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# Performance Analysis of Solar Still for Potable Water Under Different Pressure Conditions

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**Abstract**

The present work is an outlook to enhance the productivity of a basin type double slope Solar Still with variant pressure. In India three fourth of its rural population is not having access to piped and clean drinking water and the scenario is not much different even in metropolitan cities. Only in Hyderabad, government spent 1450 crores as drinking water project and also provided 20 kiloliter per month to its consumers. The need of drinking water availability is rising and becoming too expensive. Various filtration techniques are available in the market. Solar desalination proves to be one of the most sustainable filtration techniques. The current work deals with the fabrication and experimentation of double slope solar still of $2m^2$ aperture area for portable drinking water. The composition of the water to be desalinate is not the sewage water but the normal ground water having a TDS level of more than 500PPM. The material for the basin is taken to be Fibre Reinforced Plastic (FRP) for ease in manufacturing and capability to attach to acrylic sheet for transparent walls from south east and west. The basin absorber is metallic sheet of 20 gauge. . The finding is indicate that the transparent sheet used as the walls of the still leads to higher yield and thus can further be increased if different pressure levels of 0.5 to 0.75 atm be applied.

**Keywords:** Solar Still, Potable water, Energy & Energy analysis, Mathematical Modelling.

## INTRODUCTION

The afore mentioned demands or issues are placing strain on water supplies worldwide. The world's freshwater resources are diminishing as a result of growing industry, droughts in some areas that lead to desertification, and population growth. World Water Development Report: Managing Water under Uncertainty and Risk (WWAP-World Water Assessment Programme, 2012) projects that by 2050, there will be 9.1 billion people on the planet, up from 6.9 billion in 2010. The demand for food is expected to climb by 50% by 2030 and by 70% by 2050, but the demand for energy from hydropower and other renewable energy sources is expected to rise by 60% (Anon, 2012a).When compared to other industries, the agricultural sector as a whole has a significant water footprint; 70% of the water extracted by the agricultural, municipal, and industrial (including energy) sectors comes from agriculture.

The Food and Agriculture Organization of the United Nations projects an 11% rise in irrigation water usage from 2008 to 2050, according to the FAO-2011 report (Anon, 2011a). Over the past thirty years, concerns about food insecurity have grown throughout the world, and there are fewer and fewer sources of potable water available due to the needs of various sectors as previously mentioned, as well as water pollution from anthropogenic activities and industrial growth, including water consumption rates in the domestic, industrial, and agricultural sectors, industrial effluents, domestic sewage, agricultural runoff, poor water management, etc.In addition to the various uses of water resources mentioned above, clean water is necessary for human consumption, cooking, and other needs for all living things on Earth. The human body needs water for around 57% of its composition (Guyton et al., 1975; Guyton, 1976) to carry out various functions such as digestion, absorption, circulation, nutrient delivery, tissue formation, waste removal, and body temperature regulation. When the body doesn't get enoughwater, cell activityis disrupted, which can lead to chronic dehydration and occasionally cause symptoms including weakness, anxiety, headaches, dizziness, and weariness in people. 10% of the body's water loss can cause significant physiological impairments, and 20% of the body's water loss can result in immediate death (Zheng, 2017).

Although water is essential to human health, it is currently contaminated due to rapid industrialization and population increase. Large amounts of solid trash, petroleum products, salts, hazardous materials, contaminated industrial waste, and chemical waste are all present in the contaminated water. When certain metals or poisonous chemicals are combined with water, either in dissolved or suspended form, the water's quality deteriorates and it becomes unfit for use in any application without first being treated.However, when fresh water resources are destroyed by wastewater pollution, people are forced to consume contaminated water for their daily needs, further exacerbating the mismatch between supply and demand for water.

The per person's daily water requirement for survival is between 7.5 and 15 liters (lpd), depending on their needs, including (i) drinking and food: 2.5–3 lpd, (ii) basic hygiene: 2–6 lpd, and (iii) basic cooking: 3-6 lpd, according to the World Health Organization's (WHO) Technical Notes on Drinking Water, Sanitation and Hygiene in Emergencies (WHO-2011). Still, studies show that 20 liters of safe water per person per day is the minimal amount needed to achieve minimum critical levels for health and cleanliness (Anon, 2011b).

