Experimental and Theoretical Analysis of Hourly Yield for a Square Pyramid Solar Still: Effect of Water Depth, Salinity, and Heat Transfer Coefficients

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Abstract - *Freshwater suitable for drinking represents only 0.001% of the total water on Earth, with the remainder being saline, brackish, or contaminated. To mitigate the resulting water scarcity, this study investigates a renewable-energy-based desalination approach using a square pyramid solar still. The research was carried out at Kamla Nehru Institute of Engineering and Technology, Sultanpur, India (26°15'53.2"N, 82°4'21.7"E). The still was configured with a glass cover inclination of 30° and operated at two water depths: 1 cm and 2 cm. A mathematical model was developed to compute the convective and evaporative heat transfer coefficients for passive operating conditions. The theoretical hourly distillate output was estimated at 2.23 liters, whereas the experimentally obtained yield was 1.54 liters, indicating a loss of 0.69 liters, which corresponds to approximately 30.94%. The findings highlight the dependence of system performance on water depth, feed water salinity, and local climatic variables. This work offers a comparative evaluation between predicted and measured productivities for pyramid-shaped solar stills, thereby contributing to the optimization of solar-powered desalination systems*

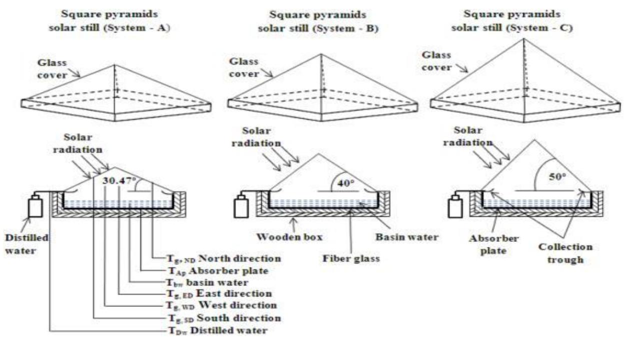
Keywords: Solar Desalination, Pyramid Solar Still, Freshwater Production, Heat Transfer Coefficients, Distillate Yield Analysis.

1. INTRODUCTION

Approximately two-thirds of the Earth's surface is covered by water, while the remaining one-third is land. Despite this abundance, only about 1% of the total water is fit for drinking; another 2% is trapped in glaciers, and the vast majority consists of saline or brackish water that is unsuitable for human consumption.

Numerous review articles have explored various solar still designs, with researchers conducting mathematical modeling and simulations to analyze performance. These studies discuss technological developments, research findings, and emerging innovations. Data have been collected to assess technical and economic feasibility as well as system performance. In recent years, many solar technologies have advanced toward commercial use and up scaling, with productivity and efficiency improved through the incorporation of latent heat storage and phase change materials. Calculations of convective and evaporative heat transfer are performed both mathematically and experimentally. Salinity levels are typically measured using total dissolved solids (TDS), with seawater containing approximately 45,000 ppm and brackish water around 10,000 ppm. Desalination is an energy-intensive process; producing roughly 1,000 m^3 of fresh water per day requires nearly 10,000 tons of fossil fuel annually [1].

1.1 Experimental setup



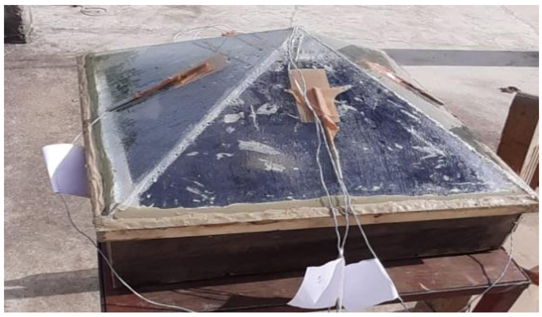


Figure 2: Experimental setup of pyramid solar still

1.2 Working Principle: The principle of solar still is very simple similar to raining, it is a natural phenomenon but for increasing efficiency and performance used various methods the basic structure of pyramid solar still is given as below in fig1 The present work, the effect of inclination angle, water depth level, active and passive mode on the hourly yield on the location the of installation at Kamla Nehru Institute of engineering and technology, Sultanpur Uttar Pradesh, India latitude 26° 15' 53.1936'' N and longitudinal 82° 4' 21.7488'' E.[15]:

Time (hr)	V (m/)	Ta (°C)	Water qty (ml)	γ (%)	p_{atm} (mb)	I_{diff} (W/m²)	I_g (W/m²)	I_{dir} (W/m²)	Tci (°C)	Tco (°C)
8:00	2.9	30.4	0	100	991.6	332	356	37	37.325	37.1
9:00	2.9	31.4	5	100	991.5	466	664	232	41.075	42.375
10:00	2.1	32.9	20	99	991.2	408	829	446	50.7	51.675
11:00	2.1	32.8	20	89	990.8	352	887	528	58.5	56.15
12:00	2.4	35.3	30	83	990.3	385	919	559	56.325	53.725
13:00	3.4	35.5	40	73	989.4	369	629	306	44.125	48
14:00	3.5	35.4	30	70	999.5	381	507	174	58.35	57.775
15:00	3	35.6	40	68	987.9	263	480	358	58.875	57.975
16:00	2.8	35.6	20	72	987.5	159	275	258	47.05	45.3

Figure: 3. Hourly observation of solar still with normal water at height 2cm on 24/06/2025

