NATURALISTA CAMPANO
ISSN: 1827-7160
Volume 28 Issue 1, 2024

Implementation and Analysis of Novel Standalone Compact Solar Still Using Heat Augmentation Techniques Integration

S. D. Dongare[1], S. K. Somani[2], H. S. Patil[3]

[1,2]Department of Mechanical Engineering, Oriental University, Madhya Pradesh, India.
[3]Department of Mechanical Engineering, GIDC Degree Engineering College, Navsari, Gujarat, India.
Email|: [1]dongare.santosh@rediffmail.com, [2]sksomani123@gmail.com, [3]hspatil28@gmail.com

Abstract: The application and analysis of a new freestanding compact solar still that uses heat augmentation techniques are the subjects of this study. In order to improve the effectiveness of water desalination and purifying procedures in isolated and desert areas, the design incorporates cutting-edge methodologies. The objective of the solar still is to enhance water production rates and overall system performance by employing heat augmentation techniques such phase change materials (PCMs), concentrators, and thermal storage devices. In order to improve evaporation rates and condensation efficiency, the research focuses on assessing how well various heat augmentation approaches work to increase the temperature differential inside the solar still. The results of experiments are used to evaluate how different factors, including as system configuration, PCM choice, ambient temperature, and sun irradiation, affect the overall performance of the solar still. Comparing the first results to conventional solar still designs, it appears that there will be significant gains in both energy efficiency and water production rates. By integrating PCMs, it is possible to store thermal energy during times of low solar radiation, which guarantees continuous water production and lessens the impact of environmental fluctuations throughout the day. Furthermore, concentrators and optical improvements direct sunlight onto the evaporator surface, increasing evaporation rates and system productivity as a whole. The results of this study improve the field of standalone compact solar still technology and present viable approaches to the problem of water scarcity in isolated and off-grid areas. In water-stressed locations, the incorporation of heat augmentation techniques offers a sustainable and affordable method for purifying and desalinating water, with potential benefits for enhancing agricultural output, environmental sustainability, and livelihoods.

Keywords: Standalone, compact, solar, solar still, heat augmentation.

1. Introduction:

An important step toward resolving urgent worldwide issues with water scarcity and sustainable energy use is the application and analysis of innovative freestanding small solar stills with heat augmentation techniques integrated. The pressing need to create effective and reasonably priced methods for purifying and desalinating water, especially in areas where there is a scarcity of water, is what drives this research. The increasing need for fresh water due to the growing global population has made alternate water sources like brackish or seawater more important. One potential remedy is solar desalination, which uses the sun's abundant and renewable energy to create clean, drinkable water. Nevertheless, conventional solar stills' low efficiency frequently prevents them from being widely used. The realization that the performance of standalone tiny solar stills may be greatly improved by incorporating heat augmentation techniques is what spurred this research. We seek to increase the overall efficiency of the solar desalination process by investigating cutting edge techniques like phase change materials, concentrated solar collectors, and sophisticated heat exchangers. Furthermore, one of the main concerns is how energy use affects the environment. Desalinating water with solar energy is in line with global initiatives to move toward environmentally benign and sustainable technology. Not only may the incorporation of heat augmentation techniques improve freshwater output, but it also helps reduce the carbon footprint that comes with using traditional desalination procedures.
The realization that the performance of standalone tiny solar stills may be greatly improved by incorporating heat augmentation techniques is what spurred this research. We seek to increase the overall efficiency of the solar desalination process by investigating cutting edge techniques like phase change materials, concentrated solar collectors, and sophisticated heat exchangers. Furthermore, one of the main concerns is how energy use affects

the environment. Desalinating water with solar energy is in line with global initiatives to move toward environmentally benign and sustainable technology. Not only may the incorporation of heat augmentation techniques improve freshwater output, but it also helps reduce the carbon footprint that comes with using traditional desalination procedures.

This work focuses on the design, implementation, and analysis of a new compact solar still that stands alone and uses heat augmentation techniques. In this work, the solar still—a tool for water distillation—is made more efficient by applying several state-of-the-art approaches. By employing heat augmentation techniques, the solar still's overall efficiency is meant to be improved, hence boosting its desalination or purification capacities. In order to meet the needs of applications in places where access to traditional energy sources is limited, the project aims to produce a small, freestanding solar still. Utilizing extra heat sources to improve the evaporation process and raise the production of distilled water is known as the integration of heat augmentation techniques. This could involve techniques like the use of sophisticated heat transfer systems, the incorporation of phase transition materials, or the concentration of sunlight using reflectors. The construction and testing of the innovative solar still design under actual conditions constitute the implementation part of the study. This makes it possible to evaluate its effectiveness and practical viability. The analysis is centered on assessing the performance parameters, which include overall system reliability, energy efficiency, and water production rate. The combination of heat augmentation techniques can yield benefits over conventional solar stills, which can be compared. This study offers important new information about how small solar stills could be improved for purifying or desalinating water. The incorporation of heat augmentation techniques has the potential to facilitate the development of more sustainable and efficient solutions, especially in areas where traditional energy sources are restricted and water resources are scarce.

