ADVANCED DESIGN TECHNIQUES IN PASSIVE SOLAR STILLS: A REVIEW

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ABSTRACT

Freshwater scarcity is a significant global issue, particularly in communities with limited access to traditional water treatment and energy facilities. Passive solar distillation, powered entirely by solar thermal energy, provides a reliable and low-cost solution for providing clean water to remote and coastal regions. This paper covers the most recent advances in passive solar still technologies, with a focus on tubular, basin type, and unconventional geometries such as hemispherical, pyramid shaped, and triangular. The study reveals how modifications in shape, absorber materials, wick assisted evaporation, phase change materials, and magnetic or nano material improved heat transfer could significantly improve distillation yield and thermal efficiency. Because of their compact structure, improved storage of heat, and wide condensation surface, passive tubular solar still stand out among the competition. The review closes by outlining design patterns, performance challenges, and future research requirements for economically viable, scalable, and efficient freshwater production systems in developing areas.

Keywords: *Passive solar stills; Tubular solar stills; Basin solar stills; Non Conventional Solar Stills, Freshwater production.*

1. INTRODUCTION

Global water scarcity has emerged as a critical challenge, affecting millions of people and expected to intensify in the coming decades. Currently, over 845 million individuals experience severe water shortages, and this number could increase to 2.8 billion by 2025 (Aende et al., 2020). The crisis is caused not only by limited freshwater resources but also by pollution, climate change, and excessive water extraction, with regions like eastern China and India experiencing the most severe impacts (Vliet et al., 2021). Desalination is a potential solution that removes salt and impurities from seawater or brackish water, leading to fresh, drinkable water. Traditional desalination processes, such as reverse osmosis, are energy intensive and frequently depend on nonrenewable energy sources, making them costly and environmentally unsound (Apolinário & Castro, 2024). In countries like Jordan, where freshwater scarcity is acute, combining desalination with renewable resources has demonstrated a sustainable pathway for long term water security (Albatayneh, 2024). These strategies align closely with global efforts to achieve the United Nations' Sustainable Development Goal 6: Clean Water and Sanitation (Vliet et al., 2021).

