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A Comprehensive Review on Advancements in Solar Still Desalination

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Solar Still, Desalination, Solar Energy, Review, Water Treatment, Active Solar Still, Passive Solar Still, Efficiency.

ABSTRACT:
Despite Earth's vast water coverage, accounting for 70% of its surface, the escalating global population exacerbates the need for freshwater, creating significant strain on limited freshwater reserves. Desalination offers a promising solution, converting saline water into clean water for various applications. Among the various desalination technologies, solar stills stand out for their sustainability, utilizing solar energy for the desalination process. Through studies of various designs, researchers have pioneered novel techniques for improved productivity. This research article provides a comprehensive examination of active and passive solar stills, delineating their respective advantages and considerations in the context of solar desalination. It comprehensively analyses advancements in these technologies, particularly focusing on their productivity and efficiency in freshwater production. The article presents a detailed comparative analysis of various solar still designs and explores the factors influencing their efficiency. Additionally, it discusses modifications and innovative design strategies aimed at maximizing productivity and efficiency. Furthermore, the review explores advancements in solar desalination techniques using novel, high-performance materials. This discussion sheds light on how such materials can contribute to enhanced solar still efficiency. Ultimately, the article aims to provide a comprehensive understanding of the factors, designs, materials, and methodologies crucial for optimizing solar still productivity. By achieving unparalleled efficiency, affordability, and environmental responsibility, the technology of solar still desalination becomes a beacon of hope for a future where accessible clean water is a reality for everyone.

1. Introduction

Water, vital for sustaining life, stands as a precious and indispensable resource essential for the survival of our planet. Earth's expansive 510 million square kilometers include 361 million square kilometers of oceans [1], yet only a small fraction, approximately 1%, of the Earth's water is readily available freshwater, primarily distributed across groundwater resources, lakes, rivers, and other minor sources. This freshwater is critical for activities such as drinking, cooking, and supporting agricultural and industrial processes. Challenges to water availability arise from factors like population growth, pollution, and climate change, leading to water scarcity in many regions and associated issues like waterborne diseases. India, with 18% of the global population, faces significant water stress, possessing only 4% of the world's water resources. A recent study by the NITI Aayog underscores the extent of water stress among Indians. Anticipating a future of diminishing freshwater resources due to the growing global population, projections by the International Energy Agency (IEA) indicate a 35% increase in primary energy demand by 2035, exacerbating the looming threat of water scarcity by 2040 if current consumption patterns persist [2].

To address the growing challenge of water scarcity, desalination, the process of separating dissolved salts and minerals from saline water, presents a vital solution for generating freshwater suitable for diverse applications. While conventional methods like reverse osmosis, electrodialysis, and membrane distillation offer substantial production, concerns about environmental impact and operational cost arise due to their reliance on non-renewable energy. Solar desalination presents a promising alternative, utilizing abundant solar energy to drive the natural processes of evaporation and condensation, effectively separating freshwater from saline water. This positions solar desalination as a prime candidate for sustainable and environmentally friendly desalination. Motivated by the need to ensure freshwater

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access and conserve energy, solar desalination stands out as a compelling solution. Coastal regions with vast stretches of unusable saline water hold significant potential for freshwater production through desalination. Its sustainability and environmental friendliness, coupled with the elimination of fossil fuel dependence and greenhouse gas emissions, make solar desalination a valuable solution. Its suitability for remote locations, low-maintenance requirements, and long lifespan further contribute to its cost-effectiveness. Solar desalination emerges as a promising technology to bolster global water security by directly addressing water scarcity and providing a reliable source of freshwater for potable consumption, agricultural irrigation, and various industrial applications.

2. Solar Still Desalination Technology

A solar still is a specialized desalination device that utilizes solar energy to convert saline or brackish water into freshwater through the processes of evaporation and condensation.

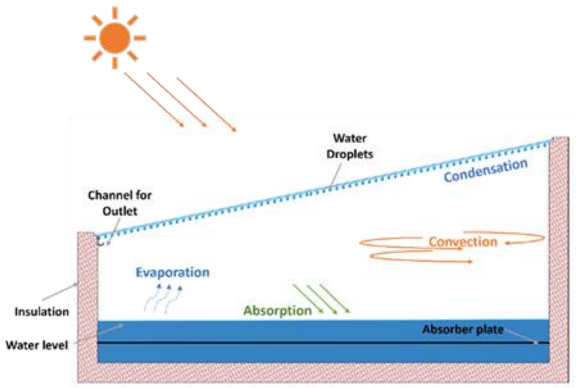

Figure 1: Schematic diagram of Conventional Solar Still.

This technology harnesses the sun's heat to induce evaporation of water from a saline source, and then condenses the vapor to produce distilled freshwater. Solar stills typically consist of a transparent cover or surface that allows sunlight to penetrate and heat the saline water, promoting the evaporation process (as shown in Figure 1) and solar energy induces the evaporation of saline water within the basin. The resulting water vapor condenses on the inclined, cool top cover. This condensate is subsequently collected as purified freshwater, while the concentrated brine, rich in residual salts, remains in the basin. Solar stills offer a sustainable and energy-efficient method for producing freshwater, particularly in regions where access to conventional water sources is limited, and they play a crucial role in addressing water scarcity challenges.

2.1 Classification of Solar Stills

Solar desalination, a sustainable approach for freshwater production, encompasses both active and passive solar stills. Understanding the distinctive features and operational mechanisms of these two types of solar stills is crucial for optimizing freshwater production in diverse environmental contexts. The categorization of different types of solar stills is illustrated below in Figure 2.

