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Experimental Optimization of a Solar Distillation Unit

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Abstract: ***Today global warming is a big issue. Ambient temperature have drastically increased, leading to severe droughts especially in those areas which receive less than average rainfall. Inadequate supply of quality drinking water especially in the rural areas have led to develop a distillation system with affordable cost and less maintenance in rural areas. Countries like India and South Africa are getting ample amount of solar energy almost throughout the year. Solar based water distillation unit- Solar still can be great solution to those kind of areas. Efficiency of the solar distillation can be improved by increasing evaporation rate which is a function of incident radiation. Further by increasing concentration of total dissolved salts in the water, base plate absorptivity and efficient energy absorbing material, by providing additional heat with solar water pre-heaters efficiency of solar still can be improved. Here experiments were carried out in order to find out optimum water bath depth and salt concentration in water in solar still for maximizing the yield. Experiments are also carried out by adding*** **heat storage material and effect of salt concentration on yield.**

Keywords— solar distillation, active and passive system, water depth in solar still, salt concentration, heat storage material

I. INTRODUCTION

Rainfall, a wonderful example of a natural solar distillation process, where all the water drains to the reservoir, is heated up by incoming solar radiation from the sun, gets converted into water vapor and gets carried away by winds. When this mixture is cooled, it condenses to water droplets and again falls back as rain. At a smaller scale the same cycle is replicated in a solar distillation unit. In today's world, power demand has tremendously increased [1-2], with an increase in global population and pollution, a limited supply of fresh drinking water is yet another big issue at hand.

Solar distillation is one of the easiest and the most convenient way to curb the water shortage in both rural and underdeveloped parts of the world. This process involves water purification by the use of low grade solar energy in which the brackish water in the basin is allowed to evaporate and then it condensed on a sloped glass cover, this yield is known as distillate. This process removes salts and other impurities from the untreated water and allows only pure water vapor to condense and get collected as yield. [3] Many researchers have done significant work in the area of solar distillation by taking various operational as well as design parameters. [4]. The objective of the experiment was to study various factors affecting the performance of solar still.[5-6] The purpose is to find out the technique by which maximum yield-drinking water can easily be produced in rural areas with available solar radiation in minimum cost. Studies have shown various factors affect the yield and they are as follows: [7 - 14]

- Ambient temperature.
- Incident solar radiation.
- Dust and cloud cover.
- Water depth in the solar still.
- Inclination of glass cover.
- Type of solar still.
- Energy absorption and storing materials
- Color of water
- Insulation thickness used at the base.
- Salt concentration of the water used.

II. EXPERIMENTAL FINDINGS

The solar still made up of Galvanized Iron (GI) was used to avoid rusting. Thickness of the sheet used is of 2mm Tempered glass of thickness 4mm with dimensions 39 inch * 43 inch is used which was placed inclined at 20°. Solar still was designed and fabricated in order to investigate Experiments were carried out on the set up at Nirma University Ahmedabad (23°12' N, 72° 54' E) for experimental analysis.

Solar still yield can be increased by supplying higher temperature water input. If solar water heater is used with solar still then yield can be increased. Out of variable listed above and different parameters, following parameters were selected for experimental analysis based on the literature survey carried out.

A. **Effect of type of system**[15]
B. **Effect of water depth**[16]
C. **Effect of adding heat storage material.**
D. **Effect of salt concentration**

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A. Effect of type of system

Different solar water heating systems can be coupled with solar distillation unit in order to increase yield. Solar collectors (FPC), Evacuated Tube Collectors (ETC) can be used with solar still.[15-16] Over here both FPC and ETC are used with solar distillation and then performance of solar distillation unit were compared. Fig. 1, 2 and 3 shows available solar intensity at different time during the day and then yield were collected. Comparison of all three options is given in fig. 4

