Performance enhancement of single slope solar still using ZnO & CuO

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Abstract : Pure water requirement for the living of human on earth has been increased with the increase in the population. Most of the water available on the earth is brackish or impure which cannot be used in its present form. The solar distillation is the best technology to resolve this problem, but the low productivity of the solar still is the biggest challenge. In this experimental paper, several factors are discussed which enhance the productivity of solar still. This research showed the fabrication of the single slop solar still with solar water heater has been done successfully and the setup is ready for experimentation. And Total yield of water is increase with respect to conventional (Without Nanoparticles) solar still 26.85 % & 69.49% respectively with the use of ZnO & CuO Nanoparticles in solar still at water depth of 3cm.When water depth is increases in day time then total yield of water is decreased.

***IndexTerms* - solar still, single slope, productivity, Nano particles, experimentation, distillation.**

I. INTRODUCTION

Nearly 1.1 billion individuals in this world have lacking access to safe drinking water. There are 26 nations do not have enough water to keep up agriculture and financial advancements. Rivers, lakes and groundwater reservoirs for fresh water requirement are going to be depleted. Most of the diseases are due to brackish water [1]. According to a survey, 79% of the water available on the surface of earth is salty and in the form of sea water. 20% of the water available is brackish and only one percent of water is available as the fresh and drinkable water [2].

Distillation is a technique to convert brackish or impure water into fresh and drinkable water. Some of the conventional distillation processes such as Multi-effect evaporation, thin film distillation, Multi-stage flash evaporation, reverse osmosis and electrolysis are the most feasible solution for large water requirements [3]. Solar still is an easy technique for distilling water which utilizes the low cost available solar energy. It is widely used to produce potable water [3][4].

Nature is carrying out the process of water desalination since ages. Oceanic water due to solar heating converts into vapors and pours down as precipitation on earth in the form of fresh water. Due to rapid expansion of population, accelerated industrial growth and enhanced agricultural production, there is ever increasing demand for fresh water. Demand of fresh water (potable water) has increased from 15-20 liters/person/day to 75-100 litres/person/day.In the study by Akash et al. [5], it was found that the maximum yield was for the least water depth [4].

Maintaining minimum depth of water in the solar still may appear dry spots. So, it is very difficult to keep the minimum depth of water in solar still. Therefore, some methods have must be invented to maintain optimum depth of water. Phadatre and Verma [6] analyzed the influence of water depth on internal heat and mass transfer in a plastic solar still of Plexiglas. An operational parameter of water depth was kept from 2 cm to 12 cm. It was found from the experiment that as depth of basin water increased the output decreased.

The basin water temperature was found inversely proportional to the basin water depth. In the experiment the convective heat transfer coefficient was reported less than the radioactive heat transfer coefficient and evaporative heat transfer coefficient was highest at that point. Singh and Tiwari [7] analyzed active and passive solar stills at various climate conditions and the effect of water depth on productivity was seen. It was found that the optimum water depth varied with the climate conditions.

Figure3 shows the monthly output of still at different water depth. Glass cover plate plays an important role to receive solar radiation from the sun. Hence the tilt angle should be such that it can receive maximum solar radiation. It is observed that the glass cover tilt angle varies according to the location and for a particular location there is one optimum tilt angle which depends mainly upon latitude and elevation [8].

Distillate output increases with increase in temperature difference between evaporating surface and condensing surface and with increase in inclination angle [9].Elango et al. [10] used nanoparticles of AlO, ZnO and SnO 2 3 2 mixed with water in 0.05% and 0.1% concentrations to enhance the rate of heat transfer and rate of water evaporation, which improved the performance of the solar still.

Production rate was maximum in case of Al O water Nano fluid which is about 2 3 29.95% higher and 12.67% and 18.63% higher production was there in case of ZnO and SnO Nano fluids respectively as 2 compared to still with water at 0.1% concentration. Sain and Kumawat [11] tested the performance of single slope single basin solar still using nanoparticles mixed with black paint on absorber.

