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A Review on the Performance Enhancement of Pyramid Solar Still in Iraq

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ABSTRACT

Water is considered the lifeblood and is used in various aspects of industrial, agricultural, and daily life. Given the importance of water and the increasing human population, it is necessary to find ways to purify saltwater, which constitutes more than 97%. One of the most important and cheapest methods for water purification is solar distillation. The pyramid solar still is one of the best ways to make maximum use of solar energy and condense water inside the still. In this paper, we seek to study all the research on the pyramid solar still that was conducted in Iraq and the methods that were used to improve productivity and efficiency, such as combining the innovative design with a hybrid nanocomposite resulted in a 69% increase in productivity, adding nanomaterials to paraffin wax resulted in a significant efficiency of 117.64%, using paraffin wax, a corrugated surface, a heater, and a cooling water shower achieved a production capacity of 15 L/day, as most studies focused on improving the process of water evaporation, heat absorption and storage, as well as improving the process of water condensation and collection.

1. INTRODUCTION

All living things, including humans, animals, and plants, depend on water. Due to population growth, forest destruction, urbanization, and the adoption of contemporary technology by the industrial and other sectors, there is currently less drinking water available; therefore, saltwater needs to be treated in order to be fit for human use. The rise in global temperatures has resulted in a reduction of groundwater resources. Additionally, just around 1% of the world's drinking water is readily available due to rising sea levels [1]. However, due to the presence of various contaminants and microorganisms, water from lakes, ponds, and rivers cannot be utilized directly for drinking. The elements above unequivocally demonstrate the paucity of drinkable water. Hence, we urgently want efficient freshwater productivity [2, 3].

Iraq is facing a severe water crisis marked by significant reductions in river flow rates, particularly for the Tigris and Euphrates, with declines of 50-60% in recent decades due to upstream dams and climate change. This has led to an estimated 30-45% of agricultural land in southern governorates like Basra becoming unproductive due to water shortages and salinization. The crisis has also caused the internal displacement of tens of thousands of people, especially in the southern marshlands, between 2018 and 2023. Furthermore, water quality has drastically deteriorated, with salinity levels in areas like the Shatt al-Arab frequently exceeding safe drinking water standards, leading to widespread health issues, as seen in Basra, with over 100,000 hospitalizations in 2018 due to contaminated water [4].

The process by which saline water is converted to fresh water is known as desalination. The saline water is evaporated using thermal energy in this process, producing clean water devoid of salts and both organic and inorganic substances [5, 6]. Nano fluid can be used to improve water evaporation inside the solar still and maximize solar energy utilization [7-9]. Lenses and mirrors are used to improve the performance of solar stills to concentrate energy and reduce heat losses [10]. The use of solar stills reduces dependence on fossil fuels, reduces carbon dioxide emissions, and improves the environment [11].

All desalination techniques require the use of fossil fuels or electricity. However, solar distillation is a technique that uses the sun's heat directly in a basic water purification apparatus to create fresh water. The apparatus, often referred to as a solar still [12]. The fact that the necessary thermal energy may be readily obtained from solar energy is one of this process's significant advantages. For this reason, solar desalination holds enormous promise for resolving the issue of water scarcity [13]. Recently, Iraq has been one of the countries that has suffered directly from the greenhouse effect, with the average temperature ranging from 16℃ to 49℃ (in summer) and from 8.5℃ to 14℃. (in winter), leading to the natural water resources along with a deficiency in rainfall [14]. A relatively high temperature climate in Iraq could be invested in a positive way using solar stills in specific regions that suffer from water scarcity for personal use.

2. SOLAR STILL

The solar still generally consists of several parts, the most important of which is the transparent cover, which is often made of glass with high transmittance to sunlight. The absorbing part consists of a metal piece coated with a coating of nano-composite material that helps absorb the most significant part of the incident sunlight and convert it into heat, as the metal piece rises above the impure water at a suitable height for it to evaporate [15-18]. Improvements can be used on the surface of the basin to increase efficiency and productivity, such as using a corrugated or raised surface [19]. The metal piece is surrounded by an insulating material to inhibit heat from dissipating outside the solar still [20].

Solar stills are easy to use and don't require a lot of specialized upkeep. Cleaning the plant, particularly the glass cover, is the only upkeep needed. As a result, it can be utilized anywhere with few issues. There are two categories for solar distillation systems: passive and active solar still [21, 22].

Solar stills are simple, with no moving parts, are cheap to build using locally available materials, are friendly to the environment with no pollution, have a low maintenance cost, and can be used in arid and salty areas. Still, their problem is their low water productivity and large area occupancy. Phase change materials can be used to improve the performance of the solar still. The phase change material (PCM) serves as an energy storage device that contributes to the continued production of the still during the night or in the absence of solar radiation [23, 24]. Producing fresh water by using a passive solar still would cost approximately 0.014$ for each kilogram of water for a 30-year-lifetime system [25]. In the study of solar stills, the focus is on energy and exergy performance as well as cost calculations and improvement in the environment [26].

Solar radiation is the only energy source used in passive solar distillers to heat the water and produce evaporation that is immediately absorbed by the basin water. Conversely, active solar still systems expand the temperature of the water and improve output by using waste heat from nearby industries and heat generated by external devices like solar ponds and collectors, or use other devices to improve the process of evaporation, condensation, or heat absorption, such as a fan or a rotating part inside the solar still [27].

When the vapor is cooled to the dew point, it starts to condense. This water is gathered in a graduated cylinder when it falls through the lid due to gravity. A considerable amount of heat from the still escapes through the glass when the basin water warms up and condenses on the underside of it. Water output drops to about 6 L/m^2 per day, and solar efficiency drops to 30–40% as a result of this heat loss. Recent research has concentrated on enhancing the original design and creating new modifications or kinds of distillers due to the poor production and efficiency of distillers [28].

3. PYRAMID SOLAR STILL

The pyramid solar still offers several advantages over traditional designs, making it a highly efficient and practical solution for solar-powered water desalination. Its pyramid shape provides a larger condensation surface area, improving freshwater output, while the inclined sides ensure efficient water collection. The design is durable, resistant to environmental factors, and retains heat better, enhancing evaporation rates. Additionally, it is cost-effective, low-maintenance, and scalable, suitable for both household and community use. By leveraging renewable solar energy, the pyramid solar still is an eco-friendly solution for producing clean water in arid or water-scarce regions [29, 30].

This study provides the first systematic review of enhancement techniques, covering all research conducted in Iraq (The geographic location of Iraq lies at 33° North latitude and 44° East longitude) [31], about the pyramid solar still from the theoretical, practical and numerical point of view and highlight the most critical factors that lead to the use of this type of stills and increase its productivity.

Algaim et al. [32] compared the efficiency of the sloping surface solar still and the pyramidal solar still. The study concluded that the pyramidal solar still is more efficient than the sloping surface solar. Figure 1 shows the experimental productivity of PSS compared with SBSS.

