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PERFORMANCE AUGMENTATION OF SOLAR DESALINATION SYSTEM USING WASTE MATERIALS AS SENSIBLE HEAT STORAGE FOR FRESHWATER PRODUCTION

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ABSTRACT

Solar distillation is one of many ways to purify water, and it is widely known as an effective and long-lasting way to turn brackish or salty water into drinking water. This technology has become more popular because it is easy to build, doesn't need much maintenance, is cost-effective, and is good for the environment. This study presents a single slope solar stills (SSSS) and double slope solar stills (DSSS) in a thorough way, both through analysis and experiments, to see how well they work in real outdoor conditions. The study compared regular solar stills with modified solar stills (MSS) and used different energy storage materials to make them work better. There were five different experimental setups that were considered: In case 1, single slope vs. double slope solar stills is compared,Incase 2, iron scraps is added in DSSS, In Case 3, black kancheyis added in DSSS, In Case 4, shaving blades, and In case 5, pebbles in DSSS. The daily water yield for various stills was recorded as follows: TSSS: 1330 ml/day, Case 1: 1890 ml/day, case 2: 2370 ml/day, Case 3: 2450 ml/day, Case 4: 3150 ml/day, Case 5: 2250 ml/day. The case 4 (shaving blades) exhibited the highest yield, increasing productivity by 136% compared to TSS. The peak energy efficiency for different solar stills was TSSS: 29%, case 1: 36.6%, case2: 46.5%, case3: 49.5%, case4: 52.5%, case5: 38.3%, with case 4 achieving the highest value of 58.5%.

KEYWORDS: Double slope solar still; PCM; Energy storage; Heat transfer coefficients; Energy; Exergy; Efficiency and Experimental.

INTRODUCTION

The worldwide water consumption is increasing by 1% due to rapid urbanization and industrialization. The scarcity of water will be the most serious problem worldwide in the coming years [1].Desalination is a process that can reduce the problem of potable water throughout the world, especially in coastal areas. In this process, potable water is extracted from brackish/saline water. Solar stills are the best and optimum solution for obtaining drinking water. There are several designs of solar stills used to obtain the maximum yield of water. Different designs of solar stills with modifications are under investigation to determine their impact on still yield [2]. The process of desalination requires a large amount of conventional fuel, such as oil, to produce potable water. These fuels also affect the environment. This is the time at which the best desalination process, which should harm the environment less,can be found[3]. Solar radiation is available throughout the year in ample amounts. The use of these types of radiation for the desalination process can impact the utilization of solar radiation other than fossil fuels [4-6].For places where there is a lot of natural solar radiation but the water quality is unfit for drinking and other uses, solar desalination may be a practical solution. Although solar stills are cost-effective and need little upkeep, their greatest disadvantage was their poor production of fresh water. Because it solely depends on solar radiation, independent of other finite energy sources like fuel and electricity, it may thus be utilized for water systems with reduced capacity requirements and self-sufficiency [7]. But the major limitation while adopting solar still as regular source of potable water is it low productivity. Therefore, researchers are working extensively to increase the productivity of solar stills to reduce the demand for potable water worldwide. Kabeel et al. (2019) conducted an experiment that combined the glass cooling cover approach and varying water depth with a TSS to augment the daily fresh yield water. The findings reveals that the TSS with 0.5 cm water depth shows the maximum productivity and obtained cumulative yield was 4.5 L/m^2, while the still with 3 cm water depth produces daily productivity of 3 L/m^2. The maximum efficiency was about 54.9 % under the optimum condition of 0.5 cm water depth [8]. Arun kumar et al. performed an experimental analysis on the solar still that incorporates thermal collectors and concentrators. The triple basin solar still combined with the parabolic concentrator obtained a fresh water production of 16.94 kg/m^2/day because the intense sunlight from the concentrator tends to raise the temperature of the lowest basin [9].