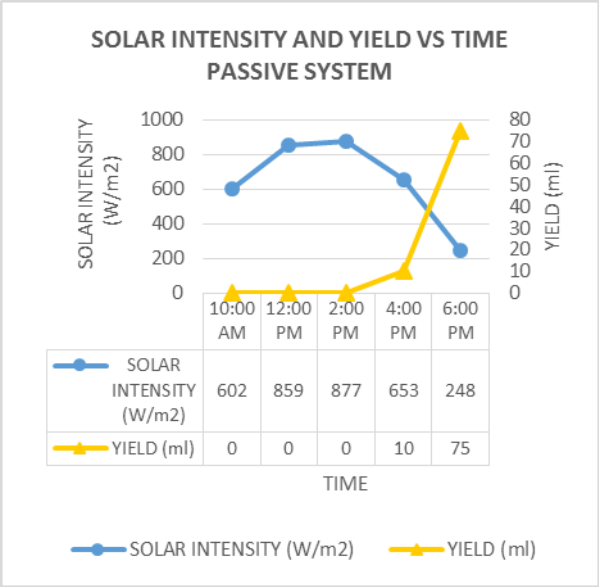

Fig. 1 Solar intensity and yield Vs time for passive system

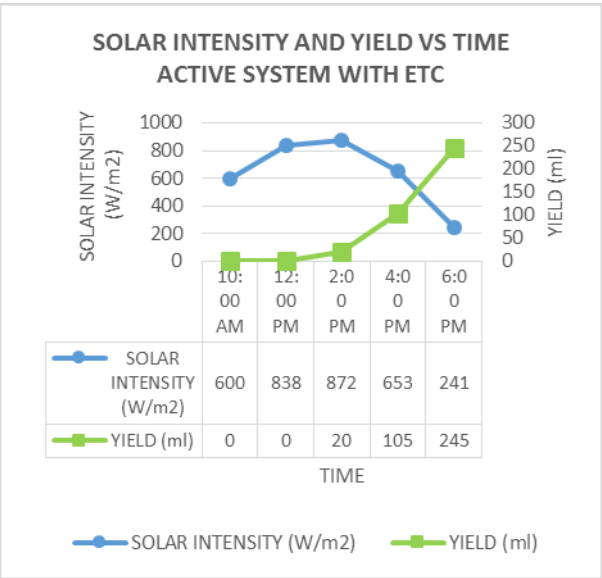

Fig. 2 Solar intensity and yield Vs time for active system with ETC

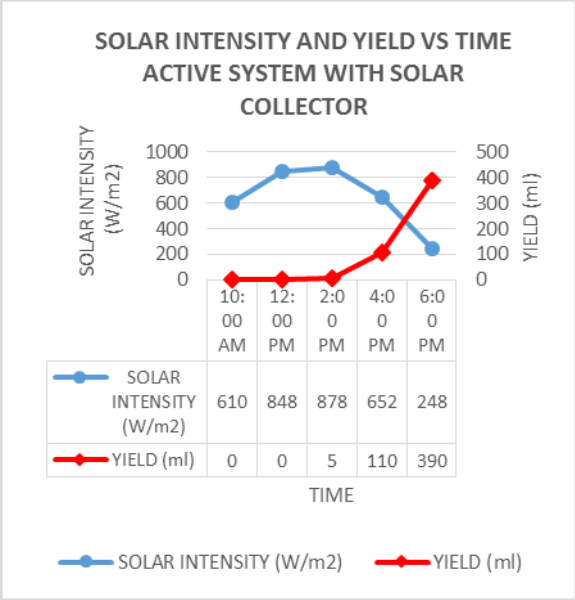

Fig. 3 Solar intensity and yield Vs time for active system with solar collector

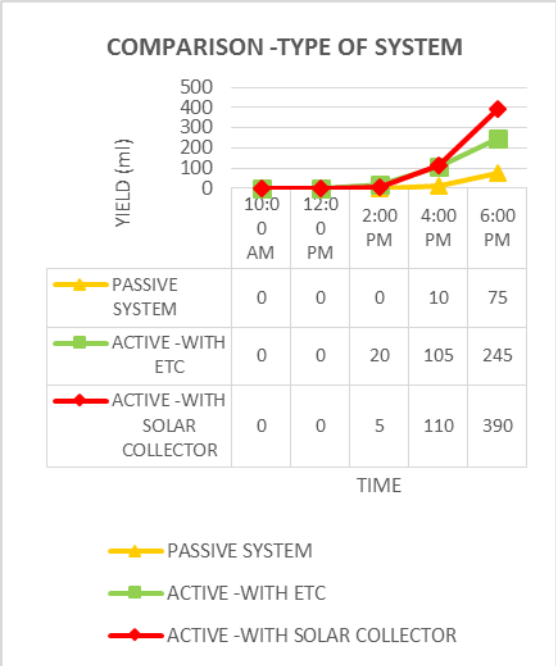

Fig. 4 Comparison of yield for passive system, active system with ETC and active system with solar collector

B. Effect of water depth

Water depth in solar still plays vital role in performance of the solar still. Literature shows that water depth in solar still is affecting the yield of the system.[17-18] Experiments were conducted with four different water depths 9cm, 10cm, 11cm 12cm in the solar still. The observations are plotted in fig 5 to 8. From the above figures we can deduce that yield available is affected by water level depth in the solar still. It can be investigated by keeping different water level in the solar still.