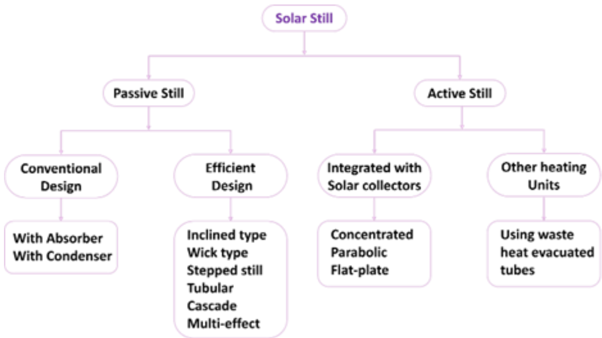

Figure 2: Categorization of Solar Stills.

Active Solar Stills: Active solar stills enhance energy input by incorporating supplementary components, including solar collectors or photovoltaic panels. These mechanisms actively enhance the heat transfer process, thereby accelerating the evaporation and condensation cycles. Active solar stills typically exhibit higher efficiency due to increased control over energy input. The integration of auxiliary power sources enables operation during suboptimal weather conditions, extending functionality. The addition of mechanical components increases the complexity of active solar stills, impacting maintenance requirements. Active solar stills rely on external power sources, potentially introducing vulnerability during power outages.

Passive Solar Stills: Passive solar stills harness solar energy without external aids, relying on natural processes such as solar radiation, conduction, and convection for heat transfer. Passive solar stills are simpler in design, reducing the need for complex components and maintenance. These stills operate autonomously, minimizing dependence on external power sources and increasing reliability. Passive solar stills may exhibit lower efficiency due to the reliance on natural energy sources and limited control over heat input. Operation is contingent on favourable weather

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conditions, potentially leading to reduced productivity during overcast days.

Manokar, A. M et al., [3] compared the performance of an active inclined solar panel basin still integrated with a Flat Plate Collector (FPC) to a passive inclined solar panel basin still (**Error! Reference source not found.** shown in Figure 3). The active still achieved a significantly higher daily yield (7.9 kg) compared to the passive still (4.3 kg). However, it is important to acknowledge that the active still's construction and maintenance costs were also higher.

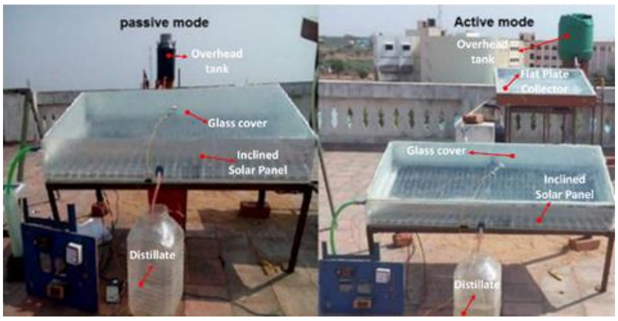

Figure 3: Experimental configurations of the inclined solar panel basin still [3].

The selection of active versus passive solar stills hinges on specific operational demands and environmental conditions. Active stills provide increased efficiency and operational flexibility, while passive stills prioritize simplicity and energy autonomy. These findings inform the selection and design of solar desalination systems tailored to diverse geographical and operational contexts.

2.2 Factors Effecting Efficiency of Solar Still

Efficiency reflects the ability to convert absorbed solar energy into usable freshwater. Evaporation and condensation are the core, interdependent processes driving freshwater production. Various factors significantly influence these processes' efficiency, including solar irradiance, still design, cover material, condensation surface area, insulation quality, and absorber material properties. A thorough understanding of these interacting parameters is critical to optimizing solar still performance. Numerous investigations have been conducted to explore the relationships between these factors and the yield of solar stills.

Incident solar irradiance, quantified as the power received from the sun per unit area, is a critical factor influencing the performance of solar stills. Studies by Omar et al. [4] and Emad A. Almuhanna [5] indicate that heightened solar intensity enhances both productivity and efficiency, with peak efficiency observed during early afternoon when solar radiation is most intense. The type of solar still design also influences evaporation and condensation rates, with considerations such as orientation, location, and atmospheric conditions

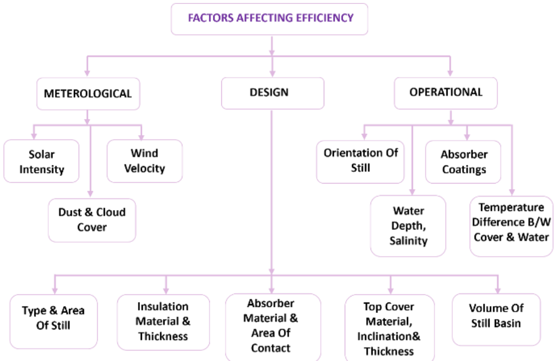

Figure 4: Various factors effecting efficiency of Solar Still.

impacting the choice of design.

Researchers have explored various solar still designs, including the single basin single sloped design tested by Muhammad Ali et al. [6], the pyramid and hemispherical designs compared by Arunkumar et al. [7], and the annual performance analysis of different designs conducted by Ibrahem Altarawneh et al. [8]. Notably, solar stills with optimal settings, such as the single slope design, have been identified as providing superior performance, yielding improvements in productivity by 28%. Additionally, solar stills with an inclination angle aligned with the local latitude exhibit enhanced efficiency, as suggested by Kuldeep et al. [9].