2. Literature Survey:

Singh et al. [1] have developed a novel method to boost the efficiency of solar still distillation units (SSDUs) by employing waste thermal energy from commercial and residential activities as an extra heat source. This plan seeks to lessen global warming while also reducing pollutants in the environment. Two SSDUs will be tested simultaneously as part of this field study.

A comprehensive analysis of latent heat thermal storage (LHTS) systems, which are specifically designed for concentrated solar energy, was presented by Ismail et al [2]. Enhancing energy storage's efficiency is the primary focus. Enhancing storage systems is essential to raising solar systems' output capacity, which raises their overall yearly performance significantly. Using COMSOL's computational power, a thorough study is carried out.

According to Hamad et al. [3], the laminar sublayer that forms inside the solar collector's channel is the reason why the solar air heater has a low heat transfer coefficient. By upsetting the smooth layer of flow, adding artificial ribs or roughness to the absorber plate's surface is a "very effective and promising technique to enhance heat transfer." The use of a trapezoidal rib in this study enhanced the solar air heater's thermal performance. The flow and heat transport characteristics were numerically investigated within a Reynolds number range of 5000 to 30000 using a RNG k-ε turbulent model. The research looked at eight different types of trapezoidal ribs arranged in patterns that either increased height in the direction of flow or in the opposite way.

The efforts made to improve a hemispherical solar still's (HSS) thermo-enviroeconomic features through various enhancements were presented by Sharshir et al. [4]. The recommended changes were applied to the HSS one after the other, and each case was analyzed and contrasted with a reference HSS.

More encouragingly, solar desalination is a sustainable way to supply freshwater in arid regions, according to research by Elsheikh et al. [5]. The Sustainable Development Goals (SDGs)—namely, SDG 6 (ensuring universal and sustainable access to clean drinking water), SDG 13 (reducing environmental impacts and mitigating climate change), and SDG 14 (promoting the sustainable use of seas, oceans, and lakes)—may be achieved through solar desalination. The most recent developments in performance-enhancing techniques for raising sun stills' (SSs') freshwater production are reviewed in this article. Energy storage materials, heat transfer strategies, cooling techniques, water agitation, water spraying, forced vibration, solar collectors, reflectors, condensers, multi-stage designs, and evaporation augmentation tactics are some of the techniques that were looked at.

A thorough examination of the most recent developments in solar-powered water desalination technology was given by Shalaby et al. [6]. "This analysis looks at and talks about the most recent designs of solar-powered desalination systems, such as membrane distillation (MD), multi-effect distillation (MED), multi-stage flash (MSF), humidification-dehumidification (HDH), reverse osmosis (RO), and solar stills with phase change materials. The fascinating water desalination technologies driven by photovoltaic and concentrating solar power (CSP) are also examined in the investigation. The study's conclusions show that the most common technique for solar thermal-powered water desalination is still reverse osmosis (RO) desalination systems driven by

photovoltaic electricity. When compared to alternative approaches, this technique yields high daily production per unit area of the solar field at a significantly reduced cost.
According to research by Farid et al. [7], feedwater heating is an essential and energy-intensive step in membrane distillation (MD) that significantly increases overall energy costs. Therefore, in order to achieve higher energy optimization, it is important to improve the thermal efficiency of the MD process. With its insights into the latest developments, stages of development, operational strategies, obstacles, and opportunities related to each water heating technology in the context of MD, this study is an invaluable resource for the scientific community.
Kaviti et al. [8] A solar still, while considered a sustainable device, filters water using the sun's abundant energy. The primary objective of this study is to boost the production of a double-slope solar still (DSSS) by adding copper tubes and parabolic fins to the basin liner. Three different situations were included in the nine days that the trials in this study were evaluated.
Sadique et al. [9] developed the methods for augmenting heat transmission with microchannel heat sinks (MCHS) which are covered in this study. Because of the multifunction, high heat flux per unit space, and smaller packing capacity of electronic devices, researchers are being pushed to develop more effective heat removal systems. This review study discusses the developments in modern cooling technology and MCHS.
Chauhan et al. [10] The most popular sustainable development method for addressing water scarcity is solar desalination. Multiple studies have shown that solar desalination reliably increases the yield of distilled water. To improve output and efficiency, solar desalination technology has been adjusted. Certain solar heat storage systems meet demand while balancing the sun's irregular cycles. Freshwater supply has been successfully ensured by solar stills (SS) and sensible and latent heat storage (LHS) materials.
In order to enhance the production of distilled water, Elsheikh et al. [11] shows how to employ a heat exchanger in conjunction with a solar desalination system. According to the current analysis, improving the distillate productivity of the solar desalination system is mostly dependent on the heat exchanger. The potential benefits and impending challenges of using a heat exchanger in conjunction with a solar desalination system are discussed here.

