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Review of effect of geometry & use of Nanofluids on performance of solar still

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Abstract:-*The world demand for potable water is increasing steadily with growing population. Water desalination using solar energy is suitable for potable water production from brackish and seawater. As the productivity of solar still depends on its geometry, basin water temperature, intensity of solar radiation, type of cover used, angle of tilt of cover, etc. Many researches and development works tried to enhance the productivity of solar stills using different methods such as changing shapes of solar stills & increasing thermal conductivity of water. In this paper review is done on how shape of solar still affects the production of water from solar still. Also how various nanofluids affect the performance of solar still?*

Keywords-*Solar still, geometry, nanofluids, productivity*

I. INTRODUCTION

Distillation is one of many processes available for water purification, and sunlight is one of several forms of heat energy that can be used to power that process. To dispel a common belief, it is not necessary to boil water to distill it. Simply elevating its temperature, short of boiling, will adequately increase the evaporation rate. In fact, although vigorous boiling hastens the distillation process it also can force unwanted residue into the distillate, defeating purification.

Distillation requires an energy input as heat, electricity and solar radiation can be the source of energy. When Solar energy is used for this purpose, it is known as Solar water Distillation. Solar Distillation is an attractive process to produce portable water using free of cost solar energy. This energy is used directly for evaporating water inside a device usually termed a “Solar Still”. Solar stills are used in cases where rain, piped, or well water is impractical, such as in remote homes or during power outages.

The use of solar thermal energy in desalination applications has so far been restricted to small-scale systems in rural areas. The reason for this has mainly been explained by the relatively low productivity rate compared to the high capital cost. However, the coming shortage in fossil fuel supply and the growing need for fresh water in order to support increasing water and irrigation needs, have motivated further development of water desalination and purification by renewable energies.

II. SOLAR STILL: WORKING

As the available fresh water is fixed on earth and its demand is increasing day by day due to increasing population and rapidly increasing of industry, hence there is an essential and earnest need to get fresh water from the saline/brackish water present on or inside the earth. This process of getting fresh water from saline/brackish water can be done easily and economically by desalination

In conventional basin type solar still, the still consists of a shallow airtight basin lined with a black, impervious material, which contains Brackish or saline water. Solar radiation received at the surface is absorbed effectively by the black surface and heat is transferred to the water in the basin. Temperature of the water increases and it increases the rate of evaporation. Solar stills use natural evaporation and condensation, which is the rainwater process. A sloping transparent cover is provided at the top. Water vapor produced by evaporation rises upward and condenses on the inner surface of the glass cover which is relatively cold. Condensed water vapor trickles down into the trough and from there it is collected in the storage container as distilled water.

III. LITERATURE REVIEW

3.1 Geometric Configurations

H E Gad[1] compared the performance of conical solar still with conventional solar still. Fig.1 shows the schematic diagram of the conical solar still.

