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Investigation on Solar Still Design to Enhance the Performance of Solar Water Desalination System

Patel Hiralben Shileshbhai*, Dr. Mohan Nathulal Giriya, Dr. Ritesh Yadav

Department of Physics, Dr. A.P.J. Abdul Kalam University, Indore (M.P.) – 452010

*hiralpatel2191995@gmail.com

ABSTRATCT

The current research aims to improve the efficiency and productivity of an inclined solar still through several methods. Firstly, various porous and energy-absorbing materials are utilised inside the still to minimize heat loss. Secondly, different wick materials and wire mesh are employed to ensure consistent thickness and wetness of the water inside the still. Thirdly, different absorber plate configurations are tested to prolong the time that water remains in the still. Lastly, a basin still is integrated to effectively utilise excess waste hot water that drains from the inclined solar still. The trials were conducted in three distinct periods. Prior to conducting experiments, the traditional and several innovative wick materials were characterised to analyse critical features such as porosity, water absorbency, water repellency, capillary rise, and heat transfer coefficient.

The suggested integrated distillation system may be used to meet the drinking requirements and other household needs of a modest family living in the southern region of Tamil Nadu, India. The payback time for the integrated solar still is 184 days, which is about equivalent to half a year. The suggested integrated solar still has a greater distillate output compared to the standard inclined solar still.

KEYWORDS : water supply, productivity, temperature, Theoretical and Experimental Performance

INTRODUCTION

Solar-distilled drinking water has a current monetary cost that is many times more than the water that is given by the majority of municipal utilities; nevertheless, it has a lower cost in terms of energy use. On the other hand, the cost of solar-distilled water is far lower than the cost of bottled water that is bought from physical stores. It is possible that solar distillation of tap water or brackish groundwater may be a pleasant and energy-efficient choice for those who are worried about the quality of the drinking water that is given to them by their municipality and who are dissatisfied with the various ways of extra purification that are accessible to them. Solar distillation of drinkable water from saline (salty) water has been conducted for a considerable amount of time in tropical and subtropical climates where there is a scarcity of fresh water. Some regions of the globe are experiencing a rising number of critical seasonal water shortages more often than ever before. An example of a distillation system that may be either tiny or big is the solar still. The water supply system is meant to meet the requirements of a single household, often generating between ½ and 3 gallons of drinking water per day. Alternatively, it may also be built to provide much larger quantities of water for an entire neighborhood or town. By covering shallow salt water basins with glass in buildings that resemble greenhouses, it is possible to partly alleviate the crisis of fresh water shortage that exists in some regions of the globe. These solar energy distillation plants are technologies that are generally simple in technology and reasonably affordable. They are particularly beneficial in situations where there is a requirement for tiny plants. This study's objective is to provide an overview of the fundamental concepts behind the process of distillation using sun stills, as well as the many kinds of solar still systems and the most current advancements in solar still systems.

LITERATURE REVIEW

Hasan, Mehedi & Roy Chowdhury, Chaitanya (2023) In the past, salination was only a regular occurrence in desert and island locations; but, in recent years, it has grown more prevalent in fertile places. This is an issue that is becoming more prevalent in a number of different countries. Several different desalination methods have been suggested as potential solutions to this issue in an effort to find a remedy. Solar still desalination is one of the methods that we have highlighted in our review study as a very important approach. Within the scope of this research, we have concentrated

mostly on the development and modification that has been suggested for solar still desalination. In addition to this, we have discovered certain integrated and infused systems that have the potential to increase the effectiveness of the traditional procedure. In regions that are geographically isolated and on islands, these methods may be useful for desalination on a smaller scale. The practicality of this research is based on the fact that it offers the authority a wide variety of possibilities for putting into practice a solar still model, as well as the adjustments that are required to improve the model's performance.