3. Methodology:

This section presents an overview of the systematic methodology that was applied to the design, construction, and assessment of the proposed solar desalination system. A solar cooker is a device that uses solar radiation to generate heat that is used to cook food contained inside a kitchen appliance. In addition, solar cookers enable the performance of several essential processes, including purification and cleansing [12]. Over time, various designs of solar cookers have been developed worldwide, and scientists and researchers are constantly striving to improve upon these designs. As a result, categorizing solar cookers appears to be a challenging task. In this study, three fundamental types of solar cookers are covered. They include cookers that are box-style, concentrating, and non-focusing. The type of collection and the temperature order are the basis for these categories. The three primary categories that fall under this domain are cookers with or without storage, cookers with or without direct or indirect heat-transferring modes, and cookers with or without tracking systems.
There is a solar box cooker that is made up of an insulated box with a glass lid that is transparent. It is routine procedure to install reflecting surfaces, often called booster mirrors, on the box to allow sunlight to enter [13]. Figure 1's schematic provides an explanation of the solar box cooker. The absorber, or the interior portion of the box, is painted black to enhance the amount of sunlight that is absorbed. It can accommodate up to four prepared food-filled cooking vessels inside the food-filled box, and it frequently has room for multiple pots [14][15]. This particular type of cooker can reach temperatures of approximately 100 degrees Celsius, which enables cooking via boiling.

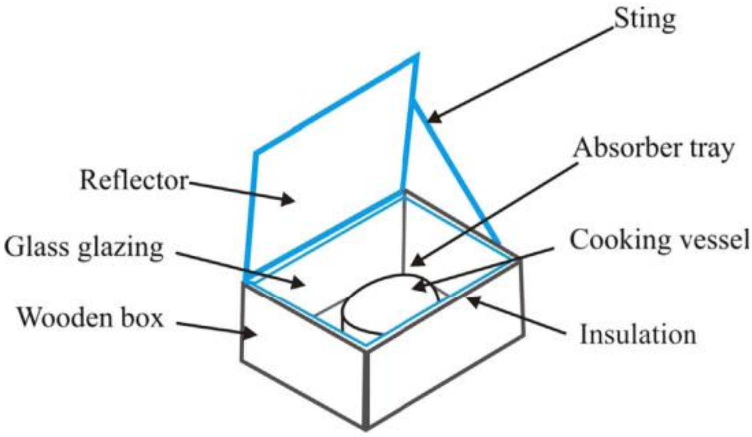

Figure 1. Mechanism for Box Solar cooker

Using an absorber plate with a high absorption factor and painted black will boost the efficiency of a solar box cooker. From the beginning to the present, this topic has drawn interest [16–19]. Heat must escape from the inside of the energy-efficient box solar cooker as little as possible in order for it to function. Consequently, a number of studies highly advise using transparent materials to insulate glass. Another crucial element for optimizing the energy output of a solar box cooker is the finishing. Researchers conducted extensive evaluations and studies on cooking equipment, focusing on his geometry. They discovered that cooking pots with cylindrical and rectangular shapes, made of aluminum or copper, and an outside layer of black paint work well with box cookers.

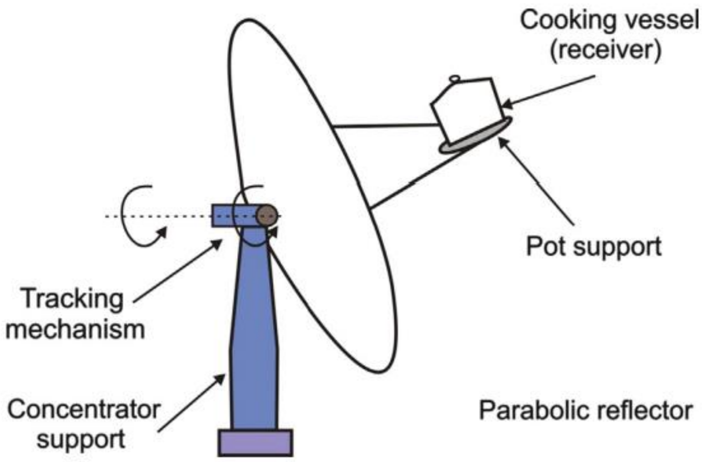

Figure 2. Mechanisms of a parabolic solar cooker

Concentrating-type cookers raise the temperature to higher levels [19] suitable for cooking a variety of food kinds by using multipurpose mirrors, Fresnel lenses, and parabolic or spherical collectors. These cookers frequently come with a 1 or 2 axis tracking mechanism that makes it possible to see the path of the sun. High reflector clarity in concentrating-type cookers allows for great optical reflection and minimal receiver temperature loss. Figure 2 illustrates the point converging paraboloid solar cooker, which is the most well-known design in this category. Its main components are a pedestal to support the cooking system and a parabolic reflector with a cooking pot positioned on the cooker's focal point. Concentrating-type cookers gained a lot of traction, and numerous theoretical concepts are still in use today worldwide.
The phrase "solar cooker" describes a gadget that cooks food using sun energy. It accomplishes this by gathering solar thermal energy and focusing it—typically with the use of lenses or reflecting surfaces—onto a cooking

surface. In areas where the fuel needed for conventional cooking methods is scarce or expensive, solar cookers are very helpful. Additionally beneficial to the environment are solar ovens.
Figure 3 illustrates the evaporation and condensation experimental setup for the solar cooker.