El-Said et al. (2020) showed that the yield of SS can be increased by using porous materials, such as wire mesh nanoparticles [10]. Krishnaet al. (2022) conducted an experiment on sensible heat storage materials, and the results revealed that they also increase the productivity of the solar still [11]. To analyse the impact of fins in double slope still, Hardik et al. (2019) used two varying types of fins; hollow circular and squared shaped fins [12, 13].Dumka et al. (2019) performed a comparative analysis between conventional still and modified still equipped with 100 sand filled cotton bags. The findings shows that the efficiency of modified still is 40% higher than conventional still [14]. Kumar et al. (2024) investigated the effect of perforated wavy tapes in FPSCs, reporting heat transfer improvements of 20.83%, 14.85%, and 6.25% for systems without wavy tape, with WT, and with 9mm perforated wavy tape (PWT), respectively [15]. To enhance the effectiveness of developed solar still, different varieties of heat absorbing materials mostly considered as waste materials is used in the basin liner of the still. Firstly, waste iron scraps as energy absorbing material. Secondly, black Kanchey is used to store the excess amount of heat. Thirdly, used shaving blades which acts as a fin is incorporated. Lastly, natural available stones are used in the basin liner to absorb the excessive solar energy.They aid in preserving a constant thermal environment inside the still by absorbingand holding onto solar heat and gradually releasing it.

TEST RIG DESCRIPTION

The two different types of solar still single and double slope type were created, compared, and tested in an outdoor setting of central portion of India in the months of November 2024. The 0.36 m^2 (0.6 m * 0.6 m) basin area was formed from 0.15 cm thicknessGI sheet. The 4 mm thick clear glass sheet act as a medium to transfer the solar energy into the basin liner is supported by the side inclined walls of the still and is slanted at 24^o, chosen according to the location of experimental location (Panchal and Shah, 2012; Sharshir et al., 2020) [16,17]. Figure 1 infers a schematic diagram of the experimental apparatus. Figure 2shows arrangement of kancheys, blades and stones in solar still. The experimental procedure consists of total 13 hours readings from early morning 7 a.m. to 7 p.m., and different parameters were measured hourly. K type thermocouples are integrated to record the temperature of various components of solar still inserted at various points as shown in figure 3.7. The findings of uncertainty analysis is displayed in table 1 by calculated using the mathematical equation provided by (Khan et al. 2016) [18].

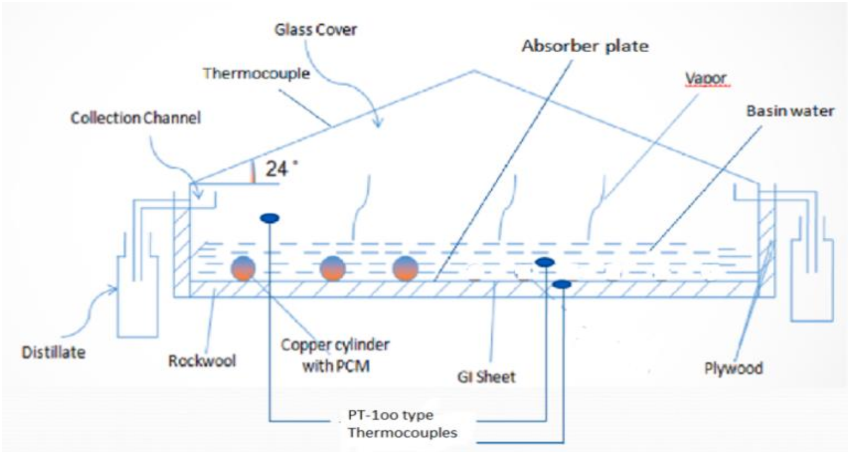

Figure 1. Line diagram of developed DSSS.

Figure 2. Arrangement of kancheys, bladesand stones in solar still.

Table 1. Findings of the uncertainty analysis.

Instrument used	Accuracy	Uncertainty value
Solar radiation measurement meter	8 W/m^2	4.33 W/m^2
K -type temperature sensor	±1 ˚C	0.06 ˚C
Measuring Flask	± 5 ml	0.6 ml

RESULT AND DISCUSSION

To maximize their overall performance, different solar stills' distillate yields are being investigated separately. The study incorporates these solar stills with practical heat storage materials to increase efficiency even more.

