Performance assessment of a modified stepped solar still in the climate of libya

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DOI: https://doi.org/10.56293/IJMSSSR.2025.5533

IJMSSSR 2025
VOLUME 7
ISSUE 2 MARCH – APRIL **ISSN: 2582 – 0265**

Abstract: Due to the huge surface, it is challenging to maintain the minimum depth in a traditional basin-type solar still. However, a basin-type stepped solar still, which minimizes the basin's area by using small trays, can try to boost production per unit area by reducing the thermal inertia of the water mass. A novel kind of stepped solar still was created and constructed for this study. Furthermore, theoretical analysis has been done to forecast the output of distilled water. The majority of the numerical models of basin-type solar stills use the temperature and vapor pressure on the water's surface and the still's cover to determine the connections between evaporative heat and mass transfer. The energy balance equations for the absorber plate, saline water, and solar still glass cover are solved in order to obtain the results of the energy balance equations. According to the results, the modified stepped still's production is roughly 83% and 103% higher than that of the conventional solar still and the stepped solar still without modification. Additionally, the modified stepped still's daily efficiency is roughly 23% higher than that of the conventional solar still and 57% higher than that of the stepped solar still without modification.

Keywords: solar thermal energy, solar desalination, stepped solar still.

Introduction

Despite being one of the oldest methods of treating water, desalination is still a widely used treatment method worldwide. Desalination techniques extract a percentage of pure water from seawater using a significant amount of energy (fossil fuels). The environment is polluted by fossil fuels. In the sun desalination process, a solar still is a device that uses solar energy to turn brackish and saline water into drinking water. Despite being a fairly basic device that is easy to construct and requires little maintenance, solar stills are expensive and not widely used due to their inferior productivity. Using the aforementioned idea, numerous sun distillation systems were created over time to purify water in various places across the globe.

Numerous studies examined the efforts made to increase the simple solar still's production.1, 2. Among the materials utilized for heat storage are glass, rubber, and pebbles.3, 4. A unique phase-changing substance was investigated as an energy storage medium at the base of a solar still.According to reports 5, 6, the output increases when energy-storing materials, wick materials, and a decrease in the basin's water depth are provided. When varying-sized sponge cubes were added to the basin, the productivity of a solar still rose from 18% to 27%.7,8 A stepped still was built and examined. When fins, sponges, and pebbles are utilized in this basin, a maximum 98% increase in output is recorded in the stepped solar still. The enhancement of salt water streams in solar stills with a miniature solar pond was also investigated. When pebble and sponge were combined with the fin type solar still, the maximum output of 100% was achieved. The maximum productivity of 80% is achieved when fins and sponges are employed in both sun stills, which are located in series with a solar pond, basin type stepped solar still, and a single basin solar still.

The utilization of fins and sponges in the stepped solar still resulted in the highest productivity of 78% when the solar pond, stepped solar still, and wick type solar still were connected in series.10. Two cascade solar stills were built, one with a latent heat thermal energy storage system (LHTESS) and the other without. The overall productivity of the still without LHTESS was found to be somewhat higher than that of the still with LHTESS. Additionally,11 used trays of varying depth and width in an experiment to examine the efficacy of a stepped solar still.

The findings demonstrated that the tray width and depth have a significant impact on the stepped solar still's yield. Additionally, it is discovered that a tray depth of 5 mm and a tray width of 120 mm yield the highest production of a stepped still. By adding internal reflectors to the vertical sides of the steps, a modified stepped solar still was tested for performance. According to the findings, the productivity of the modified stepped solar still with and without internal reflectors is 75% and 57% greater, respectively, than that of the conventional still.

13 examined the experimental performance of a solar air warmer in conjunction with a stepped solar still. In this instance, the stepped still's production is almost 85% more than that of the traditional still. This work's objective is to assess the improved stepped solar still's performance. When internal and external mirrors and fins are appropriately integrated, this system works to improve absorption and condensation.