Therefore it is crucial to have fresh, safe water for drinking and other uses (WHO-2004: Anon, 2004). As a result, the WHO and all other countries have established criteria for the maximum amount of safe drinking water that can be consumed, taking into account local technology and water quality.

A catalogue of tasters has assessed the total dissolved solids (TDS) level of drinking water and determined the following levels of palatability: excellent (less than 300 mg/l), good (between 300 and 600 mg/l), fair (between 600 and 900 mg/l), poor (between 900 and 1200 mg/l), and unacceptable (greater than 1200 mg/l). The flat, insipid taste of water with incredibly low TDS concentrations may also make it unpleasant (Anon, 2011b; Anon, 2018a).

**Need of water purification technologies**

By 2025, almost 60% of the world's population would experience a water scarcity as a result of overusing groundwater and natural resources, which are essentially sources of potable or drinking water (El-Dessouky and Ettouney, 2002). The world is fully aware of the dire repercussions and environmental damage caused by the overuse of freshwater supplies. Transporting fresh water to underdeveloped nations or communities appears to be the only viable solution to this issue, but the high expense of transportation makes this option unfeasible (Gude, 2016; Badran et al., 2017).

Since 97.5% of the water on Earth is seawater and more than 70% of people live within 70 kilometers of a sea body or ocean, all these worries about a shortage of water have brought about a sincere awareness of the need to desalinate brackish or seawater using various desalination processes that are currently available in the market or industry to meet society's needs for fresh water (Ibrahim et al., 2017).

Depending on the method used to purify the water, energy consumption can range from 2.5 to 15 kWh/m3 (Thu et al., 2016). Reverse osmosis (RO), multi-effect distillation (MED), and multi-stage flash (MSF) distillation are examples of desalination technologies that have relative market shares of 51%, 8%, and 32%, respectively.

However, these technologies are primarily dependent on grid-dependent electricity or coal-based power plants, which come with high maintenance costs and continuously add to environmental pollution, leading to the emission of greenhouse gases (Lattemann, 2010; AlMarzooqi et al., 2014).

Although conventional desalination methods can also be used to purify water, they are more energy-intensive and rely on fossil fuels, which contributes to the degradation of ecology and natural ecosystems due to carbon emissions into the atmosphere (Gude et al., 2010).

In order to combat global climate change, all of these facts encourage us to employ water purification technology that is economical, sustainable, dependable, renewable, and based on clean energy sources to generate fresh, potable water while emitting no carbon dioxide.

***Table 1:****Approximate ranges of energy demand for various desalination technologies*

| **Technology** | **Energydemand ($kWh/m^3$)** |
|---|---|
| Multi–stageflashdistillation(MSF) | 9–60 |
| multi–effectdistillation(MED) | 7–59 |
| Reverseosmosis(RO) | 2–7 |
| Electrodialysis(ED) | 0.3–8.8 |
| Capacitivedeionisation(CDI) | 0.1–2.05 |