2. Graphical Representation: The different graph is plotted with this parameter and shows the variation depending on climatic conditions

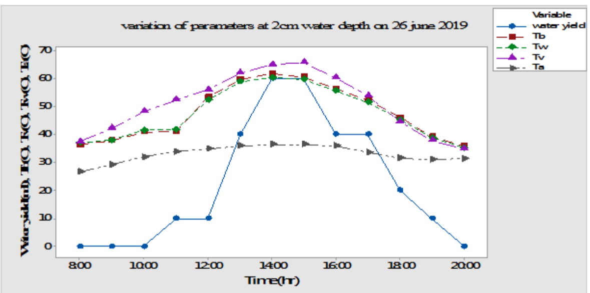


Figure: 04: variation of parameters at water depth 2 cm for normal water

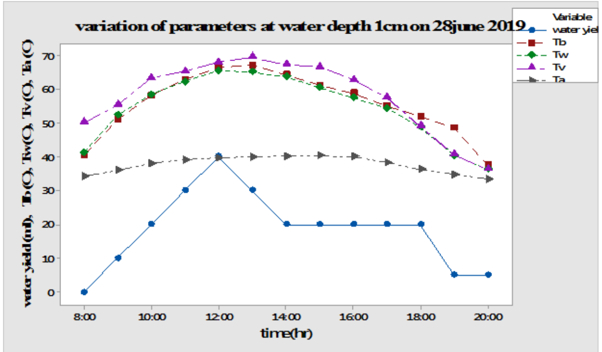


Figure: 05: variation of parameters at water depth 1 cm for normal water

2. RESULT AND DISCUSSION:

It is predicted by various methods such as computer simulation numerical technique method, periodic and transient analysis, thermal circuit, iteration method, and Sankey method, all these methods are based on Ueda and Dunkle's methods which are given for calculation of internal heat and mass transfer in the solar still.

In this experiment shows the variation of different parameters with respect to time at different water depth for normal and saline water. Experiment performed june 2025 and july 2025 at which maximum temperature difference found for more evaporation and condensation occurs, due to this more yield distillate from distillate channel. Various parameters effect for normal and saline water which is given below- .

- More yield and efficiency for saline water compare to normal water
- At higher water depth more efficient than lower one
- Optimum angle of inclination is selected for maximum efficiency and yield
- Maximum temperature difference created for glass and water for saline water
- For saline water outer and inner glass temperature is higher than normal water
- It is suitable for rural area where electricity grid is not available
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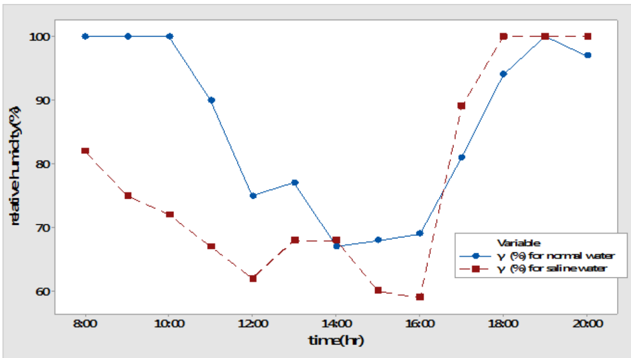

Figure 06: Variation of relative humidity with time for normal and saline water

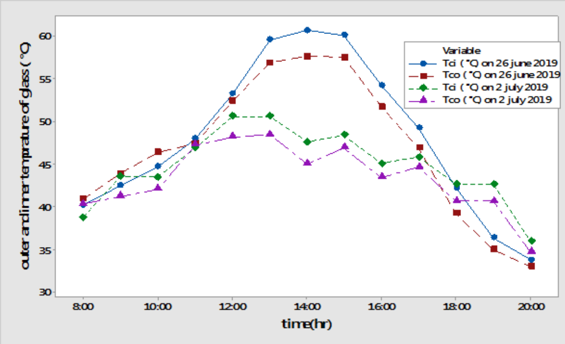

Figure 07: Variation of glass inlet and outlet temperature with time for normal and saline water

3. CONCLUSIONS: This study presented a detailed experimental and theoretical investigation of a square pyramid solar still operated under the climatic conditions of Sultanpur, Uttar Pradesh, India. The primary objective was to determine the hourly yield at water depths of 1 cm and 2 cm with a fixed glass cover inclination of 30°, using both normal and saline feed water. The key findings are summarized as follows.

Several parameters were observed to influence the performance of the pyramid solar still. Saline water yielded higher distillate output and thermal efficiency compared to normal water, which is attributed to the altered thermophysical properties of saline solution that enhance evaporation rates. Additionally, a greater water depth (2 cm) resulted in better efficiency than a shallower depth (1 cm), likely due to increased thermal mass and more sustained heat retention. The optimum glass cover inclination angle of 30° proved effective for maximizing condensate collection. Furthermore, saline water produced higher inner and outer glass cover temperatures than normal water, contributing to a greater temperature difference between the water surface and the condensing cover a key driver for evaporation and condensation.

Wind velocity, ambient temperature, relative humidity, and solar radiation intensity all showed measurable impacts on the still's productivity. Higher solar insolation and favorable ambient conditions increased the yield, while high relative humidity reduced the evaporation rate. The study also confirmed that the pyramid-shaped solar still is particularly suitable for rural and remote areas where grid electricity is unavailable, offering a passive, low-maintenance, and environmentally friendly water purification solution.

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