Study was conducted by using Al_2O_3 nanoparticles mixed with black paint to increase the radiation abruption of the absorber plate. The experiment was analyzed at water depth varying from 1 cm to 3 cm. The effect of different absorbing materials on solar distillation was analyzed by Priya and Mahadi [12]. They used no toughened Glass glazing surface tilted at angle of 25° with water Depth of 5 cm. Absorbing materials used were Ink and black dye in water solutions and the results were compared with the Distillation without any absorbing material in the water tank.

The experiment was carried out at 20 ppm, 30 ppm, 50 ppm and 70 ppm 3 concentrations of black dye and Ink in feed water. It was observed that the distillation was improved with increase in concentration and the improvement was observed from 20 Ppm to 50 ppm. Rate of evaporation was same when the Concentration was increased from 50 ppm to 70 ppm. Insulation is also an important part of still because these materials should have low conductivity and should be easily available [13].

Materials for basin and insulation in solar still prototype was evaluated by Burbano[14] they used Sawdust and Styrofoam which have low conductivity 0.09 and 0.037 respectively, and easily available, especially sawdust. Insulating thickness was kept 5 cm because a further increase in insulation thickness would result in rise the total yield. Increasing the thickness beyond 5cm has a little effect on the still production. The performance of a solar still (SS) was compared by Hasim et al. [15] using five different materials as insulation.

SS-1 was without insulation, SS-2 was with plywood, SS-3 was with glass wool and plywood, SS-4 was with 5 cm thickness of hay and plywood & SS-4 was with 5 cm thickness air gap between basin and the glass bottom. While maintaining the minimum depth in the solar still dry spot formation occurs. Therefore, for maintaining the minimum depth in the solar still, absorber plate having a stepped structure formed by Velmurugan (2008) [16].

Fifty trays of dimension 99 × 99 mm^2 were used in this experiment. Use of fins and sponge ladder were also used in this experiment on singe slope solar still which increased its productivity as shown in figure 8.Arun Kumar et al. [17] used seven solar still designs such as spherical solar still, hemispherical solar still, pyramid solar still, double basin glass solar still; concentrator coupled single slope solar still, tubular solar still and tubular solar still coupled with pyramid solar still.

All the solar stills were operated on the same climatic conditions in order to analyze the impact on productivity enhancement. Figure 9 shows the comparative view of production yield of these seven solar still designs. Compound parabolic concentrator solar assisted still showed the highest yield.

2 NOMENCLATURE

- Global solar radiation in (W/m^2)
- Ambient temperature in (Ta in ºC)
- Still water temperature , in (T_1, T_5 & T_9 in ºC)
- Vapour temperature, in (T_2, T_6 &T_{10} in ºC)
- Glass cover temperature, inner in (T_3,T_7 & T_{11} in ºC)
- Glass cover temperature, outer in (T_4,T_8 &T_{12} in ºC)
- Yield of distilled water in (M_1, M_2 & M_3ml)
- Water depth c.m.

2.1 Objective of Work

The main Objective of work In the experimental setup includes:

- Fabrication of single slope solar water distillation system.
- Performance improvement of solar still by incorporating energy storage materials.

1. Cupric Oxide (CuO)
2. Zink Oxide (ZnO)

- Effect of variation of filling water depth on the performance. Water at different levels (5,4,3 cm) will be tested.