Solar desalination has emerged as one of the most promising sustainable solutions to address global water scarcity, particularly in regions with high solar potential. By utilizing solar energy to drive the desalination process, this approach minimizes dependence on fossil fuels (He et al., 2024; Yu et al., 2024). Approximately 1.6 billion people living in rural areas currently face water scarcity, and solar desalination of brackish groundwater or seawater can provide a viable means to improve water accessibility (He et al., 2024). The integration of solar energy not only reduces operational costs but also enhances system autonomy, making it suitable remote locations. In Portugal, for example, the use of solar power in desalination decreased water production costs by about 33%, demonstrating its economic viability (Apolinário & Castro, 2024). Recent developments in solar still technologies, including both passive and active distillation systems, have further improved freshwater yield. Innovations such as the use of Parabolic Trough Collectors and advanced thermal materials have significantly enhanced thermal efficiency, leading to reduced costs with the lowest reported water cost reaching $0.009 per liter (Almajali et al., 2024). For Bangladesh, particularly its coastal regions, solar desalination presents a highly relevant and practical solution due to abundant sunlight and access to seawater. Adopting such systems could help reduce freshwater challenges in locations where conventional delivery networks are insufficient or susceptible to saline intrusion. Overall, solar desalination represents a cost effective, renewable, and environmentally sustainable pathway to tackle global and regional water scarcity. Continued research and development in this field promise to enhance technological efficiency, lower costs, and support global water sustainability goals (Wang & He, 2024). Traditional basin type solar stills, while a viable option for water desalination, come with several limitations that reduce their efficiency and practicality. One major drawback is their modest production capacity. A basic solar still (SS) with a single basin can only generate a limited amount of distilled water daily, which restricts its applicability for larger demands. Efforts to mitigate these issues have led to various modifications and designs to enhance productivity, such as the incorporation of phase change materials and nanoparticles to improve heat absorption and transfer (Işık & El, 2024; Ravivarman et al., 2023). The development of advanced passive solar still designs has significantly improved the efficiency and productivity of solar desalination systems. These innovative designs include tubular, pyramid, stepped, and wick assisted solar stills, each offering diverse advantages and performance improvements. Tubular Solar Stills (TSSs) have appeared as a promising design to enhance clean water productivity. Tubular stills with horizontal axes and those integrated with phase change materials (PCM) or wick materials show enhanced productivity, especially during nighttime. Multi effect tube stills enhance productivity by 28.70% as compared to single effect stills, while horizontal axis stills are 19.12% more productive than vertical axis stills (Akkala & Kumar Kaviti, 2022). Pyramid Solar Stills (PSSs) have been studied for their energy and exergy efficiency. The incorporation of magnetic fields can increase evaporative heat transfer coefficients, significantly improving performance. However, challenges remain in maximizing exergy efficiency, which stays relatively low despite high energy efficiency(Hammoodi et al., 2024). Wick assisted solar stills use the Marangoni effect to push salt crystals away and keep the distillation area low in salt, while a capillary wick ensures stable, long term, and efficient multistage solar water distillation for continuous use. (Shao et al., 2022). Overall, these advanced designs contribute to increased productivity, enhanced thermal performance, and economic viability of solar stills. Passive solar desalination systems often employ materials and components that are inexpensive and easily maintainable, minimizing both initial and operational costs. Additionally, passive solar desalination systems frequently focus effective heat and mass transfer, which can greatly improve freshwater yield to a level that is comparable to industrial applications. (Yang et al., 2023). The key objective of this review is to explore and summarize the latest progress in passive solar stills, focusing on how their design and materials can improve freshwater production efficiency. While frequent studies have explored active solar stills, there remains a lack of comprehensive assessment to passive solar still configurations, which offer distinct advantages in terms of geometry, heat transfer efficiency, compact shape, and improved condensation. This paper reviews different types and classifications of solar stills and examines how various systems affect their performance. It also examines new improvements, problems, and future research needs to improve the efficiency, cheap cost, and practical application of passive tubular solar stills in arid regions.

2. METHODOLOGY

The review is founded on the published research in association with passive tubular solar stills and design developments. Data on relevant research papers, review articles and conference proceedings were gathered in databases like Scopus, Science Direct, SpringerLink and Google Scholar. The search of the literature entailed the use of keywords such as passive solar desalination, solar still design improvement, tubular, basin , and unconventional geometries such as hemispherical, pyramid shaped, and triangular solar still.The latest developments were primarily included. After the initial screening, studies that focused on active systems designs were excluded. To summarise various design classifications, materials used, evaluation criteria, and other recent advances in the field of passive tube stills, nearly 30-40 relevant articles were studied. The combination of these reviews provides a clear picture of research developments, advances, and knowledge gaps in the field of passive tubular solar stills.

3. CLASSIFICATION OF PASSIVE SOLAR STILLS

The passive solar still is a device which transforms saline or brakish water into drinkable water most economically, and the solar still comes under the classification of the renewable energy sources. Furthermore, the passive solar stills are classified based upon the different catagories as shown in Figure 1.

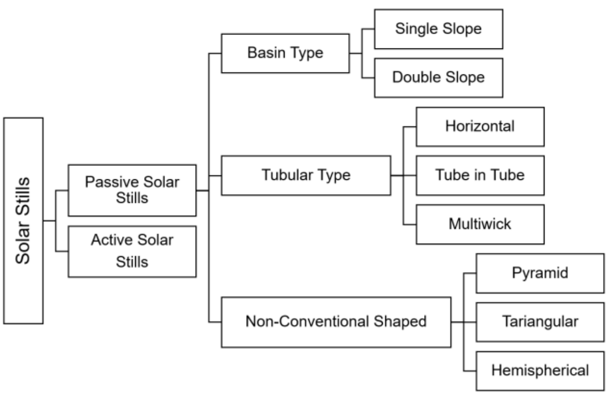

Figure 1: Classification of Passive Solar Stills

3.1 Basin Type Solar Stills

Basin-type passive solar stills use sunlight to evaporate salty water in a shallow basin before collecting the clean water on a glass cover. Better absorber mateimproveswicks, pebbles, colours, and stronger insulation improve their efficacy by allowing the water to heat up faster and generate more fresh water. Because they are simple, low-cost, and do not require external power, they are ideal for remote and water-scarce places.

