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A Review On Analysis of Solar Still With Different Inclination Angle

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ABSTRACT

Solar stills are simple and eco-friendly devices used for desalination and purification of water by utilizing solar energy. The performance of a solar still is significantly influenced by several operating parameters, among which the inclination angle of the glass cover plays a crucial role. This review paper presents a comprehensive analysis of solar stills with different inclination angles and their effects on productivity, heat transfer, condensation rate, and overall efficiency. Various experimental and theoretical studies reported in the literature are examined to identify the optimum inclination angle under different climatic conditions. The review highlights that the inclination angle affects solar radiation absorption, condensate flow, and thermal losses, thereby influencing freshwater yield. It is observed that the optimal angle generally depends on the geographical location, latitude, seasonal variation, and design configuration of the solar still. Furthermore, the paper discusses different types of solar stills, modifications adopted to improve performance, and comparative analyses of inclined and conventional designs. The findings of this review provide useful insights for researchers and engineers in designing efficient solar still systems for sustainable freshwater production in water-scarce regions.

Keywords: Solar still, Inclination angle, Solar desalination, Freshwater productivity, Heat transfer, Condensation, Thermal efficiency, Solar energy, Water purification, Sustainable water treatment.

1. INTRODUCTION

A solar still is a device that purifies water by utilizing solar energy to drive evaporation and condensation processes. Various types of solar stills exist, including large-scale concentrated systems and simple condensation traps, commonly referred to as moisture traps among survivalists. In a typical solar still, impure water is placed outside the collection area and heated by sunlight passing through a transparent cover such as glass or plastic [1–3]. As the water evaporates, the vapor condenses on the cooler inner surface of the cover and is collected as distilled water [4].

This process closely replicates the natural hydrological cycle. Solar energy heats water bodies, causing evaporation; the vapor rises, cools, and condenses to form precipitation. Similarly, in a solar still, impurities such as salts, heavy metals, and microorganisms are left behind during evaporation, resulting in pure distilled water [5–8].

Solar stills are particularly useful in situations where conventional water sources—such as rainwater, piped supply, or groundwater—are unavailable or unreliable. These include remote areas and regions affected by natural disasters or power outages [9–11]. In subtropical regions prone to hurricanes and extended power failures, solar distillation provides a reliable alternative source of potable water. Several condensation collection techniques have been developed to enhance efficiency [12].

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Access to potable water is essential not only for sustaining life and environmental balance but also for supporting agricultural and industrial activities. However, freshwater scarcity has become a major global issue due to increasing pollution of rivers and lakes from industrial discharge, as well as rapid population growth. According to global reports, more than 1.1 billion people lack access to safe drinking water, and approximately 1000 children die daily due to diseases caused by contaminated water. In water-scarce regions, this shortage may even contribute to conflicts [1]. The availability of fresh water is therefore recognized as one of the most critical challenges facing humanity.

Several advanced desalination technologies have been developed, such as multi-stage flash (MSF), multiple-effect distillation (MED) [2], thermal vapor compression (TVC) [3], membrane distillation (MD) [4], and reverse osmosis (RO) [5]. Although effective, these methods require significant energy input and skilled personnel for operation. In contrast, many regions with limited energy resources receive abundant solar radiation throughout the year, making solar-based solutions more feasible.

A solar still is a simple and widely used technology for converting brackish or saline water into potable water. It can be constructed using locally available materials and requires minimal maintenance [6]. Despite these advantages, basin-type solar stills generally suffer from low productivity. To address this limitation, researchers worldwide have proposed various design improvements and modifications to enhance performance. These include single- and double-slope solar stills [7], single-slope double-basin configurations [8], fin-type designs [9], the use of thermal storage materials such as rubber and glass balls [10,11], and the incorporation of external reflectors [12].

Furthermore, solar stills have been integrated with other systems such as flat plate collectors, solar ponds, and concentrators to improve productivity. While these approaches can significantly enhance output, they often increase the overall system cost [13]. Therefore, a key challenge lies in improving the productivity of solar stills without compromising their inherent advantage of low cost.

This challenge can be addressed by optimizing the various parameters that influence solar still performance. Such optimization requires detailed modeling of heat and mass transfer processes within the system. Computational Fluid Dynamics (CFD) modeling plays a crucial role in this regard, as it enables the simulation of evaporation and condensation phenomena while allowing flexible variation of design and operating parameters. This approach significantly reduces the time and cost associated with extensive experimental investigations for parameter optimization.