2.2 Experimental Setup And Instrumentation

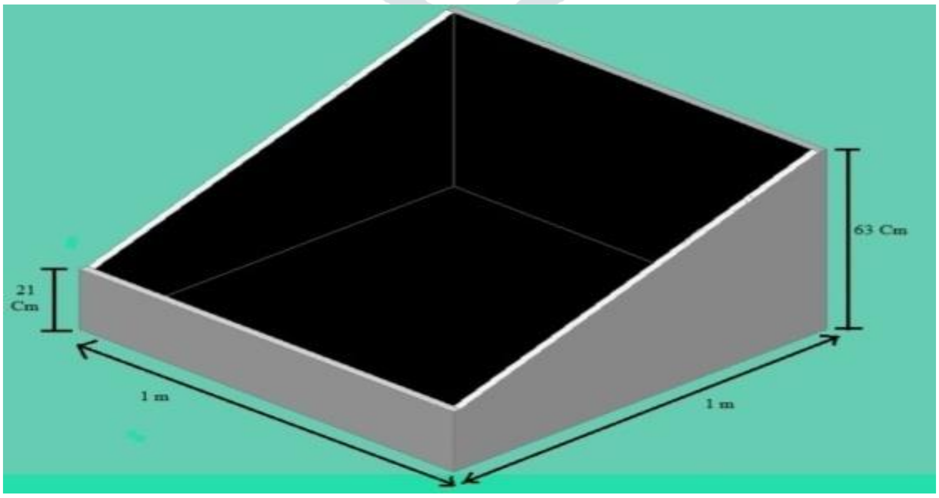


Fig: 1 D diagram of single slope solar still

The experiments were conducted in the month of August and September at Jabalpur city, Madhya Pradesh State in India. The still boxes were constructed with stiff plywood and four minute araldite was used to seal up the spaces. Then, the plywood boards were nailed together to reduce heat loss in the system. Aluminum sheets were also used for the absorber/basin due to its high thermal conductivity. The basin was painted black in order to enhance adsorption of heat by water.

The bottom surface of the still basin was also painted black to absorb a large amount of solar radiation. Moreover, the basin was properly fitted into the plywood boxes before being covered with a 4 mm thick transparent collector glazing. It was therefore fitted at the end of the glass slope. The aim was to collect and channel the distillate through a flexible hose into a plastic storage container outside the still.

2.3 Actual Experimental Setup of Single Slope Solar Still

2.4 Single Basin Solar Still Components

- Basin
- Black Liner
- Transparent Cover
- Condensate Channel
- Sealant
- Insulation
- Supply and Delivery System

Table : 1 Specification Of Solar Still

S. No.	Component	Specification
1.	Black coated iron sheet thickness	(1 x10^{-3} m)
2.	Length	1.0 m
3.	Width	1.0 m
4.	Front height	.21m
5.	Back height	0.63m
6.	Glass thickness	0.004 m
7.	Inclination angle of glass (latitude angle)	23º
8.	Effective Glass area	1.0 m²
9.	Water holding capacity	100 liters
10.	Insulation thickness	0.02m
11.	Wooden thickness	0.015m
12.	Water storage tank	50 liters
13.	Distilled water storage tank capacity	5 liters
14.	Iron stand	1.07m x1.07m x1m
15.	Wooden stand	2m height

2.6 Measuring Instrument Used;

- **Solar power meter:-**for global solar radiation measurement in W/m2
- **Digital Thermocouple:-** for temperature measurement in ºC
- **Beaker:-**for measuring of distilled water in 1ml to 1000ml
- **Mercury/alcohol thermometers:-**for measuring of ambient temperature in ºC
- **Hygrometer:-**for Measuring of relative humidity in %

Fig. 2 TES 1333R Solar Power Meter With Data Logger

Fig. 3 One Digital Thermocouple:- For Temperature Measurement

Fig. 4 One Beaker:- For Measuring Of Distilled Water In 1ml To 1000ml

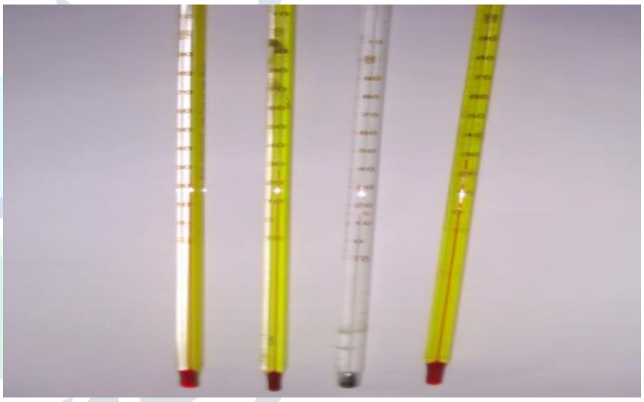


Fig. 5 Mercury/Alcohol Thermometers:- For Measuring Of Ambient Temperature InOc

Fig. 6 Hygrometer:- for Measuring of relative humidity in %

3 METHODOLOGY

1. Fabrication of 3 identical single slope solar water distillation system.
2. To find out temperature variation in both the cases, i.e. Without Nanoparticles, Zink Oxide (ZnO) & Cupric Oxide (CuO).
3. To calculate the amount of fresh water yield per day in various test conditions.
4. Effect of variation of filling water depth on the performance. Water at different levels (5,4,3 cm) will be tested