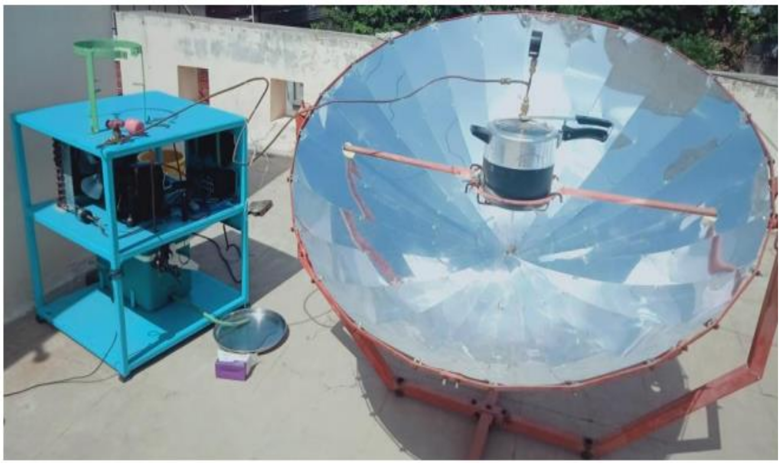

Figure 3. Proposed experimental setup of solar cooker

Figure 4 depicts the parabolic dish solar cooker that was utilized in the experimental experiments to validate the numerical model. The parabolic solar concentrator has a diameter of around 1.2 meters.

Figure 4. Photo of the experiment setup for validation of the numerical model

Examine the data on solar radiation intensity that has been recorded in order to determine seasonal variations and variations in solar energy input throughout the day. To assess overall efficiency and performance, correlate data of solar radiation intensity with other solar still performance indicators, such as water temperature, evaporation rates, and water production rates. Examine the gathered information to determine how well the solar cooker is working. The following describes the performance matrices, which include productivity, efficiency, and distillate yield.
Efficiency: Determine the efficiency of solar still using equation 1.

$$\text{Efficiency (\%)} = \frac{\textit{Distillate yield (liters)}}{\textit{solar radiation intensity}\left(\frac{kW}{m^2}\right) * \textit{surface area of the still}\ (m^2)} \times 100 \quad \text{-------- (1)}$$

Productivity: Productivity is the rate of production of cleansed water and is determined by equation 2.

$$\text{Productivity (liters/hour)} = \frac{\text{Distillate yield (liters)}}{\text{Duration of the experiment (hours)}} \quad \text{------------- (2)}$$

Distillate yield: The quantity of cleaned water gathered during a given time frame is referred to as the distillate yield. This was probably measured throughout the experiment.

4. Results and Discussions:

While there are other approaches to solar desalination, solar stills offer a low cost of operation, scalability, and convenience of use that make them a viable substitute. On the other hand, traditional solar stills' low productivity and efficiency prevent them from being widely used. As a result, researchers have been looking for creative ways to enhance the functionality of solar stills in order to get past these limitations. One such method is the use of heat augmentation techniques, which are intended to raise evaporation rates and improve overall effectiveness. This study's primary goal is to design and evaluate a small, standalone solar still that makes use of unique heat augmentation methods. Determining whether it is advantageous to incorporate heat augmentation strategies into the design of a tiny solar cooker is the primary objective of this study. Our goal is to develop a solar desalination system that, in resource-constrained regions, can generate drinkable water from saline sources. This will be accomplished by utilizing the most latest developments in solar energy, engineering, and materials research. One of the most important aspects of our research is the selection and advancement of heat augmentation technologies. Among these methods are heat storage devices, solar concentrators, and phase change materials (PCMs). These insights will be provided by the comparison itself. Aside from that, financial factors will be taken into account to assess the suggested solar still system's long-term viability and affordability. This study's main objective is to demonstrate how applying heat augmentation techniques to small freestanding solar stills can help progress solar desalination technology. We aim to pave the road for the general adoption of sustainable and successful methods for producing freshwater in areas experiencing water scarcity through interdisciplinary collaboration and meticulous study. The changes in solar radiation intensity with local time are shown in Table 1.