3.1.1 Single Slope Solar Still (SSSS)

Recent advancements in SSSS performance have primarily focused on enhancing evaporation, improving thermal conductivity, and integrating low-cost energy storage materials. For example, (Kaviti et al., 2022) investigated the effect of permanent magnets fully submerged in the basin and found that magnetic treatment significantly increased the evaporative heat transfer coefficient. Their magnetic solar stills improved internal heat transfer by 25.52% and exergy efficiency by up to 42.25%, ultimately achieving 15.78-21.66% higher distillate yield compared to conventional stills (CSS). Similarly, absorber surface modification using nanomaterials has shown substantial gains by (Balachandran et al., 2019) incorporated nano ferric oxide (Fe_2O_3) mixed with black enamel paint into the basin absorber. This still achieved a maximum yield of 4.39 kg/m²/day, outperforming both conventional and micro coated designs due to improved thermal conductivity (0.73 W/m·K) and enhanced heat absorption characteristics. Wick based designs also contribute significantly to SSSS performance.(Modi & Modi, 2019) evaluated a single slope double basin solar still illustrated in Figure 1 fitted with small piles of wick material, finding that jute cloth wicks produced 18.03% to 21.46% higher yield than black cotton wicks due to superior capillary action and film-wise evaporation enhancement. This enhancement was particularly evident at low water depths (0.01-0.02 m), where wick supported evaporation becomes dominant. Another efficient strategy is the incorporation of energy-storage materials into the basin. (Kabeel, El-Agouz, et al., 2019)used cement coated red bricks to augment thermal storage, increasing basin temperature by up to 34% and enhancing productivity by 45% compared to a CSS. Their modified solar still achieved daily yields between 5.6-6.3 kg/day, more than 60% higher than the conventional design under similar climatic conditions. Overall, the literature in Table 1 demonstrates that single slope solar stills, though inherently simple, can be significantly improved through absorber enhancements, capillary wick materials, and sensible heat storage additions. These modifications collectively contribute to higher water temperatures, better evaporation condensation dynamics, and greater freshwater output.

Table 1: Summary of Key Performance Enhancements in Single-Slope Solar Stills

Modification Type	Material / Technique	Productivity Improvement	Key Findings	Reference
Nanocoating	Nano Fe_2O_3	35-50%	Higher thermal conductivity, max 4.39 kg/m²/day	(Balachandran et al., 2019)
Wick piles	Jute vs. black cotton	18-21%	Jute wick enhances capillary evaporation	(Modi & Modi, 2019)
Energy storage	Cement-coated bricks	45-60%	Higher basin temperature, better nighttime yield	(Kabeel et al., 2019)
Magnetic treatment	Fully submerged permanent magnets	15-22% daily yield	Higher HTC, reduced surface tension improves evaporation	(Kaviti et al., 2022)

3.1.2 Double Slope Solar Still

Double slope solar stills (DSSS) are widely used passive desalination systems, preferred for their bidirectional glass cover design that enables effective solar energy capture throughout the day. Compared to SSSS, DSSS generally offer improved condensation rates due to symmetric cooling of east and west facing glass covers. However, traditional DSSS designs still suffer from relatively low freshwater output, especially during winter months, prompting numerous studies to incorporate absorber modifications, thermal energy storage materials, and nanomaterials to improve system performance. (Dubey & Mishra, 2021) increased a single basin DSSS with black dye, pebbles, and mild steel chips (5 kg each) to improve basin absorptivity and thermal mass in Figure 2. Their experiments, performed at 15° glass cover inclination, recorded a 28.4% increase in distillate yield, along with significant rises in overall heat transfer coefficient (55.7%) and thermal efficiency (25.01%) relative to the conventional DSSS. DSSS performance is also influenced by absorber materials.