2. SOLAR STILL

Environmental pollution and effective water resource management are among the most critical challenges of the twenty-first century [12]. The use of solar energy for water purification through solar stills represents an environmentally sustainable and eco-friendly solution. In this context, CFD has emerged as a valuable and cost-effective tool for simulating fluid flow and heat transfer phenomena within solar stills, as well as for optimizing their design to achieve maximum productivity. A solar still is a device used to desalinate impure water, such as brackish or saline water [14]. It provides a simple and efficient means of producing potable distilled water using solar energy, making it suitable for domestic, industrial, and academic applications.

A typical solar still consists of a shallow, triangular basin made of Fiber Reinforced Plastic (FRP). The inner surface of the basin is painted black to enhance the absorption of solar radiation. The top of the basin is covered with a transparent, inclined glass cover that allows maximum solar radiation to enter the system. The edges of the glass are sealed with the basin using tar tape to ensure an airtight enclosure [14]. The entire assembly is supported by a structure made of mild steel (MS) angles. An outlet is connected to a storage container for collecting distilled water. Provision is also made for filling water into the basin, and a small access window is included for cleaning purposes. The water is maintained in the basin as a thin layer to facilitate efficient evaporation.

Freshwater availability on Earth is extremely limited. Although more than two-thirds of the Earth's surface is covered with water, over 97% of this water is saline or polluted. Only about 2.6% constitutes freshwater, and less than 1% of this is readily accessible for human and ecological use. Despite this limited availability being theoretically sufficient to sustain life, the demand for freshwater is continuously increasing due to rapid population growth [6]. Polluted water cannot be consumed directly because it contains harmful microorganisms and dissolved contaminants. As a result, many developed and developing countries are facing severe shortages of potable water.

Currently, several technologies are used for freshwater production, including reverse osmosis, multi-effect distillation, and mechanical vapor compression. However, these methods have the major drawback of high energy consumption. In contrast, solar thermal desalination offers a low-cost and sustainable alternative for producing drinking water. Solar distillation systems are gaining increased attention due to their simplicity, ease of operation, and minimal maintenance requirements [9].

Solar stills are particularly effective in regions with high solar insolation. Under favorable conditions, a solar still can produce approximately 0.5 to 0.75 pounds of distilled water per square foot of area per day [10-15]. However, one of the main limitations of solar stills is the large surface area required for significant water production [16]. A typical solar still comprises a transparent glass or plastic cover, a basin or tray to hold water, a collection channel (often made of galvanized steel) for distilled water, and sidewalls constructed from materials such as concrete or brick. The size of the still depends on the required water output, and optimal performance is achieved when the system is oriented toward the equator [17].

In operation, the water to be distilled flows slowly from the higher end of the basin, while excess water carrying dissolved salts exits through an overflow at the lower end, thereby preventing salt accumulation and crystallization [18]. In hot and dry climates, the evaporation rate is approximately 1/8 inch of water per day. To maintain efficient performance, the water depth in the basin is typically kept between 1/2 inch and 1 inch [19].

3. PAST STUDIES

Kanka et al. (2024) [19] reviewed the published articles pertaining to the incorporation of various performance enhancing approaches into direct SSs for the generation of fresh drinking water, including nanoparticles, nano-PCM, hybrid nanoparticles, fins, and sponges. Reviewing the publications findings indicates that the production of fresh water is greatly increased by using hybrid nanoparticles and copper balls with PCM (4460 ml/-day).

Sathyamurthy et al. (2024) [20] investigated a solution by enhancing a single slope solar still (SSSS) with paraffin wax as an energy storage medium in recycled soda cans. These cans were coated with a unique mixture of black paint and carbon soot nanoparticles gathered from automobile engine exhausts to boost thermal conductivity and heat absorption. These nanoparticles, averaging 50–60 nm in size, greatly enhanced the heat absorption efficiency of the cans. Morphological examination demonstrated a consistent distribution of nanoparticles across the surfaces of the cans.

Afolabi et al. (2023) [21] analyzed double slope solar still (DSSS) integrated with PCM-TES is presented. PCM was microencapsulated with epoxy resin composite using vacuum mould-filled techniques. Conventional DSSS and DSSS-TES data collected have been compared to establish the influence of TES on productivity. Daily average temperature of the glass cover, humid air, saline water, still basin absorber and TES cavity for the DSSS-TES attained are 65.2 °C, 77.5 °C, 82.4 °C, 79.5 °C and 68.4 °C, respectively. DSSS-TES has yielded higher production, with 7.5 Litres of potable water daily and extension in operation period by 3 h has been achieved. In addition, condensation and evaporation rates increased with increase in production by 105%.