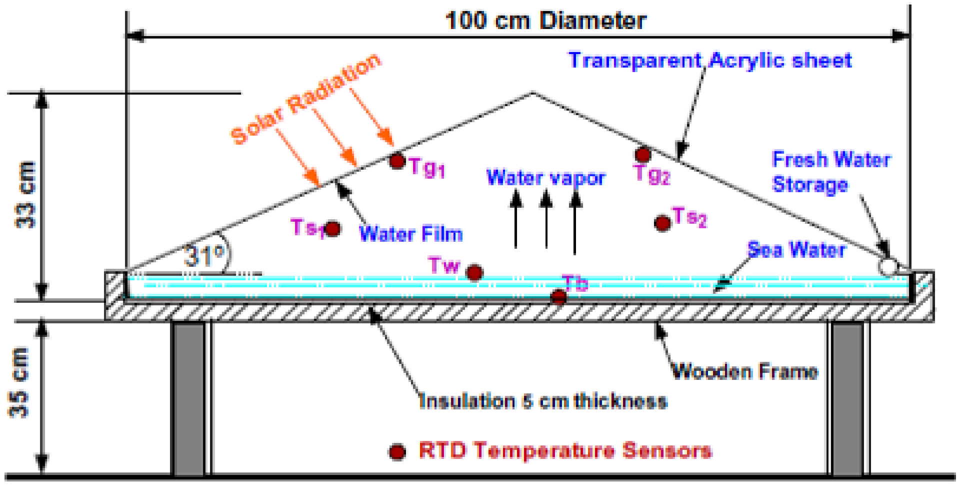


Fig. 1. Costruction Of conical solar still

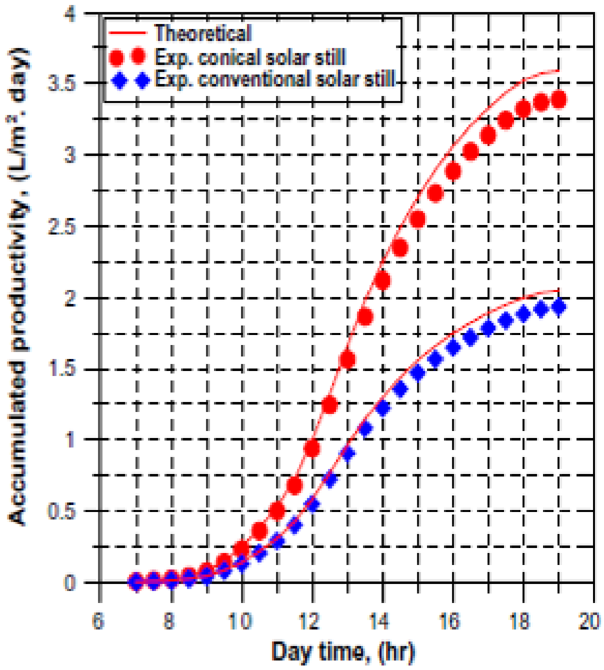


Fig. 2 Variation of productivity vs day time for conventional & conical solar still

The conical solar still consists of a galvanized iron circular base basin diameter is equal to 100 cm, cone height is equal to 33 cm, basin area is equal to 0.8 m^2. The sides and basin are covered with 0.7 mm thick galvanized iron. The cover of still is adjusted on the edge of the circular side with an angle of 31^0. The cover of still is adjusted on the edge of the circular side with an angle of 31^0. In this experiment Acrylic temperature, basin temperature, atmospheric temperature, the solar radiation and distilled water productivity were measured. In conical solar still it is observed that, the basin, water, space and acrylic temperatures reached maximum values of 75.9, 74.3, 70.1 and 66.5 ^{0}C, respectively. The maximum values for basin, water, space and acrylic temperatures for conventional solar still were 57.8, 55.9, 48.9 and 46.5 ^{0}C, respectively. The daily productivity for conical and conventional solar stills was 3.38 and 1.93 L/m^2day respectively. Fig. 2 shows variation of productivity vs day time for conventional & conical solar still.

T. Arunkumar[5] did experimental study on hemispherical solar still. In experimental setup shown in fig. 3 the water storage basin of the still was constructed with a diameter of 0.95 m and a height of 0.10 m using mild steel. The water drainage segment of 0.02 m breadth and 0.02 m height was fixed at the inner perimeter of the basin wall.