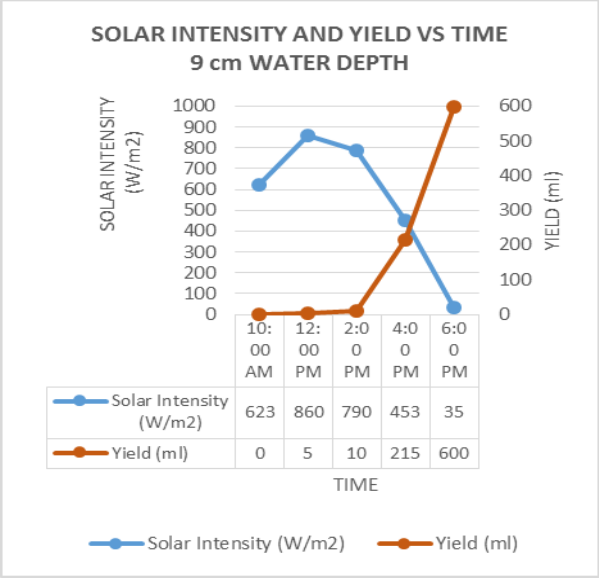

Fig. 5 Effect of 9 cm water depth on yield

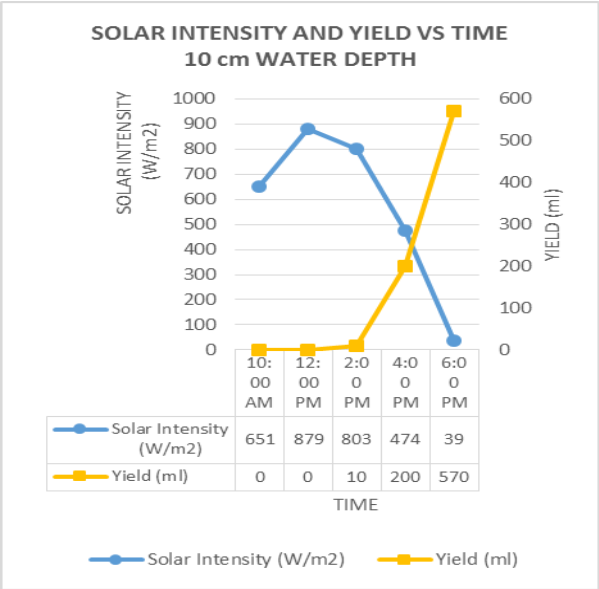

Fig. 6 Effect of 10 cm water depth on yield

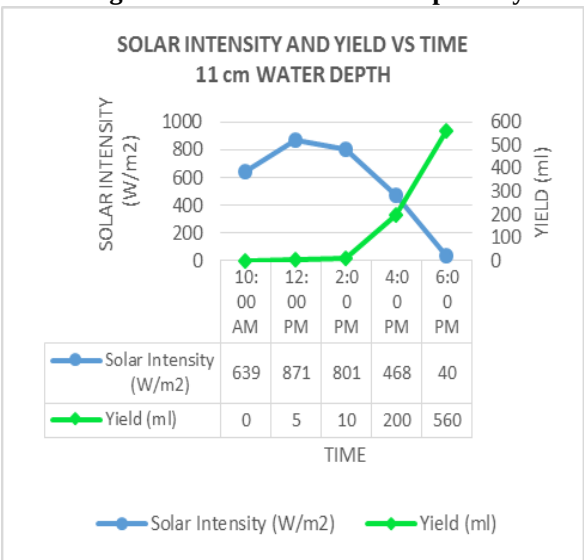

Fig. 7 Effect of 11 cm water depth on yield

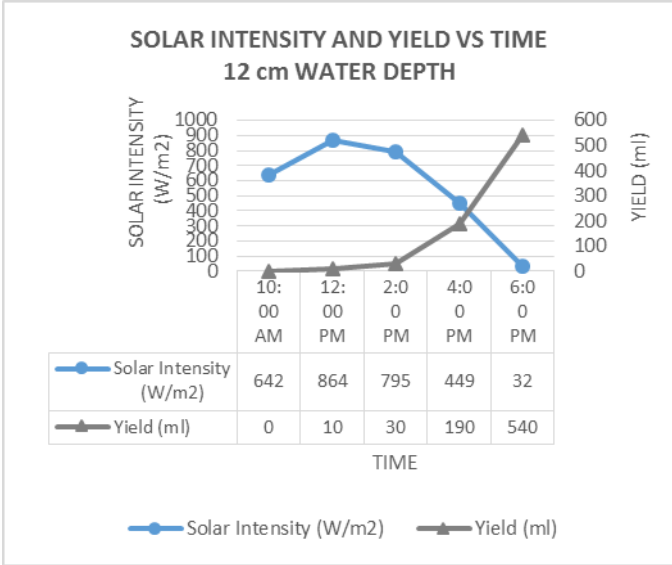

Fig. 8 Effect of 12 cm water depth on yield

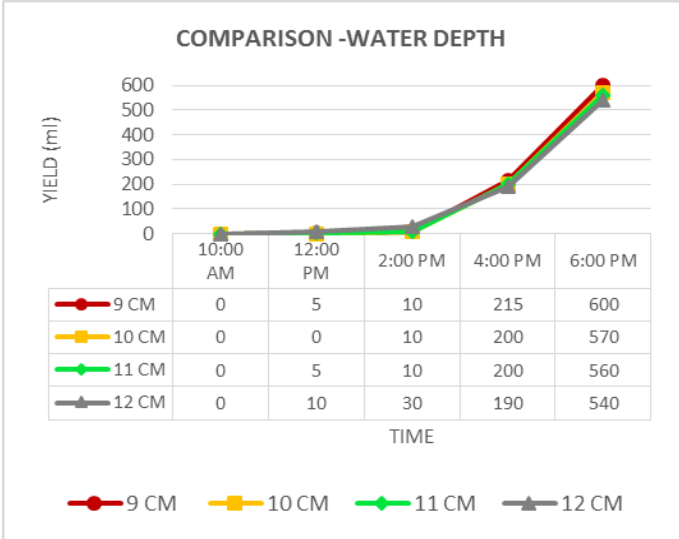

Fig. 9 Comparison of different water depth on yield

The results obtained suggests that at 9cm water level depth is optimum as at this level yield available is maximum. Yield comparison of different water level depth is shown in fig 9. The total dissolved salts in the yield amounted to 50 ppm. It can be deduced that increasing the water level depth above 9cm will eventually increase the time for water to form vapor. With more volume of water in the still, the time to heat up the basin water increases. The data from fig.9 suggests a decrease of 11% of yield when increasing the water level above 9cm to 12cm.

C. Effect of adding a heat storage material

The experimentation was conducted to study the effects of adding heat storage materials. It was conducted by fixing the water depth level at 9cm assuming that the solar intensity fairly remained same during other experiments as shown in figure 11. Literature Says about many material which can be used in solar still in order to store the heat during day period [19]. Granules and charcoal are most accepted and popular materials and that's why they experiments were carried out with both of these materials. Granules and charcoal are used as heat storage materials as it possible to achieve nocturnal distillation. The heat storing material absorbs the heat during the day and releases the heat to the basin water at night. The results obtained are plotted in following graphs.