**The Solar Distillation Process**

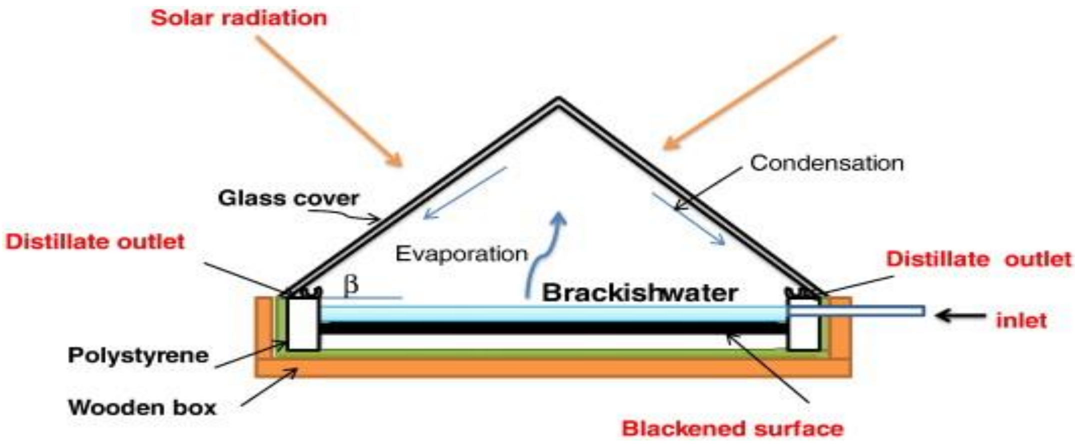


***Fig 1:*** *Solar Distillation Process*

Figure 1 shows the process of solar distillation. The solar energy passing through a glass cover water in a pan; heats up the brine or sea then rises this causes the water to vaporize. The vapor and condenses on the underside of the cover and runs down into distillate troughs.

**Technical description is as follows:**

1. The Short electromagnetic waves from the sun travel through transparent glazing materials like glass. modifications This light wavelength becomes lengthy waves of heat when it strikes a darkened surface, adding heat to the water in a shallow basin beneath the glazing. The water starts to evaporate as it gets hotter.

2. The heated vapor rises to a lower temperature. In the basin, almost all impurities are left behind.

3. Vapor condenses onto the colder glazing's underside, where it collects into water droplets or sheets.

4. Water can flow down the cover of a collection trough and into the area where it is routed into storage thanks to gravity and the tilted glass surface.

The aperture area of solar still in consideration will be 2 $m^2$. A faster rate of evaporation and an increase in the still's yield are the anticipated results.

**EXPERIMENTAL INVESTIGATION**

The double slope solar still uses sun radiation as the heat source to purify water based on the straightforward distillation theory. The fundamental idea of solar water distillation is straightforward, but it works well because it mimics how rain is naturally produced. To allow sunlight to enter the system throughout the day, the walls on the south, east, and west sides are made translucent. Compared to a traditional double-slope solar still, this modification has the advantage of utilizing solar energy—that is, incident solar radiation—for the longest possible amount of daylight, which increases yield. Heat is transferred from the sun to brackish water through a basin, which is covered in transparent walls and glass coverings.

The distillate obtained on both sides of the solar still is impacted because of the huge absorbing area for collecting the incident solar energy over the basin liner. Additionally, the temperature differential between brackish water and glass coverings affects how much yield is produced.

Because of the variable temperature disparity between the glass cover and wall on either side, the yield obtained during the day varies as well, except at midday.

Due to low glass temperature on the west side, which results in a greater amount of condensate on this side, the west side experiences a greater temperature difference when the sun moves eastward, and vice versa. The temperature of the glass covers is similar at noon, and the change in temperature between the two is about equal on both sides. This results in an equivalent quantity of yields being received on the east and west sides.The photograph of experimental setup is shown in Fig.2


***Fig 2**: Photograph of experimental setup*

**RESULT AND DISCUSSION**

At the Chhatrapati Shivaji Maharaj Institute of Technology in Panvel, Navi Mumbai, experiments have been conducted to gather the climatic data for typical days for the months of January 2024 to May 2024.

**The Following Step have been followed for the calculation of results**

**Step No. 1** Experimental measurements are made of the fabricated solar stills' hourly variations in sun intensity on the glass cover and walls, as well as the temperatures at various places.

**Step No. 2** Heat balancing equations and empirical formulae are used to estimate the conductive, convective, radiative, internal, external, and overall heat transfer coefficients based on observed experimental values.

**Step No. 3** The computed water temperature value is assessed using the HTC'c calculated values, and the value is then compared to the experimental data to confirm the experimental findings.

***Table:2** Solar radiation and Ambiet temperature on 15$^{th}$ Jan 2024 at CSMIT Panvel*

| S.NO | Time(hrs) | Ambient Temperature ($C^0$) | Global Solar Radiation ($w/m^2$) | Hourly Yield (ml) |
|---|---|---|---|---|
| 1. | 07.00 | 20 | 125 | 0 |
| 2. | 08.00 | 25 | 230 | 10 |
| 3. | 09.00 | 27 | 450 | 20 |
| 4. | 10.00 | 30 | 600 | 70 |
| 5. | 11.00 | 32 | 750 | 135 |
| 6. | 12.00 | 35 | 900 | 195 |
| 7. | 13.00 | 36 | 915 | 198 |
| 8. | 14.00 | 37 | 870 | 230 |
| 9. | 15.00 | 34 | 820 | 235 |
| 10. | 16.00 | 33 | 775 | 230 |
| 11. | 17.00 | 30 | 745 | 220 |
| 12. | 18.00 | 28 | 320 | 193 |
| 13. | 19.00 | 27 | 85 | 190 |