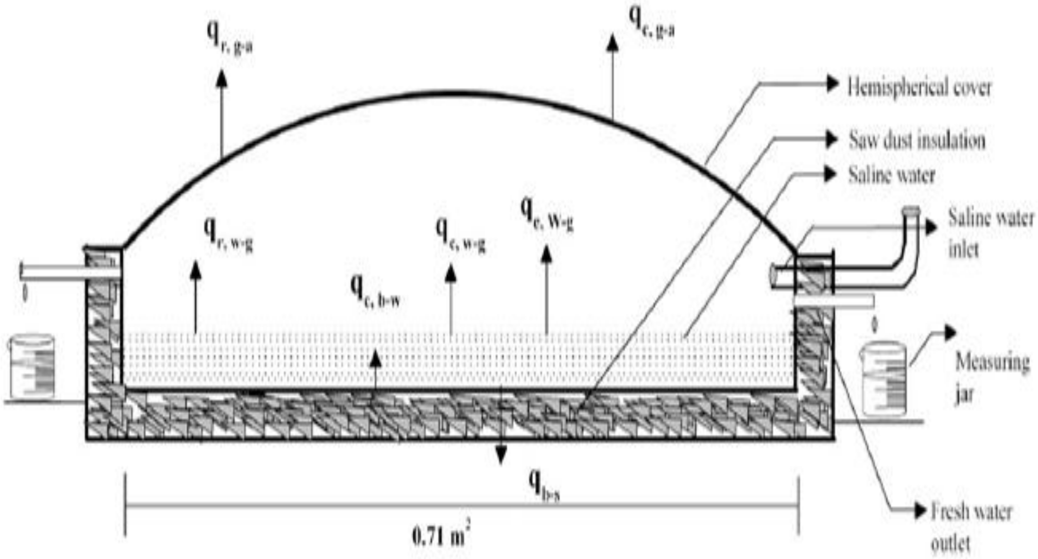


Fig. 3 Hemispherical solar still

The still was filled with saline water to a height of 0.05 m. The top hemispherical cover of diameter 0.945m and height 0.20m was constructed of transparent acrylic sheet of 3 mm thickness. Results shows that the average basin water and cover temperatures were 62°C and 41°C, respectively. The rate of yield 3660 ml/m^2/day for without cooling the top cover and 4200 ml/m^2/day for with cooling the top cover.

Kabeel[3] investigates performance of solar still with concave wick evaporation surface. Fig 4 shows schematic diagram solar still.

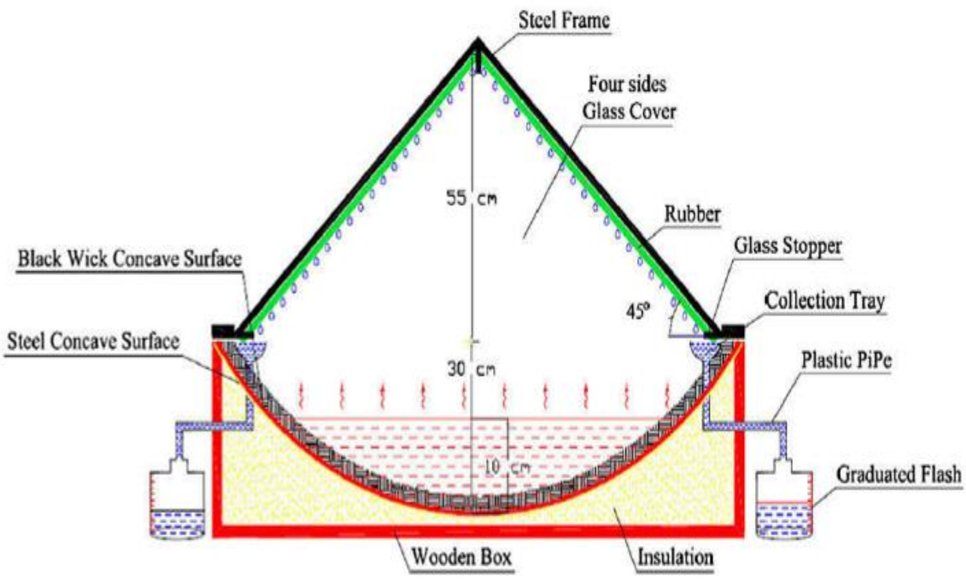
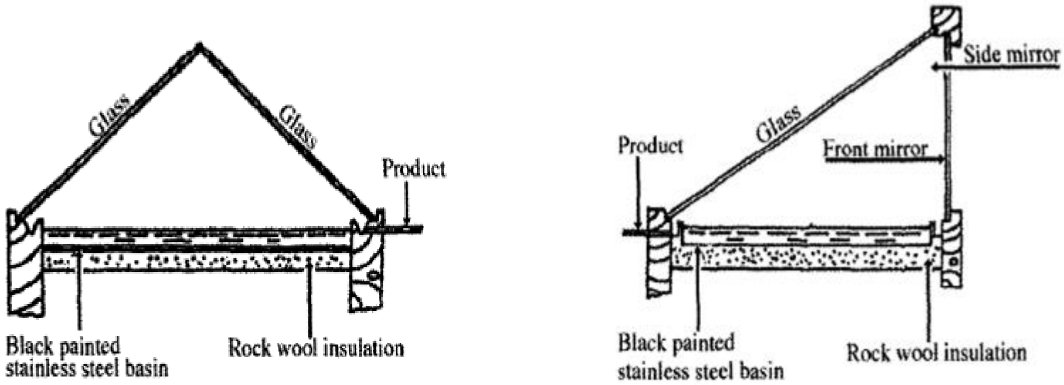


Fig. 4 Solar still with concave wick

The basin of solar still is concave with square aperture of 1.2m X 1.2m. Basin made of galvanized steel. The basin depth is 30cm at the centre. The depth of water inside the basin is 10cm. Temperature measures are brine temperature, wick temperature, glass cover temperature The instantaneous solar radiations are measured by solarmultimeter. Brine water temperature, glass cover temperature, distillate output, solar radiation, ambient air temperature are taken at regular interval of 1 hour. The maximum amount of water collected per day 4100ml/m^2. The fabrication of still costs 145.5 dollars.

