et.al.,2011. All three modes of heat transfer such as conduction, convection and radiation are considered. 1.5 Litres of pure water could be achieved from 14 litres of dirty water in six hours of time period with an efficiency of 64.37%. Total dissolved solids (TDS) in the pure water is measured as 81 ppm.

Experimental studies were performed by Pankaj, K.S., Agrawal, S.K. and Agrawal, A., 2013 on the effect of multiple porous blackened jute absorbers floated on the basin water with the help of thermocol insulation for a modified single sloped basin type still. The performance of the still with jute fabric and cotton cloth was compared. The floating porous porous absorber type still performed at higher temperatures and higher yield (12% more) obtained with jute fabric when compared with cotton cloth as absorber material. Experimental results were verified with theoretical values obtained with Dunkle's heat transfer relations. Higher heat transfer coefficients were achieved with jute fabric absorber.

Stability analysis of Al_2O_3/water nanofluid was investigated with the help of zeta potential and visual inspection methods by Rajesh et al.,2017. Visual inspection method is used to calculate the stability period of nanofluids whereas the zeta potential indicates the stability period of nanofluids. Higher zeta potential indicates higher stability period. The stability is also analysed by using dodecyl sulphate with respect to the time elapsed after preparation of nanofluids.

Preparation and stability of the Al_2O_3-water nanofluids as well as CuO-water nanofluids were reported by Lu et al., 2015. Different particle sizes and different mass fractions were explored. Two step method was employed for the preparation of the nanofluids that involves magnetic stirring and ultrasonic vibration in which sodium dodecyl benzene sulfonate was used as dispersant. The nanofluids is found to precipitate if the mass fraction and particle size is high that means stability of the suspension is worse.

Water distillation system that can purify water from any source was designed by Chendake, A.D. et al., 2015. Solar energy is utilised to heat water which will evaporate and allowed to condense on a glass surface. Impurities such as salts, heavy metals and microbiological organisms will be removed by this process and thus purified water is obtained. The model produces 1.6 litres from 12 Litres of dirty water within eight hours of time.Total dissolved solids in the distilled water is 30 ppm with process efficiency of 22.33% at water depth of 0.02 m.

Effect of various parameters such as water depth inside the solar still, sprinkler and various dies on the performance of double slope solar still was investigated by Hitesh, N.P., 2011. It was observed that condensation rate enhanced by incorporating the sprinkler. It was found that the productivity of the solar still was improved when the water level in the still is low. Presence of black die also improved the performance of the still.

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Performance analysis of two segment "V" type solar still with cement block absorber was performed by Suneesh, P.U. et al.,2013. Efficiency of the still with cement block absorber improved from 20% to 24% when compared with that of the still without the absorber. Results are provided for efficiency of the still, variation of internal heat transfer and variation of distillate yield. Glass inner and outer surface temperatures, ambient temperature and solar radiations were recorded.

METHODOLOGY

Model diagram (2D) of the experimental setup is shown in the figure below with the details. Reflecting mirrors are used to enhance the evaporation rate and the yield.