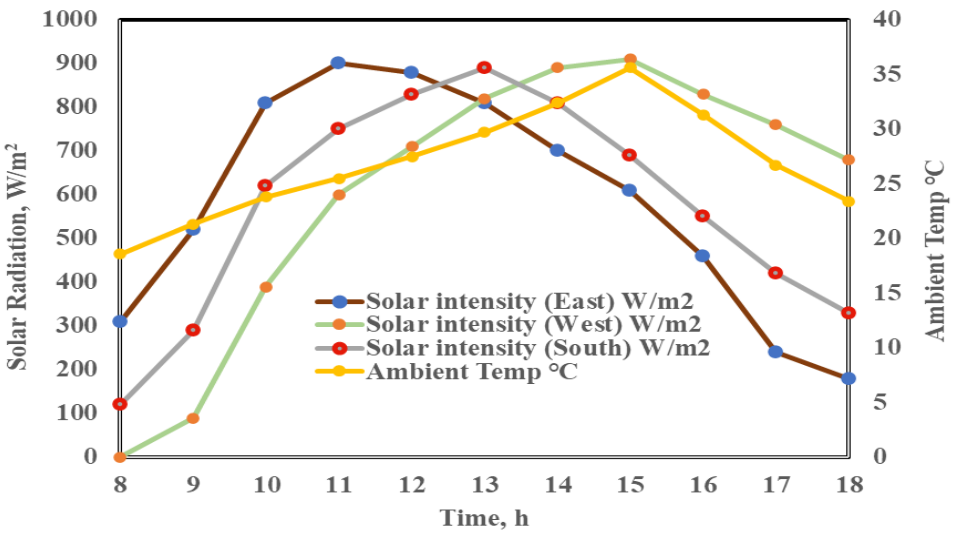

Figure 3. The hourly measured intensity of solar insolation and atmospheric temperature.

The solar intensity on the day of the experiment varied from a minimum of 90 W/m² to a maximum of 910 W/m² in the south direction as shown in figure 3. The eastern side of the glass cover received 145% more solar radiation than the western side at around 9:00 AM in the morning. The intensity on the western side was 460% higher than the eastern side by 5:00 PM (17:00 hours), indicating a significant increase. Measurements of the surrounding air temperature also showed a steady rise throughout the day. The temperature was 18.6°C at 8:00 AM and rose gradually to 35.6°C at 2:00 PM (14:00 hours). The efficiency and productivity of the solar still are greatly influenced by these changes in the sun's intensity and the surrounding temperature.

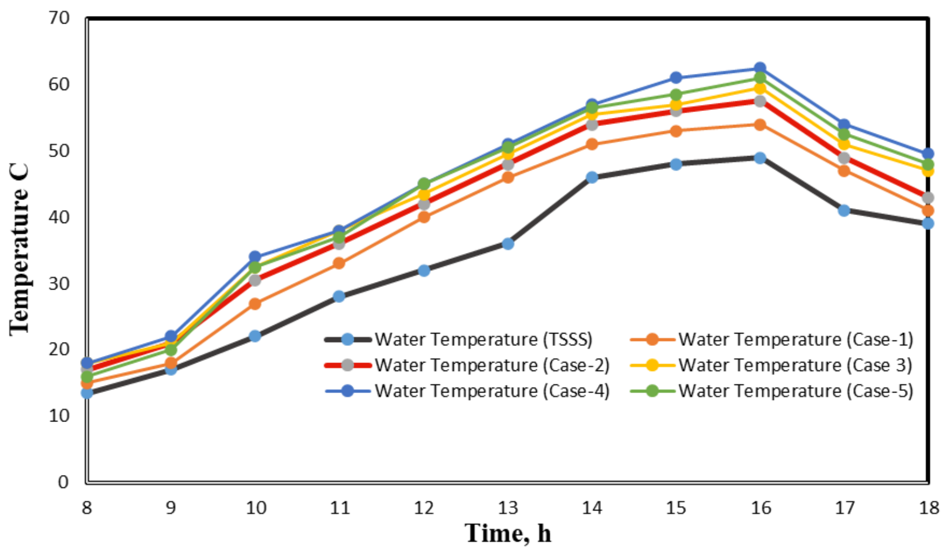

Figure 4. Time wise fluctuation of water and glass temperature of different cases of still.