Al-Harahsheh, Mohammad & Abu-Arabi, Mousa (2022) An investigation was conducted into the efficiency of a solar still with a double glass cover that was self-powered and linked to a solar collector using phase change material (PCM). Pipettes made of stainless steel that had been coated black and loaded with the necessary quantity of PCM were positioned at the base of the basin, covering the whole of its surface area. Experiments were conducted in three different modes, each of which included cooling the glass cover. The first mode consisted of the solar still being left alone (SS), the second mode involved the solar still being linked to an external solar collector (SSC), and the third mode had the solar still containing PCM and being connected to an external collector (SSCA). Sodium thiosulfate pentahydrate (STP), sodium acetate trihydrate (SAT), and paraffin wax (PWAX) were the three types of PCM that were tested for their impact on the unit performance. Additionally, the volume of PCM was also taken into consideration. It was also explored how the performance of the unit was affected by factors such as the flow rate of hot water from the solar collector, the amount of solar radiation, the overall temperature, and the wind speed. It is the combination of the aforementioned methods and factors that makes this work innovative. The goal of this study is to increase the still production while maintaining a set of controlled operating settings. The experimental work was carried out in the northern region of Jordan throughout the months of May, June, and July of 2019. The SS and SSC modes were found to have a daily productivity of 2.1 and 9.7 litres per square metre respectively throughout the month of May. When compared to May, the productivity in July was twenty percent lower than it was in May. The SSC system's productivity rose by around fifty percent as a result of the incorporation of PCM. The kind of PCM that was examined did not have a significant impact on the productivity of the unit. Due to the incorporation of the external solar collector into the SS system unit, the productivity of the system unit rose by about 340%. In comparison to the productivity of the SS unit, the total improvement in productivity achieved by the SSCP reached about 400%.

Abdelgaied, Mohamed & Abdulla, A.S. (2022) The current experimental study aims to achieve the highest possible performance improvement of a stepped solar distiller by incorporating three effective hybrid modifications on the design. These modifications include using CuO nanoparticles coated absorber surface, interior mirrors, and phase change materials below the steps. The objectives of this study are to improve the heat transfer rate, increase the intensity of solar radiation falling on a basin of saline water, and increase the operating period several hours after sunset. Tanta, Egypt was the location through which two solar distillers were conceived, manufactured, and tested. The results of the experiments indicate that the modified stepped solar distiller was able to generate an average accumulative production of 9.79 L/m2/day, which is an increase of 135.9% compared to the reference distiller's yield of 4.15 L/m2/day. When compared to the reference distiller, which had an average daily thermal efficiency of 33.3%, the use of a modified stepped solar distiller resulted in an improvement of 136.6%, bringing the average daily thermal efficiency up to 78.8%. Additionally, the reference distiller achieved an average daily exergy efficiency of 2.77%, while the use of a modified stepped solar distiller resulted in an increase of 187.4%, bringing the average daily exergy efficiency up to 7.96%. The use of the effective three hybrid optimisation adjustments is the excellent way to acquire the best performance of a stepped solar distiller, according to the data that were shown above.

Shoeibi, Shahin & Saemian, Mohammad (2022) Solar energy systems have been the subject of a significant number of research in recent years owing to their cheap energy prices, the fact that they can be used in a wide range of weather conditions, and the fact that they do not need the use of fossil fuels. Materials such as porous materials, nanoparticles, and phase transition materials have been suggested as potential candidates for improving the system's water productivity and temperature gradient. These materials have been offered as potential candidates. The uneven and porous surface of the porous materials causes an increase in the amount of solar energy that is absorbed as well as the increase in water temperature. The purpose of this review paper is to contribute to the investigation of the utilization of porous materials in the evaporation improvement of solar water desalination systems. In solar desalination systems, the use of porous materials has been shown to have a considerable impact on the rate of evaporation, as indicated by all of the previous research. After some time had passed, a summary of comparisons made in earlier articles was provided and examined in depth in order to provide researchers and engineers with assistance in developing solar still desalination systems that are more effective. Based on the

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results that were obtained, it was determined that the solar desalination process that used activated carbon as a porous medium resulted in a 90.14 percent increase in energy efficiency. In addition, the productivity of the solar still desalination process was boosted by about 42.3% and 20.9%, respectively, when aluminum fins and black steel wool fibre were used as porous materials.