Imad Al Hayek[4] compared the effect of using different design of solar still on water distillation. The two solar stills 1st asymmetrical type & 2nd is symmetrical type both having 1m^2 basin area it is made of 1.5mm galvanized SS sheet & symmetrical solar still consist of mirrors in it. Solar still tilted by an angle of 35$^{0.}$ The depth of water is used 2cm.

Thermocouple used to measured temperature of basin water, vapor temperature, inside & outside glass water temperature, ambient temperature.



(a) (b)

Fig.5 Experimental set up of symmetrical (a) & asymmetrical Solar still (b)

It is found that production is more in asymmetrical solar still compared to symmetrical because of mirrors as they reflects solar radiation received within still. The efficiency in asymmetrical solar still is 56% & that of symmetrical 45%.

3.2 Effect Of Nanofluids On Performance

As rate of heat transfer will depend on thermal conductivity, it is found that the conductivity of conventional fluid like water is less than that of metals. In solar still as working fluid is water its thermal conductivity is low. Hence the thermal conductivity can be increased by introducing metal particle in it. Now new approach is to introduce nano metal particle in water. The nanoparticles changes the transport properties & increases the heat transfer rate of water. Such fluid with solid nanoparticles suspended in liquid is called nanofluid.

As increasing thermal conductivity of water by adding nanofluids in it, many researchers have studied the performance of solar still by adding nanofluids in water. The results of these experiments are discuss below,

M. Koilraj Gnanadason[6] studied the effect of nanofluid & vacuum in single basin solar still. The solar still fabricated by Gnanadason is shown in fig. 6

Fig. 6 Experimental setup of solar still

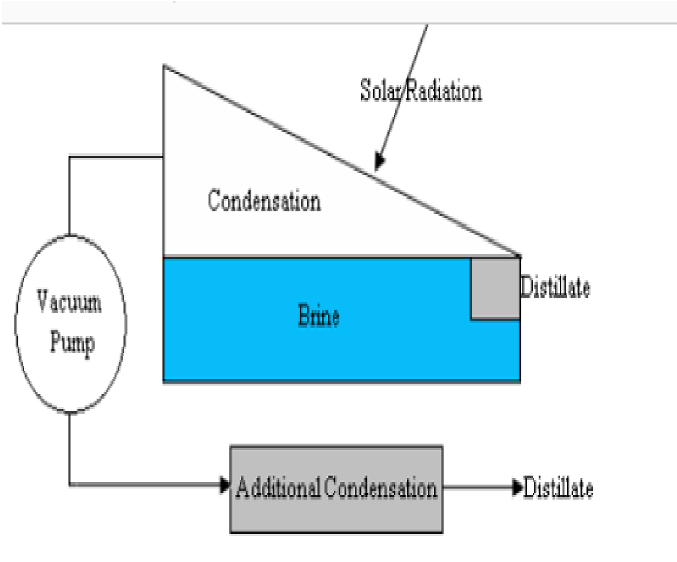


Fig 7 Vacuum solar still setup

It consist of basin made of copper sheet of dimensions 400mm X 900mm X 60mm. Top of basin is covered with glass 4mm thick tilted at an angle of 32^o.As boiling takes place at ambient temperature when pressure equals to vapour pressure. The boiling point can be reduced by decreasing vapor pressure of liquid. This is done by connecting vacuum pump to basin. Vacuum pump reduces pressure inside the basin & boiling starts at low temperature. This will improve evaporation of water. Also, addition of nanofluid Multiwalled Copper Nanotube (MW CNT) in basin water by using sodium dodecyl sulfate as surfactant increases the water temperature & evaporation rate of water in still & hence productivity.