The graph as shown in figure 4 illustrates the hourly variation in water temperature from 8:00 to 18:00 hours for a traditional single slope solar still (TSSS) and five experimental modified cases under real-time solar radiation conditions. Each curve represents the thermal performance of a distinct design modification implemented to enhance the thermal efficiency and water yield of solar distillation systems.In the traditional single slope solar still (TSSS), the water temperature gradually increased from approximately 15°C at 8:00 h to a peak of 49°C at 15:00 h, followed by a decline due to reduced solar insolation in the late afternoon. This limited temperature range indicates a lower heat retention capacity and restricted exposure to sunlight, particularly during early morning and late afternoon hours.In contrast, all modified solar stills (Case-1 to Case-5) demonstrated significantly improved thermal performance:

- Case-1: A double slope solar still showed a higher maximum water temperature of 54°C, outperforming the TSSS due to dual-sloped glazing, which enabled extended solar absorption from both the east and west directions. This design also improved heat retention by reducing structural asymmetry and associated losses.
- Case-2: Incorporating iron scraps into the basin of the DSSS led to a peak temperature of 58°C. The high thermal conductivity of metal allowed for rapid heat absorption and prolonged heat release, supporting continuous evaporation during low-solar hours.
- Case-3: The use of black kanchey further enhanced solar absorption, achieving a maximum water temperature of 60°C. The dark-colored material increased solar energy uptake and minimized heat dissipation, sustaining high evaporation rates for longer durations.
- Case-4: This configuration employed shaving blades within the basin and demonstrated the highest recorded water temperature of 61.5°C. The blades acted as fins, increasing the effective surface area for heat transfer and improving heat distribution, which significantly accelerated the heating and evaporation process.
- Case-5: The integration of pebbles into the solar still reached a maximum water temperature of 58.5°C. Due to their high thermal mass and density, pebbles stored solar heat during peak hours and released it gradually, helping to maintain elevated basin water temperatures even after solar intensity declined.

Overall, all modified systems outperformed the conventional TSSS in terms of water temperature, which directly influenced the evaporation rate and productivity of the solar still.

HOURLY YIELD

The graph in figure 5 illustrates the hourly freshwater yield (in ml) from 8:00 to 18:00 h for the traditional single slope solar still (TSSS) and five modified cases (Case-1 to Case-5) under identical environmental conditions.

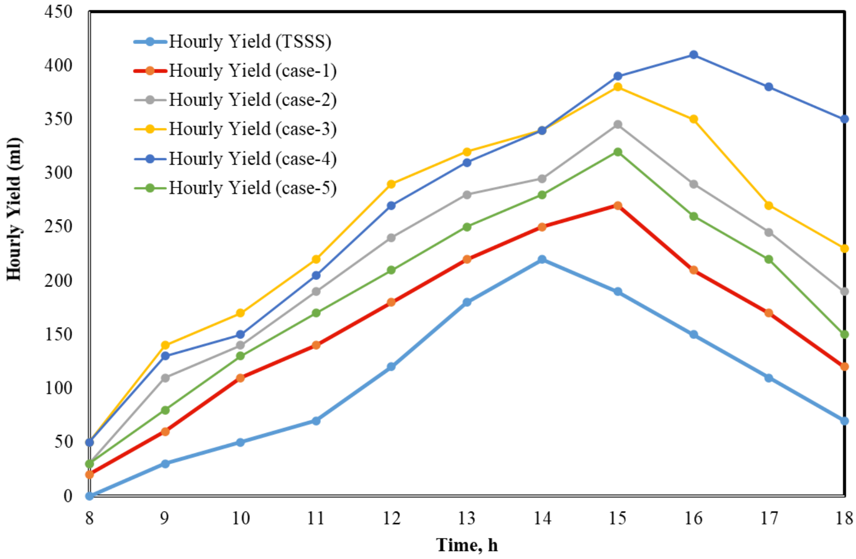

Figure 5. Time wise fluctuation of hourly yield of different cases of still.

