Desalination 532 (2022) 115692

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

An extensive review of performance enhancement techniques for pyramid solar still for solar thermal applications

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HIGHLIGHTS

- Review researchers advancements made to the pyramid solar still to enhance the distillate output.
- Different aspects in improving the performance of a pyramid solar still discussed in tabular form.
- Scope of further research & recommendations of pyramid solar still is also presented.

ARTICLE INFO

Keywords:
Solar distillation
Performance enhancement
Pyramid solar still
Distillate output

ABSTRACT

Due to the rapid increase on world population, the demand for potable water is also getting increased. The solar distillation process is one among the prominent options, for those facing shortage of water in rural areas. Many researchers have put tremendous effort in designing a solar still with better efficiency in the last decade. Current review article demonstrates the recent studies carried out on pyramid solar still to enhance the distillate output. It includes the use of use of fins, phase change materials, coatings, flat plate collector, and evacuated tube collector to enhance the distillate output of pyramid solar still. Comparison of various parameters for different solar distillation system and various aspects in improving the performance of a pyramid solar still also discussed in tabular form. At last, Scope of further research & recommendations for Pyramid solar still is added for help to researchers.

1. Introduction

The dependency on traditional methods utilizing renewable energy source for healthy and safe water is grooming across the globe. The presence of water is that fundamental necessity for all people and animals alive on earth especially in arid region, isolated areas and deserts. Many solar still designs that enhance freshwater productivity have been evolved in the last three decades. Nayi et al. [1] states that earth contains abundant of water, which covers approximately over two-third of its area. The greater part of the accessible water in present scenario is available as seawater or icecaps or combined with soil moisture within glacial areas. Over 97% world's water becomes not use for drinking purpose, 2% of clean water using drinking and other uses. Both forms don't seem to be easily reachable for human purpose. About 1% of the remaining water is to be accessed by all life on earth. Unfortunately, rapid increase of world's population leads to shortage of water

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https://doi.org/10.1016/j.desal.2022.115692
Received 16 January 2022; Received in revised form 5 March 2022; Accepted 8 March 2022
Available online 30 March 2022

circulation throughout the planet. Tiwari et al. [2] have presented that in keeping with World Health Organization (WHO), the appropriate furthest reaches of saltiness in water is 500 ppm and a couple of extraordinary reasons permitted up to 1000 ppm. The majority of the open water on globe has the saltiness up to 10,000 ppm, while seawater by and large has the saltiness scope of 35,000–45,000 ppm inside the style of complete salinity. The researchers suggested that using water with hardness less than 500 ppm can rectify the above problems and that can be achieved through proper desalination strategies.

Bulk deaths and diseases are caused by consuming unsafe potable water in developing nations [3]. Practically 50% of all passings youngsters are stricken by diarrhea and inhaling diseases within the developing countries, most of them are caused by waterborne pathogens. Panchal et al. [4] mentioned that solar still may be a mechanism, which is employed for purification process and classified by many ways. Generally, water absorbs solar light and evaporates to generate distillate output in a typical solar still, while, active solar still needs some mechanical source within the collectors or thermal storage materials assisted with solar power. As a result, an active solar still utilization as measured by distillate output productivity is higher than a solar still that is powered by the sun passively, resulting in higher quality [6]. Mamlook et al. [5] have revealed the most significant factors influencing productivity of solar still as environmental temperature, air velocity, incident radiation, water level in the basin and salt concentration. Also, authors suggested that high priority should be given for the above mentioned factors while designing productivity enhancement technique for solar still.

In this present study research works related to conventional and pyramid solar stills' performance that are carried out up to 2022 are collected and studied thoroughly. The year-wise distribution of key papers in the area of performance enhancement of solar stills is shown in Fig. 1. The procedure followed in this review paper can be clearly understood from Fig. 2.