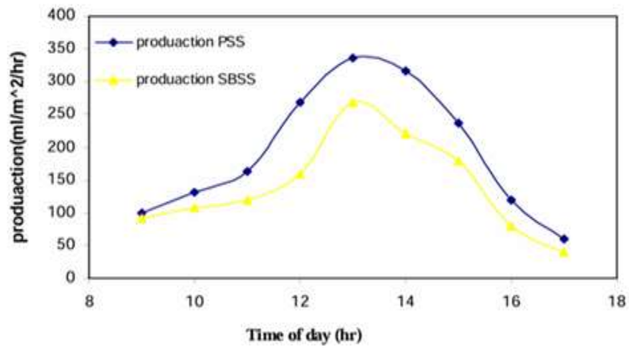

Figure 1. Experimental productivity of PSS and SBSS at [32]

Al-Madhhachi and Smaisim [33] designed a cheap, simple, and easy-to-carry pyramidal solar distiller that can be used in remote areas where it is challenging to obtain potable water and abundant solar radiation. Their design provided 2.2 L/day, as shown in Figure 2.

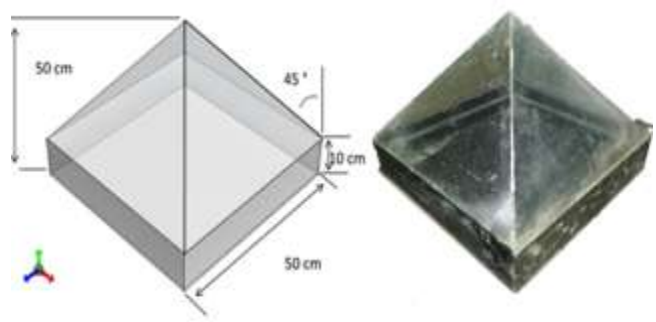

Figure 2. The portable solar still [33]

Shareef et al. [34] conducted a study that included three variables: Studying an innovative design for the pyramid, employing paraffin wax as a solar energy storage (Figure 3), as well as using a coating of a nano-composite material of copper oxide, magnesium oxide, and aluminum oxide, and then using a coating of a hybrid nano material. The results showed that using the innovative design led to an enhancement in productivity by 43.2%. Meanwhile, using paraffin wax led to an increase in productivity by 50.6%. Also, using the surface coated with the nano-material led to an increase in productivity by 61.1%. The best results are when using the innovative design with the hybrid nanocomposite, where the productivity reached 69%. Figure 4 illustrates the Productivity of two types of glass cover.

Al-Hamadani and Yaseen [35] used a pyramidal still equipped with paraffin wax as a thermal storage material, a corrugated surface to increase the absorption area, a heater inside the basin to work with a photovoltaic cell, and a cooling water shower to increase condensation, as shown in Figure 5. The best results were achieved when using both effects together, with a production capacity of 15 L/day. Figure 6 gives a comparison between experimental and theoretical work.

Figure 3. Innovation glass cover [34]

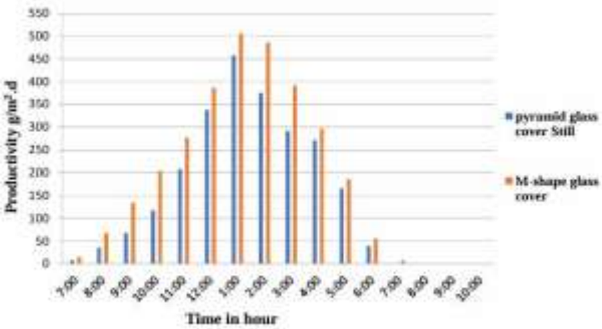

Figure 4. Hourly productivity for changing the glass cover's design [34]

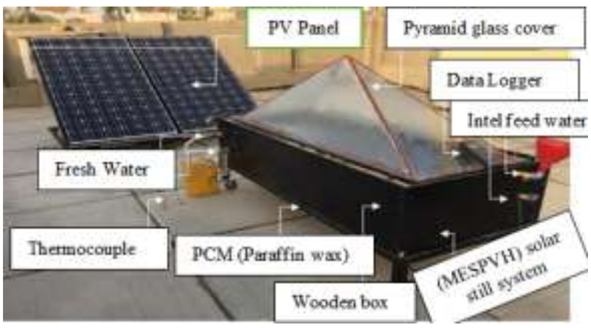

Figure 5. Photography of (MESPVH) solar still system [35]

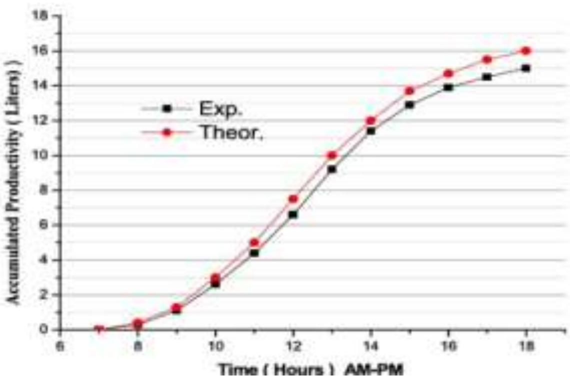

Figure 6. Theoretical and experimental accumulated productivity of (MSEPVH) [35]

Abed et al. [36] conducted a numerical study of the addition of nanomaterials to paraffin wax used as an energy storage for the purpose of improving the performance of the pyramidal solar still. The study included a comparison between the use of paraffin wax and paraffin wax with 3% nanoparticles added to it, as well as the addition of fins of different shapes to increase the surface area. The results were that the addition of nanomaterials to PCM led to an efficiency of 117.64%, and when using paraffin only, it gave an increase in efficiency of 79.41%, as shown in Figure 7.

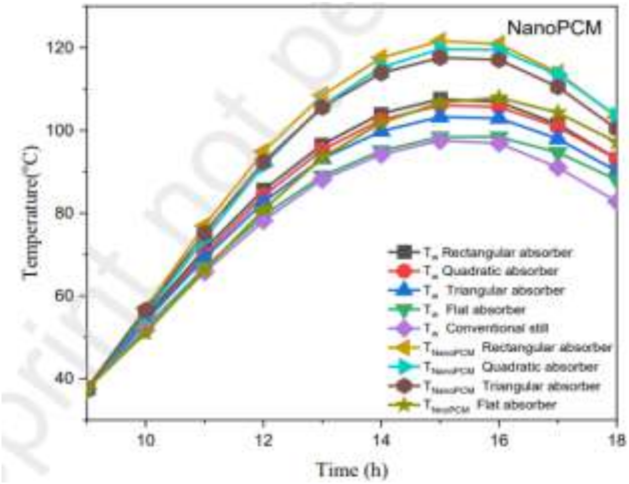

Figure 7. Brackish water and Nano PCM across various absorber configurations [36]

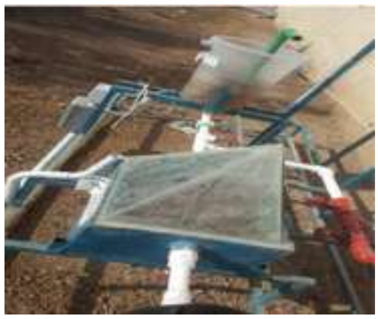

Figure 8. Photo of pyramid solar still [37]

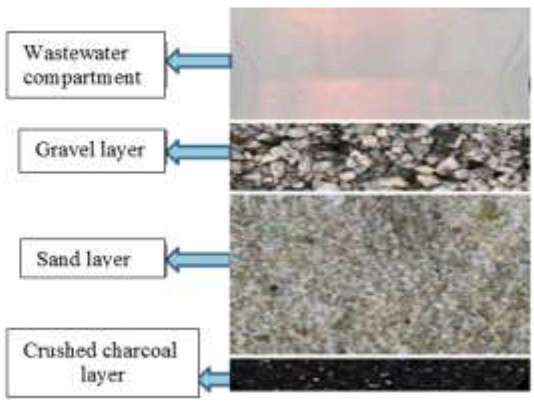

Figure 9. Schematic representation of the different layers of the filter basin [37]

Ahmed et al. [37] studied the filtration of oil well water. The study included adding a filter before the solar still as shown in Figure 8, consisting of layers of stone, sand and coal as shown in Figure 9. The results showed that using the filter gives good results in filtration, ridding the water of odors and pollutants, and increasing productivity. The results were 99% removal of biological contaminants.

