Fabrication of Experimental Setup of Solar Distillation System Integrated with Parabolic Collector

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ABSTRACT

An integrated solar distillation with a parabolic collector (SDSPC) has fabricated for drinking water and modified purification of distilled water. The system consists of a parabolic solar collector and double slope solar still at the focal point and condensing the generating evaporated water. Distillate water productivity of the SDSPC was measured along with different parameters TDS, pH and yield of distilled water, black absorber box wall temperature and contaminated water yield under the climate conditions MMMUT, Gorakhpur during January. The maximum productivity of yield distilled water 660 mL within seven hours a day was measured with absorber wall temperature 78.2 °C. The overall yield of distilled water varied from 53 ml/hr to 60 ml/hr having a peak value of 135 ml/h. The quality of contaminated water samples has been examined at 2:00 PM, TDS and pH were 630 PPM and 6.14 respectively and the results are found with guidelines for drinking water quality.

Keywords: Parabolic Collector, Double slope solar still, Yield distilled water, Absorber box temperature

1 Introduction

To survive in this world, all organisms need potable water to drink. Clean water is essential for living a healthy life, the imagine of living life in this world without water is just a imagine. Due to the rapid increase in population and pollution, natural water sources are rapidly decreasing due to which there is a drought in many places [1]. That is a challenging problem for us, this problem can be eradicated, if available, to conserve, manage, use fresh water methodically. Various techniques are used to clean potable water, out of which distillation is the easiest and renewable source of technology. It is also environmentally friendly. In ancient times, the Greeks used the promenade method on their ships to make ocean water drinkable. For humans, the solar distillation method can be the main unit for self-sufficiency and requirement fulfilment, this method does not require other energy sources like fuel, electricity, etc., which reduces the cost of equipment. There are many techniques used to purify water, out of which the use of electric RO technology is a common practice. In which electricity and water waste are excessive. RO separates impurities present in water as well as essential elements like sodium, magnesium, calcium etc. It is commonly found that purification of water through RO medium achieves 25% of filter water while 75% of water is wasted and RO is available as an expensive technology. Solar distillation is mainly done in two ways - passive and active Malik *et al.* [2] the first passive solar still was introduced by Soliman in 1982. While the active method water distillation in 1983 S.N. Rai *et al.* [3] followed by the collector, basin, and water depth to increase productivity Sanjeev Kumar *et al.* [4] required external energy to make the water potable by active diversion, at that time solar the distillation was connected to the flat plate collector, increased productivity, and performance at the same basin area, with passive solar still. This was followed by Rai and Tiwari on the external energy of solar distillation G.N. Tiwari *et al.* [5] Internal heat and mass transfer into water depth Rajesh Tripathi *et al.* [6] Work was done on the material of condensing cover to increase the performance of active solar still. Vimal Dimri *et al.* [7]. Ali, Fath, and Armstrong [8] present a comprehensive review of indirect solar

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desalination methods from a techno-economic perspective. The authors explore the various technologies employed in indirect solar desalination and assess their technical feasibility, cost-effectiveness, and potential for large-scale implementation. The article offers insights into the strengths and limitations of different indirect solar desalination techniques and highlights the key challenges and opportunities in this field. Narayan *et al.* [9] explore the potential of solar-driven humidification-dehumidification (HDH) desalination for small-scale decentralized water production. The authors explain the decentralized water production with principle of HDH system with solar driven. The author reviewed different configuration desalination system. Ghermandi and Messalem [10] provide a state-of-the-art review of solar-driven desalination using reverse osmosis (RO) technology. The article discusses the principles and operation of RO desalination, focusing on solar energy as the driving force. The authors evaluate the performance and efficiency of solar-driven RO desalination systems, along with the associated technological challenges and advancements. The review highlights the potential of solar-driven RO desalination as a sustainable and energy-efficient solution for freshwater production. Ghaffour *et al.* [11] reviewed on renewable energy-driven desalination technologies and explore the challenges and potential applications of integrated systems. The authors explain various solar and wind energy their integration with desalinations. Tzen *et al.* [12] investigation on the experimental of a only PV desalination system only for rural areas. Baharoon *et al.* [13] focused a review of CSPS (concentrating Solar power system) for an electricity generation. The authors provide an overview of various efficiency improvement and thermal energy storage systems. The revie covered various technologies, parabolic troughs, power troughs and Stirling systems for electricity generations [14].
The aim of this work is to come up with an integrated solar still with Parabolic collector design and operation that can enhance yield determine TDS, pH, and productivity with minimum costs to reach an economically viable experimental setup.