1.1. Solar still

Solar still is a device to convert saline water into portable water. A conventional solar still [7] is specified using technical aspects such as basin area, glass area, glass thickness, number of glass and slope of glass. The conventional solar still (CSS) is inexpensive to manufacture and maintain, making it more cost effective. This form of solar still can be created with materials that are readily available in the area. Because of the black surface capable of absorbing more heat, the basin is painted black. Insulating materials such as wood and sawdust are utilized to reduce heat loss from the basin. For fast evaporation, brackish water is poured inside the still basin. Due to the partial pressure created, the water evaporates and condenses on the inner surface of the glass, forming water droplets. Due to evaporation and condensation, water droplets formed on the inside surface of the glass, collected to the bottom and were kept as freshwater in a separate tank. Chaurasiya et al. [8] reviewed the techniques for productivity improvement in solar stills and concluded that passive solar stills have poor efficiency and distillate yield.

Panchal et al. [9] in their paper stated that during the demand for water in the current environmental condition, distillation technology would turn out to be popular. Many countries within the globe, having a high radiation intensity, the demand of portable water may be fairly reduced. Tiwari et al. [2] presented the non-traditional techniques to clean the contaminated water and conformed that the foremost well-known technique is distillation process. It must be built by locally existing materials with simple technology and no experts are needed, because of this it may be used everywhere with minimal maintenance problems. Many researchers have attempted to boost the still productivity by using various design and operational parameters. They success of those designs are proven by the generated potable water from saline water. Different parameters associated with solar still were analyzed and the simulated results were compared with experimental results by many researchers. The key discovery is that simulated hourly yield and cumulative yield output are quite similar to experimental data. They also demonstrated that the productivity of the still is proportional to the qualities of various temperatures recorded at different places in the still. Jobrane et al. [10] investigated the performance of several designs of solar stills with wick structures. It was discovered that the efficiency of the still was around 60%. Tiwari et al. [11] investigated the planning

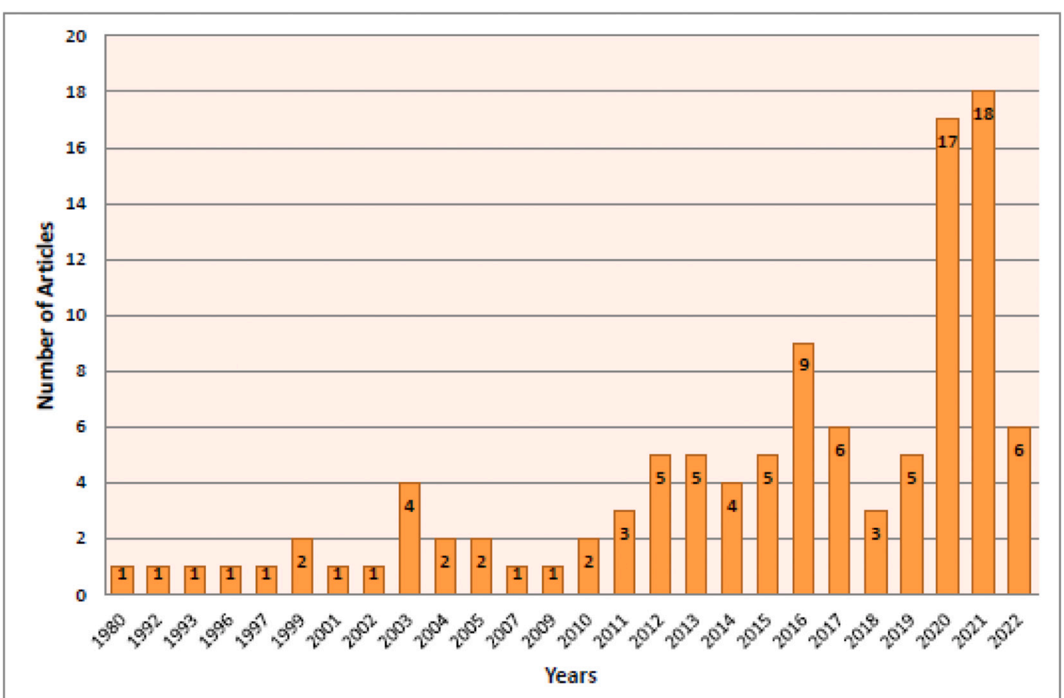

Fig. 1. Number of papers collected year-wise for review work of solar still.