Thakur, Vinay & Kumar, Nitin & Kumar, Sushil (2022) The sun desalination process is used in solar stills for the purpose of preserving the purity of water. In order to get an understanding of the components that influence the circumstances of such a process at various stages, analytical work is utilised. Through the use of a variety of methodologies, several researchers have endeavored to enhance the effectiveness and productivity of solar still equipment. There is a short assessment of the experimental work that has been done in the area of solar stills as well as the utilization of the most efficient materials in this article. Using a process that involves the employment of several Phase Change Materials (PCMs), paraffin wax is able to provide the highest possible output. This is because the approach's productivity and thermal conductivity both rises. When wicks were used in a modified still, the amount of distillate that was produced as well as the profit in terms of overall productivity were both raised. In addition, the use of graphene oxide nanoparticles resulted in an enhancement of both the thermal conductivity and the daily basis efficiency properties. Using collective PCMs, reflectors, and nano-coating paint that was combined with nanoparticles resulted in an increase in thermal efficiency as well as an improvement in the amount of fresh water that was produced. In the solar still, these phase change materials (PCMs) were quite effective, and it has been shown that paraffin wax provides the highest output and productivity in comparison to other phase change materials.

THEORETICAL MODELING

There are three different mechanisms that are responsible for controlling the flow of heat in a solar still. These processes include evaporation, radiation, and convection. In order for the solar still to function properly, it is necessary to have the internal heat and mass transfer coefficients as well as the energy balance governing equations that are based on the correlations between heat and mass transfer. Within the scope of this chapter, a theoretical investigation was carried out for each and every alteration that was implemented in the inclined sun still and the basin solar still.

ENERGY BALANCE FOR SOLAR STILLS

The energy balance equations that were used for theoretical calculations were derived from Dunkle et al. (1961), Malik et al. (1982), Zurigat & Arabi (2004), Shukla & Sooryan (2005), and Murugavel et al. (2011), as well as theoretical models. The theoretical study was performed for three distinct basin conditions (with flat, grooved, and fin-shaped absorber plate configurations) in order to determine the optimal circumstances for inclined solar still.

- **Energy balance for basin plate (b)**

$$I\lambda_g A_b \alpha_b = M_b C_b \left[\frac{dT_b}{dt}\right] + Q_{c(b-w)} + Q_{co(b-a)}$$

Here is the equation that describes the convective heat transfer that occurs between the basin plate and the water:

$$Q_{c(b\text{-}w)} = h_{c(b-w)} A_b (T_b - T_w)$$

In addition, the heat loss that occurs as a result of conduction from the basin plate to the bottom of the still may be calculated as follows:

$$Q_{co(b\text{-}a)} = U_b A_b (T_b - T_a)$$

PROCEDURE AND TOOL USED

For the purpose of the theoretical study that was based on energy balance equations, the following assumptions were determined.

♣ The inner glass surface is responsible for absorbing the latent heat that is rejected by the vapour. This results in the production of distilled water from all of the vapours.

♣ In the absorber plate, the flow of water is consistent over the whole surface.

♣ There is no discernible variation in temperature with respect to the thickness of the glass cover and the depth of the water.

♣ The condensation that takes place at the glass trough is characteristic of a film-like nature.

CHARACTERIZATION OF WICKING MATERIALS

Throughout the course of the literature review, a number of different efforts were undertaken to enhance the efficiency of solar stills of the wick-inclined kind. As a result of the assessment of the relevant literature, it has been determined that there is no research work that has been conducted on the subject of analysing the characteristics of the wick materials

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that are used in the inclined solar still. The wick material has to be characterised before the experimenting process can begin. This is necessary in order to ensure that the wicks can be used in the inclined solar stills in an efficient manner, hence increasing the distillate production.

WICKING CHARACTERS

According to the literature study of wick materials, among all the wicking characteristics, the material porosity, water absorbency, water repellency, capillary rise, and heat transfer coefficient are the most important and essential characteristics of an effective wick material.

- **Porosity**

A material's porosity is a measurement of the void spaces, sometimes known as "empty" spaces, that it contains. Porosity is expressed as a percentage between 0 and 100 percent, and it is a proportion of the volume of voids over the entire volume. In a basic manner, the porosity is brought about by its correct definition, which is (PET524).

$$\emptyset = \left(\frac{V_p}{V_b}\right) \times 100$$

The linear measurement value, which stands for the dimension of the materials, is what determines the bulk volume.

$$V_b = l \times br \times tk$$

The fluid saturation technique, which involves the material being submerged in water, may be used to calculate the volume of pores.

$$W_w = W_{sat} - W_{dry}$$

$$V_p = {W_w}/{\rho_w}$$

- **Test Method for Porosity Several methods can be employed to measure porosity:**

1. Direct methods
2. Optical methods
3. Computed tomography method
4. Imbibition methods
5. Water evaporation method
6. Mercury intrusion porosimetry
7. Gas expansion method.

