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Performance Evaluation of Double Basin V shape Solar Still

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Abstract

The escalating global population is fueling a surge in the need for potable water, exacerbating the disparity between supply and demand. To address this, alternative water purification technologies are crucial. Solar desalination emerges as an effective method, converting brackish or saline water into drinkable water using renewable solar energy. This study focuses on modifying an existing solar still into a double basin V-shape solar still coupled with a solar water heater. The V-shape double basin solar still, made from galvanized iron and glass, is assessed for solar distillation. The research involves manufacturing, testing, and evaluating the solar still's output connected to a solar water heater. Distillation rates at specified water levels are calculated and compared with other studies. Laboratory testing reveals a significant decrease in pH, total dissolved salts, hardness, and electrical conductivity in the distilled sample compared to the original, all falling within acceptable parameters. This pioneering method offers a hopeful resolution to the issue of water scarcity by leveraging solar energy for effective desalination.

Keywords: V shape solar still, water heater, desalination.

1. Introduction

A solar still is a device that uses solar heat for distillation, providing a simple method to obtain clean drinking water in remote areas. Its basic design includes a container for contaminated water, a transparent cover for sunlight entry, and a lower basin for collecting purified water. Contaminated water evaporates under sunlight, condenses on the cover, and is collected in the basin. This process effectively removes impurities and pathogens. Solar stills are cost-effective and sustainable, suitable for off-grid locations. They can also desalinate saltwater. Solar distillation in a still involves heating, evaporation, and condensation, mimicking the natural rainwater cycle. The principle is applied by filling a black-painted basin with saltwater, enclosed with a transparent, sloped glass cover. Solar radiation heats the water, causing it to evaporate, and the vapor condenses on the glass, forming droplets that slide to the collector, resulting in purified distillate water.

2.Literature Review

Tiwari et.al (1994) [2] investigated the impact of varying the inclination of the glass cover on yield and internal heat and mass transfer. Their findings indicated that yield increases with a rise in inclination during winter but decreases during summer. Moreover, they observed a notable decrease in the evaporative heat transfer coefficient with an increase in inclination in both seasons, particularly pronounced during summer.

Bassam et.al (2002) [5] examined the effectiveness of sponge cubes in increasing the surface area for water evaporation. They found that the effectiveness of sponge cubes diminished as the salinity of the basin water increased, yet they outperformed cubes made from black steel or coal.

Ali et.al(2004) [6] explored the effects of a locally crafted fin-tube collector integrated with a single-stage, basin-type solar still under local conditions. Their measurements under various operating conditions, using tap and saline water as feeds, indicated a significant rise in distilled water production. This augmentation improved solar still efficiency, leading to increased freshwater output from contaminated water sources.

Shanmugan et al. (2007) [8] pointed out that the solar still performed relatively poorly when it came to collecting water, but they suggested that this may be fixed by including an acrylic booster mirror. It was discovered that the booster mirror was reflecting too much solar radiation onto the water's surface, which accelerated the process of evaporation and distillation.

Panchal et.al (2010) [10] evaluated the performance of a Double slope Solar Still with three absorber plates made of different materials: Galvanized iron sheet, Copper sheet, and

Mild Steel sheet. Their observations concluded that more distillate was obtained from the copper absorber plate compared to the galvanized iron sheet as well as the mild steel plate.

K Sampathkum et.al (2010) [12] n this experiment, solar water heater is connected solar still in order to enhance the yield. The evacuated type solar heater is integrate with still, & experiment was done and output was studied at interval of the time and it was concluded that productivity of the still gets doubled when it was connected

Yazan Taamneh et.al (2012) [13] In this study, the effect of forced convection on a pyramid shaped still was experimentally conducted in the climatic conditions of Tafila City (south of Jordan). The designed solar still, featuring a basin area of 0.95 m^2 and a pyramid shaped transparent cover, demonstrated enhanced freshwater production through the cost-effective integration of a fan powered by photovoltaic solar panels. The results revealed a significant increase in the evaporation rate, leading to a 25% rise in daily freshwater productivity compared to a free convection solar still.

A.S. Abdullah (2013) [14] investigated the efficiency of using a solar air heater in combination with a stepped solar still. The fabrication process included the construction of a stepped solar still with a solar air-heater collector in addition to a single slope solar still, or conventional still. With combined hot air and glass cover cooling, the stepped still's water productivity increased by 112% when compared to the traditional still.

Ali. F. Muftah et al. (2014) [15] underscored the influential factors affecting the output of solar stills, with climate, design, and operational parameters emerging as the most significant. The productivity of the solar still was found to be directly linked to total solar radiation, ambient air temperature, and wind speed.

Hitesh N. Panchal (2017) [16] developed a model of a solar still in ANSYS-CFD and conducted a comparison between experimental and simulation results, revealing a satisfactory agreement between them. Parameters such as inner glass cover temperature, outer glass cover temperature, vapor temperature, and basin water temperature were identified as directly proportional to distillate output..

T. Arunkumara et.al (2018) [17] This study categorizes solar still designs with productivity greater than 5 l/m2/day and discusses modifications and heat transfer mechanisms that improve their efficiency. This review serves as a reference for future researchers focused on high productivity solar stills.

R. Lalitha Narayana et al. (2018) [18] conducted a comparative study on the performance of a solar still in passive and active modes. The active solar still yielded higher outputs attributed to the augmented radiation collection area and heat absorption rate. Additionally, the study analyzed the attributes of both initial and final samples, revealing substantially lower pH, total dissolved salt, hardness, and electrical conductivity values in the distilled sample compared to the original sample, all within acceptable limits.