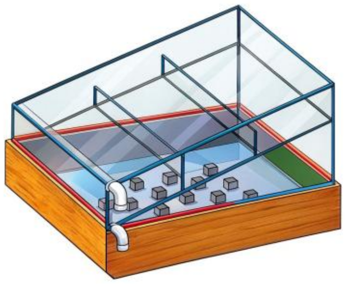

Figure 2: Single slope double basin solar still

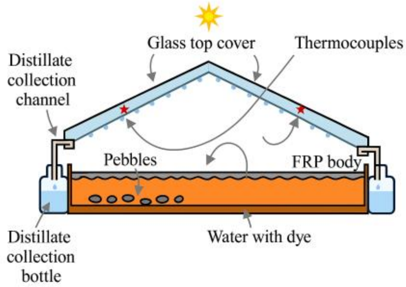

Figure 3: Double slope solar still

(Dubey & Mishra, 2021) found that partially immersed sand-filled bags boosted efficiency by about 29–31% because they stored more heat and kept the basin water warm later in the day. They also showed that adding black dye increased sunlight absorption, helping the water heat up faster. Tests on systems using dye, pebbles, and metal chips confirmed that the dye plays a major role by improving light absorption and increasing daytime evaporation. (Bait & Si-Ameur, 2017) have also explored advanced configurations such as cylindrical tubular solar collector integration. When a tubular solar energy collector was thermally coupled with a DSSS, the system achieved 31% higher passive yield due to elevated basin water temperatures (69°C peak) compared to traditional DSSS designs. Additionally, absorber type deeply affects thermal gradients. (Panchal, 2010) observed that copper absorbers consistently achieve the highest peak temperatures (60-70°C), followed by GI and mild steel, which directly correlates to higher hourly yield (400 ml/h during peak intervals). Overall, literature indicates that DSSS productivity affected by the following manner which is tabulated in Table 2.

Table 2: Summary of Performance Improvements in DSSS

Study	Modification	Improvement	Notes
Dubey & Mishra (2021)	Dye + pebbles + metal chips	28.4% yield	55.7% HTC*
(Panchal, 2010)	Copper absorber	Highest among three metals	Direct relation to thermal conductivity
(Bait & Si-Ameur, 2017)	Tubular solar collector	31% passive efficiency	High basin water temperature

*Heat Transfer Coefficient

3.2 Tubular Passive Solar Stills (TSS)

Tubular passive solar stills use a clear cylindrical body that lets sunlight enter from all sides, creating uniform heating for better evaporation and condensation. Their curved shape improves airflow and provides more condensation area, increasing freshwater output. They are lightweight, simple to build, and low maintenance, making them suitable for sunny regions. Table 4 provides a summary of performance improvements in tubular solar stills.

3.2.1 Tubular Horizontal Solar Stills

The tubular structure provides a larger effective condensation surface compared to flat or basin designs, which improves vapor condensation and freshwater collection. According to (Rahbar et al., 2015), tubular stills design Figure 3 naturally develop a clockwise recirculating flow cell inside the enclosure, improving vapor transport to the upper glass cover where most condensation occurs. The design also reduces heat losses because the water basin is partially enclosed, helping maintain higher water temperature. Experimental investigations further highlight improvements in evaporation-condensation behavior. (Ahsan et al., 2010) introduced a lightweight TSS design using a polythene film cover, making the still easier to assemble, cost-effective, and suitable for remote areas shown in

Figure 4. Their work shows that evaporation and condensation in TSS depend strongly on humid-air temperature and relative humidity inside the tube, and that a smooth circular condensation path increases collection efficiency.

