EXAMINING THE EFFICIENCY OF DIFFERENT KINDS OF SOLAR STILLS

Ravindra K Jain*

*Professor,
Department of Civil Engineering, Faculty of Engineering,
Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, INDIA
Email id: ravi.engineering@tmu.ac.in

DOI: 10.5958/2249-7137.2021.02643.4

ABSTRACT

In the area of desalination, solar is still the best technique. The solar still is a device that uses energy that is freely and abundantly accessible on our planet to turn wastewater into fresh distillate water. Fresh water is required and demanded by people all around the globe. Solar stills are used to address this issue by increasing the production of drinking water. Solar stills may be constructed even by untrained workers, using easily accessible local materials and no complicated design. The purpose of this essay is to compare the different variables that affect the solar still's output. This in-depth analysis will also shed light on the need for further study and suggestions in the field of desalination. Aristotle proposed a technique for evaporating polluted water and then condensing it for drinkable use as early as the fourth century. The first recorded work on solar distillation, however, was done by Arab alchemists in the fifteenth century.

KEYWORDS: *Basin, Desalination, Fin, Reservoir, Solar, Vapor.*

1. INTRODUCTION

A system established at Las Salinas, Chile, in 1872 was the first water distillation factory. Every day, individuals living in distant regions or islands, where transporting fresh water is costly, confront the issue of water scarcity[1]. Due to its ease of construction using locally accessible materials, low operating and maintenance needs, and environmental friendliness, solar still has some distinct benefits for usage in these isolated regions or islands. It is really fortunate that solar radiation is also strong during times of high water demand. As a result, it is advantageous to use solar energy directly by installing solar stills. Solar stills have two main advantages: clean and free electricity and environmental friendliness[2].

In a small solar pond, the ideal salinity level is 80 g/kg of water. The average daily output of distilled water using the still in conjunction with the small solar pond and sponge cubes has been found to be rising. The theoretical analysis' maximum deviation is less than 10% of the experimental analysis' maximum deviation. For this common design of the Solar Still Pond-active solar still, the optimal values of flowing water thickness and mass flow rate were 0.03m and 0.0009 kg/s, respectively[3]. The yearly average values of the daily productivity and efficiency of the still with the shallow sun pond were found to be 52.36 and 43.80 percent higher, respectively, then those obtained without the shallow solar pond.

Single-basin solar stills combined with a shallow sun pond increased production throughout the night, with lowest values of 3.0 and 1.570 (kg/m2 d) in December with and without the shallow solar pond, respectively[4]. In July, the highest daily production values were 6.68 and 5.29 (kg/m2 d) with and without the shallow solar pond. Drinking water scarcity is a growing issue in many parts of the globe. To provide sufficient drinkable water, which is currently a challenge in many developing nations. Fresh water scarcity is becoming an increasingly pressing problem in many parts of the globe. Potable water is rare in dry regions, and the development of a human habitat in these areas is highly dependent on how such water can be made accessible. The significance of providing safe drinking water cannot be overstated.

Fresh water is fast becoming the world's most valuable human resource[5]. According to the United Nations, by 2025, 63 percent of the world's population, or five billion people, would live in water-scarce regions. According to a study, approximately 2% of the earth's water supply is locked up in glaciers and ice caps, mostly in the north and south poles, and 3% is fresh water. The polar ice caps will melt, causing sea levels to increase and inundating most of the world's current land surfaces. The remainder of the world's freshwater supply (less than 1%), which is found in rivers, streams, lakes, and ponds, also includes a lot of pollutants. In developing countries, 90% of urban sewage is dumped into rivers and other bodies of water[6].

There is a massive amount of garbage produced, with just a portion of it getting handled. Untreated sewage and effluents are dumped into rivers, converting them into sewers or poisonous water sources. In the small solar pond, the ideal salinity is 80 g/kg of water. The average daily output of distilled water has been observed to be rising after combining a small solar pond and sponge cubes with the still. The theoretical analysis' maximum deviation is less than 10% of the experimental analysis'. For this common design of the Solar Still Pond-active solar still, the optimal values of flowing water thickness and mass flow rate were 0.03 m and 0.0009 kg/s, respectively. The yearly average values of the daily productivity and efficiency of the still with the shallow sun pond were found to be 52.36 and 43.80 percent higher than those obtained without the shallow solar pond. Single-basin solar stills are combined with a small solar pond to increase production at night. In December, the monthly average of daily production with and without the shallow solar pond had lowest values of 3.0 and 1.570 (kg/m2 d), respectively.