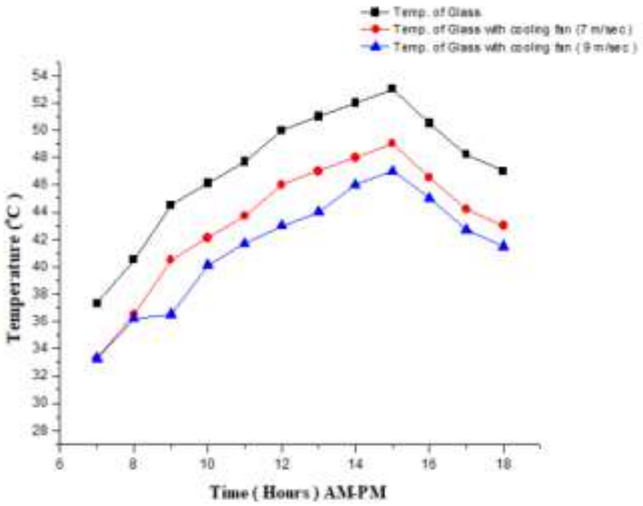

Figure 10. Effect of the external cooling fan on glass temperature (MESPVH) solar [38]

Figure 11. External cooling fan of solar still [38]

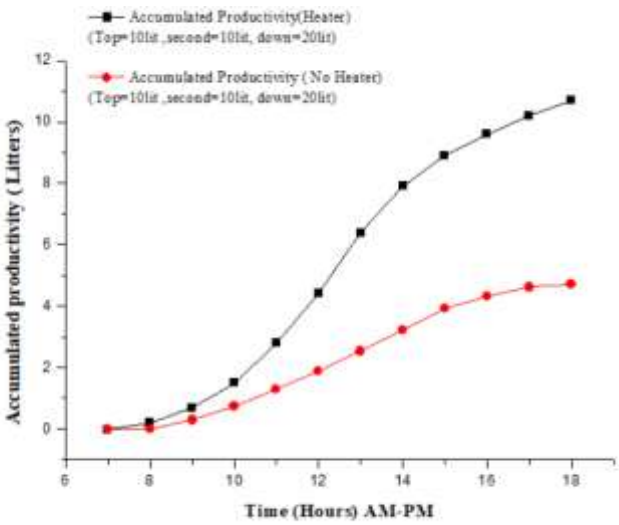

Figure 12. Accumulated productivity of the (MES) solar still system with and without a water heater [38]

Al-Hamadani and Yaseen [38] used two additions to the pyramid to improve productivity. The first is to use a heater that operates on direct current supplied by a solar panel, as shown in Figure 10. The heater will increase evaporation, which requires a second addition to condense the evaporated water by adding an external fan operated by the solar panel. The results showed an increase in efficiency of 370%. Figure 11 illustrates the effect of the external cooling fan on glass temperature. Figure 12 shows the productivity of the solar still system.

Essa et al. [39] added wicks by making 3 cm wide slits in the basin. The wicks are inserted into the water. These wicks work by capillary action, which leads to increased water evaporation. The number of wicks is 9, 16, 25, 35. Internal and external mirrors were used to increase the concentration of solar radiation inside the tank with the aid of a fan as shown in Figure 13. The results showed that using 35 wicks with the reflective mirror gives a 195% enhancement in productivity and 53% efficiency. Figure 14 shows the effect of cord number on the daily productivity.

Figure 13. Experimental test-rig [39]

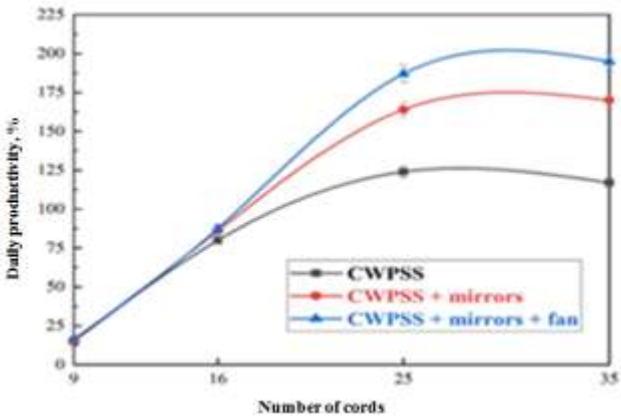

Figure 14. The effect of cord number on the daily productivity of CWPSS with and without mirrors and a fan [39]

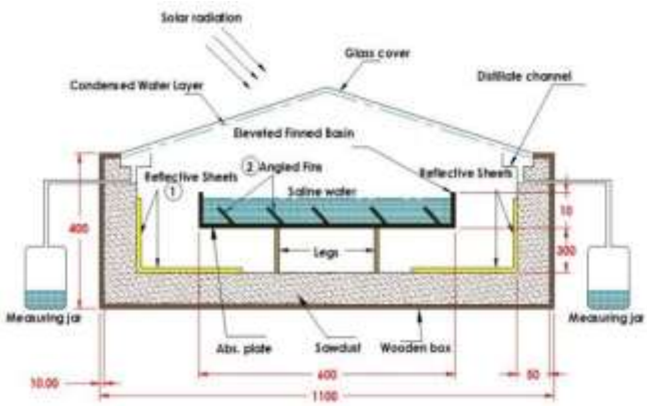

Figure 15. Diagram of the raised basin solar still with the internal reflect and inclined fin absorber [40]

Alawee et al. [40] used a 30 cm raised basin enhanced with inclined fins to increase the absorbent surface, as shown in Figure 15. The results showed that the raised basin led to a 43% increase in productivity. When the fins' effect was added, the efficiency was 59%. Figure 16 shows the temperature variation of the traditional solar still.

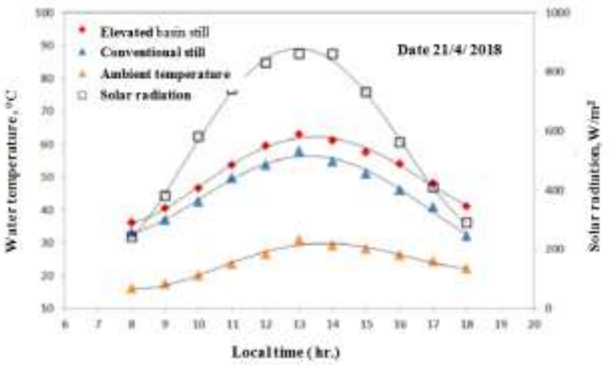

Figure 16. Temperature variation of the traditional solar still [40]

Alawee et al. [41] added four rotating cylinders inside the basin to increase the surface area exposed to the sun's rays, as well as using three heaters supplied with electrical energy from a solar panel. Different speeds were used for the rotating cylinders (0.1, 0.2, 0.5, 1, 1.5, 2) rpm as shown in Figure 17. The results showed that the best speed is 0.5 rpm, which gave an increase in productivity by 214% and thermal efficiency of 65%, as shown in Figure 18.