ANALAYSIS

In this chapter, the performance enhancement studies of inclined solar still were evaluated based on the experimental data that was collected. This evaluation took into consideration the effect of various energy-storing materials, various new wick materials and wire mesh, various new absorber configurations, and the integration of basin solar still and hot water storage tank. The productivity of inclined solar stills was investigated, and the influence of various inclination degrees on that production was analysed.

INCLINED SOLAR STILL WITH DIFFERENT ENERGYSTORING MATERIALS AND GROOVED ABSORBER

- **Variation of Atmospheric Temperature with Global Radiation**

During the experiment, the average temperature of the atmosphere and the variance in global radiation are shown in Figure 5.1. This fluctuation is shown in relation to the local time. A maximum value of 990 W/m2 of solar radiation was seen here around two o'clock in the afternoon. Throughout the days of the trial, there was no freezing temperatures and the sky was clear. Additionally, the global radiation and the temperature of the surrounding environment are almost same throughout all of the experimental days and settings. The findings of the experiments conducted on days with meteorological circumstances that were typical have been taken into consideration for analysis.

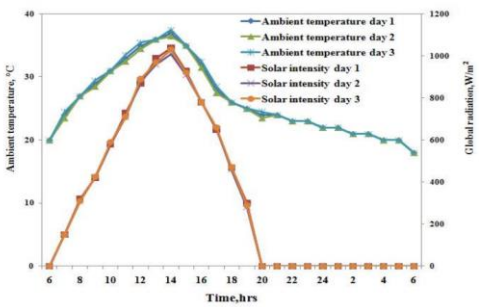

Figure 5.1 Variation of temperature and global radiation with respect to time

- **Variation of Hourly Production Rate and Total Production for Different Inclination Angles**

Figures 5.2(a) and 5.2(b) illustrate the differences in production rate and total output that occur when the still is approached from a variety of angles and inclinations. It is consistent across all slopes that the overall fluctuation in output rate from morning to evening is the same. However, the output rate for the still with a slope of 30 degrees is at its highest around two o'clock in the afternoon, and it is around

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3.770 litres per day. As shown in Figure 5.2b, the total output of still is at its highest when the still is tilted at a 30o angle. The conclusion that can be drawn from this is that the optimal inclination for the still is thirty degrees with a south direction.

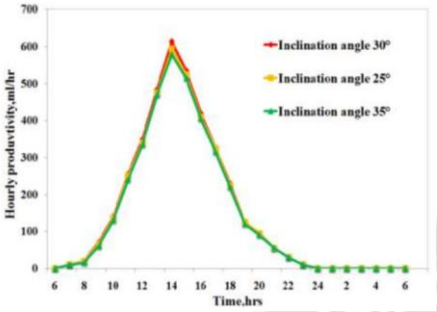


Figure 5.2(a) Variation of hourly production rate for different inclination angles

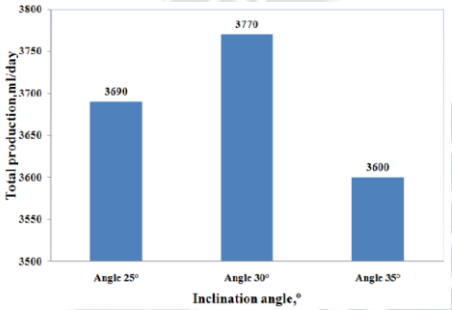


Figure 5.2(b) Variation of total production for different inclination angles

- **Variation of Basin Water Temperature and Production Rate for Various Basin Materials**

The fluctuation in the temperature of the water in the basin is shown in Figure 5.3(a) under a variety of basin conditions. The fluctuations are almost same across all settings, and the water continues to reach its highest temperature at around two o'clock in the afternoon. At the beginning of the day, the temperature in the basin that contains wick materials is greater than the temperature in the basin that contains porous materials and iron bits.