In July, the highest daily production was 6.68 and 5.29 (kg/m2 d) with and without the small solar pond, respectively. To warm the salty water, a small sun pond was utilized; therefore, a mini solar pond was combined with these stills[7]. These stills were tested separately while using the small solar pond. Sponge were utilized to expand the water exposure area, and production rose by 66%. When all of the changes were combined, the stepped solar's production improved by 100%. The schematic design of the solar still experimental set-up with the small solar pond[8]. A series connection is made between a small solar pond, a stepped solar still, and a wick type solar still.

The stepped solar still uses pebbles, baffle plates, fins, and sponges to boost production even further. It is estimated how productive people are during the day and at night. When fins and sponges were employed in the stepped solar still, the maximum production of 78 percent was discovered. More thermal energy is stored in pebbles, which is released when the sun sets[9]. When pebbles are utilized in the solar stills, greater night production is achieved. We built traditional stills as well as stepped active solar stills with a solar air heater collector. Due to the increased thermal energy provided by hot air to the active stepped solar still compared to the passive solar still, a higher saline water temperature was obtained[10].

2. DISCUSSION

The productivity of the stepped still is 30.4 percent greater than that of the conventional still at a tray depth of 5mm and without any modifications. When compared to a conventional still, the productivity of the stepped still is improved by around 85 percent in this instance. The glass cover cooling method has shown to be an effective and easy instrument for increasing the productivity of stepped solar stills (65 percent greater than traditional stills). The productivity of the stepped still is increased by using aluminum filler under the absorber plate as a simple solar energy storage device (53 percent greater than the traditional still). When both hot air and glass cover cooling were utilized, the water production of the stepped still rose by 112 percent over the traditional still. The traditional single-sloped solar still and a modified stepped solar still, both using salt water, are two kinds of solar stills.

The impact of tray depth and breadth on the stepped solar still's performance is investigated. The stepped still's maximum productivity is reached at a tray depth of 5mm and a tray width of 120mm, which is 57.3 percent greater than the traditional still. The traditional still has a water depth of 5mm and a tray width of 100mm; the glass temperature and basin water temperature of the stepped solar still are approximately 0–2°C and 0–10°C higher than those of the conventional still, respectively. This is due to two factors: (1) a smaller air volume is trapped inside the still chamber than in a conventional still, resulting in a much faster heating of the trapped air; and (2) the step-wise basin has a larger heat and mass transfer surface area than the flat basin, resulting in an increase in the stepped solar still's basin water temperature.

The glass temperature and basin water temperature of the stepped solar still are approximately 0–4°C and 0–3°C higher than those of the traditional still, respectively, with a tray depth of 5mm and a tray width of 120mm. For stepped and traditional solar stills, the daily efficiency and projected cost of 1 Lof distillate are about 53 percent –0.039 $ and 33.5 percent –0.049 $, respectively. Table 2 shows a comparison of the percentage increase in output by different writers. In an effluent settling tank, the textile effluent is cleaned. The tiny solid particles are settled and cleared in the big textile effluent settling tank. In the stepped solar still, the settled effluents are utilized as raw water.

The tiered solar still is made up of 50 trays of varying depths. The first 25 trays with a 10mm height are utilized, followed by 25 trays with a 5mm height. Fins, sponges, pebbles, and combinations of the aforementioned are used to boost the stepped solar still's output. When fins are employed in the stepped solar still, the output rate increases by 53.3 percent. The output of sponges and pebbles rose by 68 and 65 percent, respectively, when they were utilized. When fins, sponges, and pebbles are employed in this basin instead of the typical stepped solar still, a maximum increase in production of 98 percent occurs. Theoretical analysis and experimental findings are in good agreement. The theoretical and experimental analyses have a maximum variance of less than 10%.