The selection of the top cover material in a solar still is pivotal for permitting solar radiation and aiding condensation. G.N. Tiwari et al. [10] conducted research emphasizing the link between yield and the thermal conductivity of condensing cover materials. Copper, characterized by superior thermal conductivity, surpassed glass and plastic in performance. Different cover materials, such as PVC and glass, have been compared by H. A. Begum et al. [11], showcasing the impact of cover material on distilled water production. Similar studies by M.K. Phadatare et al. [12] and J. Andrew Jones et al. [13] emphasize the influence of cover materials on water temperature and freshwater yield.

The inclination angle of a solar still is a critical factor affecting its productivity, with optimal angles maximizing solar radiation capture. Various studies, including those by Trad Abderachid et al. [14] and Bilal

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A. Akash et al. [15], highlight the significance of selecting an appropriate tilt angle for optimal water production under specific conditions and latitudes.
Insulation is another pivotal factor influencing pursuance of solar still. Studies by Muthu Manokar A et al. [16] demonstrate that insulation increases water temperature and yield. Researchers have employed materials like styrofoam, thermocol, and other insulators to minimize heat loss and enhance efficiency, as shown by Bilal et al. [15] and Sahoo et al. [17].
The absorber material in a solar still significantly influences solar absorption and, consequently, overall efficiency. Research by Chandrakant Sonawane et al. [18] utilizing computational fluid dynamics (CFD) investigates the influence of diverse absorber materials on the performance of a solar desalination unit. Additionally, studies on absorber coatings by A.E. Kabeel [16] and Hitesh Panchal et al. [19] highlight the potential for increased daily yield through innovative coating technologies.
The productivity of a solar still, as noted by Suneja S and Tiwari [20], demonstrates an inverse relationship with water depth. Muthu Manokar et al. [16] further investigated the influence of different water depths on temperature and yield, highlighting the role of water depth in the storage effect within the basin. Additionally, the gap distance between the water surface and the top cover plays a significant role in distillate productivity, as highlighted by Ali. F. Muftah et al. [21] and Nazmul Islam Sarkar et al. [22]. Reductions in gap distance, such as the study by Ghoneyem [23], lead to increased daily productivity.

Table 1: Variety of materials employed for augmenting the efficiency of Solar Stills.

COMPONENTS	MATERIAL	REMARKS
Absorber	[24] Mild Steel - reached max. temp = 45˚C @ 800 GHI.	*High risk of corrosion, Maintenance.*
	[25] Black soil - reached max. temp = 41˚C @ 570 GHI.	*Massive maintenance, Risk of contamination.*
	[26]Aluminium turnings - reached max. temp = 42˚C @ 850 GHI.	*Corrosion, less durable.*
Absorber Coating	[27]Reduced Graphene oxide modified Cobalt oxide nanoparticle coating, α = 0.89.	*Moderate absorptance.*
	[28]Copper oxide nanoparticle coating, α = 0.91.	*Moderate absorptance.*
	[29]High entropy AlCrNbSiTi - based selective solar absorber coating, α = 0.92.	*Expensive, Challenging process.*
Insulation	[15]Stainless steel basin insulated with Styro foam, k = 0.038 W/m-K.	*Less durable.*
	[30]Mild steel basin insulated with 25mm thermocol, k = 0.033 W/m-K.	*Less durable.*
	[31]Galvanised steel basin insulated with wooden box, k = 0.2 W/m-K .	*Less durable.*
Top Cover	[11]Poly Vinyl Chloride (plastic), Te% = 81%.	*Less transmittance.*
	[12]Transparent glass, Te% = 85%.	*Moderate transmittance.*
	[10] Copper, Te% = 0.001%; k=195 W/m-K.	*Less transmittance, high cost.*
Still Type	[32]Single sloped solar still, η = 59.2%.	*Moderate efficiency.*
	[33]Double sloped solar still, η = 60%.	*Moderate efficiency.*
	[34]Stepped solar still, η = 76%.	*Good efficiency, High installation cost.*

In summary, a nuanced exploration of these factors and their intricate relationships is essential for advancing the understanding and optimization of solar still

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technologies. these studies collectively advance the development of efficient and adaptable solar desalination systems, offering a potential solution to the critical global challenge of water needs.

2.3 Challenges and Limitations of Solar Still Technology

Solar Absorption: In conventional solar stills, the utilization of black absorber plates, boasting a solar absorption rate of approximately 85%-90%, proves insufficient for attaining elevated water evaporation rates. Solar energy reflection from the absorber plate and conductive/convective heat losses significantly limit overall solar still efficiency.

Heat Transfer Rate: Traditional solar stills suffer from reduced heat transfer efficiency due to an air gap between the absorber plate and the water. This air layer acts as an insulator, hindering heat transfer and limiting overall performance.

Heat Retention: The role of insulation walls in mitigating loss of heat and optimizing the thermal efficiency of solar stills is paramount. Researchers have explored diverse insulation materials, including wood, acrylic, steel, thermocol, ceramic, among others, to achieve effective insulation. The selection of insulation material necessitates a meticulous consideration of factors such as thermal conductivity, durability, and cost, aiming to achieve optimal performance and longevity for the solar still.

3. Methodologies to Enhance the Productivity

Solar Absorption

Achieving enhanced solar absorption in solar stills is paramount for optimizing their performance and increasing freshwater production. Several formal strategies can be considered within the framework:

Advanced Absorber Materials: Investigating and implementing novel absorber materials with high solar absorptance is fundamental. Materials such as metal oxides, carbon-based composites, and nanomaterials, including graphene and carbon nanotubes, have demonstrated superior absorption characteristics, effectively capturing and converting solar radiation into thermal energy.