2. Analytical theory

Three different forms of solar stills—a modified stepped solar still, a stepped solar still without modification, and a conventional solar still—have all undergone theoretical examination under the same conditions. Figure 1 displays the schematic diagram of the traditional solar still. typical solar still basin area (single basin solar still) 0.5 m × 2.0 m, or 1 m^2 To improve absorptivity, the still's basin was constructed from a black-painted galvanized iron sheet. The still's cover is composed of glass. The schematic diagram of an unaltered stepped solar still is displayed in Figure 2. The dimensions and construction of the stepped still are identical to those of the conventional still.

Additionally, the stepped still's absorber plate consists of five stages, each measuring 0.1 m by 2 m. The schematic diagram of the modified stepped solar still is displayed in Figure 3.Its dimensions and construction are identical to those of a stepped solar still, with the exception of the integrated external condenser, fins, and internal and external mirrors.

However, the analytical results are obtained by solving of the energy balance equations for the basin plate, saline water and glass cover of the solar still. The temperature However, the energy balance equations for the solar still's glass cover, saline water, and basin plate must be solved in order to produce the analytical results. It is possible to continuously check the temperature of the glass cover, basin plate, and salty water.

The following presumptions were made:

1. Conditions in the solar still's transient states.
2. There is no vapor leakage from the solar still.
3. The temperature of the make-up water is ambient.
4. There is very little heat loss from the still's side.

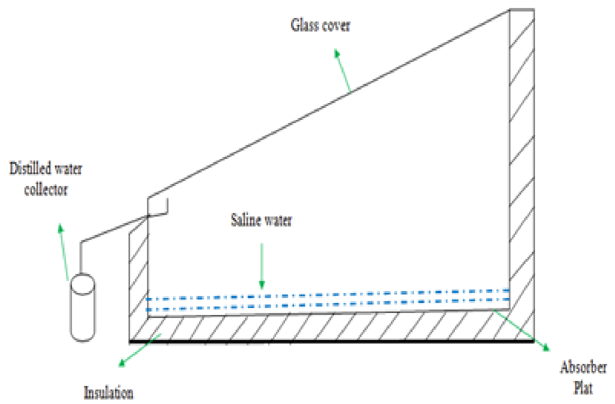

Figure 1: Schematic diagram of conventional solar still

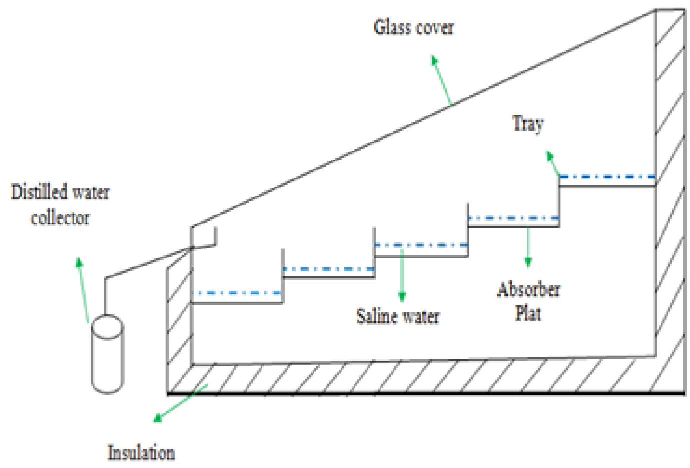

Figure 2: Schematic diagram of Stepped solar still without modification

3. Results and discussions

Three different types of solar stills—modified stepped solar still, stepped solar still without modification, and conventional solar still—have all undergone numerical computations under the identical conditions.

3.1. Effect of solar radiation on the performance of the solar still

Figure 4 shows the variation of solar radiation, ambient temperature, water temperature, and glass temperature of solar stills. It is observed that the temperatures at all points increase with time until they reach a maximum value at noon and then decrease. This is because the intensity of solar radiation increases in the morning and decreases in the afternoon. The results in Figure 4 show that the solar radiation reaches maximum values of 1100 W/m². The temperature of the saline water increases as the solar radiation increases.The productivity rate rises as a result. As solar intensity increased, the ambient air temperature rose correspondingly, and during off-sunny hours, there were declining tendencies. The lowest recorded temperature was 27 °C at 7:00 AM, while the highest recorded temperature was 36.2 °C at 12:10 PM.