Alqsair (2023) [22] focused on the numerical simulation of the surface evaporation process within a 3D solar still. Inside the solar still chamber, water is maintained at a specific level and undergoes evaporation due to solar heat. The numerical simulation utilizes computational fluid dynamics (CFD) techniques. The primary objective of this study is to enhance the performance of the solar still system by increasing the rate of surface evaporation.

Sonawane et al., (2022) [23] examines how different absorber materials influence the performance of a solar still using CFD simulation, along with economic and environmental assessments. The study compares various absorber materials based on their thermal properties and evaluates their effect on heat transfer, evaporation rate, and overall water productivity. The results indicate that materials with higher thermal conductivity significantly enhance heat absorption and distribution, leading to improved evaporation and increased distillate yield.

Ojo et al. (2022) [24] examined a single sloped basin solar still was employed for the treatment of wastewater obtained from a paint industry. The efficiency of solar distillation in the treatment of the wastewater over a period of 8 consecutive days was examined. 20 Litres of wastewater was placed inside the solar still under outdoor conditions. Approximately 5 Litres of distillate water was obtained at the end of the experiment. The quality of the untreated wastewater and its distillate were determined. In addition, solar radiation and volume of distillate obtained for each day was measured.

Dsouza and Mallikappa (2023) [25] addressed the growing need for freshwater in regions affected by water scarcity, particularly in coastal and desert areas. The focus is on evaluating the effectiveness of a solar-powered desalination system, which utilizes a single slope step type solar still and an Evacuated Tube Collector (ETC) to produce fresh drinkable water. Additionally, Computational Fluid Dynamics (CFD) analysis is conducted to gain insights into the natural convection of heat transfer within a glass tube, which creates a buoyant flow of saline water. The design consists of a solar evacuated tube, which heats up due to the exposure to sun rays and this heat is transferred to the impure/saline water (effluent). The water is then discharged to a single slope step type solar still which absorbs energy from sunlight and increases the evaporation rate in the solar still.

Prasad et al. (2023) [26] Potable water is a basic need in various aspects of daily life. The conversion of brackish water to potable water through conventional sources is costly and environmental issues are associated. In this regard, solar energy is a preference over fossil fuel or another energy source because of its cost and environment. Therefore, solar still is very popular, but the performance still must be improved to meet our potable water demand. In the present work, the productivity of the still is tested with various operational parameters such as glass plate inclination 27°, 28°, and 29°, and basin heat absorption capacity was also observed with sand, clay sand, and granite for water yield. Water yielding is also affected by water depth in basing investigated as 2, 3, and 4 cm for productivity.

4. CONCLUSION

Solar stills offer an economical and environmentally friendly solution for freshwater production using renewable solar energy. From the reviewed studies, it is evident that the inclination angle of the glass cover is one of the most important parameters affecting the performance of a solar still. The inclination angle directly influences solar radiation absorption, condensate collection efficiency, heat transfer characteristics, and thermal losses within the system. An appropriate inclination angle enhances condensation and improves freshwater yield, while unsuitable angles reduce overall efficiency.

The review also reveals that the optimum inclination angle varies according to geographical location, climatic conditions, seasonal changes, and the design of the solar still. In most cases, angles close to the local latitude provide better performance. Several researchers have also demonstrated that combining suitable inclination angles with design modifications such as fins, phase change materials, reflectors, and nanofluids can significantly enhance distillate productivity.

Overall, the analysis confirms that proper optimization of the inclination angle is essential for maximizing the efficiency and productivity of solar stills. Future research should focus on adaptive or adjustable inclination systems and advanced thermal enhancement techniques to achieve higher water production and improved economic feasibility for large-scale applications.

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REFERENCES

[1] Purnachandrakumar, D., Mittal, G., Sharma, R. K., Singh, D. B., Tiwari, S., & Sinhmar, H. (2022). Review on performance assessment of solar stills using computational fluid dynamics (CFD). Environmental Science and Pollution Research, 29(26), 38673-38714.

[2] S. El-Sebaey, M., Ellman, A., Hegazy, A., & Ghonim, T. (2020). Experimental analysis and CFD modeling for conventional basin-type solar still. Energies, 13(21), 5734.

[3] Chekifi, T., Belaid, A., Boukraa, M., Khelifi, R., & Guermoui, M. (2025). Solar still performance improvement: CFD insights and AI integration challenges. International Journal of Energy and Water Resources, 9(4), 2823-2848.