Selective Surface Coatings: Employing selective coatings on the absorber surface is a recognized method to enhance solar absorption. These coatings are designed to have high absorptance across the solar spectrum while minimizing emissivity. Common choices include selective paints or coatings with specific spectral properties tailored for optimal solar energy absorption.

Textured or Nanostructured Surfaces: Introducing surface textures or nanostructures on the absorber can improve light trapping and absorption efficiency. This design strategy maximizes solar radiation absorption by increasing the effective surface area and minimizing reflectance.

Innovative Absorber Designs: Exploring advanced absorber designs that maximize the exposure of the absorber surface to sunlight is crucial. This may involve incorporating features like fins, grooves, or other geometrical enhancements to optimize solar radiation absorption.

Integration of External Reflectors: External reflectors strategically positioned around the solar still can redirect additional sunlight onto the absorber surface. This supplementary irradiance intensifies solar absorption, particularly during periods of suboptimal solar incidence angles.

Utilization of Concentrated Solar Power (CSP) : Incorporating principles from Concentrated Solar Power, such as the use of mirrors or lenses to focus sunlight onto the absorber surface, can significantly boost solar absorption. This approach allows for the concentration of solar energy, thereby elevating absorber temperatures.

Optimized Geometry and Orientation: Carefully considering the geometry and orientation of the solar still system can contribute to improved solar absorption. The optimal positioning of the absorber plate with respect to the incident solar radiation angle ensures maximum exposure and absorption efficiency.

Regular Maintenance and Cleaning: Ensuring the cleanliness and maintenance of the absorber surface is essential. The removal of dust, dirt, or other contaminants that may accumulate on the absorber can prevent a reduction in solar absorptance over time.

By integrating these formal strategies into the design and operational considerations of solar stills, researchers can contribute to the development of more efficient systems with enhanced solar absorption capabilities.

Heat Transfer

Researchers have investigated numerous strategies and methodologies to augment heat transfer rates within solar still systems, thereby aiming to elevate overall efficiency and freshwater production. The following formal considerations offer insights into key approaches for augmenting heat transfer in solar stills:

Innovative Absorber Materials: Employing advanced absorber materials with enhanced thermal conductivity is a pivotal approach. Materials such as metal oxides, graphene, and carbon nanotubes have exhibited superior thermal properties, facilitating efficient heat absorption and transfer.

Optimized Design and Configuration: Solar still design significantly impacts heat transfer rates. Absorber plate geometry, size, and orientation all influence solar radiation capture and subsequent heat transfer to the working fluid.

Improved Surface Coatings: Applying selective coatings on the absorber surface can enhance solar absorptance while minimizing thermal emittance. Optimized coatings, such as those with high absorptance and low emittance characteristics, contribute to improved heat absorption and transfer efficiency.

Integration of External Reflectors: External reflectors strategically positioned around the solar still can redirect additional sunlight onto the absorber surface, intensifying the heat input. This augmentation of solar radiation contributes to increased temperature differentials and, consequently, enhanced heat transfer rates.

Advanced Heat Exchanger Systems: Incorporating efficient heat exchanger systems, such as fins or extended surfaces, amplifies the heat transfer area. The increased surface area enhances convective heat transfer between the absorber and the working fluid, leading to optimized overall heat transfer rates.

Latent Heat Storage Solar Still (PCMs): Integrating PCMs in the solar still system allows for the storage and controlled release of latent heat. This phase transition process aids in maintaining higher temperatures during periods of reduced solar radiation, thereby bolstering continuous heat transfer.

Optimal Working Fluid Selection: Working fluid selection significantly influences heat transfer in solar still systems. Selections that align with the desired temperature range and exhibit favourable thermophysical properties contribute to improved overall heat transfer efficiency.

Controlled Condensation Techniques: Efficient management of the condensation process is essential. Techniques promoting drop-wise condensation, as opposed to film-wise condensation, can enhance heat transfer rates due to improved contact between the vapor and the condenser surface.

By integrating these considerations into the design and operation of solar still systems, researchers can contribute to the advancement of heat transfer mechanisms, ultimately leading to improved efficiency in freshwater production.

Heat Retention

In the pursuit of augmenting the heat retention mechanism in solar stills, several strategic approaches can be explored to optimize the overall thermal performance. The enhancement of heat retention is imperative for maximizing the efficiency of the desalination process. Below are key strategies that can be considered for bolstering the heat retention mechanism:

Insulation Materials Selection: Careful consideration of insulation materials is paramount. Opting for high thermal resistance materials, such as aerogels or polyurethane foams, can minimize heat loss and enhance the overall insulation efficiency.

Multi-Layered Insulation: Implementing multi-layered insulation systems can create additional barriers against heat dissipation. This approach involves incorporating multiple layers of insulating materials with varying thermal conductivities, creating a cumulative effect in reducing thermal losses.

Reflective Coatings: Applying reflective coatings to the surfaces of the solar still can contribute to improved heat retention. Reflective materials, such as metallic films or paints with high reflectance, redirect radiative heat back into the system, preventing its escape.

Encapsulation Techniques: Employing encapsulation methods, such as vacuum sealing the system or utilizing double-glazed covers, can create an enclosed environment that minimizes convective heat losses and augments the heat retention capacity.

Phase Change Materials (PCMs): Integration of PCMs within the solar still structure can enhance heat retention during periods of reduced solar radiation. PCMs absorb and release latent heat as they undergo phase transitions, providing a reservoir of thermal energy that contributes to maintaining elevated temperatures.