Table 1. Variation of solar radiation intensity with time

Sr. No.	Time am to pm	w/m^2
1	8	300
2	9	400
3	10	650
4	11	800
5	12	900
6	13	1000
7	14	900
8	15	700
9	16	400
10	17	200
11	18	35

Solar Radiation Intensity:
The amount of solar energy that reaches a certain location over a given amount of time is referred to as solar radiation intensity. Usually, it is expressed in W/m^2. The amount of solar radiation can change depending on the season, the time of day, the atmosphere, and one's geographic position.
The solar radiation intensity variation with local time is depicted in the figure below. This graph illustrates how variations in sun radiation occur throughout time. There are 900 sun radiation units at 12 noon. This chart shows that there is a significant variation in solar radiance when the time reaches 1 pm, and a very small change in solar radiation when it reaches 18 pm.

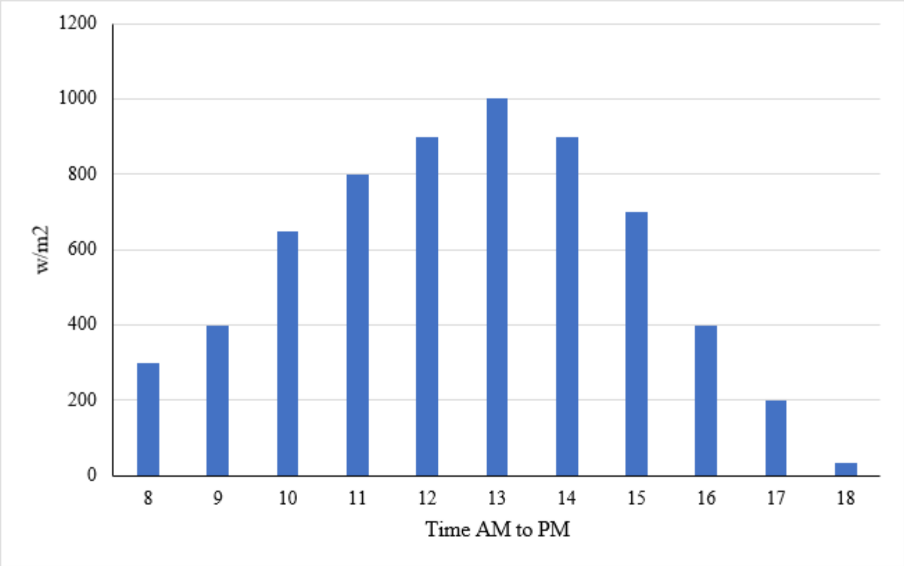

Figure 5. Variation of solar radiation intensity with local time

Ambient Temperature:
The temperature of the immediate surroundings is referred to as the ambient temperature. It is the temperature of the surrounding environment or the air when something is placed there or happens there. This phrase is frequently used in a variety of settings, including engineering applications, scientific research, and weather forecasts. A number of variables, including the time of day, season, location, and whether it is indoors or outdoors, can affect the ambient temperature. Table 2 shows how the local time and ambient temperature change.
Table 2: Variation of ambient temperature with local time

Sr. No.	Time am to pm	Ambient temperature degree Celsius
1	7	28
2	8	30
3	9	31
4	10	32
5	11	33
6	12	34
7	13	35
8	14	34
9	15	33
10	16	32
11	17	30
12	18	29

The ambient temperature curve in Figure 6 is described with respect to local time. The variation in ambient temperature with respect to local time is shown in this figure. At seven in the morning, the temperature is 28 degrees celsius. The temperature is 34 degrees celsius, which is little higher, when 12 noon arrives. When the clock reaches 1 pm, the greatest temperature recorded is 35 degrees celsius.