[4] Shoeibi, S., Kargarsharifabad, H., Rahbar, N., Ahmadi, G., & Safaei, M. R. (2022). Performance evaluation of a solar still using hybrid nanofluid glass cooling-CFD simulation and environmental analysis. Sustainable Energy Technologies and Assessments, 49, 101728.

[5] Sonker, V. K., Sharma, P., Ram, R., & Sarkar, A. (2025). A CFD simulation analysis of the effects of PCM and nanoparticles stored in copper cylinders inside a solar still. Journal of Energy Storage, 108, 115091.

[6] Kumar, R., Kumar, L., Mirjat, N. H., & Harijan, K. (2024). CFD simulation of modified solar still for effective condensation and evaporation: energy and exergy analysis. Frontiers in Water, 6, 1436169.

[7] Prasad, R., Singh, Y., Sharma, A. K., Sahu, R., Dwivedi, V. K., & Kumar, S. (2025). Performance of single slope solar still with various operation parameters—An experimental, statistical, and CFD simulation approach toward optimality. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 239(1), 158-166.

[8] Kumar, A., & Maurya, A. (2022). Experimental analysis and CFD modelling for pyramidal solar still. Materials Today: Proceedings, 62, 2173-2178.

[9] Kumar, A. (2024). ANSYS Fluent-CFD analysis of a continuous single-slope single-basin type solar still. Green Technologies and Sustainability, 2(3), 100105.

[10] Madeshwaren, V., Kathiresan, G., Pandey, P., Ramakrishna, B., Arunkumar, S. P., & Chockalingam, P. (2025). A comprehensive review of advancements in solar still efficiency via computational fluid dynamics. Multiscale and Multidisciplinary Modeling, Experiments and Design, 8(7), 332.

[11] Mostafa, M., Abdullah, H. M., & Mohamed, M. A. (2020). Modeling and experimental investigation of solar stills for enhancing water desalination process. IEEE Access, 8, 219457-219472.

[12] Yan, T., Xie, G., Liu, H., Wu, Z., & Sun, L. (2020). CFD investigation of vapor transportation in a tubular solar still operating under vacuum. International Journal of Heat and Mass Transfer, 156, 119917.

[13] Mahmoud, S., Ellman, A., Hegazy, A., & Ghonim, T. (2020). Experimental Analysis and CFD Modeling for Conventional Basin-Type Solar Still. Energies, 13(21), 5734.

[14] Flores, M., Chávez, S., Terres, H., Lizardi, A., & Lara, A. (2022, September). Thermal analysis of a solar still through CFD. In Journal of Physics: Conference Series (Vol. 2307, No. 1, p. 012008). IOP Publishing.

[15] Alipanah, F., & Rahbar, N. (2018). CFD simulation and second law analysis of weir-type cascade solar stills with different number and dimensions of steps. Desalination and water treatment, 104, 15-27.

[16] Shoeibi, S., Ali Agha Mirjalily, S., Kargarsharifabad, H., Panchal, H., & Dhivagar, R. (2022). Comparative study of double-slope solar still, hemispherical solar still, and tubular solar still using Al2O3/water film cooling: a numerical study and CO2 mitigation analysis. Environmental Science and Pollution Research, 29(43), 65353-65369.

[17] Kumar, L., Kumar, R., Salem, I. B., & Assad, M. E. H. (2026). CFD simulation of a modified solar still system with enhanced productivity. In CFD Simulations for Advances of Solar Thermal Systems (pp. 289-302). Elsevier.

[18] Jathar, L. D., Ganesan, S., Shahapurkar, K., Patil, S., Darekar, V., & Chincholi, V. (2020, July). Comprehensive review on the prediction of thermal behavior of solar stills with diverse designs. In AIP Conference Proceedings (Vol. 2247, No. 1, p. 030004). AIP Publishing LLC.

[19] Kanka, S. D., Kibria, M. G., Anika, U. A., Das, B. K., Hossain, M. S., Roy, D., & Mohtasim, M. S. (2024). Impact of various environmental parameters and production enhancement techniques on direct solar still: A review. Solar Energy, 267, 112216.

[20] Sathyamurthy, R., Ali, H. M., Said, Z., El-Sebaey, M. S., Gopalsamy, S., Nagaraj, M., ... & Alomar, T. S. (2024). Enhancing solar still thermal performance: The role of surface coating and thermal energy storage in repurposed soda cans. Journal of Energy Storage, 77, 109807.

[21] Afolabi, L. O., Enweremadu, C. C., Kareem, M. W., Arogundade, A. I., Irshad, K., Islam, S., ... & Didane, D. H. (2023). Experimental investigation of double slope solar still integrated with PCM nanoadditives microencapsulated thermal energy storage. Desalination, 553, 116477.