Selective Absorber Surfaces: Utilizing selective absorber surfaces with high absorptance and low emissivity characteristics can aid in retaining absorbed solar energy within the system. This approach minimizes radiative heat losses from the absorber surface.

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Thermal Mass Incorporation: Integrating materials with high thermal mass, such as water containers or rocks, within the solar still structure can serve as heat sinks during periods of low solar availability, gradually releasing stored thermal energy to sustain the desalination process.

Adjustable Covering Systems: Implementing adjustable covering systems, such as movable insulation panels or shutters, enables the modification of the system's exposure to external elements, optimizing heat retention based on prevailing environmental conditions.

By judiciously combining these strategies, a comprehensive and effective heat retention mechanism can be established within the solar still, leading to heightened overall efficiency and sustained desalination performance.

4. Advancements in Solar Still Desalination Technology

In contemporary times, solar still desalination has witnessed significant advancements. Researchers are actively engaged in devising innovative designs to enhance efficiency, addressing the global demand for freshwater. The subsequent table (**Error! Reference source not found.**) offers a comprehensive overview of the recent progressions in solar still desalination technology.

Table 2: Advancements in Solar Still designs promoting the yield.

DESIGN	DESCRIPTION
Solar Still with Collector	Srithar et al. [35] employed a parabolic dish collector (PDC) to concentrate solar energy on a triple-basin solar still (TBSS) equipped with cover cooling. To enhance internal heat transfer, the basins incorporated fins containing either river sand or charcoal as energy storage media. Their findings revealed that the PDC-TBSS configuration with cover cooling achieved the highest distillate productivity, reaching approximately 16.94 kg/m² per day.
Parabolic Concentrator-Integrated Solar Still	Arunkumar et al. [36] reported a daily freshwater yield of 6.4 L/m² from a combined CPC-CTSS-SSSS system, demonstrating the potential of integrating a compound parabolic concentrator-concentric tubular solar still (CPC-CTSS) with a single slope solar still (SSSS) for enhanced productivity.
Air-assisted solar still	Joy et al. [37] investigated on the Solar Still assisted with a hot air blower that augment system productivity. The findings indicated that introducing an air blower into solar still's basin resulted in a daily yield of 5 litres per square meter.
Reflector-augmented solar still	Khalifa and Ibrahim [38] investigated the impact of internal and external reflectors on a basin-type solar still with a 1 m² basin area. They reported a maximum daily freshwater production of 6.08 L/m²/day for the still without reflectors. Incorporation of external reflectors increased productivity to 6.26 L/m²/day, while the combination of both internal and external reflectors achieved the highest yield of 6.70 L/m²/day.
Heat Pump-Assisted Solar Still	Halima et al. [39] theoretically investigated the integration of a heat pump within a solar still basin [39]. Their analysis revealed a significant enhancement in productivity, achieving a daily yield of 13.5 kg/m².
Solar Still designed with PV in basin	Manokar et al. [40] integrated a photovoltaic (PV) panel within the basin of a solar still for a dual purpose: solar radiation absorption and electricity generation. Their experiments revealed a maximum daily yield of 7.3 kg/m² for this novel solar still design.
Advanced Absorber Designed Solar Still	Hansen and Murugavel [41] evaluated the performance of a stepped solar still with three different absorber plate designs: flat, grooved, and fin-type. Their experiments revealed that the fin-type absorber configuration achieved the highest daily distillate output of 5210 ml/m².

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Solar Still integrated with different absorber materials	Pal et al. [42] compared the performance of black cotton and jute wicks in a Double Slope Solar Still (DSSS) for freshwater production. Their experiments revealed that a black cotton wick achieved a superior daily yield of 9012 ml/m², exceeding the yield of 7040 ml/m² obtained with a jute wick, both at a water depth of 2 cm.
Encapsulated Phase Change Material Concentric Tube Solar Still	Arunkumar et al. [43] experimentally evaluated a Compound Parabolic Concentrator (CPC)-assisted Concentric Circular Tubular Solar Still (CCTSS) with and without phase change material (PCM). The CPC-CCTSS achieved a daily productivity of 5.779 L/m², while the configuration without PCM yielded 5.330 L/m²/day.
Weir Type Solar Still comprising Phase Changing Material	Dashtban and Tabrizi [44] reported a significant enhancement in productivity for a weir-type cascade stepped solar still integrated with a Paraffin Wax (PW) energy storage medium. The inclusion of PW increased daily freshwater production from 5.1 kg/m² to 6.7 kg/m², representing a 31% improvement. Similarly, thermal efficiency rose from 47% to 64% with the incorporation of PW.
Solar Still with fins	Srivastava and Agraval [45] reported enhancement in productivity using a single-basin solar still with porous fin absorbers (7.5 kg/m²/day) compared to a conventional design (6.5 kg/m²/day).
Solar Still with Sponges as absorbers	Ensafisoroor et al. [46] reported a daily productivity of 5.37 L/m² for a stepped solar still (SSSS) incorporating sponge cubes within the basin compared to 4.8 L/m² for the SSSS alone. This finding suggests that sponge cubes enhance evaporation heat transfer within the solar still.
Solar Still with marbles, pebbles, black stones as Absorbers	Shanmugan et al. [47] investigated the impact of various basin liner materials on solar still performance. Their experiments employed white marbles, pebbles, black stones, calcium stones, and iron scraps placed individually within the basin. Notably, calcium stones yielded the highest distillate production, reaching 5.78 kg/m²/day.
Inclined Still coupled with Pyramid Solar Still	Kumar et al. [48] theoretically investigated a combined pyramid and inclined solar still with baffles, demonstrating that baffles in the inclined section increased the heat transfer area and consequently enhanced freshwater production. Their analysis considered eight basin water masses ranging from 20 to 100 kg, with the highest productivity of 7.05 L/m² achieved at a water mass of 20 kg.