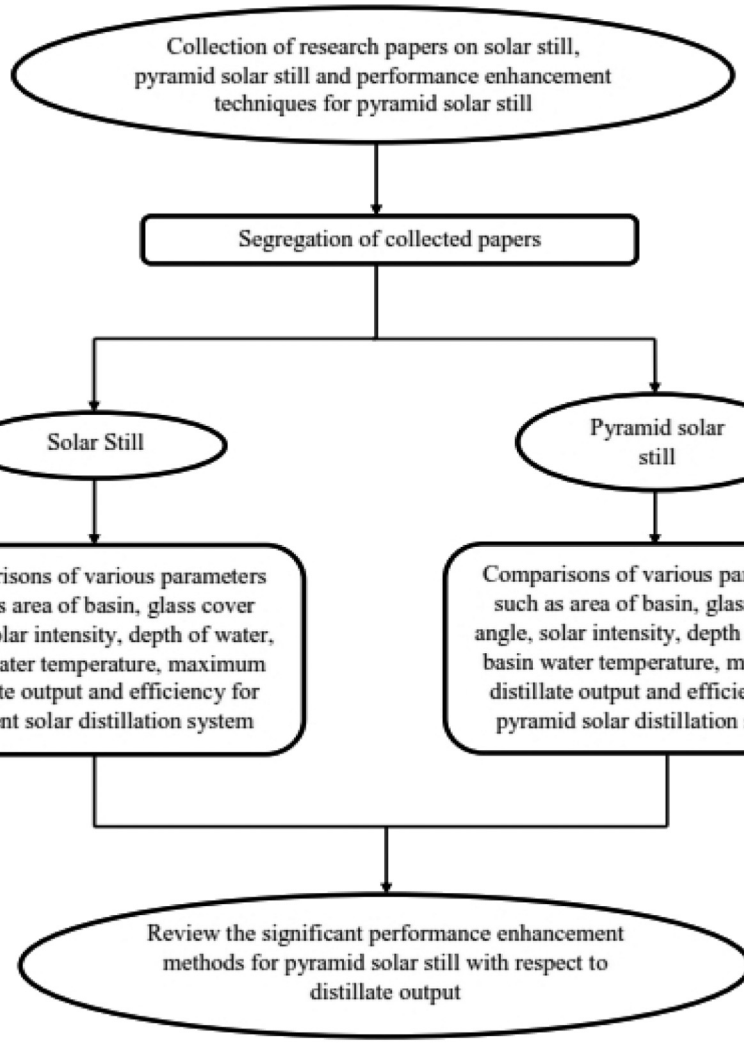

Fig. 2. Steps followed in the present work.

parameters for various components of a multi-basin solar still. The authors discovered that a lower water depth results in the highest daily production. Sodha et al. [12] studied the performance of a double basin solar still and discovered that increasing the insulation thickness to 4 cm can enhance the distilled output yield. The results show that average daily output of the still was 36% ahead of that of conventional still. Patel et al. [13] explains that during the salt harvesting season, most of the salt workers need to have clean water within the salt farm where the bottom water is salty. The authors have designed and constructed stepped type basin still. For improving the performance of solar still is integrated with evacuated tube collector and it is called Active solar still. By enhancing the evacuated tube collector within the still basin, the maximum daily yield of 8.1 l/m^2/day was achieved. Al-Hayek and Bardan [14] have investigated the impact of various solar still designs. The yield of asymmetric greenhouse-type solar stills outperforms symmetric-type sun stills by 20%, according to the authors. They also proposed that, in order to increase the productivity of solar stills, water depth and sun intensities should be taken into account. Voropolus et al. [15] examined the still characteristics as well as predicament vessel. Based on the result, they showed that the hybrid system delivered larger productivity of distilled output. Nafey et al. [16] experimented with black rubber and black gravels inside the basin of a traditional solar still. The heat storage medium was the sandwiched layer. According to the findings of the experiments, brine production of 60 l/m^2 enhances productivity by 20% in black rubber of 10 mm layer, whereas brine output of 20 l/m^2 boosts productivity by 19% in black gravels of 20 to 30 mm layers. They came to the conclusion that black gravel absorbs and releases incident solar radiation faster than black rubber. Naim et al. [17] found that by using charcoal granules as absorbing medium within the solar still, the distillate output gets increased by 15% as a replacement of wick-type solar stills. Kalogirou [18] investigated different systems in terms of key criteria such as preliminary energy consumption, sea water treatment requirements, cost and suitability for alternative energy operation. The multiple-effect boiling system is also shown to be effective after studying various types of processes, leading to the conclusion that the multiple-effect stack type evaporator is best suited for alternative energy consumption. Meukam et al. [19] have experimentally studied two solar stills like single section and double section with the slope angle of 16° for alcohol distillation process. Panchal et al. [20] reviewed the effect of varied parameters like design, operational and climatic variables that contributes to the solar still's performance. Panchal et al. [21] have discussed various approaches for improving distillate yield from active solar stills. Essa et al. [22] have suggested that the stepped solar distiller, with or without condenser to enhance the distillate output. Sathyamurthy et al. [23] has stated that the cost of potable water from the modified still grows dramatically as the volume of fresh water produced decreases due to increase of solar still's fabrication cost. Panchal et al. [24] discovered that addition of fins to a double basin solar still with evacuated tubes increased distillate yield by 25%. Bumataria et al. [25] used mono and hybrid nanofluids in heat pipes as a new trend which aimed to improve the heat transfer rate performance. Panchal et al. [26] have proved that the improvement of distillate yield with experiments on fins in solar still.