[22] Alqsair, U. F. (2023). Numerical simulation and optimization of surface evaporation in a 3D solar still for improved performance. Results in Engineering, 20, 101554.

[23] Sonawane, C., Alrubaie, A. J., Panchal, H., Chamkha, A. J., Jaber, M. M., Oza, A. D., ... & Burduhos-Nergis, D. P. (2022). Investigation on the impact of different absorber materials in solar still using CFD simulation—economic and environmental analysis. Water, 14(19), 3031.

[24] Ojo, O. M., & Obiora-Okeke, O. A. (2022). Performance evaluation of a solar still for industrial wastewater treatment. Materials Today: Proceedings, 62, S1-S6.

[25] Dsouza, V. L., & Mallikappa, D. N. (2023). Performance analysis of step type solar still and comparison of the performance with evacuated tube collector coupled with single slope step type solar still. Materials Today: Proceedings.

[26] Prasad, R., Singh, Y., Sharma, A. K., Sahu, R., Dwivedi, V. K., & Kumar, S. (2023). Performance of single slope solar still with various operation parameters—An

ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

experimental, statistical, and CFD simulation approach toward optimality. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 09544089231172015.

[27] Shelake, A., Kumbhar, D., & Sutar, K. (2023). Desalination using solar stills: A review. Environmental Progress & Sustainable Energy, 42(3), e14025.

[28] da Silva Junior, L. G., de Oliveira, J. P. J., Ribeiro, G. B., & Ferreira Pinto, L. (2023). Experimental and Numerical Analysis of a Low-Cost Solar Still. Eng, 4(1), 380-403.

[29] Aghakhani, H., Ayatollahi, S. M., & Hajmohammadi, M. R. (2023). Proposing novel approaches for solar still performance enhancement by basin water heating, glass cooling, and vacuum creation. Desalination, 567, 117011.

[30] Hammoodi, K. A., Dhahad, H. A., Alawee, W. H., & Omara, Z. M. (2023). A detailed review of the factors impacting pyramid type solar still performance. Alexandria Engineering Journal, 66, 123-154.

[31] Arunkumar, T., Sathyamurthy, R., Denkenberger, D., & Lee, S. J. (2022). Solar distillation meets the real world: a review of solar stills purifying real wastewater and seawater. Environmental Science and Pollution Research, 29(16), 22860-22884.

[32] Shoeibi, S., Kargarsharifabad, H., Rahbar, N., Ahmadi, G., & Safaei, M. R. (2022). Performance evaluation of a solar still using hybrid nanofluid glass cooling-CFD simulation and environmental analysis. Sustainable Energy Technologies and Assessments, 49, 101728.

[33] El-Sebaey, M., Ellman, A., Hegazy, A., & Ghonim, T. (2020). Experimental analysis and CFD modeling for conventional basin-type solar still. Energies, 13(21), 5734.

[34] Nadgire, A. R., Barve, S. B., & Ithape, P. K. (2020). Experimental investigation and performance analysis of double-basin solar still using CFD techniques. Journal of The Institution of Engineers (India): Series C, 101, 531-539.

[35] Shanmugan, S., Essa, F. A., Gorjian, S., Kabeel, A. E., Sathyamurthy, R., & Manokar, A. M. (2020). Experimental study on single slope single basin solar still using TiO2 nano layer for natural clean water invention. Journal of Energy Storage, 30, 101522.

[36] Roslan, J., Kan, W. E., Rahman, A. A., Suliman, M., & Isha, R. (2020). Charcoal characterization and application is solar evaporator for seawater desalination. In IOP Conference Series: Materials Science and Engineering (Vol. 736, No. 2, p. 022107). IOP Publishing.

[37] Yan, T., Xie, G., Liu, H., Wu, Z., & Sun, L. (2020). CFD investigation of vapor transportation in a tubular solar still operating under vacuum. International Journal of Heat and Mass Transfer, 156, 119917.

[38] Keshtkar, M., Eslami, M., & Jafarpur, K. (2020). Effect of design parameters on performance of passive basin solar stills considering instantaneous ambient conditions: a transient CFD modeling. Solar Energy, 201, 884-907.

[39] Patel, S. K., Singh, D., Kumar, B., & Singh, D. (2020). solar desalination technology: physicochemical parameters estimation of contaminated & treated water of gomti River, Lucknow (UP), India. Int. J. of Recent. Tech. and Engg, 8, 86-692.