5. Discussion

This article provided a nuanced exploration of active and passive solar stills, elucidating their advantages and considerations. This study has recognized and examined the pivotal elements affecting the efficiency of solar stills, offering recommendations based on evidence for the most advantageous design options and material choices. This research prioritizes developing practical and affordable solar still technologies that are accessible and sustainable solutions for water-scarce, underserved communities. The emphasis on these crucial aspects guarantees that the technology developed is not only efficient but also easily applicable and adaptable to the distinct requirements of these communities. In summary, this research conducted an in-depth examination of the multitude of factors prompting the efficiency of solar stills, exploring diverse designs, and scrutinizing the behaviour of crucial components. Novel materials were investigated to enhance productivity. Additionally, the study included a concise literature survey encompassing various designs of solar still.

6. Recommendations and Future Scope

To improve solar still productivity and efficiency, researchers have explored a wide range of modifications, with extensive studies dedicated to each approach.

Despite these advancements, there remains ample room for innovative exploration to develop a compact, affordable, and efficient solar still suitable for domestic installation, catering to the needs of nuclear families. The following recommendations provide valuable insights for further studies, rectifications, and modifications of solar stills:

- While high productivity in solar desalination often demands extensive absorber area, integrating desalination units with waste heat sources, like engine exhaust or industrial processes, could optimize land use and potentially enhance efficiency.
- The incorporation of unique materials capable of enhancing solar insolation interception, possibly through the utilization of nanoparticle materials, holds the potential to significantly improve productivity and efficiency.
- The combination of external and internal reflectors, optimized for view factors, presents a promising strategy to increase productivity without necessitating larger still designs.
- Efficient utilization of latent heat released during condensation can further accelerate the desalination process.
- PCMs hold promise for enhancing desalination output during darkness and winter months. Their effectiveness hinges on the selection of materials with high latent heat storage capacity, potentially in combination with porous membrane technology.
- Continuous exploration and conceptualization of absorber area designs, along with trials involving different fabricating materials, can unveil more efficient solar still configurations.
- The selection of condenser materials and designs should prioritize encouraging drop-wise condensation over film-wise condensation to facilitate a better heat transfer rate.

These recommendations provide a foundation for ongoing research, offering avenues for further exploration and refinement in the quest for more effective and practical solar desalination solutions.

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References

[1] M. Kumar and A. Puri, “A review of permissible limits of drinking water,” *Indian Journal of Occupational and Environmental Medicine*, vol. 16, no. 1. pp. 40–44, Jan. 2012. doi: 10.4103/0019-5278.99696.

[2] Aarhus University, “Worldwide water shortage by 2040,” *ScienceDaily*, Jul. 19, 2019. Accessed: Jan. 17, 2024. [Online]. Available: www.sciencedaily.com/releases/2014/07/140729093112.htm

[3] A. M. Manokar, D. P. Winston, J. D. Mondol, R. Sathyamurthy, A. E. Kabeel, and H. Panchal, “Comparative study of an inclined solar panel basin solar still in passive and active mode,” *Solar Energy*, vol. 169, pp. 206–216, Jul. 2018, doi: 10.1016/j.solener.2018.04.060.

[4] O. O. Badran and M. M. Abu-Khader, “Evaluating thermal performance of a single slope solar still,” *Heat and Mass Transfer/Waerme- und Stoffuebertragung*, vol. 43, no. 10, pp. 985–995, Aug. 2007, doi: 10.1007/s00231-006-0180-0.

[5] E. A. Almuhanna, “Evaluation of Single Slop Solar Still Integrated With Evaporative Cooling System for Brackish Water Desalination,” *Journal of Agricultural Science*, vol. 6, no. 1, Dec. 2013, doi: 10.5539/jas.v6n1p48.

[6] M. Ali Samee, U. K. Mirza, T. Majeed, and N. Ahmad, “Design and performance of a simple single basin solar still,” *Renewable and Sustainable Energy Reviews*, vol. 11, no. 3. pp. 543–549, Apr. 2007. doi: 10.1016/j.rser.2005.03.003.

[7] T. Arunkumar, R. Jayaprakash, and A. Ahsan, “A comparative experimental testing in enhancement of the efficiency of pyramid solar still and hemispherical solar still.”

[8] I. Altarawneh, S. Rawadieh, M. Batiha, L. Al-Makhadmeh, S. Alrowwad, and M. Tarawneh, “Experimental and numerical performance analysis and optimization of single slope, double slope and pyramidal shaped solar stills,” *Desalination*, vol. 423, pp. 124–134, Dec. 2017, doi: 10.1016/j.desal.2017.09.023.

[9] K. H. Nayi and K. V. Modi, “Pyramid solar still: A comprehensive review,” *Renewable and Sustainable Energy Reviews*, vol. 81. Elsevier

Ltd, pp. 136–148, 2018. doi: 10.1016/j.rser.2017.07.004.

[10] V. Dimri, B. Sarkar, U. Singh, and G. N. Tiwari, “Effect of condensing cover material on yield of an active solar still: an experimental validation,” *Desalination*, vol. 227, no. 1–3, pp. 178–189, Jul. 2008, doi: 10.1016/j.desal.2007.06.024.