Panchal et al. [27] have reviewed the energy storage materials utilized by different authors to boost the distillate yield from the solar still. They concluded that in addition of various energy absorbing materials like charcoal particles, absorbing plates, black rubber, black ink, black dye, high heat absorbing stones, coated and uncoated materials placed inside the basin, causes distilled output by the solar still's productivity could be improved. Panchal et al. [28] built a double basin solar still with evacuated tubes at a depth of two centimetres within the basin. The authors improved the still's output by using energy storage materials such as pebbles, black granite gravels, and calcium stones. The end result shows that the calcium stones gave better performance than black granite gravels and pebbles during sunshine and off-sunshine hours. Also, they found that by augmenting the still with evacuated tubes, the productivity of the solar still can be enhanced. Panchal et al. [29] investigated with floating plates made of aluminium and iron within the solar still. They found that aluminium plate delivered better performance than iron plate in terms of distillate output. Panchal et al. [30] varied the water levels as 0.03 mm, 0.04 mm, and 0.05 mm and tested the double basin solar still with evacuated tubes. Supported by experimentation, the daily yield of solar still has obtained 11.064 kg at 0.03 mm water level. They concluded that lower water depth increased the distillate output as compared with higher water depth. Algaim et al. [31] claimed that the pyramid and simple solar still could produce maximum daily distillate output of 7.368 l and 5.57 l respectively. Khalifa et al. [32] have carried out research on a basin-type improved thermal still. They examined the still by passing preheated feed water within the solar still which resulted in better performance and efficiency. Kalita et al. [33] in their work, designed and constructed an absorber plate and attached it with the basin and also studied the effect of various performance parameters of the solar still. The experiments were conducted at four different stages. The distilled production was 3.94 l/m^2/day at the fourth stage, which is 117.32% more than the first stage output. Kabeel et al. [34] studied the performance of a solar-powered membrane distillation device. According to the results, the still's maximum distillate yield and efficiency were 33.55 l/day and 49.01%, respectively. Fath [35] conducted an experiment with two effects of the solar distillation unit by improving the performance of the still. Under the atmospheric conditions of Dhahran, Asia, the best daily distillate yield was 10.7 l/m^2/day. Eltawil et al. [36] worked on various customised solar stills and compared them to standard solar stills. A flat plate collector and an exterior condenser are used in the redesigned still. Based on the investigation, authors found that the productivity increased by 51% for external condenser and 72% for flat plate collector compared to conventional solar still. El-Sebaii et al. [37] examined the performance of triple-basin solar stills. During the day, the highest productivity found in the lower basin is greater than the productivities of the centre basin and bottom basin, and at midnight, these activities are reversed. They concluded that the daily distilled output was 12.635 l/m^2/day. Eldalil et al. [38] investigated a new way to enhance solar still performance through the use of vibratory harmonic effect The distillate yield and efficiency of a solar still improved by adding black helical wires were found to be 3.4 l/m^2/day and 35%, respectively. The distillate yield and efficiency were also determined to be 5.8 l/m^2/day and 60% with vibrations. Cappelletti et al. [39] constructed a double basin solar still to boost the productivity of the distilled output by utilizing heat energy released from condensing water steam. The daily productivity range was examined and found to be 1.7 to 1.8 l/m^2/day. They also discovered that the still's efficiency was 16%. Bait et al. [40] studied