3.1 Nano Particles Used

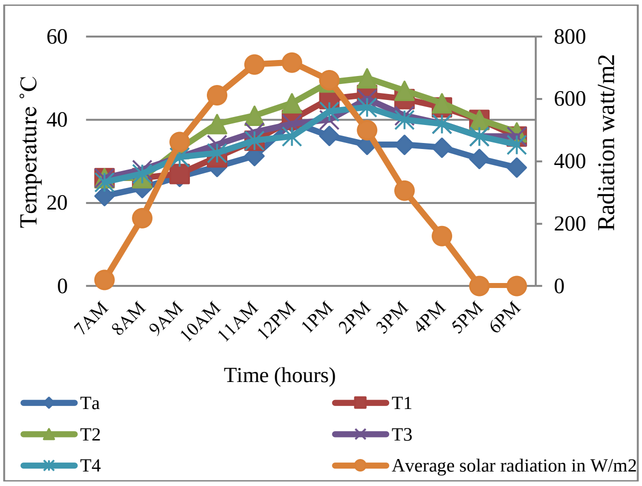
Fig. 8 Zink oxide (ZnO)

Fig. 7 Cupric oxide (CuO)

Table: 2 Properties of Nanoparticles

S. No.	Properties	ZnO	CuO
1	Form	Nanoparicle	Nanoparicle
2	Colour	White	Black
3	pH	7	6.1
4	Molar mass	81.406 g/mol	79.545 g/mol
5	Density	5.6 g/cm3	6.315 g/cm3
6	Melting point	1974 0C	1326 0C
7	Boiling point	1974 0C	2000 0C
8	Solubility in water	0.0004%	Insoluble
9	Refractive index	2.013	2.63

4 RESULTS



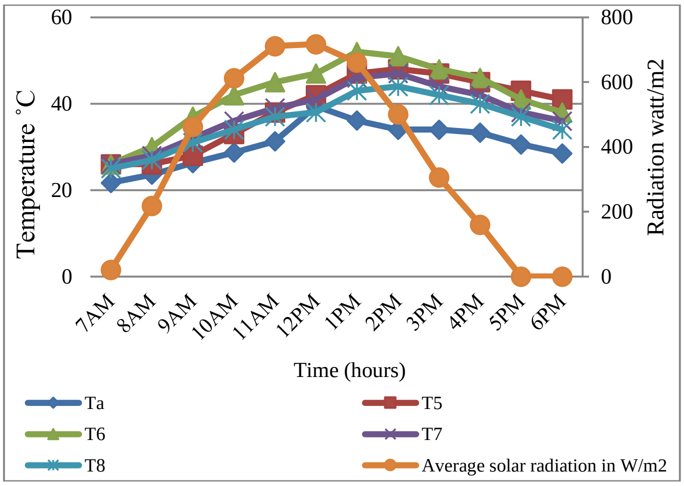
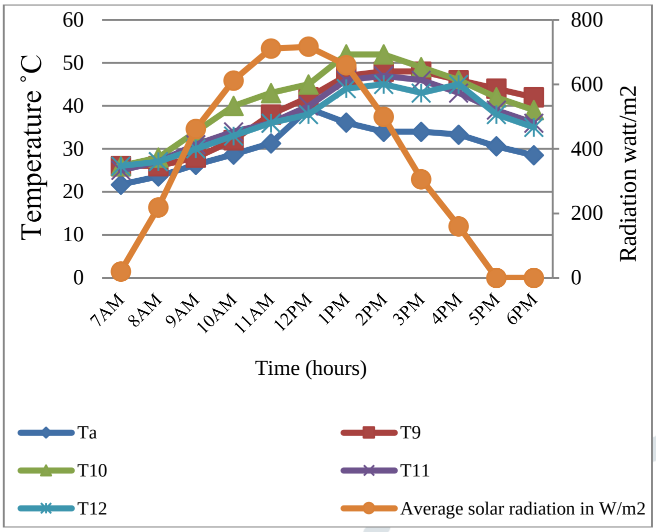


Fig. 9 Variation of ambient parameters in solar still without Nanoparticles at 3 cm water depth

Fig. 10 Variation Of Ambient Parameters In Solar Still With (Zno)At 3 Cm Water Depth