Kalpesh V. Modi et.al (2018) [19] this study tested the use of different wick materials in single-slope double-basin solar stills to increase their productivity. In the experiment, the yields of two unique stills—one with jute fabric and one made with black cotton cloth—each with a different water depth were contrasted. The still with the jute fabric proved to yield more than the one with the black cotton cloth.

Bilal et al. (2019) [20], introducing energy storage material to the basin increased the solar still's night output yield. On the other hand, it turned out that during the day, the yield dropped as the total weight of the identical storing substance increased. This study demonstrates how using sensible energy storage materials with low thermal conductivity and high porosity impacts the solar still are efficiency and distillate output.

Vivekanand Krishnaswamy and colleagues (2019) [22] conducted a comparative analysis of the efficiency and output of a V-shape single basin solar still operating in both passive and active modes (coupled with a flat plate collector). Their study revealed that the distillate output increased in active mode compared to passive mode, albeit with a decrease in efficiency.The study highlighted a scarcity of experimental investigations on V-type solar stills coupled with solar water heaters. The purpose of this experimental study was to examine the distillation of saline water by the use of a V-type solar still in conjunction with a flat plate solar-powered water heater. Key problems with solar distillation systems that have been identified are high initial costs, which result in high expenses per unit production, and the need to increase productivity (i.e., LPD/m^2). Productivity at a 50 mm level of water in an active mode was examined experimentally.

2. Methodology

I. Experimental Setup

Figure 1 : Experimental Setup

The experimental setup depicted in Fig. 1 was installed on the rooftop of a building in Virar West, Maharashtra. The lower basin of the V-type solar still is constructed from 16-gauge galvanized iron sheet, measuring 1m x 1m x 0.3m, with its base painted black to maximize heat absorption. The upper basin consists of 6 mm thick glass, sharing the same dimensions as the lower basin. Figure 1 depicts how the setup is put together. In order to stop heat loss, Rockwool is used as insulation on all surfaces of the bottom basin, including the base and side sides. The glass forms a V shape because it is angled at a 22° angle to the horizontal. Oriented east-west, the glass surface acts as a condensation surface for water vapor that has evaporated. The brackish water gets heated using an evacuated solar heater type before being fed into the solar still. The solar still is then filled with this heated water, which increases the rate of evaporation and boosts production.

II. Experimental Procedure:

Location: Virar, Palghar district, Maharashtra, India (19.4564° N, 72.7925° E) Period: April and May 2022 (Summer season)

Saline tap water stored in a black water tank.

Opening the valve of the water tank initiates water flow into the solar water heater. Solar water heater heats the water. Opening the solar water heater valve directs heated water into both basins of the solar still. Water depth in each basin maintained at 50mm daily at 8 am.

Condensation occurs on the inner surface of the top glass in both basins. Condensate droplets roll down to the V edge and into plate/pipe channels at a 2° tilt. Sloped plate/pipe directs condensed water outside into a measuring jar/drum via a connected pipe. Collection and measurement of condensed water in each jar for each basin. Hourly temperature recording for each basin: a) Inner surface of Basin b) Vapor space of Basin c) Outer surface of Basin d) Water temperature of Basin e) Ambient temperature. Hourly measurement of condensate. Solar radiation calculated theoretically due to unavailability of a solarimeter (pyranometer). Productivity is calculated and compared with productivity of [22]. Samples of output distilled water and input saline water sent to the laboratory for testing.

III.Results and Discussion

The experiments were conducted between 9 am and 5 pm, during which the still was connected to a solar water heater. Figure 2 illustrates the outcomes of the tests performed over a span of 7 days, commencing from 02/05/2022 to 08/05/2022. The initial water level was set at 50 mm. The experiment commenced with the transfer of hot water from the storage tank to the still, maintaining the water level at 50 mm. Productivity is more in v shape double basin compare to v shape single basin.Figure.3 shows the laboratory report, for parameters like pH, TDS, Hardness and EC values, for input saline tap water v/s output distillate water, it is observed that the output collected is under the acceptable limit.

V-shaped double basin result		V-shaped single basin result	
Date	Total output distillate water for double basin (in ml)	Date	Total output distillate water for single basin (in ml)
02-May	4050	23-Jan	1790
03-May	4530	25-Jan	2225
04-May	4600	26-Jan	595
05-May	4700	27-Jan	640
06-May	4640	29-Jan	1890
07-May	4580	30-Jan	2215
08-May	4450	31-Jan	2135

Figure 2: Comparison of result of V-shape single and double basin


kalpin WATERTECH

ANALYTICAL TEST REPORT

Figure 3: Test report

3. Conclusion

The V-shaped double basin solar still is an innovative design that enhances the efficiency of distillation by utilizing two separate basins. This design increases evaporation and condensation rates, leading to a remarkable 100% average increase in the productivity of distilled water. Laboratory reports for parameters like pH, TDS, Hardness, and EC values confirm that the output distillate water falls within acceptable limits, showcasing its purification effectiveness. In conclusion, this solar still proves highly efficient in water purification, especially in sun-rich areas, owing to its dual-basin configuration, increased sunlight exposure, and elevated water temperature. The V-shaped design shows promise for providing clean water in remote locations despite potential variations in sunlight, water temperature, and still size and orientation.

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