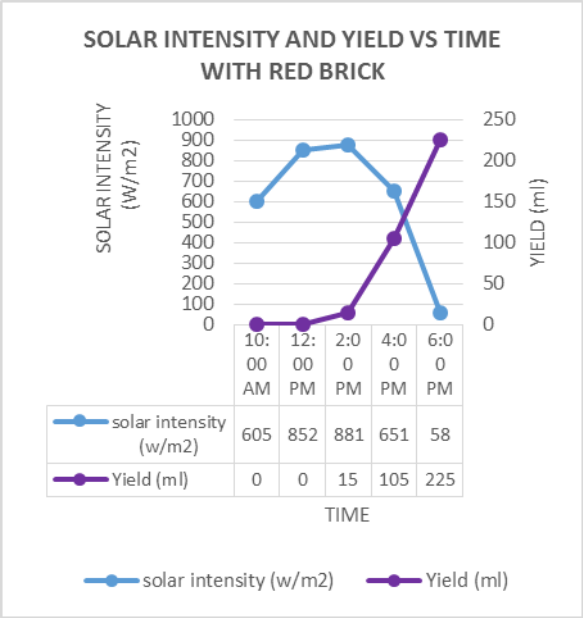

Fig. 10 Yield with red brick in solar still

Yield was collected with red brick, granules and Charcoal [20]. The graph of solar intensity at different time during the day and available yield was plotted in following graphs expressed as fig 10,12and 13.

Fig. 11 Solar still with granules.

Results shows that yield available with the help of Charcoal is significantly high as compared to red brick and granules.

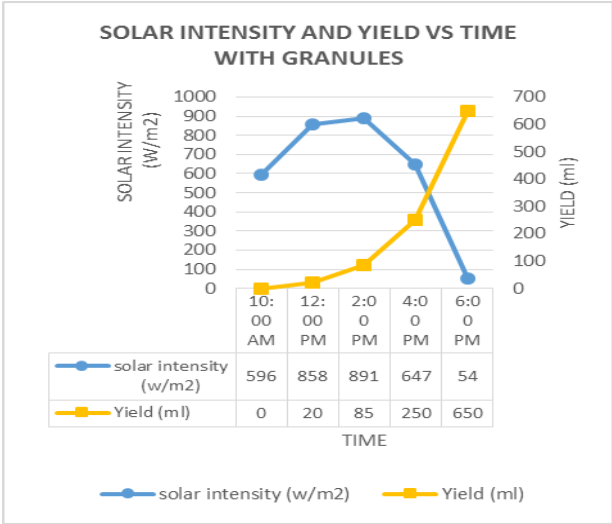

Fig. 12 Yield with granules in solar still

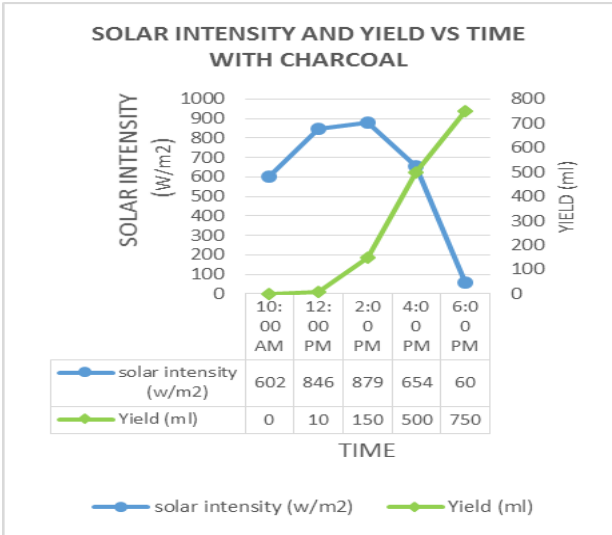

Fig. 13 Yield with charcoal in solar still

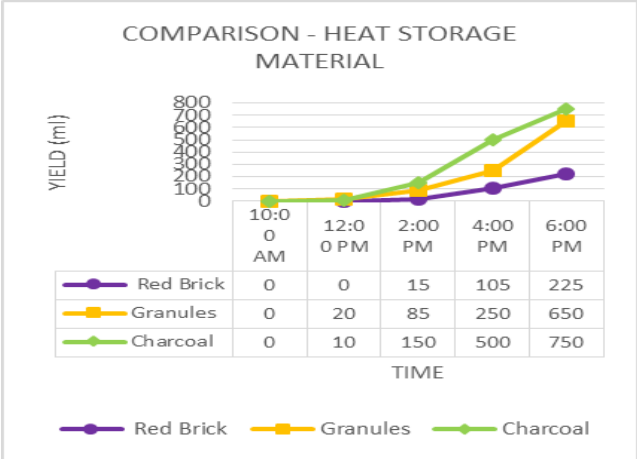

Fig. 14 Comparison of yield with Red brick, Granules and Charcoal

It can be deduced that an increase in yield was due to the absorptivity of the granules or charcoal placed in the solar still. There was an increase of around 8% with granules and around 25% with charcoal, compared to the normal solar distillation still without any heat absorbing material.