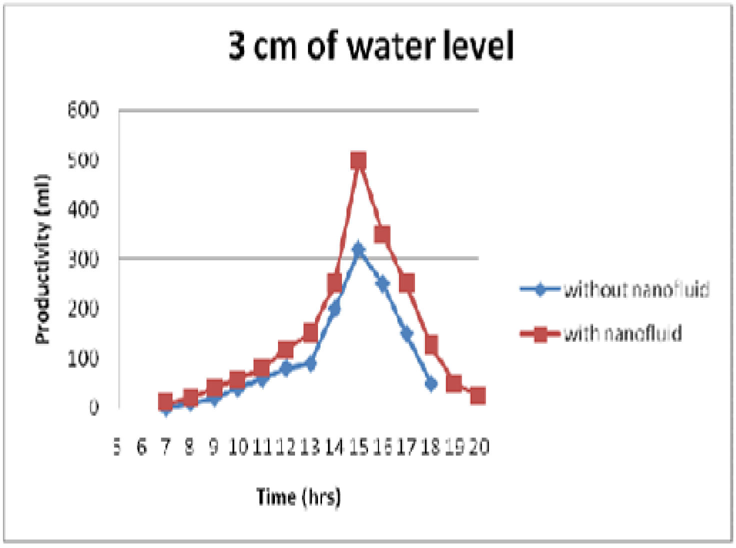


Fig. 8. Variation of productivity with & without nanofluid

In this experimental study various operating conditions are examined such as different water depth, ambient temperature, effect on productivity with & without nanofluid. The temperature of ambient, basin water, glass plate are measured. Th1e productivity for different water depth 2cm, 3cm, 5cm. It is found that output of still decreases with increase of water depth. Graph shown in fig. 8 shows variation of productivity with respect to time with & without nanofluid. . Due to vacuum efficiency of still increases by 40%. Also addition of nanofluid increases efficiency by 50%. Average daily output recorded was 4 lit/day. For basin area of 0.36m^2.Total cost of project was 15000 Rs.

T.Elango[10] compares the performance of solar still (Fig. 9) with different water nanofluids. The basin area of solar still was 0.5m x 0.5m (0.25m^2). It was fabricated by using 10mm GI sheets. Inclination of window glass is 30^o where as one wall height is 0.1m & of other is 0.389. The various nanofluids like aluminium oxide (Al_2O_3), Zink Oxide (ZnO), Iron Oxide (Fe2O3), & Tin oxide (SnO2) were selected on basis of thermal conductivity & cost.

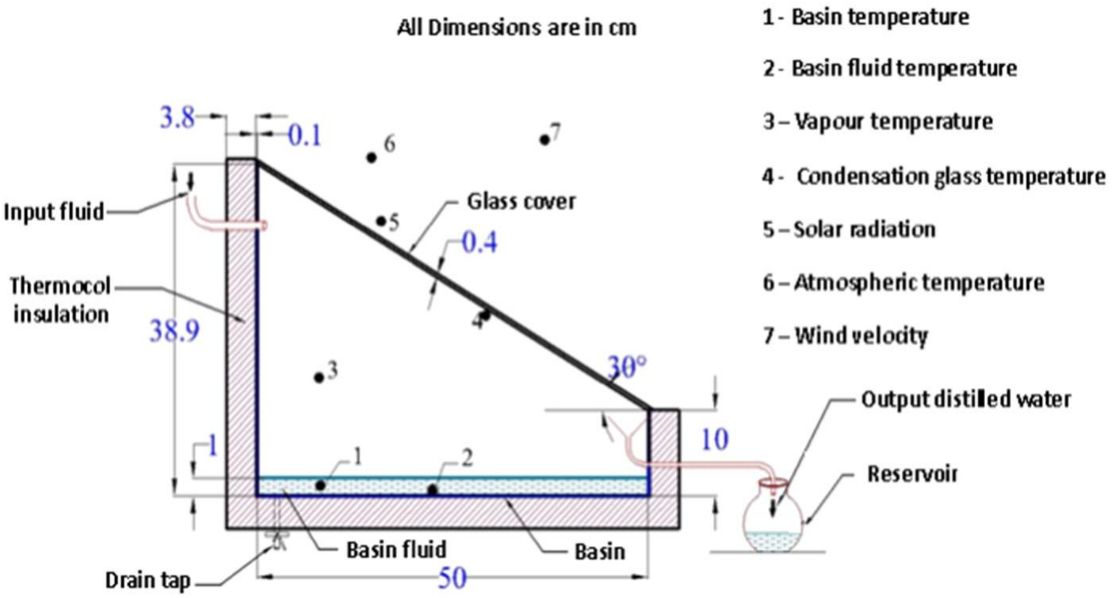


Fig. 9 Single basin single slope solar still

Table 1. Effect of different nanofluid on thermal conductivity of water

Nanofluids	Concentration	Thermal conductivity (W/m^2 K)	Percentage of increment (%)
Aluminum Oxide (Al_2O_3)	0.1%	0.6355	10.34
Zinc Oxide (ZnO)	0.1%	0.6105	5.25
Tin Oxide (SnO_2)	0.1%	0.6215	7.155