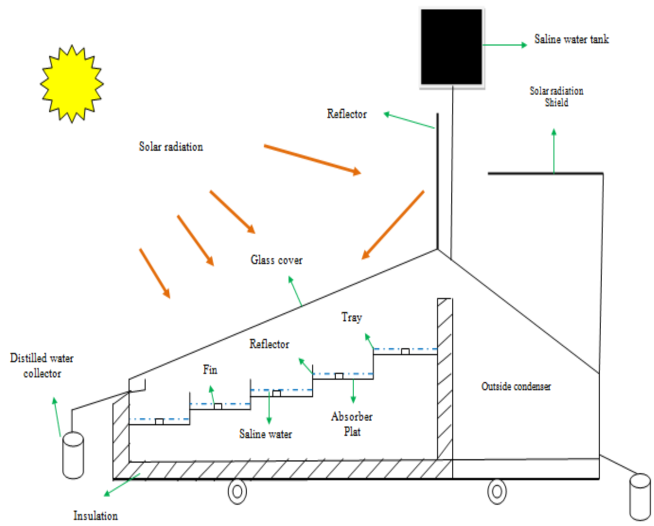

Figure 3: Modified stepped solar still schematic diagram.

Furthermore, the maximum basin water temperature of the modified stepped solar still, the unmodified immersed solar still, and the traditional solar still was approximately 73.7 °C, 60.2 °C, and 54.6 °C, respectively, as shown in Figure 4. The highest glass temperatures of the conventional solar still, modified stepped solar still, and immersed solar still without modification were around 49.1 °C, 54.9 °C, and 69 °C, respectively.

Due to the increased solar radiation, which raises both the ambient temperature and the temperature of the solar still, the performance of the solar still improved in the middle of the afternoon. Figure 4 shows that the modified stepped sun still's saline water and glass temperatures are approximately 13.5 °C, 19.1 °C, and 14.1 °C, 19.9 °C higher than those of the conventional solar still and the immersed solar still without modification.

This is due to the stepping still's reflector being added. This reflector raises the water and glass temperatures of the stepped solar still by reflecting a portion of the radiation onto the water's surface. Accordingly, stepped solar stills had faster evaporation and condensation rates than traditional

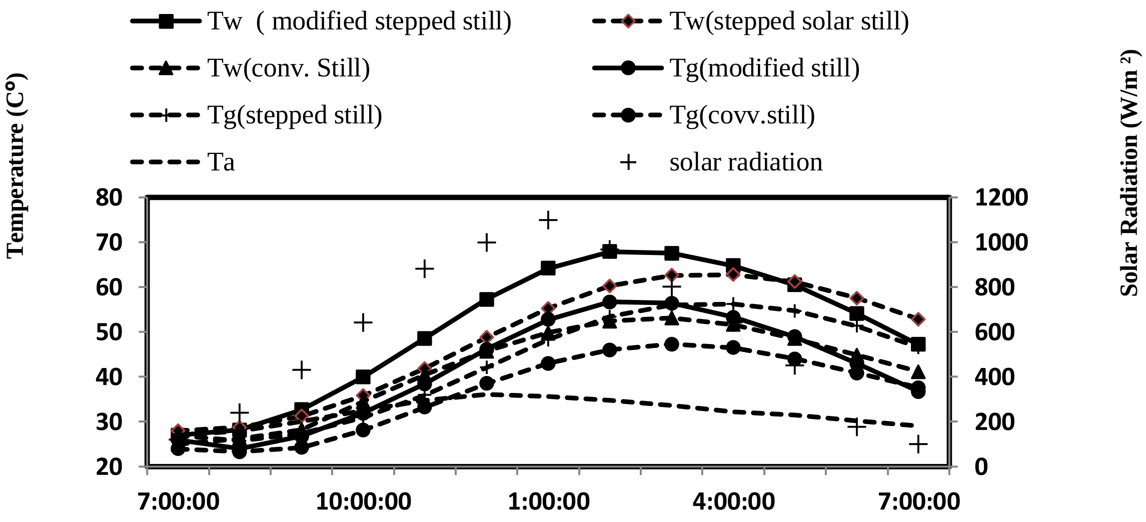

Figure 4: The hourly temperature variation and solar radiation for modified stepped solar still, stepped solar still without modification, and conventional solar still