on improving the performance of tubular solar collectors, discovered that the daily productivity of distilled output for passive stills was 2.77 kg/m^2 and that for active stills was 4 kg/m^2. Also, the improvement in performance was noticed and it was approximately 31%. Agrawal et al. [41] determined that the modified solar still produces 62% more distilled output than a regular solar still. Under equal meteorological conditions, the distillate production of a still using sponge cubes ranges from 18% to 273%. They also recommended that jute fabric be used to increase the output of solar stills in areas with a lot of difficult terrain. Yadav et al. [42] have studied different designs of still with the area of 1 m^2 and obtained highest productivity and thermal efficiency range of 12.48 l/day and 17.4 to 45% by evacuated tube coupled with solar still system. Abu-Arabi et al. [43] examined three different types of solar stills: regenerative, conventional, and still with double glass cover cooling. According to study, the regenerative still produced 70% more energy than a conventional solar still. Salem et al. [44] examined the performance of a solar distillation unit experimentally. In order to boost the productivity of the distilled output, floating sponge layer is introduced into the solar still. The daily productivity of and thermal efficiency of the still have been calculated to be around 5 l/m^2/day and 37%, respectively based on the experiments. In addition, it has been discovered that the cost of a litre of clean water can be lowered by 35% when compared to a typical still unit. Naveenkumar et al. [45] investigated phase transition materials such as a mixture of micro aluminium powder and wax, saturated fatty acid, octadecanoic acid, capric-palmitic acid, dodecanoic acid, bitumen, tetradecanoic acid, salt, permanganate of potash, sodium acetate, and paraffin in a variety of solar stills. The researchers discovered that wax produced the highest efficiency, exergy efficiency, and distillate yield when compared to other phase transition materials in the still basin. They also discovered a 37% and a 12% increase in thermal efficiency and distillate production, respectively. Panchal et al. [46] reviewed the productivity of the distilled output of a solar still using thermoelectric modules, solar flat plate collectors, evacuated tubes collectors, and compound parabolic concentrators. The thermoelectric modules with solar still were found to be better suitable for obtaining distilled water from groundwater. Das et al. [47] suggested various ways to improve the solar still's productivity. The authors of this study focused on improving the productivity of stills by changing the absorber plate, condenser attachment, use of reflectors, humidification-dehumidification units, coupled thermal energy storage materials, use of Nanoparticles, photovoltaic thermal module combination, and thermoelectric coolers. Also they suggested that by using sand as heat absorbing medium, considerable decrease in the price of the system may be obtained. Attia et al. [48] investigated the impact of aluminium balls on distillate output productivity in a solar distillation unit. The daily productivity of modified solar still and traditional solar still is 5.09 kg and 3.71 kg, respectively. They discovered that the daily thermal efficiency (TE) and exergy efficiency (EE) of conventional solar still are 27.5% and 1.84%, respectively, while the same terms for modified solar still are 40.1% and 2%. It has been concluded that for modified solar still, thermal and exergy efficiency increased by 31.6% and 36.3% than conventional solar still. Bamasag et al. [49] investigated a solar-heated direct contact membrane distillation system that uses evacuated tube collectors. The experiments are conducted in indoor and outdoor conditions. The results show that in the indoor environment, the advance in permeate solar flux was higher at lower feed flow rates. Elashmawy [50] compared the performance of a tubular solar still using a rectangle trough with clothing and a half-cylindrical