| | | | | |
|---|---|---|---|---|
| 14. | 20.00 | 26 | 0 | 55 |
| 15. | 21.00 | 25 | 0 | 50 |
| 16. | 22.00 | 24 | 0 | 25 |
| 17. | 23.00 | 23 | 0 | 15 |
| 18. | 00.00 | 21 | 0 | 10 |
| 19. | 01.00 | 20 | 0 | 10 |
| 20. | 02.00 | 19 | 0 | 8 |
| 21. | 03.00 | 18 | 0 | 10 |
| 22. | 04.00 | 19 | 0 | 8 |
| 23. | 05.00 | 19 | 10 | 8 |
| 24. | 06.00 | 20 | 50 | 15 |
| | | | | **2140** |

Ambient air temperature  and Global solar radiation  are plotted in the following picture, which is based on experimental observational data collected for the composite climatic state of Panvel, Navi Mumbai, on a normal day in January 2024 at a depth of 0.01 m. Global solar radiation is shown to progressively increase from morning to midday (about 11:00–12:00 hrs.) and then decrease until the end of daylight hours, as seen in Fig. 3 on January 15, 2024.

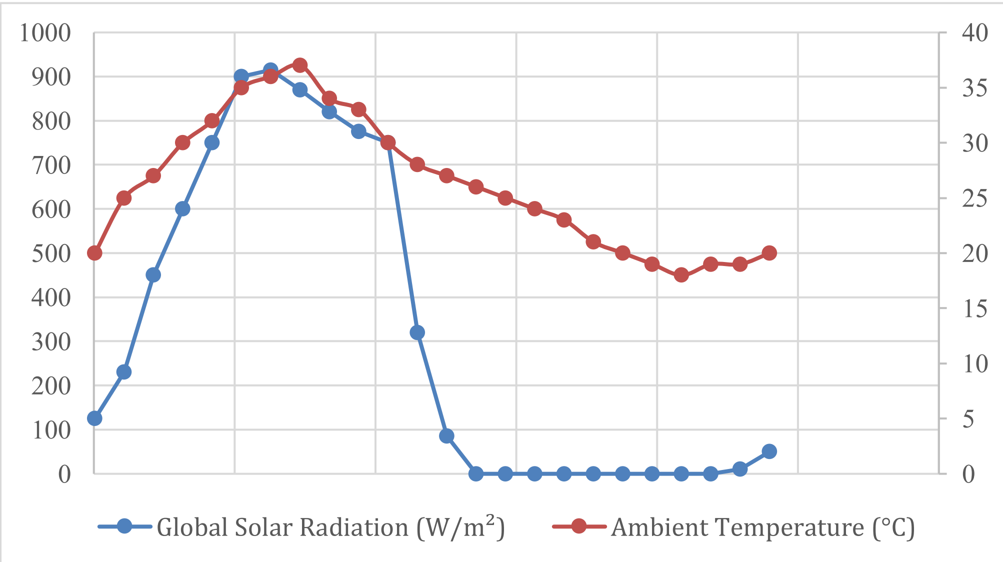


***Fig 3**: Solar radiation and Ambiet temperature on 15th Jan 2024 at CSMIT Panvel*

At 13:00 hours, the highest recorded value of sun radiation across the globe was 915 W/m2. Between 09:00 and 15:00, the measured solar radiation varied from 676 W/m2 to 572 W/m2.

The difference between the measured and average solar radiation values for this time period (09:00–15:00) was more closely aligned.At 14:00, the highest recorded ambient temperature was 36 °C. It was discovered that the average ambient temperature was 29.8 °C. Throughout the experimentation period, fluctuations in wind velocity were detected, ranging from 0.0 m/s to 3.2 m/s. It was discovered that the average wind speed was 0.82 m/s.