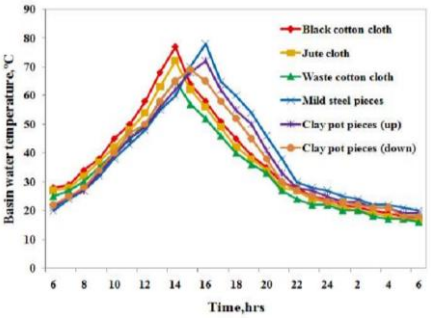


Figure 5.3 (a) Variation of basin water temperature for various basin materials

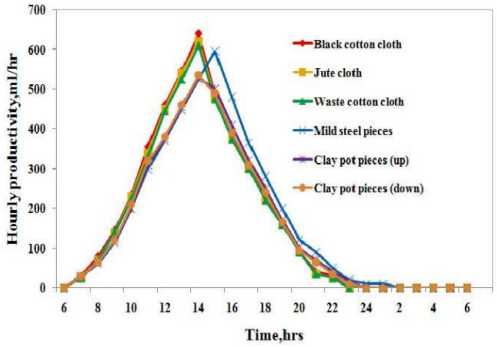
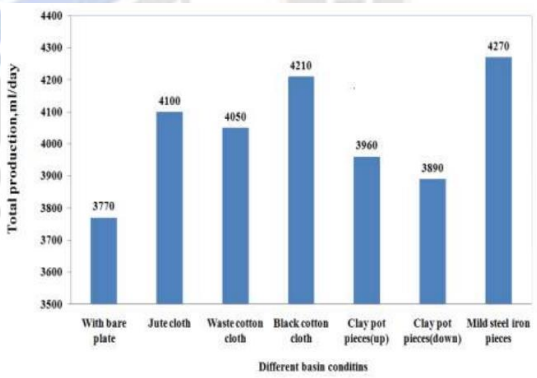


Figure 5.3 (b) Variation of productivity for various basin materials

- **Comparison of Total Productivity for Various Basin Materials**

Among the several wick materials that are used in the inclined still, the black cotton fabric is the one that exhibits the greatest diffusion effect and enhances the evaporation rate, so ensuring that the output rate remains high (4.21 litres per day). It is because of the iron pieces' larger energy storage capacity that they are able to release their stored energy, which in turn improves the nighttime output and results in an increase of 4.27 litres per day in total productivity.



INCLINED STILL WITH DIFFERENT NEW WICK MATERIALS AND STEEPED-WIRE MESH ABSORBER

- **Variation of Wind Velocity with Global Radiation**

During the course of the experiment, the variation in wind velocity according to global radiation is shown in Figure 5.8. This variation is shown in relation to local time. At this location, the levels of solar radiation are at their highest around 1.30 p.m., while the wind speed is at its lowest in the morning and rises in the evening. The findings of the experiments conducted on days with consistent weather conditions have been taken into consideration for analytical purposes.

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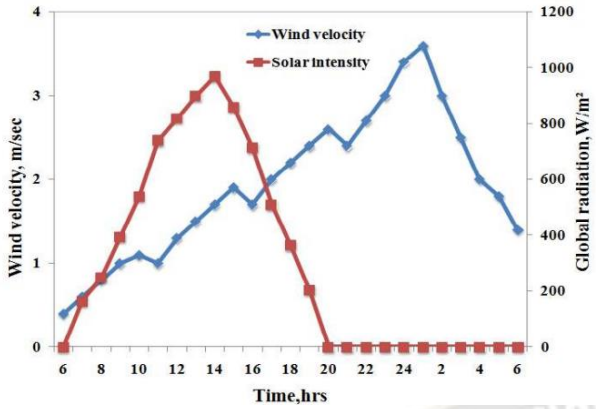

Figure 5.8 Variation of wind velocity with global radiation

- **Variation of Different Temperature Elements with Optimum Productivity**

Figure 5.9 illustrates the range of temperatures that may be found within the still while it is operating at its highest possible level of production. At 2.30 o'clock in the afternoon, it was noted that the vapour had reached its highest temperature, which was 80 degrees Celsius, within the still. At a time of 2.30 p.m., the temperature of the glass and the water in the basin were measured to be 71 degrees Celsius and 69 degrees Celsius, respectively, for the maximum productivity condition.