The goal of this study is to evaluate the impact of different thermal enhancement materials and design modifications on the productivity of solar stills.

- The TSSS (Traditional Single Slope Still) exhibited the lowest productivity, with a peak yield of 220 ml at 15:00 h, and a gradual decline thereafter. This lower performance is attributed to limited solar capture and inefficient heat retention.
- Case-1 (Double Slope Solar Still - DSSS) improved water production over TSSS, with a peak of 270 ml at 15:00 h, leveraging dual-angle glazing for extended sunlight exposure and better heat distribution.
- Case-2 (DSSS + Iron Scraps) showed enhanced performance due to the high thermal conductivity of metal, which absorbed solar radiation rapidly and released heat gradually. This resulted in a maximum yield of 330 ml at 15:00 h, 50% higher than TSSS.
- Case-3 (DSSS + Black Kanchey) reached 345 ml at 15:00 h. The dark-coloredkanchey stones absorbed more heat and retained it longer, sustaining evaporation rates even after peak solar hours. This modification led to an 85.3% increase in daily yield over TSSS.

- Case-4 (DSSS + Shaving Blades) demonstrated the highest productivity, with a peak yield of 395 ml at 15:00 h. The blades acted as thermal fins, significantly increasing surface area for heat transfer, leading to the highest total daily yield (3150 ml), 136% more than TSSS.
- Case-5 (DSSS + Pebbles) achieved 315 ml at 15:00 h. The pebbles' high thermal mass stored solar energy and released it steadily, resulting in improved productivity and extended operational hours even during low insolation periods.

Across all cases, the maximum yield occurred between 14:00 and 15:00 h, aligning with peak solar radiation. The modified systems demonstrated not only higher evaporation rates but also superior thermal inertia, enabling continuous distillate output beyond peak hours.

CUMULATIVE YIELD

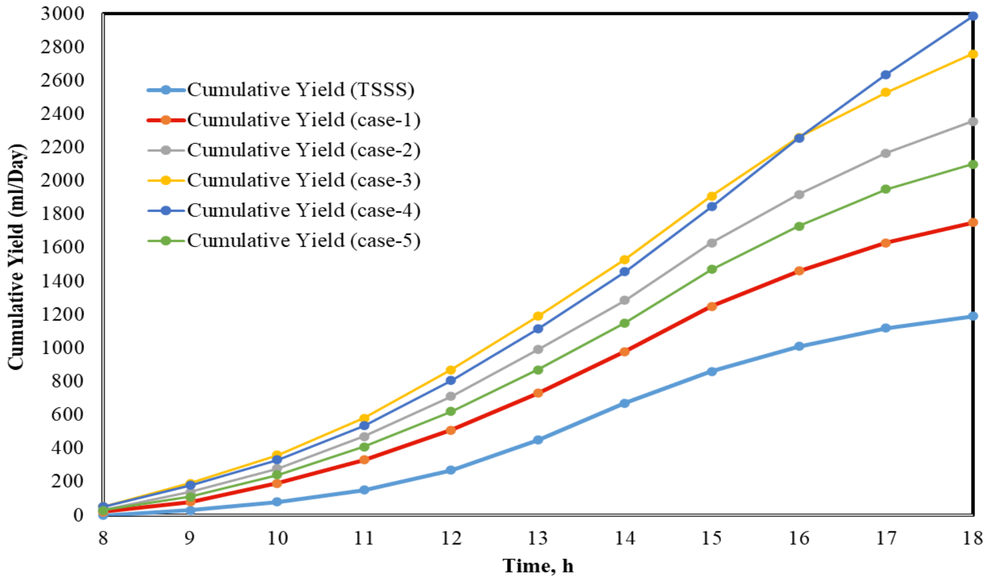

Figure 6. Time wise fluctuation of cumulative yield of different cases of still.