Figure 17. Rotating cylinders and accessories [41]

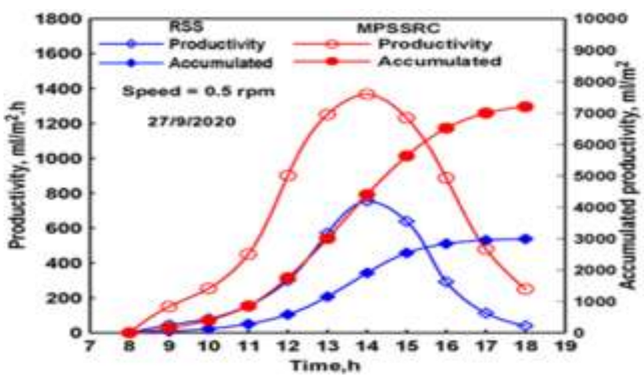

Figure 18. Solar still productivity with 0.5 rpm [41]

Hammoodi et al. [42] made a theoretical study on the three models of the pyramid solar still. Firstly, conventional pyramid solar still, as shown in Figure 19; secondly, adding the effect of a magnetic field, and then an electric field to a pyramidal solar still. The results showed that the evaporation heat transfer coefficient peaked at 14:00, reaching 25.05 W/m².°C for the conventional pyramid solar still (CPSS), 32.33 W/m².°C for the magnetic pyramid solar still (MPSS), and 40.98 W/m².°C for the electro-magnetic pyramid solar still (EMPSS), as shown in Figure 20.

Omara et al. [43] employed a dish-shaped absorber (CDPSS) and a convex cylinder absorber (CCPSS) in place of a flat absorber, as shown in Figure 21. The suggested absorber shapes decreased the water depth inside the distiller to the bare minimum while increasing the surface areas of exposure and evaporation provided by wicks of different materials, such as jute and cotton. In addition, the absorbent surface was coated with nano-materials of (TiO_2), (CuO), and silver, as the nano-material was in the form of a composite material with different depths. The results concluded that the best diameter of convexity was 15 cm and the best nano-material was silver, followed by copper oxide, and then titanium oxide. It gave an improvement in productivity by 78% and a 45% improvement in efficiency. Figure 22 illustrates the solar radiation and temperature differences.

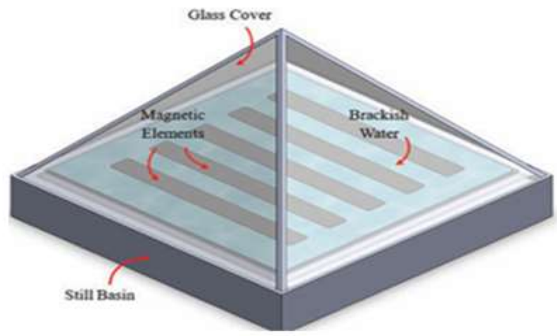

Figure 19. 3D symbol of pyramid solar still includes magnetic field (MPSS) [42]

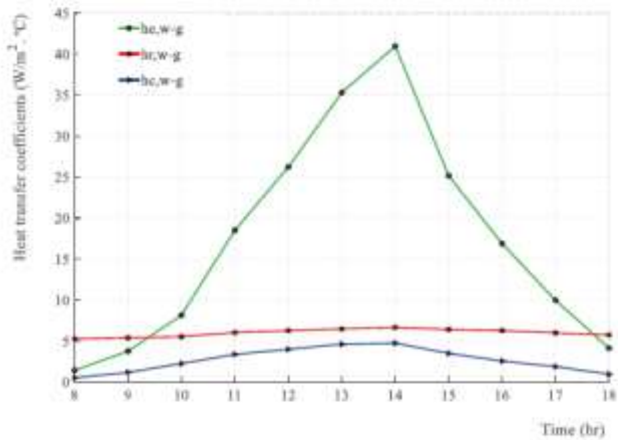

Figure 20. Hourly variant of heat transfer coefficients of EMPSS with magnetic fields [42]

Researcher Hammoodi et al. [44] to increase the evaporation process in the pyramid still through two techniques. The first was adding wicks to increase evaporation and increase the surface area of heat-absorbing surfaces. The second was using two mirrors to increase the concentration of sunlight inside the solar still. It was found that using wicks increases productivity by 122% and efficiency by 53%. When adding the effect of mirrors, 170% increase in productivity and a 48% increase in efficiency, as shown in Figure 23.

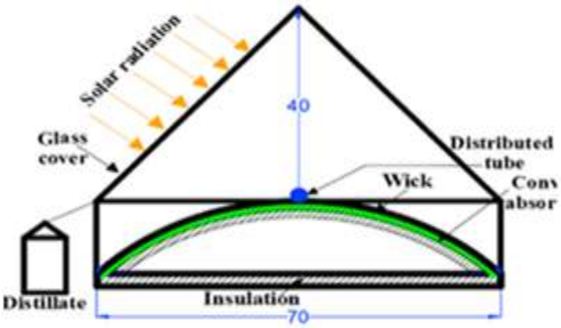

Figure 21. Schematic of the investigated distillers [43]

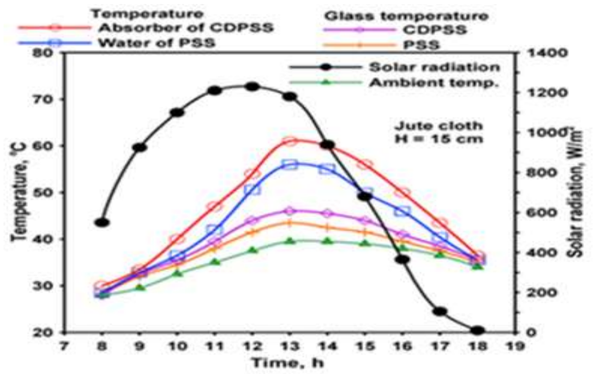

Figure 22. Solar radiation and temperature differences of CDPSS and PSS [43]

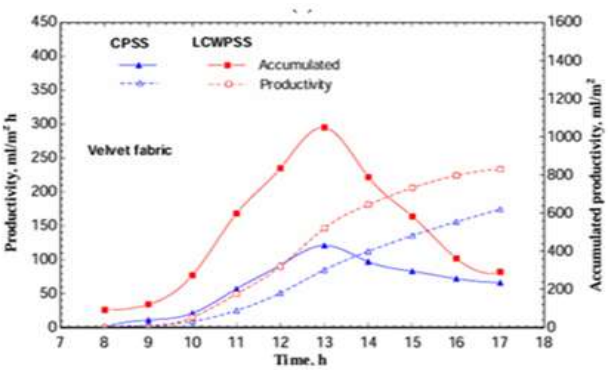

Figure 23. The hourly productivity of velvet textile [44]

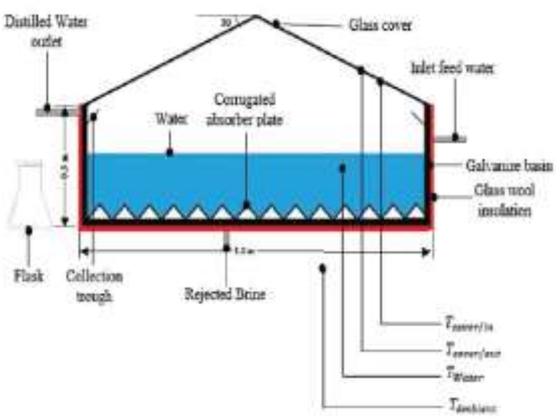

Figure 24. Schematic of Pyramid-shaped solar still device [45]

Fadhil and Abed [45] studied a pyramid still using three variables: Firstly, studying the solar still without coating the absorbent surface. Secondly, studying the effect of adding the coating. Lastly, we studied the effect of adding the coating to a corrugated surface and the water depth effect, as shown in Figure 24. The best results were when the surface was corrugated and coated, where the efficiency reached 94% when the water depth was 2 cm.