trough without clothing. The researcher got a maximum of 1.66 l/day without clothing from a tubular solar still with a half-cylindrical trough. It was concluded that tubular solar still was best suited for compact towns and houses with a large roof surface. Rahbar et al. [51] in their study, during winter days in Iran assessed the performance of tubular and triangular solar stills. The tubular solar still showed an improvement in the distillate yield by 20% when compared to triangular solar still. For tubular and triangular solar stills, experimental thermal efficiencies of 41% and 35% were obtained. Asbik et al. [52] undertaken exergy analysis of a passive solar still with organic PCM as a heat storage mechanism. As a phase change material, paraffin wax was used. It was discovered that the use of PCM resulted in a significant increase in water productivity. Tabrizi et al. [53] studied the impact of a thermal energy storage device for latent heat on the performance of a cascade solar still. Organic paraffin wax PCM was used in the experiment. The lowest flow rate yielded the highest production. Ansari et al. [54] revealed that the choice of PCM is based solely on the maximum temperature of saline water. Rao et al. [55] reported that the thermal stability of the PCM was improved, and it prevented the loss of thermal deposition when paraffin wax containing 3% aluminium nitrate was used. Moses et al. [56] experimented with carbon nanotubes and indicated that they can increase the productivity of a single-basin solar still by almost 50%. Mohamed et al. [57] constructed a solar still with porous basalt stones and compared with a solar still without stones and found that the exergy efficiency increased by 123%. Using an evacuated tube heat pipe solar collector (ETHP-SC) and a new type of external condenser, Shoeibi et al. [58] researched single-slope solar stills. According to the findings, fresh water production utilizing an external condenser and ETHP was 2.13 times than that of traditional process. Shoeibi et al. [59] have investigated the solar still's output and found that it increased by roughly 5.7% after the basin being nano-coated. Hussain et al. [60] have extensively studied the heat transfer phenomenon of solar still under double diffusive natural convention. Shoeibi et al. [61] studied the effect of fins on the performance of solar electrical and thermal utilities. Shoeibi et al. [62], using hybrid nanofluid glass cooling technique, created a new model for calculating the freshwater productivity of solar still. On the thermoelectric solar still, economic and environmental analyses are carried out by Shoeibi [63]. Siamak et al. [64] have identified the sodium hypochlorite generator's intake discharge rate as 62% of the desalination system's brine water exit discharge rate. The vacuum desalination system's financial analysis was studied by Kariman et al. [65]. Siamak et al. [66] found that the linear solar collectors in the cogeneration system generates 16,479 l of fresh water a day and also, lowers the CO_2 emissions by 37,216 t per day. For dynamic performance modelling of an upgraded solar still a machine learning prediction approach was used by Ali et al. [67]. Jafari et al. [68] suggested that the ideal places for solar still installation are hot, arid areas with high solar radiation or those with a higher water tariff. The improvement in solar intensity and efficiency is frequently attributed to a drop in feed water temperature. For outdoor conditions the typical H_2O production is 0.37 kg/m^2/h for single absorbing area. The entire outcome of the setup was found to be 0.7 kg/day of water. Various designs of solar stills have been evaluated by a number of reviewers [69–71]. From the past studies, it is marked that solar distillation method may be a short term solution to produce H_2O. The comparison of various parameters such as area, slope angle, solar intensity, water depth, water temperature, wind speed, productivity of distillate output, still efficiency and enhancement of various methods for solar stills are validated in Table 1.