[11] H. A. Begum, M. A. Yousuf, and K. S. e Rabbani, “Effect of top cover material on productivity of solar distillation unit,” *Bangladesh Journal of Medical Physics*, vol. 9, no. 1, pp. 11–16, Jul. 2018, doi: 10.3329/bjmp.v9i1.37303.

[12] M. K. Phadatare and S. K. Verma, “Effect of cover materials on heat and mass transfer coefficients in a plastic solar still,” *Desalination Water Treat*, vol. 2, no. 1–3, pp. 254–259, 2009, doi: 10.5004/dwt.2009.290.

[13] J. Andrew Jones, L. W. Lackey, and K. E. Lindsay, “Effects of wind and choice of cover material on the yield of a passive solar still,” *Desalination Water Treat*, vol. 52, no. 1–3, pp. 48–56, 2014, doi: 10.1080/19443994.2013.784715.

[14] T. Abderachid and K. Abdenacer, “Effect of orientation on the performance of a symmetric solar still with a double effect solar still (comparison study),” *Desalination*, vol. 329, pp. 68–77, Nov. 2013, doi: 10.1016/j.desal.2013.09.011.

[15] B. A. Akash, M. S. Mohsen, and W. Nayfeh, “Experimental study of the basin type solar still under local climate conditions,” *Energy Convers Manag*, vol. 41, no. 9, pp. 883–890, Jun. 2000, doi: 10.1016/S0196-8904(99)00158-2.

[16] A. Muthu Manokar *et al.*, “Effect of water depth and insulation on the productivity of an acrylic pyramid solar still – An experimental study,” *Groundw Sustain Dev*, vol. 10, Apr. 2020, doi: 10.1016/j.gsd.2019.100319.

[17] B. B. Sahoo, N. Sahoo, P. Mahanta, L. Borbora, P. Kalita, and U. K. Saha, “Performance assessment of a solar still using blackened surface and thermocol insulation,” *Renew Energy*, vol. 33, no. 7, pp. 1703–1708, Jul. 2008, doi: 10.1016/j.renene.2007.09.009.

[18] C. Sonawane *et al.*, “Investigation on the Impact of Different Absorber Materials in Solar Still Using CFD Simulation—Economic and Environmental Analysis,” *Water (Switzerland)*, vol. 14, no. 19, Oct. 2022, doi: 10.3390/w14193031.

[19] H. Panchal, P. Boka, K. Sharma, M. I. H. Siddiqui, and D. Dobrotă, “A case study on distillate output of solar still using toner waste powder coated absorber plate,” *Case Studies in Thermal Engineering*, vol. 53, Jan. 2024, doi: 10.1016/j.csite.2023.103903.

[20] S. Suneja and G. N. Tiwari, “Effect of water depth on the performance of an inverted absorber double basin solar still.” [Online]. Available: www.elsevier.com/locate/enconman

[21] A. F. Muftah, M. A. Alghoul, A. Fudholi, M. M. Abdul-Majeed, and K. Sopian, “Factors affecting basin type solar still productivity: A detailed review,” *Renewable and Sustainable Energy Reviews*, vol. 32. pp. 430–447, Apr. 2014. doi: 10.1016/j.rser.2013.12.052.

[22] Md. N. I. Sarkar, A. I. Sifat, S. M. S. Reza, and Md. S. Sadique, “A review of optimum parameter values of a passive solar still and a design for southern Bangladesh,” *Renew Wind Water Sol*, vol. 4, no. 1, Dec. 2017, doi: 10.1186/s40807-017-0038-8.

[23] A. Ghoneyem, “Experimental study on the effects of the cover and numerical prediction of a solar still output,” *Middle East Technical University*, 1995, Accessed: Jan. 17, 2024. [Online]. Available: https://hdl.handle.net/11511/9631

[24] R. Samuel Hansen and K. Kalidasa Murugavel, “Enhancement of integrated solar still using different new absorber configurations: An experimental approach,” *Desalination*, vol. 422, pp. 59–67, 2017, doi: 10.1016/j.desal.2017.08.015.

[25] A. Riahi, K. W. Yusof, B. S. M. Singh, E. Olisa, N. Sapari, and M. H. Isa, “The performance investigation of triangular solar stills having different heat storage materials,” *International Journal of Energy and Environmental Engineering*, vol. 6, no. 4, pp. 385–391, Dec. 2015, doi: 10.1007/s40095-015-0185-x.

[26] D. Tiwari and A. Kumar Rai, “Effect of Sensible Energy Storage Medium on The Productivity of Solar Still,” *International Journal of Mechanical Engineering and Technology*, vol. 7, no. 4, pp. 1–7, [Online]. Available:

http://iaeme.comwww.jifactor.comhttp://iaeme.com

[27] G. G. Welegergs *et al.*, "Single-Layered Biosynthesized Copper Oxide (CuO) Nanocoatings as Solar-Selective Absorber," *Applied Sciences (Switzerland)*, vol. 13, no. 3, Feb. 2023, doi: 10.3390/app13031867.

[28] X. Zeng *et al.*, "Thermal stability of high entropy graded solar selective absorbers deposited by non-equilibrium RF magnetron sputtering," *J Alloys Compd*, vol. 944, p. 169248, May 2023, doi: 10.1016/j.jallcom.2023.169248.

[29] N. Murugesan *et al.*, "Improving selectivity of thin film solar absorber by cobalt oxide grafted reduced graphene oxide," *Opt Mater (Amst)*, vol. 138, p. 113629, Apr. 2023, doi: 10.1016/j.optmat.2023.113629.