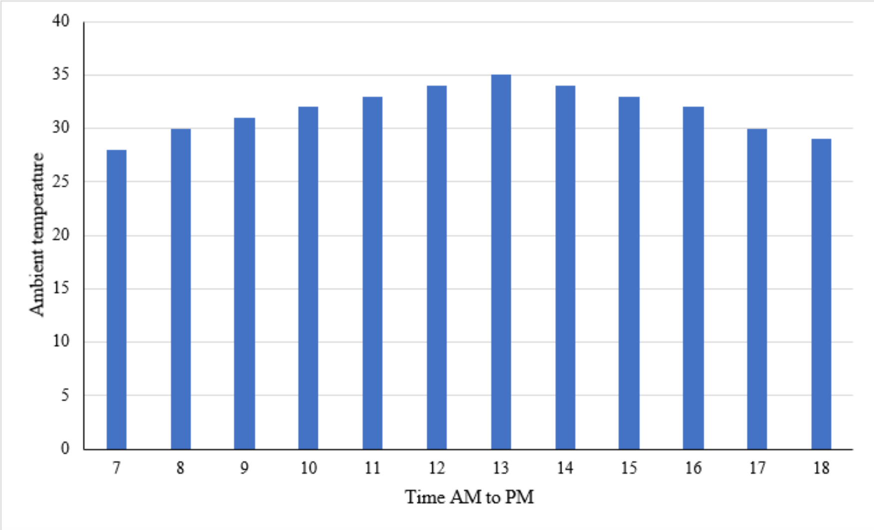

Figure 6. Variation of ambient temperature with local time

Wind velocity:
Wind velocity refers to the speed at which air moves in a particular direction. It is typically measured in units such as meters per second (m/s), kilometers per hour (km/h), or miles per hour (mph). Wind velocity can vary greatly depending on factors such as local geography, temperature differentials, and atmospheric pressure gradients. It is a key factor in weather forecasting and has implications for various activities, including aviation, sailing, and wind energy generation.
Table 3 shows the variation of wind velocity with local time.
Table 3. Wind velocity (m/s)

Sr. No.	Time am to pm	Wind velocity m/s
1	7	1
2	8	1.7
3	9	2.2
4	10	3.8
5	11	3.5
6	12	4.5
7	13	3.8
8	14	3.3
9	15	3.5
10	16	2.8
11	17	3.3
12	18	3.5

The wind velocity graph is depicted in Figure 7 and is characterized with local time as follows. This graphic illustrates the relationship between wind velocity fluctuation and local time. The wind speed is 1 m/s, which is quite low, when the time reaches 7 am. The wind velocity is 3.8 m\s, which is somewhat higher, when 10 am arrives. As can be seen below, at 12 noon, the wind reaches its maximum velocity of 4.5 meters per second.

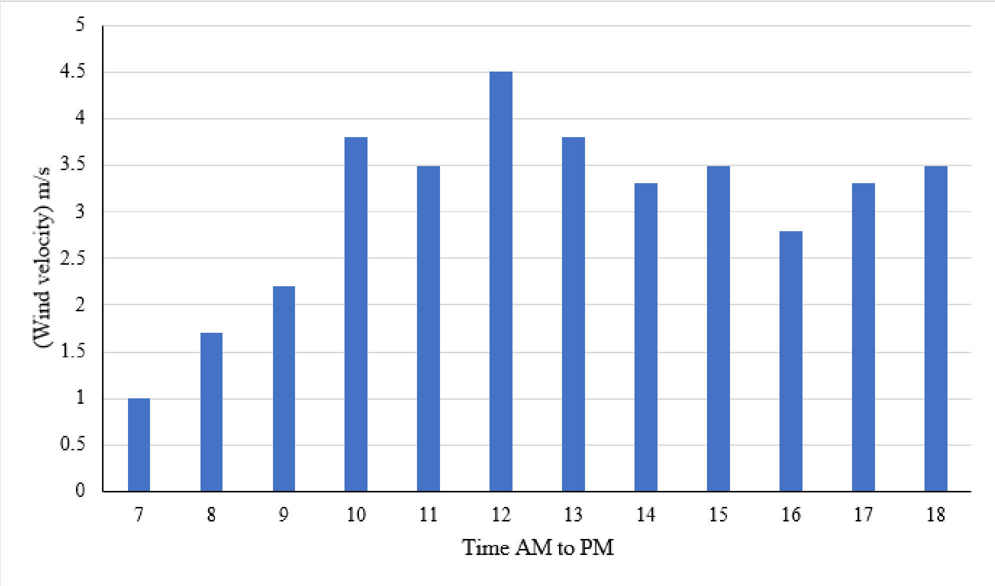

Figure 7. Variation of wind velocity

The average daily temperature and incident solar radiation in w\m2 are compared in Table 4. Table 4 indicates that the ambient temperature is 39 degrees Celsius and that there is a large amount of solar radiation incident in May. It is clear that there is a significant amount of solar radiation in July, with an average temperature of 27 degrees Celsius and 60 watts per square meter.

Table 4. Comparison of Ambient temperature and solar radiation

Month	Avg daily temperature (ambient temperature)	Incident solar radiation in w\m2	Pandhar pur
Jan	21	230	231
Feb	25	280	270
Mar	31	330	296
Apr	37	340	304
May	39	350	304
Jun	30	300	305
Jul	27	60	273
Aug	26	170	126
Sep	27	300	198
Oct	24	310	216
Nov	21	265	260
Dec	17	280	215

The average daily temperature (ambient temperature) and incident solar radiation are compared in Figure 8, as may be seen below. According to this statistic, January has a low ambient temperature and a high sun radiation incidence. It is evident that in July, when the outside temperature is 27 degrees Celsius, there is a high level of solar radiation of 60 w/m^2. As demonstrated below, at 39 degrees Celsius ambient temperature, solar radiation is exceptionally high at 350 watts per square meter.