Internal reflectors keep the stepping solar steady. The impact of reflecting mirrors on the vertical sides of the stepped still's steps on distillate yield rate and performance was studied.Fins, sponges, and wicks were incorporated into the basin of the single basin solar still to increase its production. Analytical solutions to the governing energy balance equations were compared to experimental findings. The experimental findings were extremely close to those predicted by the theory. The theoretical and experimental findings were separated by 10.1 percent on average. The still's average evaporation rate was just 2 L/m2. When the wick type solar still was utilized, production improved by 29.6%. The difference between theoretical and experimental findings was 10.8%. The productivity of the basin solar still integrated with a sponge increased owing to the sponge's capillary action, which produces an increase in evaporation.

The theoretical and experimental analyses had a maximum divergence of less than 6.2 percent. The sponge volume to basin water ratio was kept constant at 20%. A cross-sectional image of the basin types solar, which still has fins to enhance the absorber plate's surface. As a result, the temperature of the absorber plate and the saline water rose. Productivity rose as the temperature differential between the water and the glass grew. Five fins were utilized in this study, with heights, lengths, and widths of 35, 900, and 1 mm, respectively. When fins were employed, yield rose by 45.5 percent. The theoretical findings were found to be in excellent accord. The difference between theoretical and experimental findings was 10.8%. In the fin type single basin solar still, sponges, stones, black rubber, and sand are utilized; fins serve as an expanded surface, and the temperature of the water rises, increasing the output.

When the sun intensity varies from 740 to 760W/m2, the productivity rises from 0.34 to 0.36 L/m2 with the Fin, with sand and without sand in the solar still. Obviously, this is due to the sand increasing the heat capacity of the basin plate; productivity increases from 0.2 to 0.19 L/m2 when the wind velocity increases from 0.6 to 0.7 m/s. Increased wind velocity reduces productivity and increases convective heat losses at the glass's top surface. When fin, sand, and sponges are employed in a single-basin solar still, the output increases by up to 75%. The findings indicate that this change has a significant impact on productivity. According to the economic study, the estimated payback time for such stills is one year. In comparison to the fins integrated basin plate, the average evaporation rate in the traditional solar still is 1.66 L/8 h lower, i.e., evaporation rate 53 percent.

A horizontal evaporation surface and a condensing surface inclined 14 degrees to the horizontal plane were used in an ethanol solar still. A solar still's performance is improved by the fin incorporated into the basin plate. The solar still was fed with a 10% ethanol solution as a feedstock. When the number of fins that raised an effective absorptance was increased, the model projected yet efficiency might rise to 46 percent. The suggested improved still with porous fins performed better in winter and summer trial studies, with reduced base heat loss owing to the basin water being cooler. In February, the day time distillate was 56 percent higher and the 24hour duration was 48 percent higher than the traditional still, while in May, the day time distillate was 23 percent higher and the 24hour duration was 15 percent higher.

In the month of May, the modified still constructed of expanded polystyrene foam with excellent insulating properties produced the greatest production of 7.5 kg/m2. With the assistance of thermocol insulation, the experimental and theoretical analyses of a single-sloped basin type solar still, consisting of numerous low thermal inertia floating porous absorbers floating next to each other on the basin water, are confirmed. The modified produces a 68 percent increase in production on a clear day and a 35 percent increase on a partly clear day. The dual reflector booster had to be maintained with the larger mirror facing south and the smaller mirror facing east during the first part of the day, until 12:00 noon, when it had to be reoriented with the smaller mirror facing west and the longer mirror facing south again.

The dual reflector booster increases gain by 79 percent over the modified still without it. Because of the lower depths, the water depth has no impact on the modified still. The performance of the finned and corrugated solar stills is tested and compared to that of the conventional still under the same Egyptian climate conditions in order to improve the productivity of the basin solar stills by increasing the surface area of the absorber and rate of heat transfer between the saline water and absorber. When fins were employed, daily production rose by around 20%, and with the corrugated still, it increased by about 17%. Finned, corrugated, and traditional solar stills had daily efficiency of around 41, 40, and 34 percent, respectively. When fins are utilized, daily productivity increases by around 40%, and when the corrugated still is used, daily productivity increases by about 21%. In this instance, the finned, corrugated, and conventional solar stills had daily efficiencies of 47.5, 41, and 35 percent, respectively.