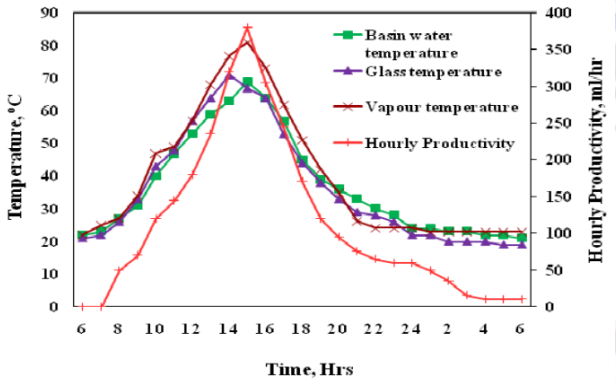

Figure 5.9 Variation of different temperatures with productivity for optimum condition

- **Comparison in Productivity for Different Basin Conditions**

The results of this inquiry are summarized in Table 5.1, which also includes a comparison of the distillate productivity improvement from the first set of experiments that were used as a reference (Wood pulp wick material with flat absorber). When steeped absorber plates and wire mesh-steeped absorber plates were employed instead of the flat absorber, the distillate productivity rose by 15% and 29.2%, respectively, according to the table for wood pulp wick material. Furthermore, when the polystyrene sponge wick material was combined with flat absorber, steeped absorber, and wire mesh-steeped absorber plates, the distillate productivity from the reference was raised by 25.6%, 42%, and 58%, respectively.

Table 5.1 Comparison in productivity for various basin conditions

S.No.	Basin conditions of the inclined type solar still	Wick materials used in the basin					
		Wood pulp paper		Polystyrene sponge		Water coral fleece	
		ml /day	% increase	ml /day	% increase	ml /day	% increase
1.	Flat absorber	2,500	Reference	3140	25.6	3635	45.4
2.	Steeped absorber	2,875	15	3550	42	3930	57.2
3.	Wire mesh-steeped absorber	3,230	29.2	3950	58	4280	71.2

- **Comparison of Theoretical and Experimental Performance**

The optimal productivity adjustment, which consisted of a wire-mesh-soaked absorber with water coral fleece, was taken into consideration for a short discussion in an inclined still. This was done in order to confirm the experimental findings with theoretical. When it comes to the temperature of the basin water for the inclined still that has the highest possible output, Figure 5.14 illustrates the contrast between the experimental data and the theoretical data.

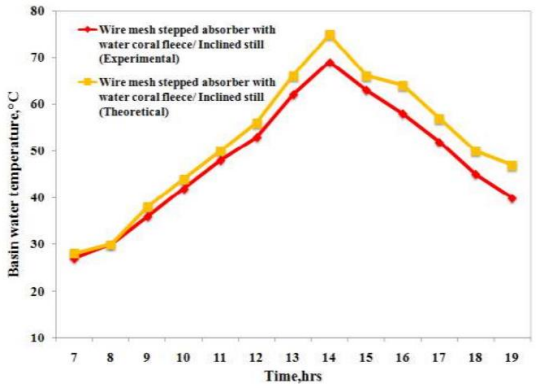

Figure 5.14 Hourly variation of theoretical and actual basin water temperatures for inclined still

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All of the absorbers were placed in the inclined still at two o'clock in the afternoon, and the experimental and theoretical values of the highest basin water temperatures are shown in Table 5.2. Within the wiremesh immersed absorber, a maximum variation of 10.1% was measured in this particular instance.

Table 5.2 Experimental and theoretical values of maximum basin water temperatures for inclined still

S. No	Date	Different basin conditions	Basin water temperature (°C) at2.00p.m		
			Inclined still / Water coral fleece wick		
			Experimental	Theoretical	%Deviation
1	20.03.14	Flat absorber configuration	59	62	5.1
2	25.03.14	Steeped absorber configuration	63	69	9.5
3	20.04.14	Wire-mesh steeped absorber configuration	69	76	10.1

When it comes to the hourly productivity of the inclined still operating under optimal conditions, Figure 5.15 illustrates the contrast between the experimental data and the theoretical data from the experiment. With a variance of 6.1% for inclined still with the wire-mesh immersed absorber and water coral fleece wick material, the water temperature values that were estimated from the theoretical model were closer to the values that were observed in the experiment.