When 1% concentration is used table 1 shows % increase in thermal conductivity of water due to addition of nanofluid. Fig. 11 shows Al_2O_3 posses high thermal conductivity follow by SnO_2, ZnO. The result shows that maximum 935ml/day was obtained for Al_2O_3, for SnO_2 805ml/day, for ZnO 750ml/day. The efficiency is high (29.95%) for Al_2O_3 compared to SnO_2 (18.63%) & ZnO (12.67%)

A E Kabee[7] enhanced the performance of solar still by integrating it with external condenser & using nanofluids in it. Two solar still set up manufactured shown in fig. 10 & tested. One set up is conventional solar still & other consist of condenser with nanofluids added in water.

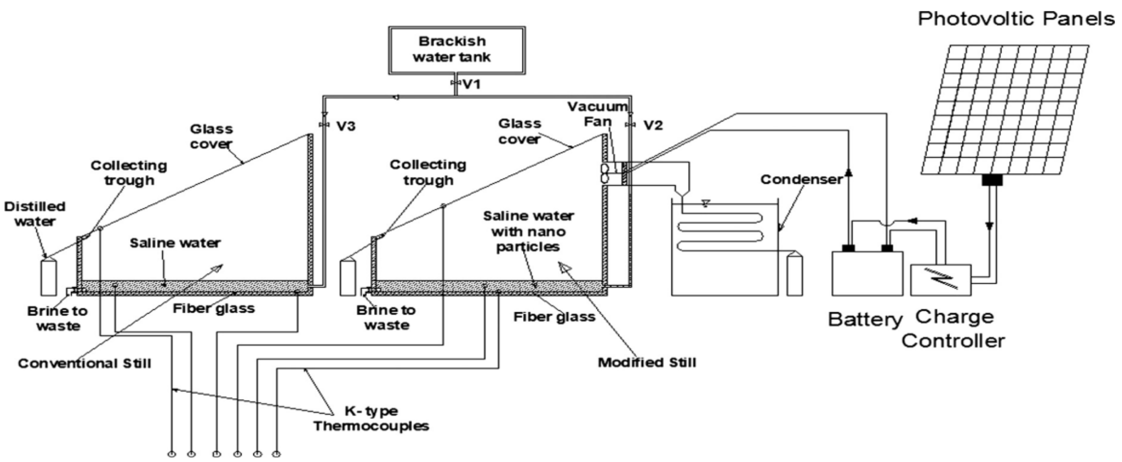


Fig. 10 Experimental Setup of modified solar still.

Performance of both still is compared. The conventional solar still has basin area $0.5m^2$, high side wall depth 450mm & low side wall depth 160mm. Basin covered with glass sheet of 3mm thickness K type thermocouple used to measure temperature of ambient, basin water, glass plate. The modified still has same dimensions as that of conventional solar still but it consist of fan and condenser unit. Fan & condensation unit increases the temperature difference between basin water & glass surface & hence increases the productivity.

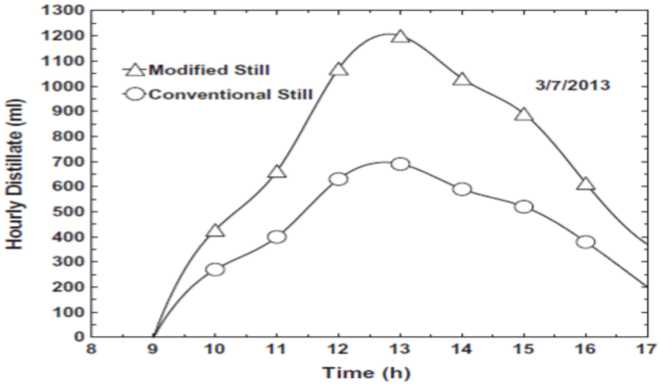


Fig. 11 Hourly distillate Vs time of day for modified & Conventional still

To further increase the output the nano particles of aluminum oxide are mixed with water. It is found that by adding 0.2% of Al_2O_3. Thermal conductivity increases by 10.3%. The effect of nanofluid on performance of solar still without external condenser is shown in fig. 11. basin water temperature increases by nanofluid by 2.5°C. & also amount of water collected as output is more for basin having nanofluid compared to conventional solar still. It is found that productivity increases by 116% with fan & nanofluid and by 76 % by only nanofluid. Total fixed cost of project is 103 dollars.