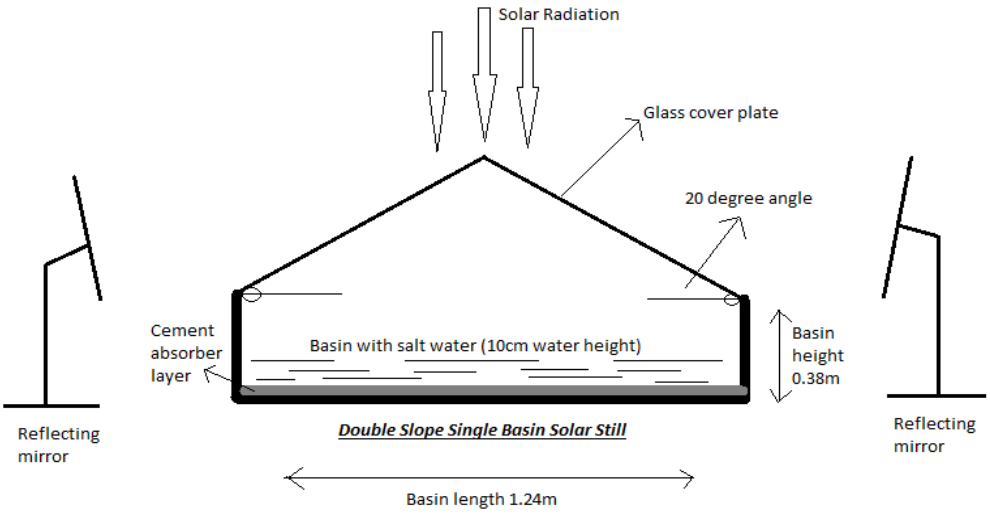

Figure 1: 2D diagram of the proposed model

The nano fluid chosen is Al_2O_3 water based which is prepared using a dispersant of Sodium Dodecyl Sulphonate (SDS). The Al_2O_3 nanoparticles are added into the base fluid- water along with the SDS particles. The mixture is then left on the magnetic stirrer for 2 hours to ensure the particles are dispersed throughout and left to rest for 3-5days. The Al_2O_3 nanofluid is then tested for its pH, conductivity, and stability.

The preparation of nanofluid was done at different ratios and concentrations. The first batch mixed at a 1:1 ratio was found to be unstable and could not be used. The second was then prepared at a 1:2.5 ratio and was more stable than batch one with a pH value of 6.8.

The final batch concentrations were calculated using a formula which helped to calculated the mass required to go into the mixture according to the volume percentage needed in the final suspension.

$$\phi = \frac{1}{\frac{100}{m}\frac{\rho_{np}}{\rho_{bf}} + 1} \times 100\%$$

Where, ϕ = volume concentration

ρ_{np} = density of nanoparticles

ρ_{bf} = density of base fluid

m = mass of nano particles

The Al_2O_3 water based nanofluid was prepared in the lab using dry aluminium oxide nanoparticles and sodium dodecyl Sulphonate as the dispersant to help the nanoparticles dissolve in the base fluid better. Water was chosen to be the base fluid as it is non-toxic.

3.92g of nanoparticles was mixed into 500ml with the same 3.92g of dispersant. The mixture was stirred manually for 30minutes and then placed on the magnetic stirrer for 2 hours. After the mixture was stirred on the magnetic stirrer, it was then placed in the shaker for another 3 hours after which the nanofluid suspension was left to rest before further testing.

$$\phi = \frac{1}{\frac{100}{m} \times \frac{\rho np}{\rho bf} + 1} \times 100$$

$$0.01 = \frac{1}{\frac{100}{m} \times \frac{3890}{1000} + 1}$$

$$\frac{1}{0.01} = \frac{100}{m} \times \frac{3890}{1000} + 1$$

$$\frac{1}{0.01} - 1 = \frac{100}{m} \times 3.890$$

$$99 = \frac{389.0}{m}$$

$$m = \frac{389.0}{99}$$

$$m = 3.9293g$$

The prepared nanofluid suspension was then tested for pH levels, thermal conductivity and its stability. Visual inspection was also done by showing a light through the suspension to judge the dispersion of the nanoparticles through the mixture. The pH of the nanofluid was found to be 8.5 which is considered to be fair and usable.

Present the materials, methods, survey, questionnaire etc used for the study. Author should explain whether this study is experimental, or review study, or simulation based or survey based. Discuss software, hardware's used during study with their brand names. Mention all research conditions, assumptions, theories followed. This section should be easy enough for any reader to repeat the study under similar conditions.

Figure 2 Nanofluid suspension on magnetic stirrer

Table 1 provides the choice of materials with their justifications.