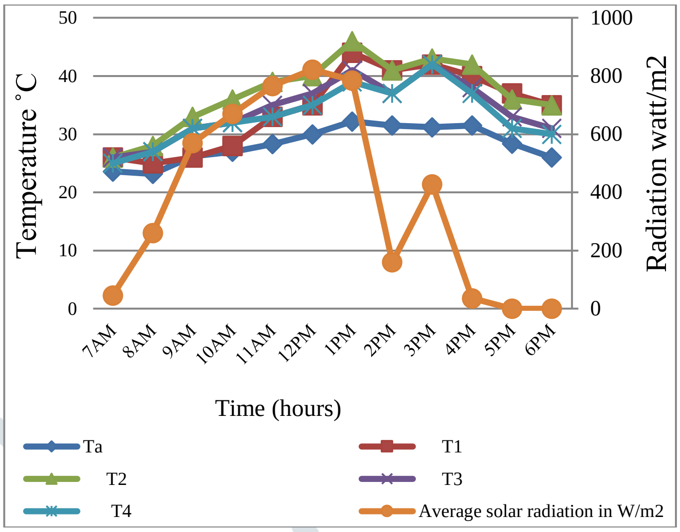
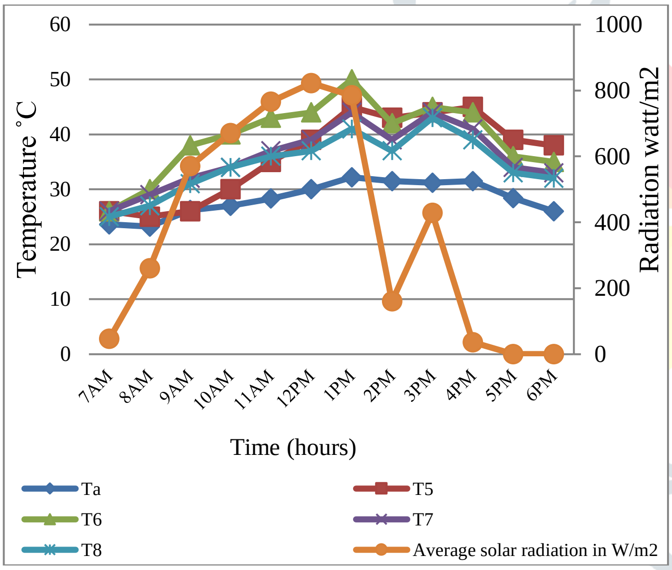


Fig. 11 Variation of ambient parameters in solar still with (CuO) at 3 cm water depth

Fig. 12 Variation of ambient parameters in solar still without nanoparticleat 4 cm water depth



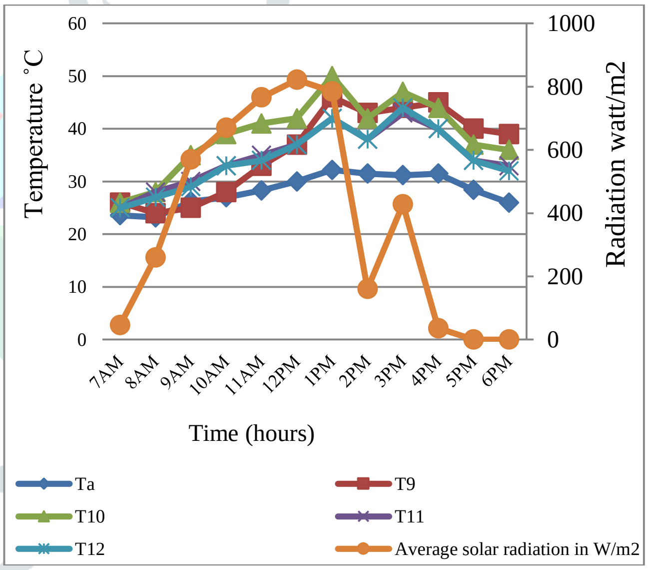


Fig. 13 Variation of ambient parameters in solar still with (ZnO)at 4 cm water depth

Fig. 14 Variation of ambient parameters in solar still with (CuO) at 4 cm water depth