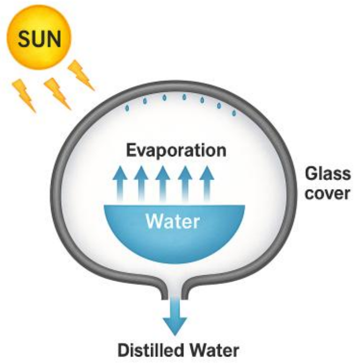

Figure 4: Tubular solar still

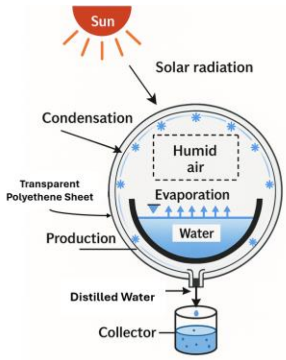

Figure 5: Modified Tubular solar still

The TSS geometry has also been compared with other shapes. (Rahbar et al., 2017) compared tubular vs triangular passive stills and found that tubular stills achieve better water production due to stronger recirculating zones and lower entropy generation, which enhances overall thermodynamic performance. Overall, tubular still demonstrates reliable performance due to their symmetric geometry, high condensation area, and compact design, making them suitable for small-scale freshwater production in sunny regions.

3.2.2 Multiwick and Tube in Tube Passive Tubular Stills

Wick-based and tube-in-tube tubular stills improve desalination by integrating capillary driven thin film evaporation with rapid tubular heating. In multiwick systems, jute or similar fibres raise water

Table 3: Passive Tubular Solar Still Designs Orientation, Structure & Performance Enhancements

Solar Still Type	Orientation	Cover Material	Basin / Inner Material	Key Numerical Findings	Source
Tubular Solar Still (TSS)	Horizontal	Glass/ Plexiglas	Semi-circular metal/plastic trough	Tubular still productivity 20% higher than triangular; entropy generation 17.4% lower	(Rahbar et al., 2017)
Lightweight Polythene TSS	Horizontal	Polythene sheet	Vinyl/plastic trough	CFD* modeling and experiment match within 15%; stable internal condensation	(Ahsan et al., 2010)
Multiwick Tubular Still	Horizontal	Glass tube	GI*/FRP* trough + jute wick	Multiwick TSS gives 8-13% more output than simple TSS;	(Kumar & Anand, 1992)
Tube in Tube Passive Still (Tray + Fabric)	Horizontal	Transparent plastic tube	PVC inner tube with composite fibers	Tube in Tube (Black Jeans) = 7.64 L/m²·day; Tube in Tube (Jute) = 7.37 L/m²·day; 72-73% higher yield than simple Tray in Tube	(Bari et al., 2016)
Corrugated-Absorber Tubular Still	Inclined	Transparent polycarbonate	Semi-circular corrugated galvanized sheet	Thermal efficiency increased by 26%, productivity increased about 25%,	(Elshamy & El-Said, 2018)

*Computational Fluid Dynamics, *Galvanized Iron, *Fiber Reinforced Plastic

into a thin film that warms and evaporates faster than thicker water levels in traditional sun stills. (Kumar & Anand, 1992) showed that the tubular multiwick design yields 8-13% more freshwater than a simple tubular still and up to 18% higher output than a conventional basin-type multiwick still due to the increased condensing surface and reduced thermal mass inside the tube. Tube in Tube systems extend this improvement by using a PVC inner absorber tube wrapped with composite fibers and enclosed within a transparent outer cylinder, allowing 360° solar penetration and an enlarged condensation surface. (Bari et al., 2016), showed that this lightweight, low-cost tube-in-tube system is portable and suitable for small-scale desalination. The Tube in Tube (Black Jeans) and Tube in Tube (Jute) systems deliver 72-73% more water than the conventional Tray in Tube type, increasing efficiency from 42% to around 70-73%. These enhancements result from wick-assisted evaporation, thin-film heat transmission, and improved internal heating, making multiwick and tube-in-tube stills particularly effective passive desalination solutions.