2 Materials and Construction

The double slope was designed on basis of still basin with following dimension 126 cm radius. The Still was painted with black paint for absorption of solar radiation. The dimension of inlet pipe is used for water poured into basin still. The still box is dimensioned of thickness still 45 cm. Length 30 cm. Height 20 cm the top of cover is made up of glass of thickness 4 mm. at the temperature is maintained for covering glass. Black coated box is used to absorber at focal point. At high temperature it contains contaminated water for distillation. The volume of the basin is about 8 litres.

2.1 Solar parabolic collector

The reflector of a PDC has the shape of a paraboloid, The disc wrapped with aluminium foil for increasing temperature at focal point (see Figure 1). The incident solar radiation is reflected by the collectors onto a focal line, which directs the concentrated solar energy towards a receiver. The receiver absorbs the energy, causing the temperature of the fluid inside to increase.

Figure 1: *Parabolic Collector*

Figure 2: *Black coated Still basin*

2.2 Black coated steel basin

Black coated box is used to absorber at focal point. At high temperature it contains contaminated water for distillation. The volume of the basin is about 8 litres (see Figure 2).

2.3 pH meter

The pH meter is a scientific instrument utilized for the determination of the acidity or alkalinity of water, commonly referred to as pH (see Figure 3). In this experiment it is used as a measuring pH of contaminated water, distilled water, and drinking water with respect to temperature.

2.4 TDS meter

Total Dissolved Solids (TDS) refers to the amount of dissolved present in potable water. Figure 4 depicts TDS instrument used in the experiment.

Figure 3: *pH meter*

Figure 4: *TDS meter*

2.5 Mineral cartridge

The essential minerals are added back into the distiller water through the Mineral Cartridge (see Figure 5). Adding minerals and maintaining optimal pH levels are essential components in achieving a balanced environment. The addition of calcium to water is being investigated. The study focuses on removing harmful ions that contribute to water pollution.

Figure 5: *Mineral Cartridge*

Figure 6: *Hygrometer*

2.6 Hygrometer

A hygrometer is a digital instrument used to measure the several types of properties. This instrument is also known as weather measuring device hygrometer is mainly used to measure the combined effect of condensation and evaporation in the atmosphere and temperature (see Figure 6).

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2.7 Thermocouple

The Thermocouple is a commonly used temperature measuring sensor in various applications (see Figure 7). Thermocouples consist of a junction formed by joining two wires of different metals at one end.

Figure 7: *Thermocouple*

Figure 8: *Double Slope Glass*

2.8 Channel

The condensate generated is observed to flow over the inclined to cover and subsequently descend into the passage. The channel, which is responsible for extracting distilled water, is a significant component of the process. The potential materials that could be utilized in this study include P.V.

2.9 Double slope glass

The water vapor gets condensed on the double slope and falls on channel pipe to get distill. The slope is 32° (see Figure 8).

3 Experimental Setup

A Fabrication of active and passive solar still distillation integrated with parabolic collector has been made. Mineral cartridge is applied to the system to convert distill water into potable water. The still black box contains contaminated water. When sunrays fall on still box it absorb the heat and water get evaporated and get condensed through double slope glass through channel. From channel the distill water get collected into the bottle. The distill water is mineral less. A Mineral cartridge is added to the distill water it helps to maintain a perfect balance of pH in water, and it adds calcium to water and make it safe and purified for drinking and remove ions that cause water pollution. After adding minerals, the water gets pure to drink (see Figure 9).