Abhinav K R Singh[9] evaluates performance of solar still with & without nanofluid. The setup were manufactured from Tin sheet having dimensions 48cm X 56cm. The depth of walls are 39.87cm & 28.59cm as shown in fig. Two RTD (PT 100) used for measurement of temperature & solar radiometer used for solar radiation measurement. Top cover is of 5mm glass at an angle of $30^{0.}$

	Length (cm)	Width (cm)	Height Front (cm)	Height Back (cm)
Inner	77.72	55.11	21.59	21.59
Outer	78	56	39.87	39.87

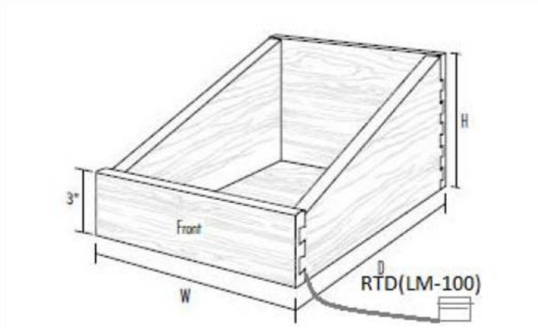


Fig.12 Constructional details of solar still

Nanoparticles of Aluminium powder (Al_2O_3) is insoluble in water so 2 way method is used. For the preparation of nanofluid Al_2O_3 nanopowder added to 4lit in ratio of 10:2 & also sodium dodecyle benzene sulphonet as dispersant.

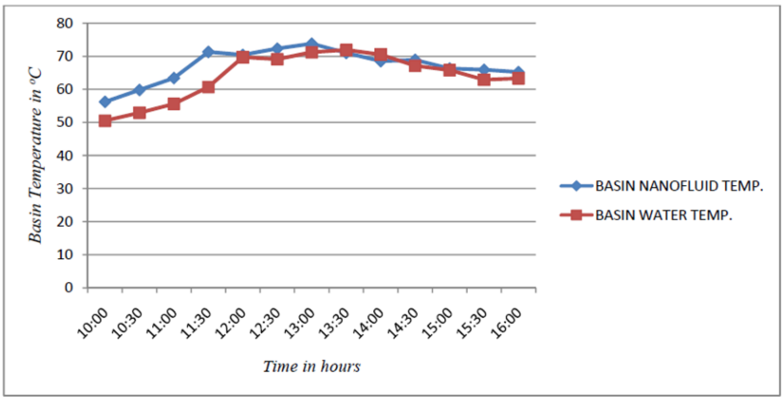


Fig 13 Effect of nanofluid on basin water temperature

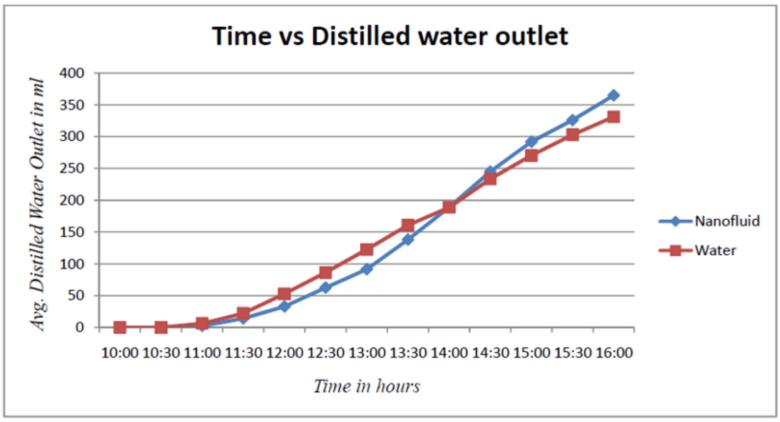


Fig. 14 Effect of nanofluids on distillate water outlet

Experimental result shown fig 14 & 15 shows that due to nanofluid thermal efficiency increases by 5%. Graph shows variation of basin temperature, average distilled water with respect to time in hours with & without nanofluid.