In order to determine the best wicks to be used in solar stills, Hammoodi et al. [46] studied various types of wicks in a pyramidal solar still to determine which type of wick could give the best enhancement and increase the production of the still. The researchers studied the use of light cotton, heavy cotton, jute, and velvet fabrics, which were then coated with black paint to increase absorbency. A reflective mirror is also used. The results indicated that using light cotton resulted in the best results, with an increase in productivity of 136.6%. And 55% in the efficiency. Figure 25 below shows the productivity hourly variation.

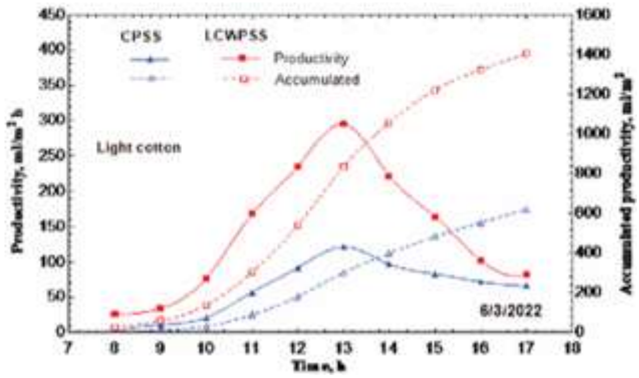

Figure 25. Productivity hourly variation and overall cumulative productivity using different wicks, light cotton [46]

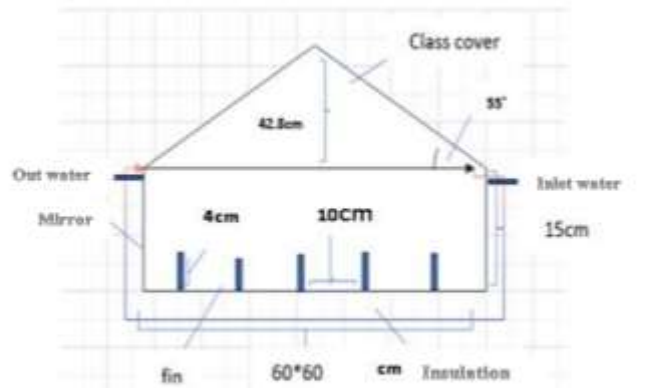

Figure 26. Side-view of the solar still [47]

Ali and Ali [47] added fins to raise the surface area of the basin, which increased the absorbed energy and evaporation. These fins were square and had a circular diameter. The pyramid angle was also studied between 45° and 55° with the addition of internal mirrors, as shown in Figure 26. The results showed that the highest efficiency of 90% was obtained when the angle of the pyramid was equal to 45° with the inclusion of square fins, as shown in Figure 27.

Mohammed et al. [48] studied a pyramidal solar still with fins. The fins were of two types: the first was hollow cylindrical perforated fins, and the second was inclined rectangular perforated fins. In addition, the basin surface was coated with a nano-composite material, TiO_2, and graphene. The results showed that using the inclined rectangular perforated fins gave an efficiency of 55.9%, and that using the nano-composite material gave an efficiency of 82.1%, as shown in Figure 28.

Figure 27. Hourly efficiency variation with respect to time with Intensity of solar radiation [47]

Alawee et al. [49] studied the type and number of wicks on the productivity of distilled water. Two kinds of wicks were investigated, namely cotton and jute. Slits in the upper basin that elevated 3 cm from the lower basin were made. The upper basin was covered with wick material, and wick cords were dangled to work with capillary properties, as shown in Figure 29. Four slots (9, 16, 25, and 35) were used. The results showed that using jute fibers provided better efficiency. The best number of slots was 25, which increased the productivity to 122% and efficiency to 53% as shown in Figure 30.

Alawee et al. [50] studied a pyramidal solar still equipped with internally suspended wicks that absorb water by capillary action from the basin and equipped with baffles to reduce the water level inside the basin and increase its thermal energy. The absorbent surface was coated with several types of nano-composite materials, where the surface was coated with silver, copper oxide, and titanium oxide. The results showed that the CPSD painted with silver nanocomposite materials provided an increase in productivity of 176% and an efficiency of up to 60.4% as shown in Figure 31.

Table 1 shows a summary of the most important results obtained by the researchers and the place where the research was conducted.

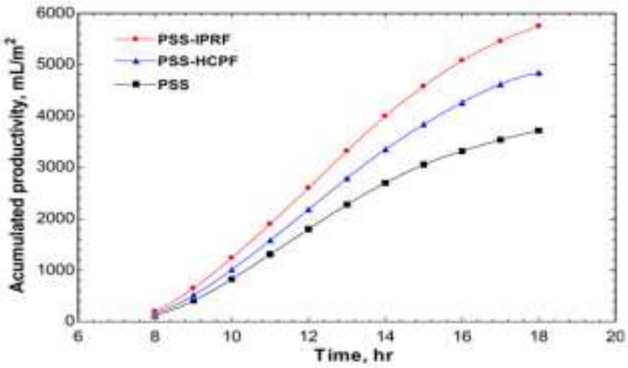

Figure 28. Productivity evaluation between PSS-IPRF and PSS-HCPF [48]