The cumulative yield performance of the traditional single slope solar still (TSSS) and five modified double slope solar still (DSSS) configurations is illustrated in Figure 6. The results clearly demonstrate that the integration of various thermal enhancement materials significantly improves the freshwater productivity throughout the operational period (8:00 to 18:00 h). The TSSS exhibited the lowest cumulative yield, reaching approximately 1330 ml/day by the end of the experiment, indicating its limited thermal retention and evaporation capacity. In contrast, Case-1 (DSSS without additional materials) achieved a cumulative yield of 1890 ml/day, benefiting from its dual-sloped design that captures solar radiation from both the east and west sides, thereby enhancing heat distribution and retention.

Further modifications to the DSSS showed even greater improvements. Case-2, which incorporated iron scraps in the basin liner, achieved a cumulative yield of 2370 ml/day. The high thermal conductivity of the metal allowed for rapid heat absorption and sustained thermal release, boosting evaporation rates. Case-3, which used black kanchey stones, resulted in a cumulative yield of 2450 ml/day due to their ability to absorb and store heat more effectively, thereby extending the productive hours of the still. Case-5, involving the use of naturally available pebbles, reached 2250 ml/day, leveraging their high thermal mass to maintain elevated basin temperatures even during low solar radiation periods. Among all modifications, Case-4, which incorporated used shaving blades as fins, demonstrated the highest cumulative yield of 3150 ml/day. The blades increased the effective heat transfer surface area and improved thermal distribution within the basin, resulting in a 136% improvement over the traditional still and a 66.3% gain over the basic double slope configuration. These results affirm that employing waste-derived or naturally available sensible heat storage materials within DSSS significantly enhances solar still performance and freshwater yield under real outdoor conditions.

ENERGY EFFICIENCY

Figure 7 illustrates the variation in energy efficiency over time for different modified solar still (CASE) configurations compared to the traditional solar still (TSS).

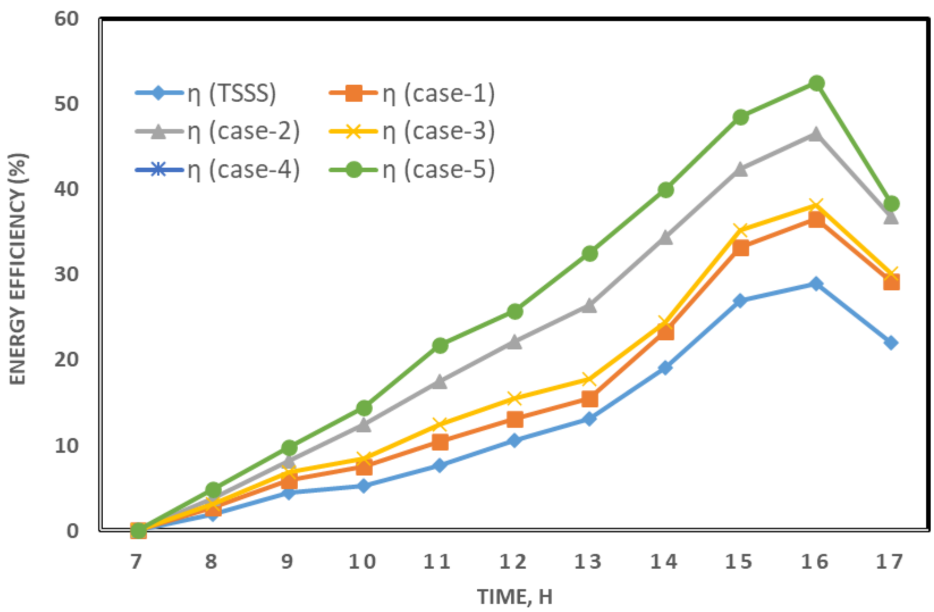

Figure 7. Variation of energy efficiency with time of modified stills.