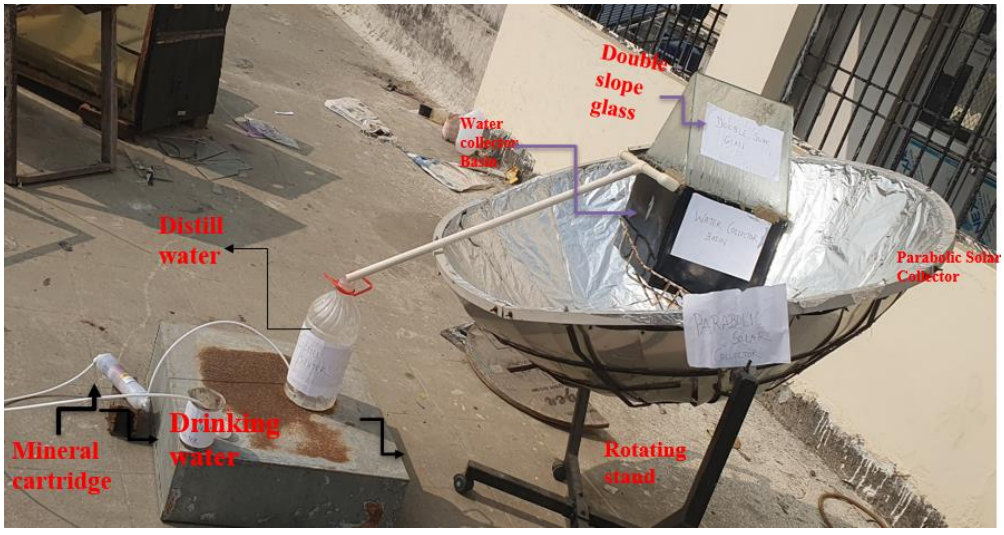

Figure 9: *Experiment Setup*

4 Results and Discussion

The study involved conducting experiments over the course of a day, from sunrise to sunset. Hourly recordings were made to measure the temperature of water in the black box, as well as the levels of distill water, TDS, and pH.

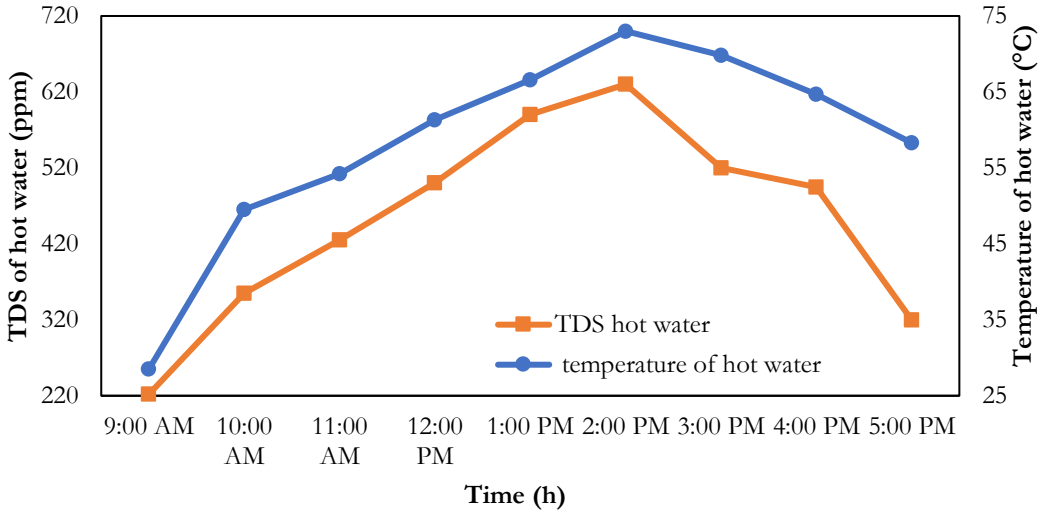

Figure 10: *Temperature of hot water and TDS of yield water with respect Time*

Figure 10 has been plotted for the TDS of hot water and temperature of hot water with respect to time hours. In this graph, it is showed that TDS get increases when water temperature gets raised and highest TDS range is obtained around 2 pm. TDS get decreases when the temperature of water gets low with respect to time due reduction in sun energy availability.