Table 1: Choice of materials with their justifications

Sl. No.	Components	Materials	Properties
1	Main base of the still	Wood	• Rigid and insulating material. • Cheaper and lower weight.
2	Absorber in the basin	Concrete	• High radiation absorption and thermal conductivity. • Immune to corrosion.
3	Top cover (condenser)	Hardened glass	• Transparent to solar radiation. • Non-absorbent of water and non-toxic.
4	Condensate collection pipe	PVC	• Non-toxic and non-corrosive.
5	Sealant	Silicon	• Not affected by high temperature. • Long lasting. • Water resistant.
6	Condensate collection tank	Plastic	• Non-toxic • Resistant to corrosion
7	Tank	Plastic	• Non-toxic • Resistant to corrosion
8	Radiation absorbent	Black board paint	• High absoption of radiation. • Insoluble in water • Non-toxic

9	Nanofluid	Al_2O_3 water based nanofluid	• High thermal properties • Enhances heat absorption by water
10	External Reflectors	Mirrors	• Highly reflective

Fabrication of the still was completed as shown in Figures 3 and 4 and tested for its performance.

Figure 3 Double slope solar still

Figure 4 Double slope solar still with reflector

The completed still was once again filled with water and tested for any leakage. After which, the basin of the still was filled with sea water up to 10cm in height for maximum evaporation. The basin of the still held a volume of 97litres of water at a height of 10cm.

The output of the solar still was recorded for 5 days without nanofluid, using seawater. The pH, turbidity, conductivity and TDS of the sea water and the distillate were analysed and compared against the standard parameters.

To test the pH, turbidity and TDS of the sea water and the distillate, samples were taken to the laboratory to be tested using the specialized equipment. After 5 days of testing the output without the nanofluids, 100ml of nanofluid was introduced into the basin of the still with the sea water. The presence of nanofluid showed an increase in the distillate collected in addition to a faster rate of evaporation.

FINDINGS / RESULTS

The solar still was put into test in Muscat, where the maximum temperature reached up to 45°C in the summer month of May, which is an ideal condition to use a solar still. The still was placed in an open area with no obstacles blocked the sunlight from reaching the still.

The still was placed on a wooden stand to prohibit any heat from being lost into the surroundings. The water was filled into the still at 7am daily and the distillate was collected until 5pm. The maximum surrounding temperatures were recorded between 12noon and 3pm where temperatures went up to 45°C, during which the distillate output was highest. The still was checked every few hours and refilled when the water was almost fully evaporated.

The distillate collected was measured in volume for 5 days without nanofluids. Then the Al_2O_3 water based nanofluid was added along with the sea water and the output was measure for another 5 days. Finally, the average of the results was compared and analyzed to study the effect of the nanofluid on the production rate of the solar still.

100ml of the nanofluid was added to the 97 litres of water supplied into the still and it showed a higher rate of evaporation of water from the start of the day to the end. It was observed that the nanofluid did increase the solar absorptivity of the water making it evaporate at a higher rate than without the presence of the nanofluid.

Table 2: Output of the still without nanofluids

Time	Atmosphere Temperature (°C)	Distillate Collected (litres)
8am	35	0.5
9am	36	0.8
10am	38	1.3
11am	39	1.5
12noon	40	2.3
1pm	42	3.2
2pm	43	3.5
3pm	42	3.3
4pm	37	1.8
5pm	35	1.2

Table 3: Output of the still with nanofluids

Time	Atmosphere Temperature (°C)	Distillate Collected (litres)
8am	36	1.3
9am	37	1.7
10am	38	2.4
11am	40	2.9
12noon	41	3.9
1pm	43	4.5
2pm	44	5.3
3pm	43	4.6
4pm	40	3.8
5pm	36	3.5

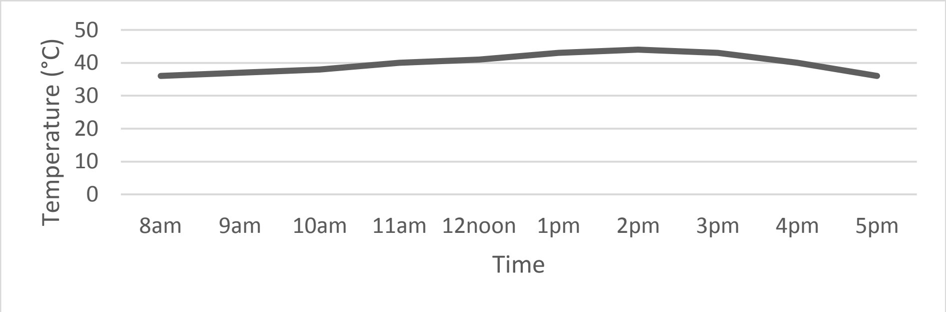

Figure 5 Variation of average atmospheric temperature with respect to time

It is clear from Figure 4 that the temperature was highest during 1pm and 3pm daily which means the maximum evaporation took place at that time when the highest distillate volume was collected.