The energy efficiency trends exhibit a gradual increase during the initial hours of solar exposure, reaching their peak efficiency at approximately 16 hours, followed by a declining pattern as solar radiation decreases toward sunset. The maximum energy efficiency values recorded for different solar still modifications are as follows: TSS (Traditional Solar Still): 29%, CASE-1: 36.6%, CASE-2: 46.5%, CASE-3: 49.5%, CASES-4: 52.5%, MSS-5: 38.3%. Among all configurations, CASE-4 exhibited the highest peak energy efficiency of 58.5%, which is significantly greater than the conventional TSS (29%). The observed increase in energy efficiency can be attributed to enhanced thermal energy retention and improved heat transfer mechanisms facilitated by the incorporation of sensible heat storage materials. The sharp rise in energy efficiency during peak sunlight hours is primarily due to the larger temperature gradient between the basin water and the glass cover. A higher temperature difference accelerates the evaporation-condensation process, leading to greater freshwater production and improved thermal performance. The use of shaving blades in CASE-4 contributed to the highest average energy efficiency of 26.24%, which can be attributed to the fin effect, enhancing heat dissipation and evaporation rates. Other modifications also demonstrated improved performance, with CASE-2, CASE-3, and CASE-5 achieving average energy efficiencies of 22.81%, 24.45%, and 17.49%, respectively, while TSS exhibited the lowest average efficiency of 12.71%. The experimental results confirm that modifications incorporating thermal enhancement techniques, such as shaving blades (CASE-4), kanchey stones (CASE-3), and iron scrap (CASE-2), contribute to higher energy efficiency by optimizing heat absorption and retention mechanisms. The findings reinforce the effectiveness of passive heat storage materials in enhancing the overall performance of solar stills, making them more suitable for efficient and sustainable desalination applications.

CONCLUSIONS

In-depth analytical and experimental research on solar stills is presented in this study, highlighting their potential as one of the best ways to alleviate the world's freshwater shortage. The outcomes of the present study is:

- The daily accumulative yield of different solar stills was recorded as follows: TSSS: 1190 ml/day, CASE-1: 1750 ml/day, CASE-2: 2355 ml/day, CASE-3: 2760 ml/day, CASE-4: 2985 ml/day, CASE-5: 2100 ml/day.
- Among all modifications, CASE-4 (with shaving blades) demonstrated the highest increase in yield, surpassing: TSS by 150%, CASE-1 by 70.3%, CASE-2 by 26.5%, CASE-3 by 8.5%, CASE-5 by 42.5%

- Energy storage materials enhanced heat retention and extended productivity beyond peak sunlight hours. The stored heat continued to release after peak hours, keeping basin water warm and sustaining evaporation rates.
- The peak energy efficiency recorded for different solar stills was: TSS: 29%, CASE-1: 36.6%, CASE-2: 46.5%, CASE-3: 49.5%, CASE-4: 52.5%, CASE-5: 38.3%
- CASE-4 (shaving blades) exhibited the highest peak energy efficiency of 58.5%, which was significantly higher than TSS (29%).
- Thermoelectric modules can be employed to increase evaporation rate while simultaneously producing the heating and cooling effect.

REFERENCES

1. K. S. AlQdah, K. A. Alharbi, S. A. Alharbi, M. A. Almutairi, O. M. Alsuhimi, and M. S. Aljuhani, "Design, Fabrication and Performance Evaluation of a Semi-Cylindrical Solar Still Working in Medina Region," *Arab. J. Sci. Eng.*, vol. 47, no. 7, pp. 8567–8575, 2022, doi: 10.1007/s13369-021-06351-7.
2. F. A. Essa et al., "Extracting water content from the ambient air in a double-slope half-cylindrical basin solar still using silica gel under Egyptian conditions," *Sustain. Energy Technol. Assessments*, vol. 39, p. 100712, 2020, doi: https://doi.org/10.1016/j.seta.2020.100712.
3. *Sofiane, M. I. H. O. U. B., &Abdelilah, B. E. N. A. H. M. E. D. (2024). Predicting the Impact of Different Cooling Systems on the Performance of Parabolic Trough Concentrating Solar Plant based on Real Data. Solar Energy and Sustainable Development Journal, 13(2), 264-285.*
4. *Ahlem Z., Toufik S., Abderrezak M. (2024). Optimizing a Sustainable Power System with Green Hydrogen Energy Storage for Telecommunication Station Loads. Solar Energy and Sustainable Development Journal, 14(1), 19-41.*
5. Agrawal, R., Sharma, T., Gupta, M., Singh, A., Upadhyay, H., & Shrivastava, A. (2023). Augmenting the productivity of double slope solar still by incorporating sensible and latent heat storage materials. *International Journal of Ambient Energy*, *44*(1), 616-625.
6. Yugbodh, K., Agrawal, R., Ahmed, S. F., Jain, E., &Sarangapani, K. (2024, August). Energy and economic analysis of semi cylindrical and single slope solar still. In *AIP Conference Proceedings* (Vol. 3178, No. 1). AIP Publishing.