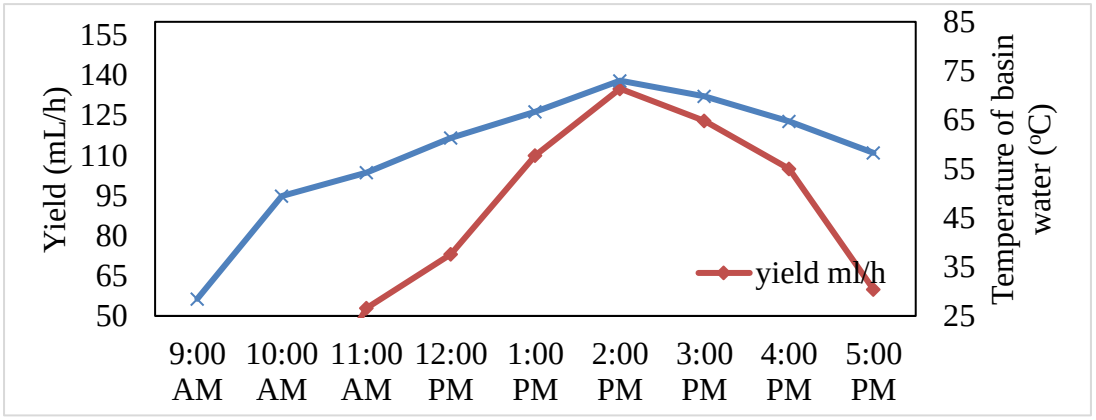

Figure 11: *Temperature of basin water and yield water with respect Time*

Figure 11, plot is drawn for the yield water and temperature of basin water with respect to time hours. This graph shows that temperature of water increase, its yield also increases. Mainly yield started at 11:00 am, the highest yield achieved at 2:00 pm when temperature of water is high.

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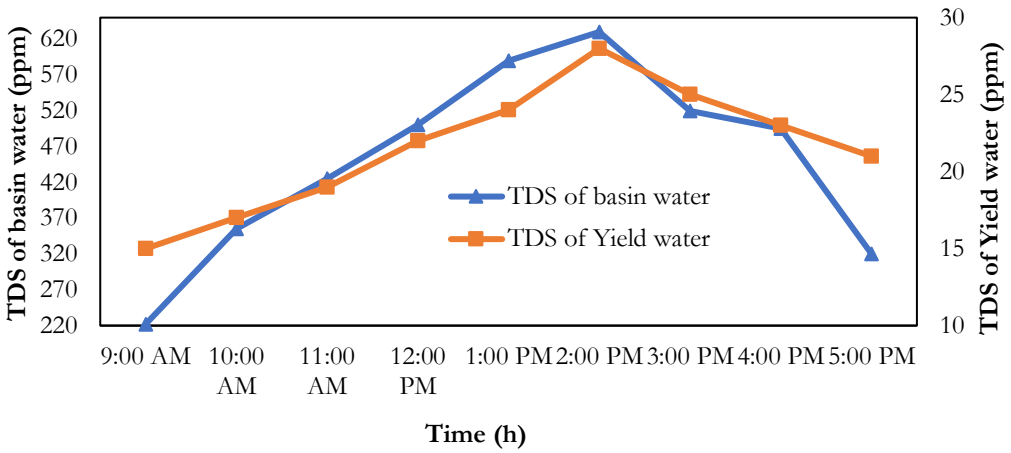

Figure 12: *TDS of basin water and TDS of yield water with respect Time*

Figure 12, this graphical representation has been done for TDS of basin a basin water and TDS of output/yield water. Initially, TDS of yield water is higher due to lower temperature as the less availability of sun rays. It can be observed that as the time passes TDS of yield water becomes lower to TDS of basin water. Its maximum value obtained at 2 pm which still less than the basin water TDS.