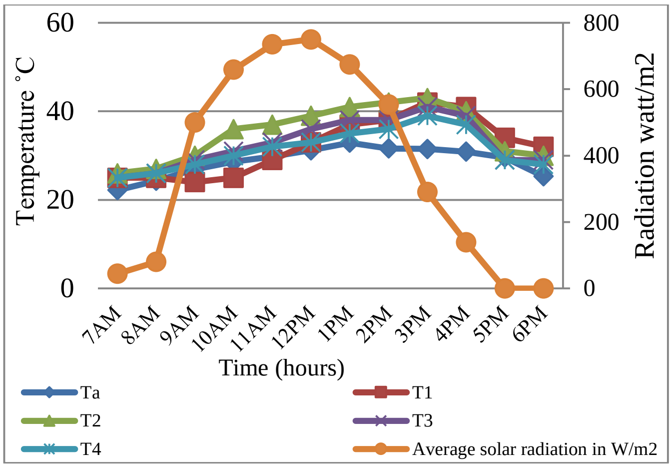


Fig. 15 Variation of ambient parameters in solar still Without nanoparticles at 5 cm water depth

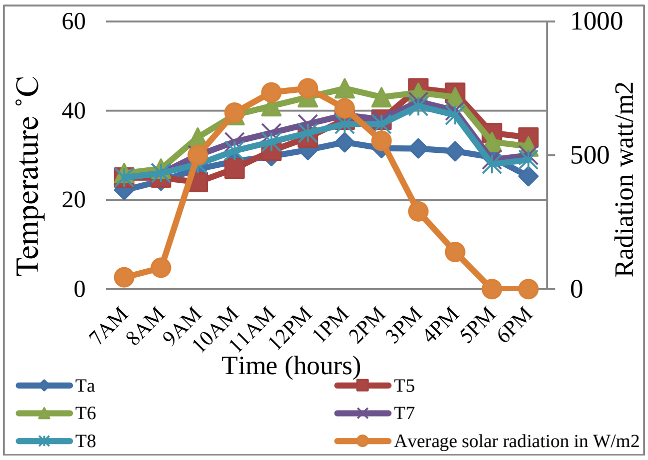


Fig. 16 Variation of ambient parameters in solar still with ZnO at 5 cm water depth

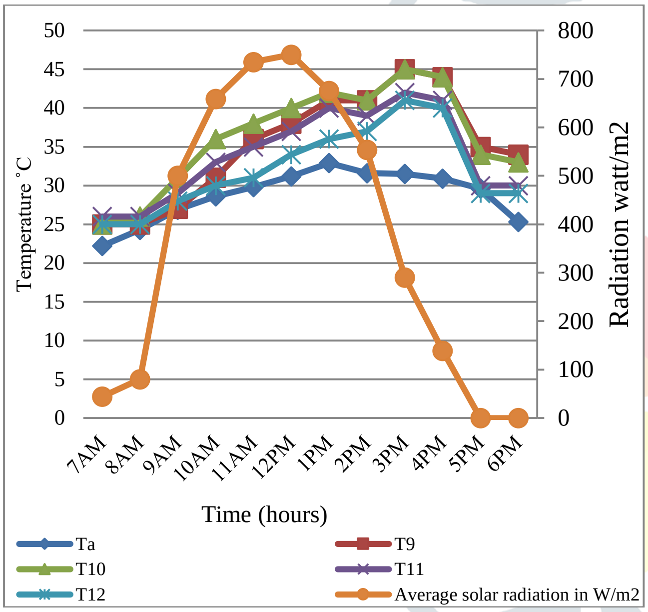


Fig. 17 Variation of ambient parameters in solar still with (CuO) at 5 cm water depth