3.3 Non Conventional Design Solar Stills

Non-conventional solar stills are complex structures that aim to enhance the limited production of typical basin stills. Shapes such as hemispherical, pyramidal, stepped basin, and triangular absorb more sunlight, retain heat better, and increase evaporation. Many people apply trays, wicks, thermal storage, or guided water flow to increase evaporation area and maintain temperature stability. These designs improve both light capture and heat use, making freshwater production more efficient and reliable in a variety of climates.

3.3.1 Hemispherical Shaped Solar Still

Among these, hemispherical solar stills (HSS) have attracted significant interest due to their ability to collect solar radiation from all directions without requiring tracking. (Arunkumar et al., 2012) designed an acrylic-covered hemispherical still Figure 5 (3 mm thick, approximately 0.945 m in diameter), reporting daily yields between 3.66 and 4.20 kg/m²/day, with efficiency increasing from 34% to 42% when top cover cooling was applied. Similar geometric advantages were confirmed by (Ismail, 2009), who developed a transportable hemispherical solar still illustrated in Figure 6 producing 2.8-5.7 L/m²/day, achieving a maximum efficiency of 33%. (Panchal & Shah, 2013) combined experimental measurements with ANSYS Computational Fluid Dynamics (CFD) simulations and demonstrated strong agreement between predicted and measured water temperatures, vapor temperatures, and distillate output. Their hemispherical still, constructed with a mild-steel absorber and acrylic dome, achieved peak distillate production near 0.29 kg/h under the climatic conditions of Mehsana, India, confirming the reliability of CFD tools for solar still performance estimation.

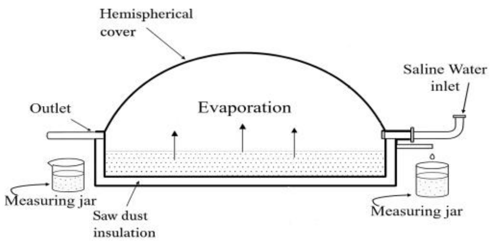

Figure 6: Hemispherical solar still

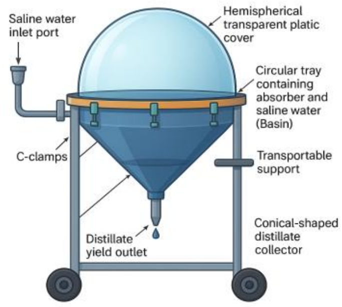

Figure 7: Transportable hemispherical solar still

Another notable non-conventional configuration is the semi circular trough absorber solar still shown in Figure 7. In this system, the basin absorber adopts a curved geometry, combined with strategically placed baffles to increase water residence time and extend thermal interaction. (Sathyamurthy et al., 2015) demonstrated that the use of baffles effectively increased the thermal exposure of water, leading to earlier onset of evaporation, increased droplet formation on the inner glass surface, and higher distillate output. Their results indicated a 16.66% improvement in daily freshwater yield compared to a conventional still. The study also highlighted the role of wind speed and unsteady outdoor conditions in influencing condensation rates across different times of the day.