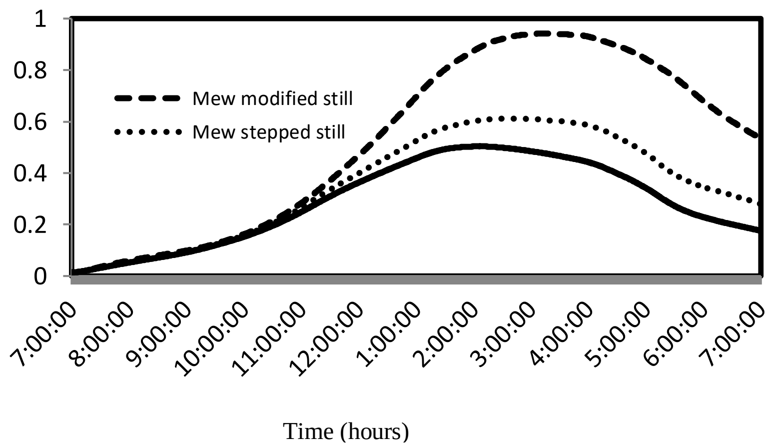

Figure 5: presents comparisons between variations of hourly productivity of modified stepped solar still, stepped solar still without modification and conventional solar still

When the modified stepped solar still is operated during sunshine hours, the hourly productivity is observed to increase significantly. The modified stepped solar still, the unmodified immersed solar still, and the conventional solar still have the highest hourly productivity values of 1.158, 0.652, and 0.541 (kg/m²h), respectively. Therefore, 9.9, 5.4, and 4.3 (kg/m² d) are the equivalent daily productivities acquired. The daily productivity of the modified stepped solar still is observed to be 83% higher than that of the conventional solar still and 103% higher than that of the stepped solar still without modification.

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4. Efficiency of solar stills

The three solar stills' daily efficiency was shown in Figure 6. Because the modified stepped still has more water evaporation and condensation than its counterparts, the results shown that its efficiency is higher than that of the conventional solar still and the immersed solar still without alteration.

The findings showed that the modified stepped still, the unmodified immersed solar still, and the conventional solar still had daily efficiency of roughly 60.2%, 48.7%, and 39.2%, respectively.

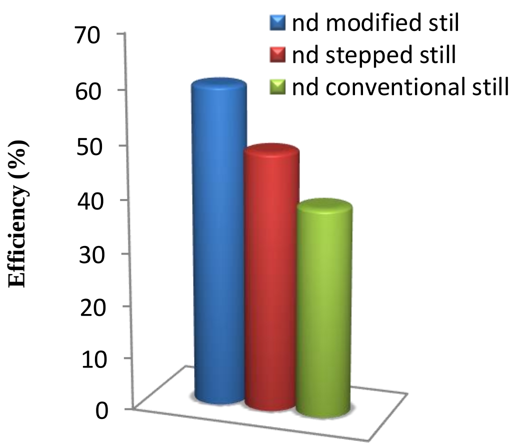

Figure 6: The daily efficiency of modified stepped solar still, stepped solar still without modification and conventional solar still.

5. Conclusion

A transient mathematical model for a modified stepped solar still, an unmodified immersed solar still, and a conventional solar still that could maintain the minimum depth in the basin was provided in order to increase the evaporation rate. A modified stepped solar still's performance was examined and contrasted with that of a conventional solar still and a steeped solar still without any modifications.

The findings demonstrate that the new modification can significantly improve the thermal performance of a modified stepped solar still; the corresponding daily productivities are 9.9, 5.4, and 4.3 (kg/m² d) accordingly. The production rate of the modified stepped solar still is 83% higher than that of the conventional solar still and 83% higher than that of the immersed solar still without modification.

The daily efficiency of the conventional solar still, the modified stepped still, and the immersed solar still without modification is about 39.2%, 48.7%, and 60.2%, respectively. As a result, it was discovered that the suggested model can accurately forecast the still's daily output and efficiency.

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