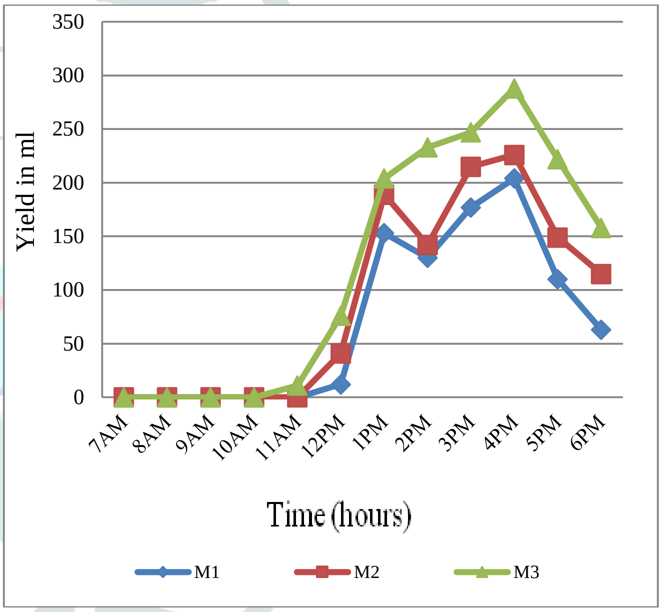


Fig. 18 Yield (ml) V/S time (hour) for solar stills water depth (3 cm)

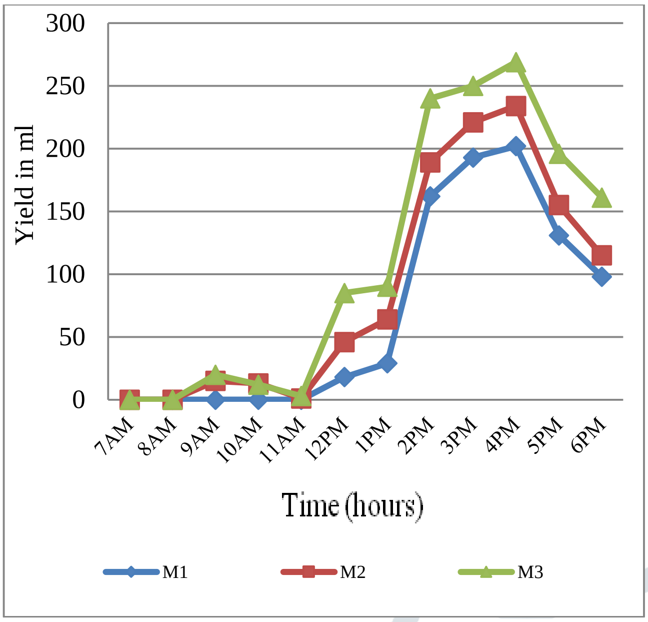


Fig. 19 Yield (ml) V/S time (hour) for solar stills water depth (4 cm)

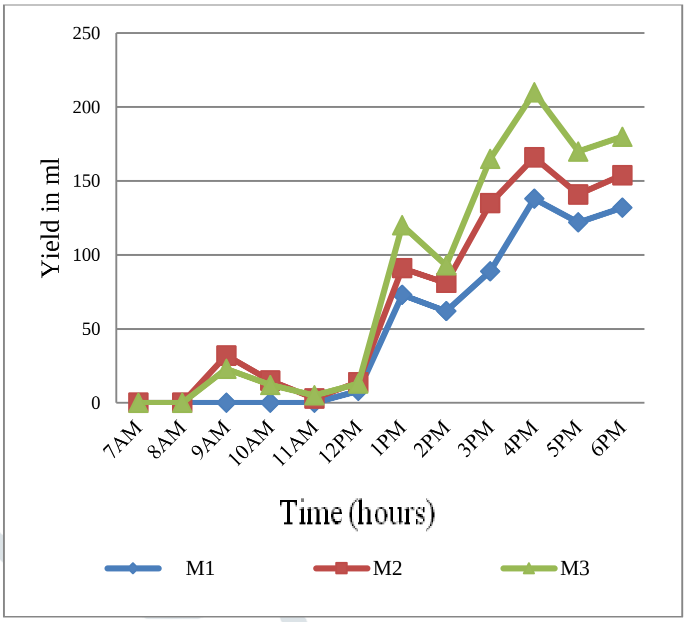


Fig. 20 Yield (ml) V/S time (hour) for solar stills water depth (5 cm)

Fig 21 shows the accumulated distilled water modified still (ZnO and CuO) yield is respectively up to 832,991 ml/m^2 day for the solar still while its value was 624 ml/m^2 day for the conventional solar still (without nanoparticles) at water depth of 5 cm (07.00 am to 06.00 pm).
The accumulated distilled water modified still (ZnO and CuO) yield is respectively up to 1053,1326 ml/m^2 day for the solar still while its value was 833 ml/m^2 day for the solar still (without nanoparticles) at water depth of 4 cm (07.00 am to 06.00 pm).
The accumulated distilled water modified still (ZnO and CuO) yield is respectively up to 1077,1439 ml/m^2 day for the solar still while its value was 849ml/m^2 day for the solar still (without nanoparticles) at water depth of 3 cm (07.00 am to 06.00 pm).