***Table 3****: The hourly variation of basin, vapor,and inner and outer glass surface,temp.*

| S.NO | Time(hrs) | Average Ambient Temperature ($C^0$) | | | |
|---|---|---|---|---|---|
| | | $T_b$ | $T_{og}$ | $T_{ig}$ | $T_v$ |
| 1. | 07.00 | 30 | 27 | 28 | 30 |
| 2. | 08.00 | 37 | 33 | 34 | 37 |
| 3. | 09.00 | 46 | 35 | 37 | 46 |
| 4. | 10.00 | 53 | 44 | 43 | 53 |
| 5. | 11.00 | 63 | 49 | 47 | 62 |
| 6. | 12.00 | 66 | 56 | 52 | 66 |
| 7. | 13.00 | 68 | 60 | 59 | 71 |
| 8. | 14.00 | 66 | 54 | 53 | 58 |
| 9. | 15.00 | 63 | 49 | 47 | 54 |
| 10. | 16.00 | 59 | 44 | 43 | 52 |
| 11. | 17.00 | 56 | 39 | 39 | 51 |
| 12. | 18.00 | 47 | 37 | 37 | 42 |
| 13. | 19.00 | 43 | 34 | 34 | 36 |
| 14. | 20.00 | 38 | 29 | 29 | 34 |
| 15. | 21.00 | 31 | 28 | 27 | 32 |
| 16. | 22.00 | 28 | 24 | 25 | 27 |
| 17. | 23.00 | 26 | 22 | 23 | 24 |
| 18. | 00.00 | 23 | 23 | 22 | 20 |
| 19. | 01.00 | 22 | 22 | 21 | 19 |
| 20. | 02.00 | 19 | 18 | 18 | 18 |
| 21. | 03.00 | 18 | 17 | 17 | 18 |
| 22. | 04.00 | 17 | 13 | 16 | 17 |
| 23. | 05.00 | 16 | 12 | 14 | 16 |
| 24. | 06.00 | 23 | 12 | 14 | 19 |

As seen in Figure 4. Every temperature profile has been seen to progressively climb as incident solar intensity rises, reaching its maximum values in the afternoon and then declining in the evening and night.At 13:00 hours, the highest temperatures recorded for the basin, vapor, inner, and outer glass surface were determined to be 68°C, 71°C, 59°C, and 60°C, respectively..

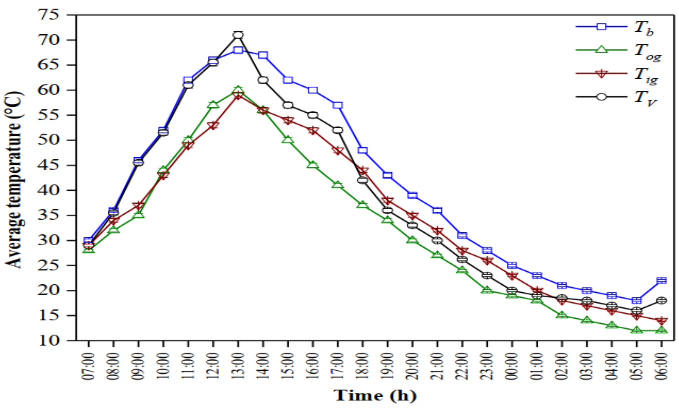


***Fig 4**: The hourly variation of basin, vapor, and inner and outer glass surface temperatures*

The standard deviations corresponding to these temperatures were determined to be 17.04 °C, 17.54 °C, 4.25 °C, and 15.08 °C, in that order. Throughout the course of the experiment, an average temperature difference of 2.57 °C was observed between the inner glass surface and the vapor. On January 15, 2024, the standard deviation of the water's temperature was determined to be 16.98 °C.

## CONCLUSION

The research work is essential to find the feasibility of the solar desalination process for sustainable filtration process. The maximum temperature of the water was found to be around $68^0$C which is quite low as compared to evaporation temperature of $100^0$C and thus leads to low evaporation rate and thus the suggestion of having a low vapour pressure will lead to higher evaporation rate. The higher evaporation rate leads to higher yield rate and more sustainable filtration process.

The suggested solution to the water problem can be considered only after having the study of ecological foot print with the implementation of a vacuum pump which leads to higher power consumption and thus the price of filtered water also increases.

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