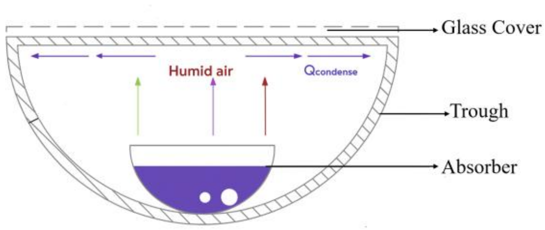

Figure 8: Semi circular solar still Figure

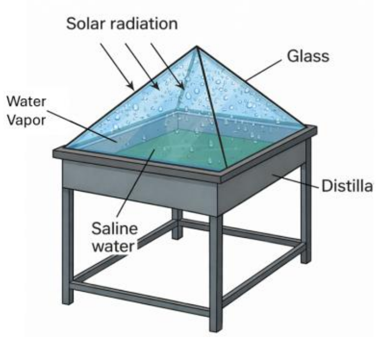

Figure 9: Pyramid-shaped solar Still

3.3.2 Pyramid Shaped Solar Still

Pyramid-shaped solar stills (PSS) represent another important category of non-conventional solar desalination systems. (Eze J.I & Ojike O, 2012) compared rectangular and pyramid type stills shown in Figure 8 and found that, although the rectangular design slightly outperformed the pyramid in total water collected, the pyramid still offered more uniform condensation due to its multi sided glazing configuration, achieving an efficiency of roughly 28.9%. Following developments significantly improved the productivity of the basic pyramid configuration. For example (Kabeel, Sathyamurthy, et al., 2019) incorporated TiO_2 nanoparticles doped in black paint onto the absorber plate and observed that water temperature increased by nearly 1.5°C at comparable water depths shown in Figure 9. This modification increased the accumulated daily distillate yield by 6.1% relative to the uncoated pyramid still, with maximum yield reaching 6.6 kg/m²/day at 1 cm water depth. An even more substantial enhancement was achieved by integrating thermally superior absorbed materials and cooling mechanisms.

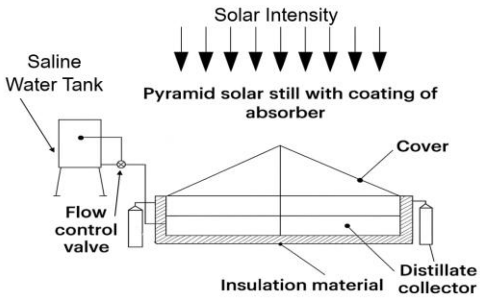

Figure 10: Modified Pyramid solar Still by (Kabeel, Sathyamurthy, et al., 2019).

Further improvements to pyramid still performance were demonstrated by (Kabeel et al., 2017) through the integration of a v-corrugated copper absorber plate resting over a paraffin-based phase change material (PCM). This design improved heat transfer rates during sunshine hours and provided thermal storage during late afternoon and evening periods. Their experiments revealed that the accumulated daily yield increased from 3.5 to 6.6 L/m²/day, indicating an 87.4% improvement over the conventional pyramid still. As shown in Table 5, the v-corrugated absorber plate PCM combination ranks among the most effective modifications reported in non-conventional solar still research.

3.3.3 Triangular Shaped Solar Still

For the additional non-conventional systems (Ahsan et al., 2014) conducted a detailed evaluation of a low cost triangular solar still (TrSS) designed using lightweight and locally available materials such as PVC pipes, polythene film. Their experimental setup is demonstrated in Figure 10, showing the triangular cover and rectangular trough basin. The study focused on how solar radiation, ambient temperature, and especially initial water depth influence productivity. Results demonstrated an *inverse* relationship between water depth and distillate yield, where shallower depths consistently produced higher evaporation due to lower thermal inertia. On the other hand (Sathyamurthy et al., 2014) presented a comprehensive review of how design and climatic parameters influence the productivity of triangular-pyramid solar stills illustrated in Figure 11. The study highlighted that glass cover inclination, absorber temperature, wind speed, and water depth are critical variables, with the pyramid geometry promoting uniform solar capture throughout the day. This work supports experimental findings by showing that performance improvements are tightly linked to maintaining optimal thermal gradients between the water surface and condensing cover.