D. Effect of salt concentration

It was found in literature that salt concentration in water also matter a lot for yield production with solar still. [21] Different samples of salt concentrated water were taken and used in solar still in order to find the perfect correlation. The experimentation here involves two different water samples with different total dissolved salt concentrations. [22] The objective for carrying out this experiment was to analyze the effects of salt concentrations on the yield of the distillate obtained. Two different salt concentration was taken which are available at various sites. Salt concentration of 450 ppm was obtained from the university tap in contrast 100 ppm concentration was obtained from the other site-SGVP hostel. 9 cm water level was maintained and the yield for both salt concentrations. The results were obtained as follows:

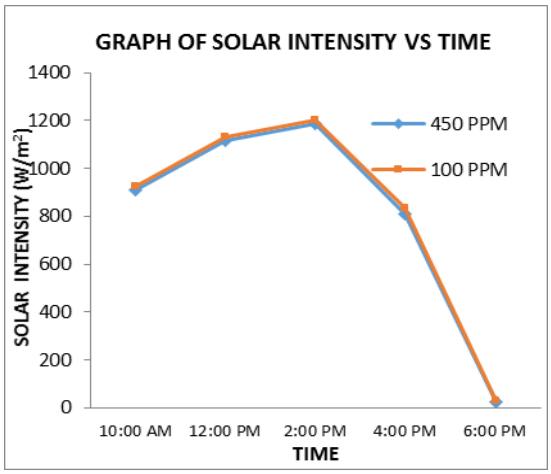

Fig. 15 Observation of total dissolved salts Yield vs. time.

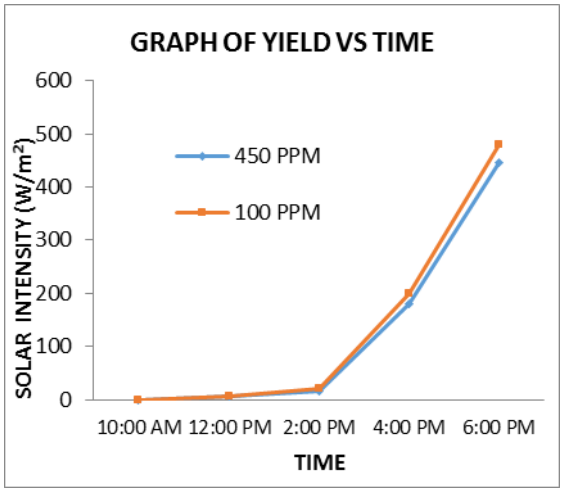

Fig.16 Observation of total dissolved salts Solar intensity vs. time.

It was found that 100 ppm water condensed with more yield of around 8% compared to the other which has higher salt concentration. However, both produced a yield having 30 ppm of total dissolved salts. It can be deduced that the reason for achieving a higher yield with low salt concentration is due to the solar radiation absorption rate. Presence of salt concentration and scaling in the basin would absorb some of the heat and therefore there would be less heat available for water.

III. CONCLUSION

From the experimentation it can be conclude that it is possible to increase the nocturnal distillation by adding heat storage material like red brick, granules, Charcoal etc. It is possible to increase the yield by softening the hard water with the use of reagents and softeners. It is concluded that Charcoal can increase yield amount by almost 3 times higher as compared to granules and red brick. Further it reveals that active system of solar still and solar collector can produce more yield as compare to passive system and active system with ETC with same amount of solar radiation available.

At last it as found that water which contains more salt concentration will have less absorption rate and hence yield will reduce. While doing the experiment with 100 ppm water which generally a tap water and 450 ppm water, 100 ppm water is giving slightly higher amount of yield. Generally water still is useful in areas where drinkable water is scarce. Generally Seashore areas are facing this kind of difficulties. So if sea water is used over here in solar still for distillation purpose than probably it would give lesser yield as compared to where less ppm water is used in solar still.

In future, more experiments can be done to get a desirable total dissolved salt in water of about 80-100ppm which is recommended for drinking purpose. It is possible to add chemicals to the distillate so as to reach the drinkable limit of total dissolved salts.

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