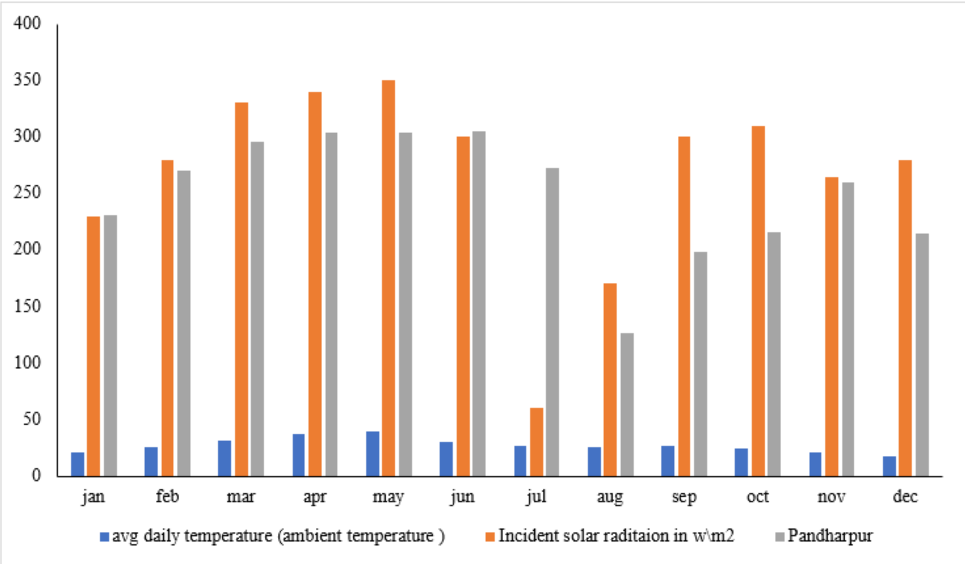

Figure 8. Comparison of Ambient temperature and solar radiation based on Monthly

5. Conclusion:

This is a major breakthrough in solar desalination technology—the implementation and study of a unique freestanding tiny solar still that uses heat augmentation techniques. More output and efficiency are achieved while using this procedure to turn contaminated or salted water into drinkable water. To do this, innovative design components like phase change materials or reflecting coatings are combined with heat augmentation technology. The design incorporates compactness for scalability and usage in various scenarios, especially in areas where water scarcity is a significant problem. This study's extensive testing and analysis not only validates the practicality and effectiveness of the recommended system, but it also provides valuable data for its eventual implementation and optimization, which will ultimately aid in addressing the global water crisis and advancing the creation of sustainable water solutions.

Utilizing solar energy for water purification has shown encouraging results when a new freestanding compact solar still with heat augmentation techniques is put into practice and analyzed. Phase change materials and concentrating mirrors are two examples of cutting edge heat augmentation techniques that have been integrated into the system to improve its efficiency in converting solar radiation into heat that can be used for processes like water evaporation and condensation. Furthermore, because ambient temperature and incident solar radiation have a direct impact on the system's overall productivity and efficiency, regulating these environmental elements has proved essential to maintaining the solar still's performance. The relationship between incoming solar radiation and ambient temperature highlights the dynamic interaction between environmental elements that shapes our surroundings. The thermal state of the immediate surroundings, or ambient temperature, is determined by a number of variables such as time of day, location, and seasonal changes. It is a key indicator of weather trends, energy use, and general comfort levels in both indoor and outdoor environments.

The entrance of solar energy onto the Earth's surface, on the other hand, is represented by incident solar radiation, which is essential for maintaining ecosystems, regulating weather patterns, and producing renewable energy. Its intensity varies throughout the day and in different parts of the world because of things like surface albedo, latitude, and air conditions.

6. References

1. Singh, Jesa, Vinayagam Sivabalan, and Bhajan Lal. "Introduction to Desalination." Gas Hydrate in Water Treatment: Technological, Economic, and Industrial Aspects (2022): 1-14
2. Ismail, M. M., Dincer, I., & Bicer, Y. (2024). Modeling and simulation of nano-enriched latent heat thermal storage system for concentrated solar energy. Journal of Energy Storage, 78, 110071.
3. Hamad, R. F., Alshukri, M. J., Eidan, A. A., & Alsabery, A. I. (2023). Numerical investigation of heat transfer augmentation of solar air heater with attached and detached trapezoidal ribs. Energy Reports, 10, 123-134.