Table 1. Summary of studies in the review

Reference	Modifications	Improvement Productivity	Efficiency	Location
Algaim et al. (2013) [32]	A comparison between the sloping surface SS and the pyramidal SS		65% for PSS, 55% for SSS	Basra
Al-Madhhachi and Smaisim (2021) [33]	On designing a cheap, simple, PSS	2.1 L/day	60%	Najaf
Shareef (2024) [34]	Innovative design, paraffin wax Mixed black paint with hybrid nanoparticles	5.86 L/day	77.5%	Hilla
Al-Hamadani and Yaseen (2021) [35]	Paraffin wax, photovoltaic heater and Corrugated basin	15 L/day		Baghdad
Abed et al. (2024) [36]	- NanoPCM and PCM	-117.64% -79.41%	-112.34%	Najaf
Ahmed et al. (2023) [37]	- Filter before the solar still		99%	Samawah
Al-Hamadani and Yaseen (2019) [38]	- DC- water heater - External fan	370%		Baghdad
Essa et al. (2021) [39]	- Wick, internal, external mirror - Fan	195%	53%	Baghdad
Alawee et al. (2021) [40]	- Raised basin - Inclined fins		43% 59%	Baghdad
Alawee et al. (2021) [41]	- Four rotating cylinders - Three heaters	214%	65%	Baghdad
Hammoodi et al. (2024) [42]	Magnetic field and Electrical field		theoretical	Baghdad
Omara et al. (2022) [43]	- Convex cylinder absorber and dish nano composite paint	78%	45%	Baghdad
Hammoodi et al. (2023) [44]	- Wick - External mirror	170%	48%	Baghdad
Fadhil et al. (2024) [45]	Water depth and corrugated basin		94%	Anbar
Hammoodi et al. (2023) [46]	- Wick	136.6%	55%	Baghdad
Ali, N. and Ali, O.M. (2024) [47]	Circular fins and Pyramid angle		90%	Kirkuk
Mohammed et al. (2022) [48]	- Perforated fins and nanocomposite		55.9%, 82.1%	Baghdad
Alawee et al. (2021) [49]	- Wicks - Raised basin	122%	53%	Baghdad
Alawee et al. (2021) [50]	- Wicks and baffles	176%	60.4%	Baghdad

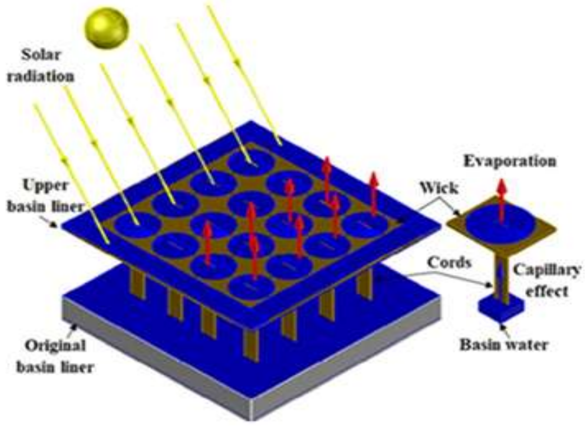

Figure 29. The two corded parallel basin liners [49]

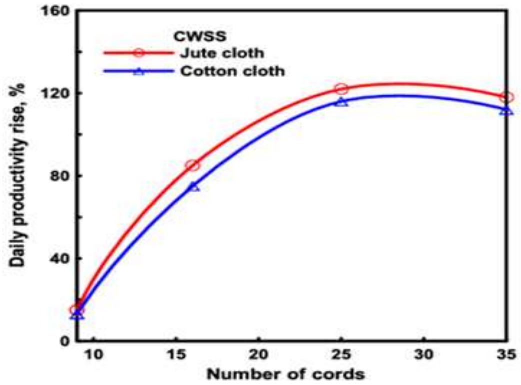

Figure 30. The effect of wick type and number of cords on the productivity [49]

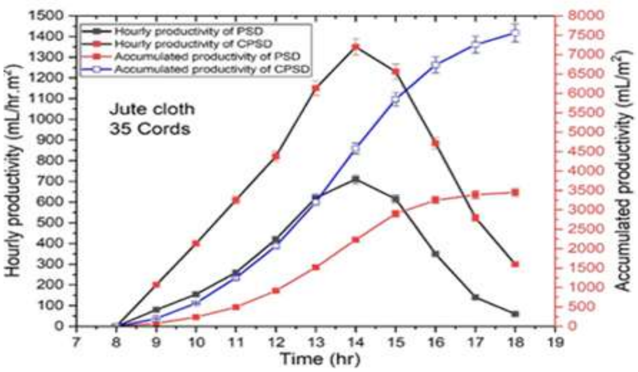

Figure 31. Hourly and total productivity of PSD and CPSD with 35 jute cords without baffles [50]

4. CONCLUSION

The efficiency of pyramidal solar stills is the result of a complex interaction between the prevailing climatic conditions on site, the engineering design of the still, the quality of the materials used, and the operational settings. To achieve maximum efficiency, all of these factors must be considered when designing and operating the solar still

1-The importance of the pyramidal solar still is highlighted by the fact that the sunlight is perpendicular to the absorbing surface.

2-The productivity of the pyramid solar still is affected by the ambient conditions, as well as the temperature of the prepared water and the water level.

3-Some studies have added external devices to the solar still. These devices either add an external filter to reduce the percentage of pollutants in oil well water or increase the condensation process.

4-Several studies have been conducted to study PCM use as a heat storage medium. Most studies used paraffin wax, which improved productivity by 77%. However, no other material has been tested.

5-Adding nanomaterials to paraffin wax to increase the heat reservoir's thermal capacity resulted in a 112% improvement in efficiency.

6-The use of wicks and improving the evaporation process and water absorption has been studied extensively, and it has been shown that jute is the best material.

7-Coating the tank's surface with a nanocomposite material led to a significant improvement in productivity, but other materials, such as graphene, need to be studied.

8-Most research has focused on increasing the evaporation process and improving the absorption of solar energy, so there is a need to study the efficiency of the condensation process and propose ways to increase it.

5. RECOMMENDATIONS

- Further Optimization of Condensation Processes. This might include investigating novel glass cover materials with enhanced thermal conductivity or anti-fogging properties.
- Exploring Novel Nanocomposite Materials for Enhanced Absorption and Storage, future work could delve into synthesizing and testing new combinations of nanoparticles (e.g., graphene-based, metallic nanoparticles, specific metal oxides) with various base materials to further improve solar absorptivity, thermal conductivity, and heat storage capacity within the still.
- Advanced Phase Change Material (PCM) Integration and Encapsulation: Beyond paraffin wax, future research could explore alternative PCMs with different melting temperatures suited for specific climate conditions or those with higher latent heat capacities.
- Synergistic Combination of Wicks/Reflectors with PCMs/Nanomaterials.

REFERENCES

[1] Al-Madhhachi, H., Min, G. (2018). Key factors affecting the water production in a thermoelectric distillation system. Energy Conversion and Management, 165: 459-464. https://doi.org/10.1016/j.enconman.2018.03.080

[2] Kumar, P.N., Manokar, A.M., Madhu, B., Kabeel, A.E., Arunkumar, T., Panchal, H., Sathyamurthy, R. (2017). Experimental investigation on the effect of water mass in triangular pyramid solar still integrated to inclined solar still. Groundwater for Sustainable Development, 5: 229-234. https://doi.org/10.1016/j.gsd.2017.08.003

[3] Murad, M.E., Alawee, W.H., Dhahad, H.A. (2024). Advanced techniques for augmenting the performance of double-slope solar stills: A comparative study. Desalination and Water Treatment, 320: 100581. https://doi.org/10.1016/j.dwt.2024.100581

[4] AL-Hudaib, H., Adamo, N., Bene, K., Ray, R., Al-Ansari, N. (2025). Application of decision support

systems to water management: The case of Iraq. Water, 17(12): 1748. https://doi.org/10.3390/w17121748

[5] Attia, M.E.H., Hussein, A.K., Rashid, F.L., Ali, B., Saggai, S., Biswal, U., Rout, S.K., Bdulameer, S.F., Barik, D. (2024). Use of electrolysis to produce H2 from natural and modified water. Energy Technology, 12(1): 2300918. https://doi.org/10.1002/ente.202300918