The findings show that the finned and corrugated solar stills have better production than the traditional still. When finned and corrugated solar stills were employed, production rose by 40 and 21 percent, respectively, with a reduced depth amount of salty water 30 L. For finned, corrugated, and traditional solar stills, the daily efficiency and projected cost of 1 L of distillate are about 47.5 percent –0.041 $, 41 percent –0.047 $, and 35 percent –0.049 $, respectively. Under the basin liner, a sandy heat reservoir is created, which is useless in traditional basin solar stills. During low-intensity solar radiation and at night, the sandy heat reservoir serves as a heat source for the basin water.

During this period, more than 12% of total water production occurs. Adding a heat reservoir to a traditional basin solar system costs approximately 10% of the overall building cost. As a result, the expense of having an integrated heat reservoir is offset by the improvement in nighttime production. The heat reservoir is integrated with the solar still in the basin, so pumping systems and operators do not need to switch to night mode. The distilled water produced is tested and found to be safe for drinking and household use. Other kinds of solar stills may easily include an integrated heat reservoir due to the simplicity and cost-effective design. The basin was connected to a vapor adsorbent pipe network made up of an activated carbon methanol pair. Because of the sensible heat absorption by the activated carbon and the latent heat of vaporization by the methanol, losses from the bottom of the still are minimized.

When sponges, gravels, sand, black rubbers, and some of their combinations were utilized, a new solar still integrated with a vapor adsorption bed at the basin was developed, constructed, and evaluated to improve the still's productivity. The innovative still's performance was compared to that of a traditional solar still. The distillate production rate in the vapor adsorption was between 3.1 and 4.3 kg/m2, while the distillate production rate in the traditional still was between 1.9 and 2.3 kg/m2. The greatest difference between theoretical and experimental results was less than 6%.The modified stepped solar still with trays (5mm depth 120mm width) and the standard solar still were investigated experimentally and theoretically. The experimental distillate yield rate of the modified stepped solar still with and without internal reflectors is about 75 and 57 percent greater than that of the traditional still, respectively.

3. CONCLUSION

The following conclusion may be made as a consequence of the foregoing review of the different kinds of solar stills: Comparative examinations of the different types of solar stills and their output are shown. A solar still with floating porous absorbers, extended porous fins, effluent using fin type, fin plate, sponges, pebbles, black rubber, sand, wick, depth of water, latent heat, concentrator internal and external reflectors, concave wick evaporation surface, and reciprocating spray feeding, individually or in combination, can increase the solar still's productivity. The review, which includes precise conclusions derived from different authors' analyses of various types of solar stills, will help the average individual understand past designs and performance, as well as manufacture an ultra-new design with optimal design parameters for increased productivity.

REFERENCES:

1. V. Velmurugan and K. Srithar, "Performance analysis of solar stills based on various factors affecting the productivity - A review," Renewable and Sustainable Energy Reviews. 2011.
2. V. Velmurugan and K. Srithar, "Solar stills integrated with a mini solar pond - analytical simulation and experimental validation," Desalination, 2007.
3. A. A. El-Sebaii, M. R. I. Ramadan, S. Aboul-Enein, and N. Salem, "Thermal performance of a single-basin solar still integrated with a shallow solar pond," Energy Convers. Manag., 2008.
4. Z. M. Omara, A. E. Kabeel, and A. S. Abdullah, "A review of solar still performance with reflectors," Renewable and Sustainable Energy Reviews. 2017.
5. A. K. Kaviti, A. Yadav, and A. Shukla, "Inclined solar still designs: A review," Renewable and Sustainable Energy Reviews. 2016.
6. Z. M. Omara, A. S. Abdullah, A. E. Kabeel, and F. A. Essa, "The cooling techniques of the solar stills' glass covers – A review," Renewable and Sustainable Energy Reviews. 2017.
7. K. Selvaraj and A. Natarajan, "Factors influencing the performance and productivity of solar stills - A review," Desalination. 2018.
8. A. E. Kabeel, Z. M. Omara, and M. M. Younes, "Techniques used to improve the performance of the stepped solar still-A review," Renewable and Sustainable Energy Reviews. 2015.
9. A. E. Kabeel, Z. M. Omara, F. A. Essa, A. S. Abdullah, T. Arunkumar, and R. Sathyamurthy, "Augmentation of a solar still distillate yield via absorber plate coated with black nanoparticles," Alexandria Eng. J., 2017.
10. A. E. Kabeel and S. A. El-Agouz, "Review of researches and developments on solar stills," Desalination. 2011.