7. Agrawal, R., Singh, K. D. P., & Paswan, M. K. (2020). Review on enhancement of thermal conductivity of phase change materials with nano-particle in engineering applications. *Materials Today: Proceedings*, *22*, 1617-1627.
8. Kabeel, A. E.; Sharshir, S. W.; Abdelaziz, G. B.; Halim, M. A.; Swidan, A. Improving Performance of Tubular Solar Still by Controlling the Water Depth and Cover Cooling. *J. Cleaner Prod.***2019,** *233,* 848–856. DOI: 10.1016/j.jclepro.2019.06.104
9. Arunkumar, T., Velraj, R., Denkenberger, D., Sathyamurthy, R., Vinothkumar, K., Porkumaran, K., & Ahsan, A. (2016). Effect of heat removal on tubular solar desalting system. *Desalination*, *379*, 24-33.
10. E. M. S. El-Said, S. M. Elshamy, and A. E. Kabeel, "Performance enhancement of a tubular solar still by utilizing wire mesh packing under harmonic motion," *Desalination*, vol. 474, p. 114165, 2020, doi: https://doi.org/10.1016/j.desal.2019.114165.
11. K. J. Khatod, V. P. Katekar, and S. S. Deshmukh, "An evaluation for the optimal sensible heat storage material for maximizing solar still productivity: A state-of-the-art review," *J. Energy Storage*, vol. 50, p. 104622, 2022, doi: https://doi.org/10.1016/j.est.2022.104622.
12. Jani, H.K.; Modi, K.V. Experimental performance evaluation of single basin dual slope solar still with circular and square cross-sectional hollow fins. Sol. Energy 2019, 179, 186–194. [CrossRef].
13. Elashmawy, M. Improving the Performance of a Parabolic Concentrator Solar Tracking-Tubular Solar Still (PCST-TSS) Using Gravel as a Sensible Heat Storage Material. *Desalination***2020,** *473*. DOI: 10.1016/j.desal.2019.114182, 114182
14. Dumka, P.; Sharma, A.; Kushwah, Y.; Raghav, A. S.; Mishra, D. R. Performance Evaluation of Single Slope Solar Still Augmented with Sand-Filled Cotton Bags. *J. Energy Storage***2019,** *25*. DOI: 10.1016/j.est.2019.100888, 100888
15. Kumar, A., Singh, K. D. P., & Agrawal, R. (2024). Intensification of thermal characteristics of flat plate solar water heater using triangular perforated wavy tape. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, *238*(17), 8838-8849.
16. Panchal, H. N., and P. K. Shah.2012. "Effect of VaryingGlassCoverThickness on Performance of SolarStill: in a WinterClimateConditions." *International Journal of Renewable Energy Research (IJRER)* 1 (4):212–23
17. Sharshir, S. W., M. A. Eltawil, A. M. Algazzar, R. Sathyamurthy, and A. W. Kandeal.2020. "Performance Enhancement of SteppedDoubleSlopeSolarStill by

UsingNanoparticles and LinenWicks: Energy, Exergy and EconomicAnalysis." *Applied Thermal Engineering* 174: 115278. DOI: 10.1016/j.applthermaleng.2020.115278, PubMed: 115278

18. Khan, M. M. A.; Ibrahim, N. I.; Saidur, R.; Mahbubul, I. M.; Al-Sulaiman, F. A.Performance Assessment of a SolarPoweredAmmonia–WaterAbsorptionRefrigerationSystem with StorageUnits. *Energy Convers.Manag.* **2016,** *126,* 316–328.