[6] Younis, O., Hussein, A.K., Attia, M.E.H., Aljibori, H.S.S., Kolsi, L., Togun, H., Jirawattanapanit, A. (2022). Comprehensive review on solar stills-latest developments and overview. Sustainability, 14(16): 10136. https://doi.org/10.3390/su141610136

[7] Hussein, A.K., Li, D., Kolsi, L., Kata, S., Sahoo, B. (2017). A review of nano fluid role to improve the performance of the heat pipe solar collectors. Energy Procedia, 109: 417-424. https://doi.org/10.1016/j.egypro.2017.03.044

[8] Rostami, S., Sepehirad, M., Dezfulizadeh, A., Hussein, A.K., Shahsavar Goldanlou, A., Shadloo, M.S. (2020). Exergy optimization of a solar collector in flat plate shape equipped with elliptical pipes filled with turbulent nanofluid flow: A study for thermal management. Water, 12(8): 2294. https://doi.org/10.3390/w12082294

[9] Hussein, A.K., Rashid, F.L., Rasul, M.K., Basem, A., Younis, O., Homod, R.Z., Abdulameer, S.F. (2024). A review of the application of hybrid nanofluids in solar still energy systems and guidelines for future prospects. Solar Energy, 272: 112485. https://doi.org/10.1016/j.solener.2024.112485

[10] Ghodbane, M., Hussein, A.K. (2021). Performance analysis of a solar-driven ejector air conditioning system under El-Oued climatic conditions, Algeria. Journal of Thermal Engineering, 7(1): 172-189. https://doi.org/10.18186/thermal.847334

[11] Hidouri, K., Togun, H., Rashid, F.L., Abed, A.M., Hussein, A.K., Ali, B., Biswal, U. (2021). Environmental studies for various simple and hybrid solar still configurations: A comprehensive review. Journal of Thermal Engineering, 10(6): 1698-1714. https://doi.org/10.14744/thermal.0000877

[12] Tiwari, G.N., Dimri, V., Singh, U., Chel, A., Sarkar, B. (2007). Comparative thermal performance evaluation of an active solar distillation system. International Journal of Energy Research, 31(15): 1465-1482. https://doi.org/10.1002/er.1314

[13] Gevorkov, L., Domínguez-García, J.L., Trilla, L. (2025). The synergy of renewable energy and desalination: An overview of current practices and future directions. Applied Sciences, 15(4): 1794. https://doi.org/10.3390/app15041794

[14] Al-Jaf, S.J., Al-Taai, O.T. (2020). Impact of ozone gas on air temperature change in Iraq and some surrounding countries. Journal of Physics: Conference Series, 1660(1): 012074. https://doi.org/10.1088/1742-6596/1660/1/012074

[15] Hussein, A.K. (2015). Applications of nanotechnology in renewable energies-A comprehensive overview and understanding. Renewable and Sustainable Energy Reviews, 42: 460-476. https://doi.org/10.1016/j.rser.2014.10.027

[16] Hussein, A.K., Walunj, A., Kolsi, L. (2015). Applications of nanotechnology to enhance the performance of the direct absorption solar collectors. Journal of Thermal Engineering, 2(1): 529-540. https://doi.org/10.18186/jte.46009

[17] Hussein, A.K. (2016). Applications of nanotechnology to improve the performance of solar collectors-Recent advances and overview. Renewable and Sustainable Energy Reviews, 62: 767-792. https://doi.org/10.1016/j.rser.2016.04.050

[18] Liu, C., Wu, Y., Li, D., Ma, T., Hussein, A.K., Zhou, Y. (2018). Investigation of thermal and optical performance of a phase change material filled double-glazing unit. Journal of Building Physics, 42(2): 99-119. https://doi.org/10.1177/1744259117708734

[19] Benabderrahmane, A., Benazza, A., Hussein, A.K. (2020). Heat transfer enhancement analysis of tube receiver for parabolic trough solar collector with central corrugated insert. Journal of Heat Transfer, 142(6): 062001. https://doi.org/10.1115/1.4046440

[20] Nayi, K.H., Modi, K.V. (2018). Pyramid solar still: A comprehensive review. Renewable and Sustainable Energy Reviews, 81: 136-148. https://doi.org/10.1016/j.rser.2017.07.004

[21] Hashim, A.Y., Al-Asadi, J.M., Alramdhan, W.T. (2010). An attempt to solar still productivity optimization; solar still shape, glass cover inclination and inner surface area of a single basin solar still, optimization. Basrah Journal of Science, 28(1): 39-48.

[22] Hussein, A.K., Rashid, F.L., Togun, H., Sultan, H.S., Homod, R.Z., Sadeq, A.M., Kolsi, L. (2024). A review of design parameters, advancement, challenges, and mathematical modeling of asphalt solar collectors. Journal of Thermal Analysis and Calorimetry, 149(1): 41-61. https://doi.org/10.1007/s10973-023-12674-4

[23] Li, D., Li, Z., Zheng, Y., Liu, C., Hussein, A.K., Liu, X. (2016). Thermal performance of a PCM-filled double-glazing unit with different thermophysical parameters of PCM. Solar Energy, 133: 207-220. https://doi.org/10.1016/j.solener.2016.03.039

[24] Hussein, A.K., Attia, M.E.H., Abdul-Ammer, H.J., Arıcı, M., Hamida, M.B.B., Younis, O., Abidi, A. (2023). Experimental study of the impact of low-cost energy storage materials on the performance of solar distillers at different water depths. Solar Energy, 257: 221-230. https://doi.org/10.1016/j.solener.2023.04.013

[25] Basim, M.A., Alomar, O.R. (2024). Impacts of adding porous media and phase change material on performance of solar water distiller system under Iraq climatic condition: An experimental study. Energy Storage, 6(6): e70038. https://doi.org/10.1002/est2.70038

[26] Attia, M.E.H., Hussein, A.K., Radhakrishnan, G., Vaithilingam, S., Younis, O., Akkurt, N. (2023). Energy, exergy and cost analysis of different hemispherical solar distillers: A comparative study. Solar Energy Materials and Solar Cells, 252: 112187. https://doi.org/10.1016/j.solmat.2023.112187

[27] Hussein, A.K., Rashid, F.L., Rasul, M.K., Basem, A., Younis, O., Homod, R.Z., Rout, S.K. (2025). Enhancing hemispherical solar stills thermal performance by using nanotechnologies–recent advances and overview. Environmental Technology Reviews, 14(1): 127-141. https://doi.org/10.1080/21622515.2025.2458093

[28] Younis, O., Hussein, A.K., Attia, M.E.H., Rashid, F.L., Kolsi, L., Biswal, U., Alazzam, A. (2022). Hemispherical solar still: Recent advances and development. Energy