CONCLUSION

Based on the findings of both experimental and theoretical study, it was discovered that specific research techniques and results may increase the performance of inclined solar stills. The following conclusions can be drawn from these findings.

Utilising water coral fleece with wire mesh–stepped absorber plate allowed for the maximum amount of distillate to be produced in the inclined solar still, which was 4.28 litres per day. When compared to the basic flat absorber material, the fin-shaped absorber configuration produced the greatest distillate production in an inclined solar still. This was 25.7% greater than the output of the flat absorber material.

The integrated still with fin shaped absorber had a daily distillate productivity of 5.21 litres for a collecting surface of 1.3 square metres, which was 74.25% greater than the standard inclined still's productivity. The integrated still with fin shaped absorber had a daily hot water production of 9.72 litres, and the total efficiency of the integrated still with hot water storage was 14.6% greater than that of the integrated still. total, the integrated still was more efficient than the integrated still.

REFERENCES

1. Hasan, Mehedi & Roy Chowdhury, Chaitanya & Kumar, Durjoy. (2023). Recent Advancement in Solar Water Desalination: A Comprehensive Review.
2. Al-Harahsheh, Mohammad & Abu-Arabi, Mousa & Ahmad, Maysam & Mousa, Hasan. (2022). Self-powered solar desalination using solar still enhanced by external solar collector and phase change material. Applied Thermal Engineering. 206. 118118. 10.1016/j.applthermaleng.2022.118118.
3. Abdelgaied, Mohamed & Abdulla, A.S. & Abdelaziz, Gamal & Kabeel, Abd Elnaby. (2022). Performance improvement of modified stepped solar distillers using three effective hybrid optimization modifications. Sustainable Energy Technologies and Assessments. 51. 101936. 10.1016/j.seta.2021.101936.
4. Shoeibi, Shahin & Saemian, Mohammad & Kargarsharifabad, Hadi & Hoseinzadeh, Siamak & Rahbar, Nader & Khiadani, Mehdi & Rashidi, Mohammad. (2022). A review on evaporation improvement of solar still desalination using porous material. International Communications in Heat and Mass Transfer. 138. 106387. 10.1016/j.icheatmasstransfer.2022.106387.
5. Thakur, Vinay & Kumar, Nitin & Kumar, Sushil & Kumar, Naresh. (2022). A brief review to improve the efficiency of solar still using efficient phase change materials. Materials Today: Proceedings. 64. 10.1016/j.matpr.2022.04.119.
6. Shelake, Amit & Kumbhar, Dnyaneshwar & Sutar, Kailasnath. (2022). Desalination Using Solar Stills: A Review. Environmental Progress & Sustainable Energy. 10.1002/ep.14025.
7. Mohiuddin, Shaik & Kaviti, Ajay & Rao, Talluri & Sikarwar, Vineet. (2022). Historic review and recent progress in internal design modification in solar stills. Environmental Science and Pollution Research. 29. 10.1007/s11356-022-19527-x.
8. Taha, Obai & Hussein, Ahmed & Attia, Mohammed & Aljibori, Hakim & Kolsi, Lioua & Togun, Hussein &

Ali, Bagh & Abderrahmane, Aissa & Subkrajang, Khanyaluck & Jirawattanapanit, Anuwat & Ahmadi, Hossein. (2022). Comprehensive Review on Solar Stills—Latest Developments and Overview. Sustainability. 10.3390/su141610136.

9. Abbaspour, Mohammadreza & Ramiar, Abas & Esmaili, Qadir. (2022). Efficiency improvement of vertical solar stills – A review. Solar Energy. 235. 19-35. 10.1016/j.solener.2022.02.027.

10. Mohsenzadeh, Milad & Aye, Lu & Christopher, Philip. (2022). Development and experimental analysis of an innovative self-cleaning low vacuum hemispherical floating solar still for low-cost desalination. Energy Conversion and Management. 251. 10.1016/j.enconman.2021.114902.