[30] P. Anburaj, R. Samuel Hansen, and K. Kalidasa Murugavel, "Performance of an inclined solar still with rectangular grooves and ridges," *Applied Solar Energy (English translation of Geliotekhnika)*, vol. 49, no. 1, pp. 22–26, Jan. 2013, doi: 10.3103/S0003701X13010027.

[31] S. B. Danjuma, "Analysisof Solar Distillation System for CleanWater Distribution: A Review," *International Journal of Advances in Scientific Research and Engineering*, vol. 09, no. 07, pp. 71–80, 2023, doi: 10.31695/ijasre.2023.9.7.9.

[32] B. B. Sahoo and C. Subudhi, "Performance enhancement of solar still by using reflectors-jute cloth-improved glass angle," *Journal of Engineering Research*, vol. 16, no. 1, pp. 1–10, 2019, doi: 10.24200/tjer.vol16iss1pp1-10.

[33] B. A. Akash, M. S. Mohsen, O. Osta, and Y. Elayan, "EXPERIMENTAL EVALUATION OF A SINGLE-BASIN SOLAR STILL USING DIFFERENT ABSORBING MATERIALS," 1998.

[34] V. Velmurugan, S. Senthil Kumaran, V. Niranjan Prabhu, and K. Srithar, "Productivity enhancement of stepped solar still - Performance analysis," *Thermal Science*, vol. 12, no. 3, pp. 153–163, 2008, doi: 10.2298/TSCI0803153V.

[35] K. Srithar, T. Rajaseenivasan, N. Karthik, M. Periyannan, and M. Gowtham, "Stand alone triple basin solar desalination system with cover cooling and parabolic dish concentrator," *Renew Energy*, vol. 90, pp. 157–165, May 2016, doi: 10.1016/j.renene.2015.12.063.

[36] T. Arunkumar *et al.*, "Effect of heat removal on tubular solar desalting system," *Desalination*, vol. 379, pp. 24–33, Feb. 2016, doi: 10.1016/j.desal.2015.10.007.

[37] N. Joy, A. Antony, and A. Anderson, "Experimental study on improving the performance of solar still using air blower," *International Journal of Ambient Energy*, vol. 39, no. 6, pp. 613–616, Aug. 2018, doi: 10.1080/01430750.2017.1324817.

[38] A. J. N. Khalifa and H. A. Ibrahim, "Experimental study on the effect of internal and external refl ectors on the performance of basin type solar stills at various seasons," *Desalination Water Treat*, vol. 27, no. 1–3, pp. 313–318, Mar. 2011, doi: 10.5004/dwt.2011.2088.

[39] H. Ben Halima, N. Frikha, and R. Ben Slama, "Numerical investigation of a simple solar still coupled to a compression heat pump," *Desalination*, vol. 337, pp. 60–66, Mar. 2014, doi: 10.1016/j.desal.2014.01.010.

[40] A. M. Manokar, D. P. Winston, A. E. Kabeel, and R. Sathyamurthy, "Sustainable fresh water and power production by integrating PV panel in inclined solar still," *J Clean Prod*, vol. 172, pp. 2711–2719, Jan. 2018, doi: 10.1016/j.jclepro.2017.11.140.

[41] R. Samuel Hansen and K. Kalidasa Murugavel, "Enhancement of integrated solar still using different new absorber configurations: An experimental approach," *Desalination*, vol. 422, pp. 59–67, Nov. 2017, doi: 10.1016/j.desal.2017.08.015.

[42] P. Pal, P. Yadav, R. Dev, and D. Singh, "Performance analysis of modified basin type double slope multi–wick solar still," *Desalination*, vol. 422, pp. 68–82, Nov. 2017, doi: 10.1016/j.desal.2017.08.009.

[43] T. Arunkumar and A. E. Kabeel, "Effect of phase change material on concentric circular tubular solar still-Integration meets enhancement," *Desalination*, vol. 414, pp. 46–50, Jul. 2017, doi: 10.1016/j.desal.2017.03.035.

[44] M. Dashtban and F. F. Tabrizi, "Thermal analysis of a weir-type cascade solar still integrated with PCM storage," *Desalination*,

vol. 279, no. 1–3, pp. 415–422, Sep. 2011, doi: 10.1016/j.desal.2011.06.044.

[45] P. K. Srivastava and S. K. Agrawal, "Winter and summer performance of single sloped basin type solar still integrated with extended porous fins," *Desalination*, vol. 319, pp. 73–78, Jun. 2013, doi: 10.1016/j.desal.2013.03.030.

[46] H. Ensafisoroor, M. Khamooshi, F. Egelioglu, and K. Parham, "An experimental comparative study on different configurations of basin solar still," *Desalination Water Treat*, vol. 57, no. 5, pp. 1901–1916, Jan. 2016, doi: 10.1080/19443994.2014.979238.

[47] S. Shanmugan, B. Janarthanan, and J. Chandrasekaran, "Performance of single-slope single-basin solar still with sensible heat storage materials," *Desalination Water Treat*, vol. 41, no. 1–3, pp. 195–203, Mar. 2012, doi: 10.1080/19443994.2012.664714.

[48] P. Naveen Kumar, D. G. Harris Samuel, P. K. Nagarajan, and R. Sathyamurthy, "Theoretical analysis of a triangular pyramid solar still integrated to an inclined solar still with baffles," *International Journal of Ambient Energy*, vol. 38, no. 7, pp. 694–700, Oct. 2017, doi: 10.1080/01430750.2016.1181569.