From Table 1 it is clearly understood that conventional solar stills have efficiency less than 45%. Particularly in Indian conditions, the still efficiency is less than 40%. Majority of the researchers reported the improvement in distillate output but failed to record the still's efficiency. However, a key finding on pyramid solar still is reported that the efficiency of pyramid solar still (PSS) is above 60%. This is an inspiration for the present study on PSS. Many studies have been carried out to improve the distillate yield of passive and active solar stills. The reported literatures are focused on technology improvement and advancement within the area of solar still, parameter optimization and still methods that are essential to overcome the drawbacks of conventional solar still. The four side triangular solar still is one among the prominent methods to cross the restrictions imposed by conventional solar still. Based on the previous review, current study focuses on advanced technologies and methods used by researchers for improving the productivity of distilled output of pyramid solar still system.

As pyramid solar still shows promising improvement in productivity, a detailed extensive review is carried out on performance enhancement techniques. Different methodologies and the operating parameters related to pyramid solar still are also reviewed and presented for further research. The objective of this study is to review all of the advancements made to the PSS to enhance the distillate output.

2. Pyramid solar still

Pyramid solar still [73] is an effective method used for converting brackish water to potable water. Triangular glass covers are used to form the top surface of pyramid still. Two designs of glass cover are adopted during the design of top surface which is above the basin of pyramid solar still. One is three faced triangular shape still and the other one is four faced triangular shape still. Majority of the researchers focused on additional attachments like fins, heat pipes and wick material for improving the performance of the still. Few others concentrated on phase change materials, nano particles and nano tubes for enhancing the distillate output. The performance of the pyramid solar still is influenced by design, operating and ambient parameters and the key variables can be understood from Fig. 3. The above approaches adopted by the researchers for improving the productivity of pyramid solar stills are discussed in the following section.

2.1. Various methods for increasing the production of the pyramid solar still

Kabeel et al. [74] made an evaluation on the performance and a comparison study between a modified pyramid solar still and a traditional pyramid solar still Authors have constructed and investigated for 3 four side triangular shape still at the atmospheric conditions for Egypt. In the experimentation, three kinds of set-ups were dispersed to boost productivity of solar still with the basin area of 0.64 m^2. From the experimental investigation, authors found that 4.02 l/day, 5.75 l/day and 8.1 l/day for three kind of still setups. Table 2 shows that by adding circular fins with PCM, day by day productivity and efficiency are enhanced by 101.5% and 99.5% over that of the traditional four faced triangular still.

Fallahzadeh et al. [75] suggested a new model that can improve the distillate of conventional pyramid still. As shown in Fig. 4, the authors investigated two different working fluids (water and ethanol) with three different filling ratios in Mashhad, Iran, using a typical pyramid still combined with an evacuated tube reflector. They stated that putting a heat pipe solar collector in a conventional pyramid still enhanced the temperature difference between the glass cover and the water within the basin, hence increasing the solar still's hourly and cumulative production. For both fluids, three different filling ratios of 30%, 40%, and 50% were used during the experiment. According to the findings, the accumulated yield for the modified pyramid solar still and conventional pyramid solar still was enhanced to 6.97 l/m^2 and 3.300 l/m^2, respectively. Manokar et al. [76], in their work, looked at the impact of fluctuating water level from 1 to 3.5 cm on the still output by with and without insulation. The authors designed and used a square pyramid with a basin size of 0.25 m^2.

The still was manufactured by Galvenized Iron (GI) sheet as basin material and acrylic glass material as top cover to boost the productivity. With and without insulation of the pyramid solar still by 1 cm water level within the basin, the maximum distillate productivity was 3.72 kg/m^2 and 3.27 kg/m^2. Kumar et al. [77] coupled pyramid still with conventional solar still to enhance the clean water productivity as shown in Fig. 5. Authors maintained the water in the still basin at various levels, in order to increase the productivity. Based on the analysis, authors observed that minimum water depth of 0.02 m in the still basin produced 79.05% distillate output in the coupled system. Kabeel et al. [78] conducted a comparison study of classic pyramid solar stills and modified pyramid solar stills in climate conditions of Egypt. Both stills are made of GI sheet with a thickness of 1.5 mm and have a basin dimension of 750 mm × 750 mm × 150 mm, as illustrated in Fig. 6.

The modified pyramid solar still was equipped with a high thermal conductivity graphite plate (thickness 25 mm) and a cooling glass cover. The graphite plate is used to store energy during periods of high

Table 1
Comparison of various parameters for different solar distillation system.