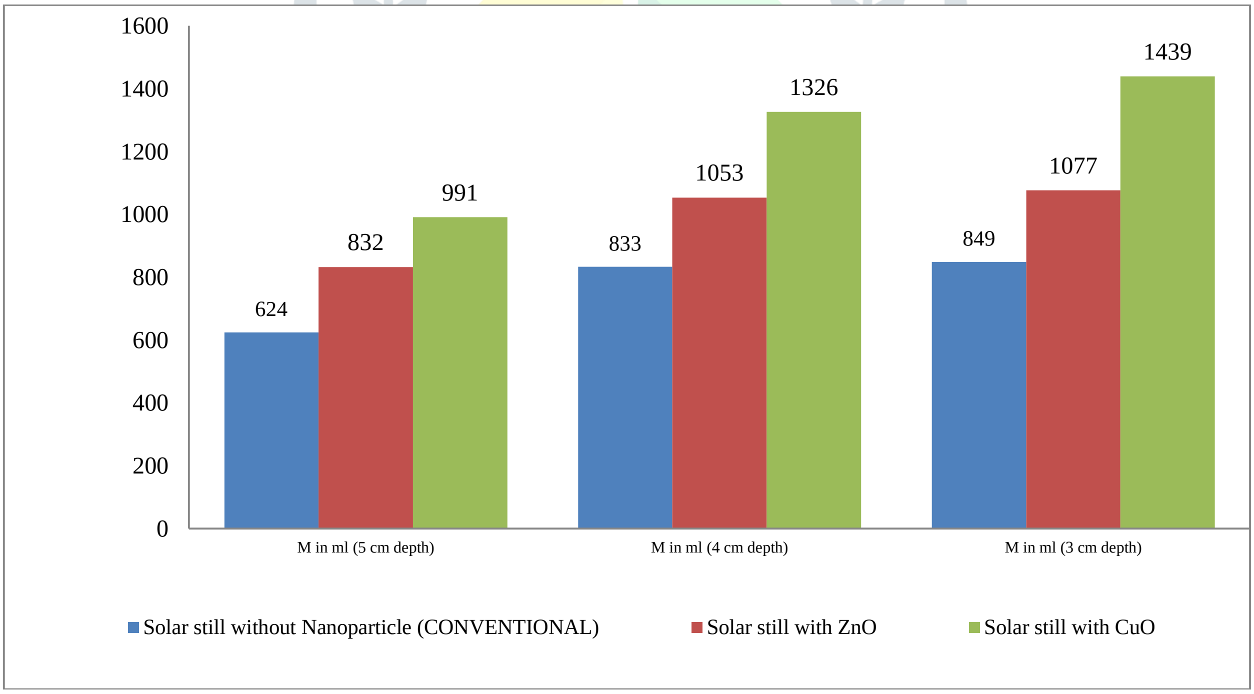


Fig. 21 Variation of yield productivity of solar still without Nanoparticles, ZnO&CuO

5. CONCLUSION

- The fabrication of the single slop solar still with solar water heater has been done successfully and the setup is ready for experimentation.

- Total yield of water is increase with respect to conventional (Without Nanoparticles) solar still 33.33 % & 58.81% respectively with the use of ZnO&CuO Nanoparticles in solar still at water depth of 5cm.
- Total yield of water is increase with respect to conventional (Without Nanoparticles) solar still 26.41 % & 59.18% respectively with the use of ZnO&CuO Nanoparticles in solar still at water depth of 4cm.
- Total yield of water is increase with respect to conventional (Without Nanoparticles) solar still 26.85 % & 69.49% respectively with the use of ZnO&CuO Nanoparticles in solar still at water depth of 3cm.
- When water depth is increases in day time then total yield of water is decreased.

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