Lovedep Sahota[13] studied the effect of Al_2O_3 nanoparticles on performance of passive double slope solar still. Their setup fabricated in fibre reinforeced plastic. With top cover of 4mm thick transparent glass at angle of 30^0. Area of surface of base is 2x1 m^2. Al_2O_3 nanofluid is added to basin water to increase the productivity.

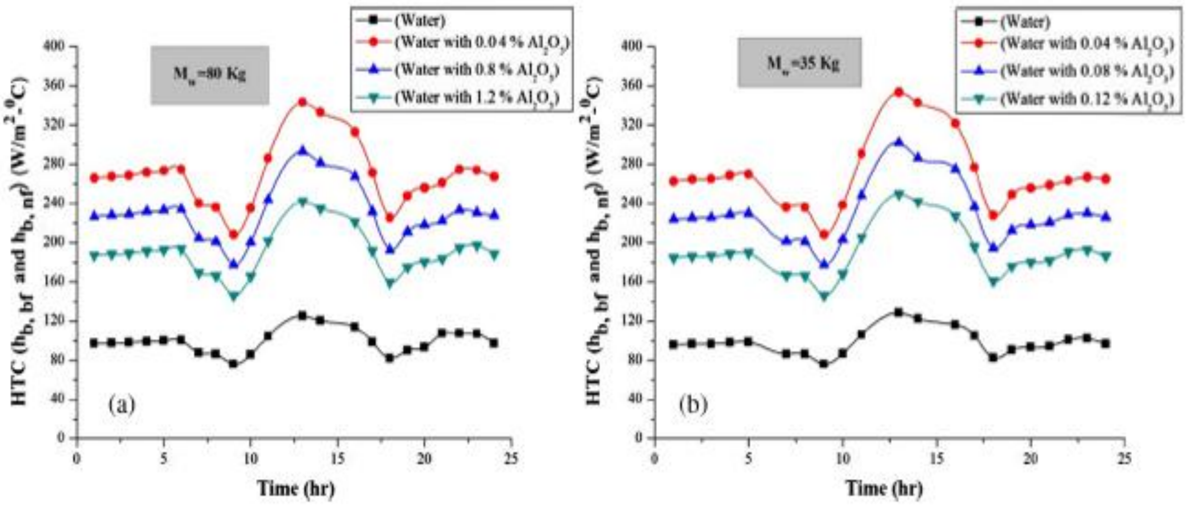


***Fig. 16 Variation of heat transfer coefficients with respect to time and concentration of nanofluid*.**

Heat transfer coefficients calculated for basefluid & nanofluid (with 0.04%, 0.08%, & 0.12%) for 35kg & 80kg mas of fluid. It is found that heat transfer coefficients for 35kg of water mass is higher than that of 80kg. The fig. 16 shows that with increase in concentration of nanofluid convective heat transfer increases. Also daily yield found from still increases with concentration of nanofluid in water.

Table 2 Total yied obtained for different nanofluid concentration in water

Total yield ($\dot{M}_{bf}$)		Al_2O_3 nano particles concentration $\varphi_p(\%)$	Total yield (($\dot{M}_{nf}$))		Enhancement in the total yield (%)	
80 kg	35 kg		80 kg	35 kg	80 kg	35 kg
1.628	2.445	0.04	1.725	2.665	5.9	8.9
		0.08	1.753	2.691	7.6	10
		0.12	1.765	2.744	8.4	12.2

Table 2 shows amount of yield collected for 35kg & 80kg water .For 0.12% concentration of Al_2O_3 in water increases daily yield by 12.2% for 35kg mass & that of 8.4% for 80kg mass.

IV. CONCLUSION

The review shows that by using various shapes the amount of water collected through solar still can be increased. The conical solar still has advantage of decreasing shadow effect which is present in conventional solar still so it can absorbed solar radiation throughout the day. In the hemispherical solar still shape of hemisphere is difficult to manufactured. Thermal conductivity improvement of basin water by using nanofluids can improved performace of solar still. From the experiment performed by Elango by using different nanofluids it shows that more the conductivity of nano materials more productivity of solar still. Also Lovedeep's experimental analysis shows that with increase in concentration of nanofluid we increase the heat transfer coefficient & productivity of water.

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