4. Sharshir, S. W., Omara, M. A., Joseph, A., Kandeal, A. W., Elsaid, A. M., El-Said, E. M., ... & Abdelaziz, G. B. (2023). Thermoenviroeconomic performance augmentation of solar desalination unit integrated with wick, nanofluid, and different nano-based energy storage materials. Solar Energy, 262, 111896.
5. Elsheikh, A., Hammoodi, K. A., Ibrahim, A., Mourad, A. H. I., Fujii, M., & Abd-Elaziem, W. (2023). Augmentation and evaluation of solar still performance: A comprehensive review. Desalination, 117239.
6. Shalaby, S. M., Hammad, F. A., & Zayed, M. E. (2023). Current progress in integrated solar desalination systems: Prospects from coupling configurations to energy conversion and desalination processes. Process Safety and Environmental Protection.
7. Farid, M. U., Kharraz, J. A., Sharma, S., Khan, R. J., Khanzada, N. K., Deka, B. J., ... & An, A. K. (2023). Technological advancements in water heating approaches for membrane distillation desalination process: From bulk to localized heating. Desalination, 117235.
8. Kaviti, A. K., Teja, M., Madhukar, O., Teja, P. B., Aashish, V., Gupta, G. S., ... & Sikarwar, V. S. (2023). Productivity augmentation of solar stills by coupled copper tubes and parabolic fins. Energies, 16(18), 6606.
9. Sadique, H., & Murtaza, Q. (2022). Heat transfer augmentation in microchannel heat sink using secondary flows: A review. International Journal of Heat and Mass Transfer, 194, 123063.
10. Chauhan, V. K., Shukla, S. K., & Rathore, P. K. S. (2022). A systematic review for performance augmentation of solar still with heat storage materials: A state of art. Journal of Energy Storage, 47, 103578.
11. Elsheikh, Ammar H., Hitesh N. Panchal, Shanmugan Sengottain, Naser A Alsaleh, and Mahmoud Ahmadein. "Applications of heat exchanger in solar desalination: current issues and future challenges." Water 14, no. 6 (2022): 852.
12. Cuce E, Cuce PM. A comprehensive review on solar cookers. Appl Energy 2013;87:1399–421.
13. Muthusivagami RM, Velraj R, Sethumadhavan R. Solar cookers with and without thermal storage: a review. Renew Sust Energy Rev 2010;14:691–701.
14. Saxena A, Varun, Pandey SP, Srivastav G. A thermodynamic review on solar box type cookers. Renew Sust Energy Rev 2011;15:3301–18.
15. Khan BH. Non-conventional energy resources. New Delhi, India: Tata McGraw Hill Publications; 2008.
16. Kothari DP, Singal KC, Ranjan R. Renewable energy resources and emerging technologies. New Delhi, India: Prentice-Hall; 2008.
17. Tripanagnostopoulos Y, Souliotis M, Nousia Th. Solar collectors with colored absorbers. Sol Energy 2000;68:343–56.
18. Lahkar PJ, Samdarshi SK. A review of the thermal performance parameters of box type solar cookers and identification of their correlations. Renew Sustain Energy Rev 2010;14:1615–21.
19. Sharaf E. A new design for an economical, highly efficient, conical solar cooker. Renew Energy 2002;27:599–619.
20. Arenas JM. Design, development and testing of a portable parabolic solar kitchen. Renew Energy 2007;32:257–66.
21. Franco J, Cadena C, Saravia L. Multiple use communal solar cookers. Sol Energy 2004;77:217–23.
22. Mulani, A. O., & Mane, P. B. (2019). High-Speed area-efficient implementation of AES algorithm on reconfigurable platform. Computer and Network Security, 119.
23. Mulani, A. O., & Mane, D. P. (2018). Secure and area efficient implementation of digital image watermarking on reconfigurable platform. International Journal of Innovative Technology and Exploring Engineering, 8(2), 56-61.
24. Mulani, A. O., & Mane, P. B. (2014, October). Area optimization of cryptographic algorithm on less dense reconfigurable platform. In 2014 International Conference on Smart Structures and Systems (ICSSS) (pp. 86-89). IEEE.
25. Takale, S., & Mulani, A. (2022). DWT-PCA Based Video Watermarking. Journal of Electronics, Computer Networking and Applied Mathematics (JECNAM) ISSN, 2799-1156.
26. Mulani, A. O., Jadhav, M. M., & Seth, M. (2022). Painless machine learning approach to estimate blood glucose level with non-invasive devices. In Artificial Intelligence, Internet of Things (IoT) and Smart Materials for Energy Applications (pp. 83-100). CRC Press.
27. Jadhav, H. M., Mulani, A., & Jadhav, M. M. (2022). Design and development of chatbot based on reinforcement learning. Machine Learning Algorithms for Signal and Image Processing, 219-229.
28. Mandwale, A., & Mulani, A. O. (2014, December). Implementation of Convolutional Encoder & Different Approaches for Viterbi Decoder. In IEEE International Conference on Communications, Signal Processing Computing and Information technologies.

29. Ghodake, R. G., & Mulani, A. O. (2018). Microcontroller Based Automatic Drip Irrigation System. In Techno-Societal 2016: Proceedings of the International Conference on Advanced Technologies for Societal Applications (pp. 109-115). Springer International Publishing.
30. Shweta Sadanand Salunkhe and Altaf O Mulani (2024). Solar Mount Design Using High-Density Polyethylene. NATURALISTA CAMPANO. Volume 28, Issue 1, 2024.