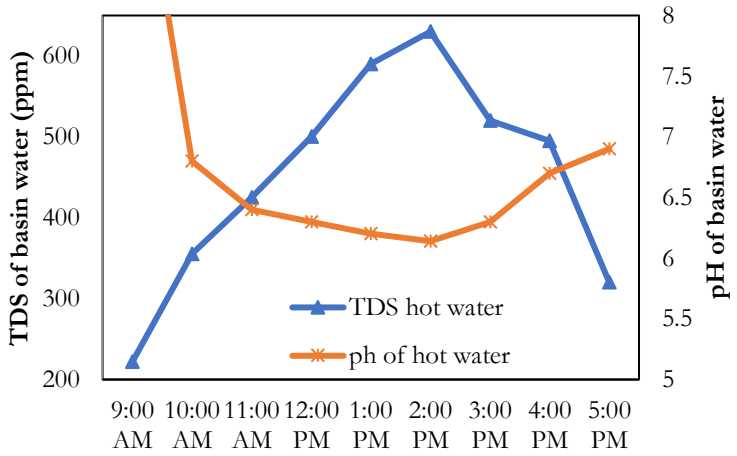

Figure 13: *TDS of basin water and pH of basin water with respect temperature*

Figure 13 shows the relation of water pH level with water temperature which is depended hourly solar irradiation. In this graph it shows that when temperature of water gets heated the TDS of hot water also increases but pH gets decreases. As the availability of sun energy increases, it causes more absorption of energy which results excess heat and more hydrogen ions are produced. Higher hydrogen ions make reduction in pH value.

5 Conclusions

In the present work, parabolic solar collector has been integrated with double slope glass solar distillation still. Mineral cartridge is applied to the given system to increase the TDS level and maintain pH of output water to use it as potable water.

- All the readings are taken between 9 AM-5 PM. In the experiment the temperature of hot water and temperature of black box are measured w.r.t time.

- While the corresponding hot water temperature obtained at this time is 69 °C. Since the peak temp is being obtained at 2 pm resulted the peak value of yield as 135 ml/h.
- As the time proceeds, the availability of solar energy reduces. Hence output yield also get reduced. The overall yield varied from 53 ml/hr. to 60 ml/hr. having peak value of 135 ml/hr.
- TDS of water in still basin and TDS of yield water are evaluated. As the trend obtained by experiment TDS of water has proportional relation with temperature of water. TDS of water is increasing as the temperature of water increases. pH of virtually pure water with no dissolved salts resulted in a value of 5.6.
- The pH of water tends towards neutral behavior as the total dissolved solid increases. Initially contaminated water with pH of 9.8 has been taken. The lowest obtained pH value is 6.14 at 2 pm.
- The TDS level of water is influenced by various factors, including natural sources, sewage, urban run-off, industrial wastewater, chemicals utilized in water treatment, and the water's inherent characteristics.

The present study investigates the properties and characteristics of piping materials utilized in water conveyance hardware. In the experiment performed, TDS value of distilled yield water ranges from 15 to 221 ppm with a peak value at 2 pm. The maximum value enhances at 2 pm.

6 Declarations

6.1 Study Limitations

There are no limitations that significantly affect the research outcome.

6.2 Acknowledgements

The authors would like to thank the mechanical engineering department of MMMUT Gorakhpur for providing laboratories to conduct experiments smoothly and successfully.

6.3 Warning for Hazard

The “Fabrication of the Experimental Setup of the Solar Distillation System Integrated with a Parabolic Collector” does not involve any chemicals, procedures, or equipment with unusual hazards.

6.4 Competing Interests

The authors declare no conflicts of interest.

6.5 Publisher’s Note

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How to Cite

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