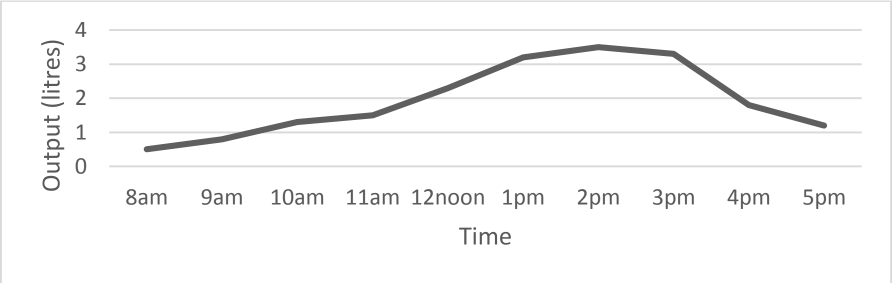

Figure 6 Analysis of distillate collected vs. time (without nanofluids)

Figure 5 shows the relationship between the volumes of distillate collected without nanofluid against the time. The highest yield of more than 2litres was obtained during the hours of the highest temperature between 12 noon and 3pm.

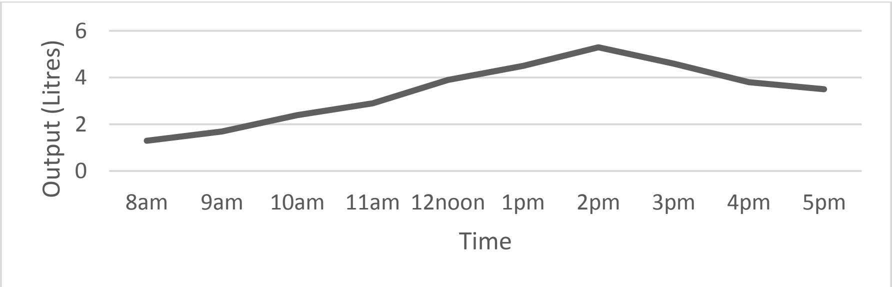

Figure 7 Analysis of distillate collected vs. time (with nanofluids)

Figure 6 shows the relationship between the volumes of distillate collected with the nanofluid against the time. The highest yield of more than 4litres was obtained during the hours of the highest temperature between 12noon and 3pm.

Table 4: Test results of PH, Turbidity and TDS of water samples

Parameters	Sea water	Distillate collected		Standard values
		without nanofluid	*with nanofluid*	
pH	7.6	6.8	7.1	7.0
Turbidity	0.05UNT	0.01UNT	0.02UNT	<1 UNT
TDS	54.3ppt	22.56ppt	23.26ppt	<600 ppm

The solar still was supplied with 97litres of water without nanofluid and had an output of 19.4litres of distillate, which means 20% production rate.

With the addition of the nanofluid, the distillate output was 33.9litres, which makes the production rate 35%, which shows the increase in production by 15%. Moreover the PH, Turbidity and the TDS of distillate is on par with the standard values as evident from the Table 4 above.

The economic value of the still depends on several different factors such as the cost of construction and cost of maintenance. The total amount needed to construct the solar still amounted to RO. 49.2. With the output collected of 19litres per day and the rate of 1 litre= RO. 0.200, the cost of the solar still can be covered in less than two weeks that is without nanofluids. With the use of nanofluid, the output was 34litres with which the cost of the still can be covered in one week, after which the initial investment is returned and the water collected is free of charge.