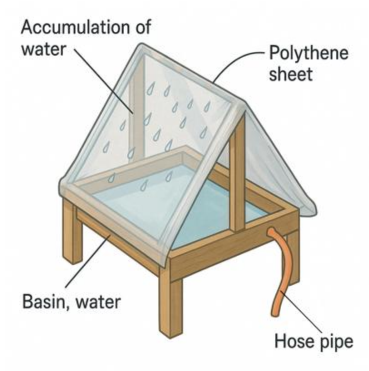

Figure 11: Low cost Triangular solar still

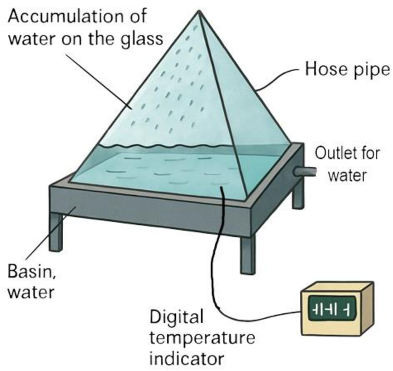

Figure 12: Triangular solar still

Table 4: Summary of Non-Conventional Solar Still Findings

Solar Still Type	Cover Material	Basin Material	Key Numerical Findings	Source
Hemispherical Solar Still	Acrylic dome (3 mm)	Mild steel absorber plate	Yield: 3.66-4.20 kg/m²/day; Efficiency increased from 34% to 42% with cover cooling	(Arunkumar et al., 2012)
Transportable Hemispherical Still	Acrylic hemispherical cover	Mild steel basin	Yield: 2.8-5.7 L/m²/day; Max efficiency 33%	(Ismail, 2009)
Pyramid Still with TiO_2 Black Paint Absorber	4 mm clear glass	Mild steel coated with TiO_2 nano-black paint	Water temp increased 1.5°C; Yield improved by 6.1%. Max yield 6.6 kg/m²/day	(Kabeel, Sathyamurthy, et al., 2019)
V Corrugated Pyramid Still with PCM	3 mm glass	Copper V corrugated absorb with 44 kg paraffin (PCM)	Yield increased from 3.5 to 6.6 L/m²/day (87.4%); Higher nighttime evaporation	(Kabeel et al., 2017)
Semi Circular Trough	Flat glass sheet (3 mm)	PVC trough absorber + baffles	Daily yield increased 16.66%; Faster droplet formation due to enhanced water residence time	(Sathyamurthy et al., 2015)
Triangular Pyramid Solar Still	Glass cover (tilted at latitude angle)	Black-coated basin; insulated walls	Productivity influenced strongly by glass angle, low water depth, absorber temperature; enhanced uniform solar capture due to multi sided geometry	(Sathyamurthy et al., 2014)
Low Cost Modified Triangular Solar Still	Single glass cover	Blackened basin; low-cost insulation materials	Shallow water depth increased yield significantly; improved thermal retention enhanced productivity	(Ahsan et al., 2014)

4. CONCLUSIONS

This review explored recent improvements in passive solar still technologies, including as tubular, basin-type, and a few unconventional designs. The key findings reveal that better geometry, enhanced absorber coatings, wick based thin film evaporation, phase change materials, and high conductivity components that promote heat retention and condensation all contribute to increased productivity. Unconventional designs such as hemispherical, pyramid and triangular stills regularly outperform simple basin systems because they capture more sunlight and manage heat more effectively. Overall, the literature confirms that even basic passive stills can achieve much higher output with the right structural and thermal enhancements. A major conclusion of this review is the strong advantage of tubular solar stills. Their cylindrical shape allows sunlight to enter from multiple directions, supports steady internal air circulation, and provides more condensation area than flat designs. Multiwick and tube in tube variations further increase performance by creating thin water films that evaporate quickly and improve heat and mass transfer. Tubular stills also provide better insulation and more uniform temperatures, ensuring consistent freshwater yield even as weather conditions change. These properties make them ideal for decentralised desalination. The study also emphasises the tremendous potential of tubular and other sophisticated non-conventional systems for providing sustainable water supply in underdeveloped countries. Their low cost, use of local materials, simple construction, and ability to operate without electricity make them ideal for rural and coastal areas facing water shortages. As solar desalination continues to grow, these passive technologies provide practical, ecofriendly, and scalable solutions for improving access to clean drinking water. Future research should focus on long term testing, hybrid systems, improved thermal storage, and strategies for large scale manufacturing to maximize their impact on global water scarcity.

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AI USE DECLARATION

AI based tools were used for language clarity and grammatical improvement. The authors take full responsibility for the originality, accuracy, and integrity of the content, analysis, and conclusions presented in this paper.

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