Reports, 8: 8236-8258. https://doi.org/10.1016/j.egyr.2022.06.037
[29] Hammoodi, K.A., Dhahad, H.A., Alawee, W.H., Omara, Z.M., Yusaf, T. (2023). Pyramid solar distillers: A comprehensive review of recent techniques. Results in Engineering, 18: 101157. https://doi.org/10.1016/j.rineng.2023.101157
[30] Hussein, A.K., Rashid, F.L., Abed, A.M., Sultan, H.S., Togun, H., Attia, M.E.H., Khutar, N.M. (2024). Review of recent designs, performance, and configurations for the pyramid solar still. International Journal of Energy and Water Resources, 9: 1145-1176. https://doi.org/10.1007/s42108-024-00309-9
[31] Abd-El-Mooty, M., Kansoh, R., Abdulhadi, A. (2016). Challenges of water resources in Iraq. Hydrology Current Research, 7(4): 1000260. https://doi.org/10.4172/2157-7587.1000260
[32] Algaim, H., Alasdi, J.M., Mohammed, A.J. (2013). Study of efficiency for the pyramidal solar still (PSS) in Basra city, Iraq. Archives of Applied Science Research, 5(5): 62-67.
[33] Al-Madhhachi, H., Smaisim, G.F. (2021). Experimental and numerical investigations with environmental impacts of affordable square pyramid solar still. Solar Energy, 216: 303-314. https://doi.org/10.1016/j.solener.2020.12.051
[34] Shareef, A.S., Kurji, H.J., Hamzah, A.H. (2024). Modifying performance of solar still, by using slices absorber plate and new design of glass cover, experimental and numerical study. Heliyon, 10(1). https://doi.org/10.1016/j.heliyon.2024.e24021
[35] Al-Hamadani, A.A., Yaseen, A.H. (2021). A multistage solar still with photovoltaic panels and DC water heater using a pyramid glass cover enhanced by external cooling shower and PCM. Heat Transfer, 50(7): 7001-7019. https://doi.org/10.1002/htj.22214
[36] Abed, A.F., Alshukri, M.J., Hachim, D.M. (2024). Improving solar still performance via the integration of nanoparticle-enhanced phase change materials: A novel pyramid-shaped design with a numerical simulation approach. Journal of Energy Storage, 97: 112980. https://doi.org/10.1016/j.est.2024.112980
[37] Ahmed, I.H., Al-Murshedi, T.F., Jawad, R.A.M., Hashim, A.K., Ovuoraye, P.E. (2023). Experiment of treating polluted wastewater resulting from petroleum refineries using a pyramid solar still distillation system to eliminate hydrocarbon toxicity. Desalination and Water Treatment 313: 106-115. https://doi.org/10.5004/dwt.2023.30076
[38] Al-Hamadani, A.A., Yaseen, A.H. (2019). Experimental study of multi effect stages pv panels solar still to enhance the productivity by utilizing water heater and cooling fan. Journal of University of Babylon for Engineering Sciences, 27(2): 275-286.
[39] Essa, F.A., Alawee, W.H., Mohammed, S.A., Abdullah, A.S., Omara, Z.M. (2021). Enhancement of pyramid solar distiller performance using reflectors, cooling cycle, and dangled cords of wicks. Desalination, 506: 115019. https://doi.org/10.1016/j.desal.2021.115019
[40] Alawee, W.H., Dhahad, H.A., Ahmed, I.S., Mohammad, T.A. (2021). Experimental investigation on an elevated basin solar still with integrated internal reflectors and inclined fins. Journal of Engineering Science and Technology, 16(1): 762-777. https://doi.org/10.5004/dwt.2021.26730
[41] Alawee, W.H., Mohammed, S.A., Dhahad, H.A., Abdullah, A.S., Omara, Z.M., Essa, F.A. (2021). Improving the performance of pyramid solar still using rotating four cylinders and three electric heaters. Process Safety and Environmental Protection, 148: 950-958. https://doi.org/10.1016/j.psep.2021.02.022
[42] Hammoodi, K.A., Dhahad, H.A., Alawee, W.H., Omara, Z.M. (2024). Energy and exergy analysis of pyramid-type solar still coupled with magnetic and electrical effects by using MATLAB simulation. Frontiers in Heat and Mass Transfer, 22(1): 217-262. https://doi.org/10.32604/fhmt.2024.047329
[43] Omara, Z.M., Alawee, W.H., Mohammed, S.A., Dhahad, H.A., Abdullah, A.S., Essa, F.A. (2022). Experimental study on the performance of pyramid solar still with novel convex and dish absorbers and wick materials. Journal of Cleaner Production, 373: 133835. https://doi.org/10.1016/j.jclepro.2022.133835
[44] Hammoodi, K.A., Dhahad, H.A., Alawee, W.H., Omara, Z.M. (2023). Enhancement of pyramid solar still productivity through wick material and reflective applications in Iraqi conditions. Mathematical Modelling of Engineering Problems, 10(5): 1548-1556. https://doi.org/10.18280/mmep.100506
[45] Fadhil, O.T., Abed, W.M. (2024). Experimental investigation on a pyramid solar still under Iraq climate conditions. AIP Conference Proceedings, 3009(1): 030014. https://doi.org/10.1063/5.0190411
[46] Hammoodi, K.A., Dhahad, H.A., Alawee, W.H., Omara, Z.M., Essa, F.A., Abdullah, A.S. (2023). Improving the performance of a pyramid solar still using different wick materials and reflectors in Iraq. Desalination and Water Treatment, 285: 1-10. https://doi.org/10.5004/dwt.2023.29226
[47] Ali, N., Ali, O.M. (2024). Effect of square and perforated fins on improving the efficiency of the classic pyramidal solar still. NTU Journal of Renewable Energy, 6(1): 68-77. https://doi.org/10.56286/4988k764
[48] Mohammed, S.A., Basem, A., Omara, Z.M., Alawee, W.H., Dhahad, H.A., Essa, F.A., Al-Amiery, A.A. (2022). Pyramidal solar stills via hollow cylindrical perforated fins, inclined rectangular perforated fins, and nanocomposites: An experimental investigation. Sustainability, 14(21): 14116. https://doi.org/10.3390/su142114116
[49] Alawee, W.H., Essa, F.A., Mohammed, S.A., Dhahad, H.A., Abdullah, A.S., Omara, Z.M., Gamiel, Y. (2021). Improving the performance of pyramid solar distiller using dangled cords of various wick materials: Novel working mechanism of wick. Case Studies in Thermal Engineering, 28: 101550. https://doi.org/10.1016/j.csite.2021.101550
[50] Alawee, W.H., Abdullah, A.S., Mohammed, S.A., Dhahad, H.A., Omara, Z.M., Essa, F.A. (2022). Augmenting the distillate yield of cords pyramid distiller with baffles within compartments. Journal of Cleaner Production, 356: 131761. https://doi.org/10.1016/j.jclepro.2022.131761

NOMENCLATURE

CCPSS convex cylinder, pyramid solar still

CDPSS	dish absorber pyramid solar still
CPSD	pyramid solar distiller
CPSS	convention pyramid solar still
CWSS	modified solar distiller
CWPSS	cord wick pyramid solar still
EMPSS	electro-magnetic pyramid solar still
HCPF	hollow cylindrical and perforated fins
IPRF	inclined perforated rectangular fins
LCWPSS	light cotton wick pyramid solar still
MPSS	magnetic pyramid solar still
MPSSRC	modified pyramid solar still with rotating cylinders
PCM	phase change material
PSS	pyramidal solar still
PSS-HCPF	pyramidal solar still with hollow perforated cylindrical fins
PSS-IPRF	pyramidal solar still with inclined perforated rectangular fins
Rpm	revolutions per minute
RSS	reference solar still
SBSS	single basin solar still
TiO_2	titanium dioxide
CuO	cupper oxide