CONCLUSION

The availability of clean drinking water around the world is decreasing day by day. Most rural areas do not have access to potable water for their daily consumption needs. This project was aimed at targeting this issue. Solar stills are a simple and cost efficient way to convert saline or brackish water into potable drinking water.A single basin double slope solar still was constructed in this project using wood and a concrete layer inside the wooden basin as the absorber to increase the thermal absorptivity. Al_2O_3 water based nanofluid was prepared in the laboratory according to the specifications and was used in the feed water of the solar still to enhance the output. The results were then compared to analyze the effect of the nanofluid on the output of the solar still. The constructed solar still was tested in an open area with maximum access to solar radiation during the summer in the month of May 2018. The solar still was tested without the nanofluid and had a total yield of 19.4litres from the 97litres supplied and the yield increased to 33.9litres with the addition of the nanofluid. The rate of distillate production was increased by 15% with the addition of nanofluid to the feed water. The collected distillate was then tested and found to have acceptable specifications making it safe for consumption. The payback period of the still was calculated to be less than two weeks without the nanofluid and one week with the use of nanofluid in the feed water.The solar still can be used to purify saline water into potable drinking water and can provide advantageous in times of drought. The solar still is made of durable materials and can be used for a long period of time without issues, if constructed correctly. The solar still is mainly aimed at areas without direct access to drinking water. With its simple construction and barely any maintenance cost, project requires only the initial investment in the raw materials and at the same time the project can provide a very basic necessity to people with no other option.

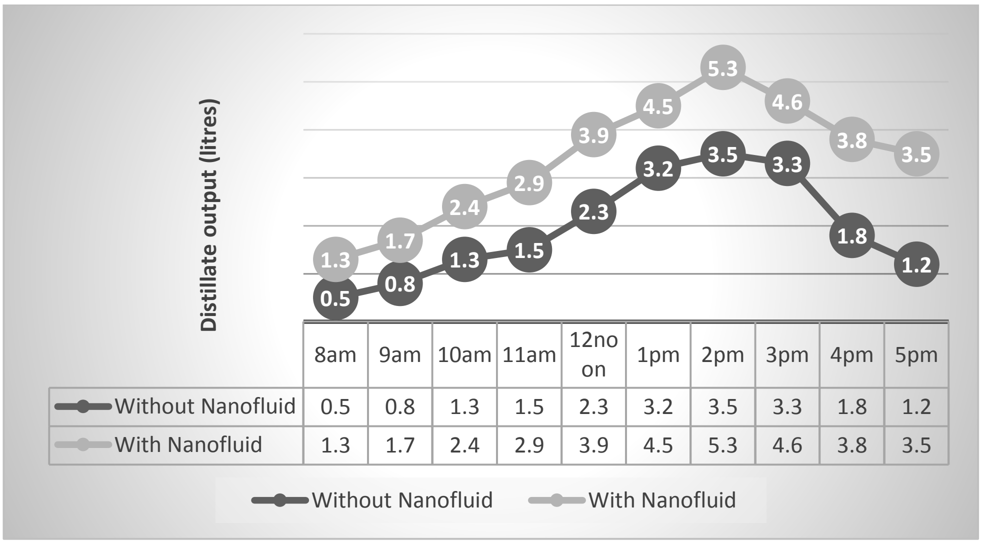

Figure 8 Comparative analysis of distillate collected without and with nanofluid

LIMITATION AND STUDY FORWARD

The project was carried out and the results obtained were successful. However, more can be done to further improve the output of the solar still such as 1. Different nanofluids can be used to increase the yields of distillate 2. Sprinkler system can be used to cool the cover glass that can also increase the rate of condensation on the glass 3. Internal reflectors can be fitted inside the solar still to increase the concentration of solar radiation to the water 4. Steps can be constructed inside the basin to reduce the height of the water and increase the rate of evaporation 5. Blackened jute cloth can be used as an absorber inside the basin. The use of jute cloth has proved to increase the yield by up to 10%.

CONFLICT OF INTEREST AND ETHICAL STANDRADS

There is no conflict of interest with the present organisation and no unethical practices followed in doing the project.

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