S·no	Reference	Location	Area (m^2)	Slope angle (deg)	Solar intensity (W/m^2) or (MJ/m^2) per day	Water depth (m)	Basin water temperature (°C)	Wind speed (m/s)	Maximum/average productivity (l/m^2) or (kg/m^2) or (ml/m^2) per day	Still efficiency (%)	Inference
1	Panchal et al. [9]	Patan	1	23	700	–	50.2	–	3.53	–	–
2	Tayeb et al. [72]	Egypt	0.24	–	3500	–	63	–	300	14.9 to 21.8	8.98 to 49.87%
3	Sodha et al. [12]	India	0.72	10	342.5	0.06	–	–	–	–	36%
4	Patel et al. [13]	India	2.1	19	980	0.04	70.5	–	8.1	–	–
5	Al-Hayek and Bardan [14]	Jordan	1	35	–	0.02	Symmetric: 85 Asymmetric: 75	–	3 to 5.5	–	Asymmetric still 20% greater than the symmetric still
6	Voropolus et al. [15]	Greece	12.5	30	17.19	–	70	–	Day: 38% Night: 64%	–	–
7	Nafey et al. [16]	Egypt	0.25	15	–	–	–	–	–	–	At 60 l/m^2 brine, productivity rises 20%, while at 20 l/m^2 brine, productivity rises 19%.
8	Naim et al. [17]	Egypt	0.5	–	–	–	–	–	1.36	–	15%
9	Meukam et al. [19]	–	–	16	–	–	–	–	–	–	48% for single slope and 71% for double slope
10	Panchal et al. [28]	India	0.326	35	800	0.02	–	–	Calcium: 4.3 Black gravels: 3.4	–	Calcium stones 74% higher than black gravels
11	Panchal et al. [4]	India	1	35	800	0.02	–	–	–	–	56% by introducing evacuated tubes and 67% by combination evacuated tubes and 10 mm to 30 mm size black granite gravel
12	Panchal et al. [29]	India	1	30	800	0.04	–	–	Al plate: 3.7 GI plate: 3.1	–	145% for aluminium and 122% for Galvanized iron plate
13	Panchal et al. [30]	India	0.326	35	800	0.03 to 0.05	–	–	11.064	–	Productivity increases 107% at 0.03 m and 102% at 0.04 m water depth than 0.05 m
14	Algaim et al. [31]	Iraq	0.25	–	–	–	–	–	PSS: 7.36 SSS: 5.55	PSS: 66.5% SSS: 43.4%	Pyramid solar still 132% greater than simple solar still
15	Kalita et al. [33]	India	1	27	130 to 859	–	–	–	3.94	–	4 stage double glass step 117.32% higher than double step basin
16	Kabeel et al. [34]	Egypt	–	–	–	–	–	–	33.55	49.01%	–
17	Fath [35]	Egypt	–	–	900	–	–	–	10.7	–	–
18	Eltawil et al. [36]	Egypt	0.5	30	–	–	–	–	–	–	56% for passive still and 82% for active still
19	El-Sebaii et al. [37]	Egypt	–	–	1057	–	74.1	–	12.635	–	–
20	Eldalil et al. [38]	Egypt	2.064	30	900	–	–	–	5.8	60%	132%
21	Cappelletti et al. [39]	Italy	0.165	30	27 to 28	–	–	–	1.7 to 1.8	16%	–
22	Bait et al. [40]	Algeria	–	–	–	–	Passive: 70 Active: 80	–	Passive: 2.77 Active: 4	–	31% for passive still and 40% and 80% for active still
23	Agrawal et al. [41]	India	0.51	24	–	0.03	51.2	–	–	–	Modified still increased 62% than conventional still
24	Yadav et al. [42]	India	–	–	–	–	–	–	12.48	17.4 to 45%	–
25	Abu-Arabi et al. [43]	Oman	–	–	800	–	–	–	–	–	Regenerative still 70% greater than simple solar still
26	Salem et al. [44]	Egypt	1	–	–	0.01	–	–	4.9	37%	with sponge 58.1% and 55.3%
27	Naveenkumar et al. [45]	India	–	–	–	–	–	–	–	37%	12%

(continued on next page)

Table 1 (*continued*)

S-no	Reference	Location	Area (m^2)	Slope angle (deg)	Solar intensity (W/m^2) or (MJ/m^2) per day	Water depth (m)	Basin water temperature (°C)	Wind speed (m/s)	Maximum/ average productivity (l/ m^2) or (kg/m^2) or (ml/m^2) per day	Still efficiency (%)	Inference
28	Attia et al. [48]	Algeria	0.25	10	1100	–	MSS: 50.36 CSS:47.55	–	MSS: 5.09 CSS: 3.71	MSS: 31.6% CSS: 40.1%	27.16%

Fig. 3. Parameters influencing pyramid solar still distillate output.

Table 2
Evaluation of three configuration pyramid solar still [74].

Description	Still alone	Combination of (still + circular fins)	Combination of (still + circular fins + PCM)
Productivity (l/ m^2/day)	4.02	5.75	8.1
Yield gain (%)	–	43	101.5
Daily efficiency (%)	32.2	45.9	64.3
Daily efficiency gain (%)	–	42.4	99.5

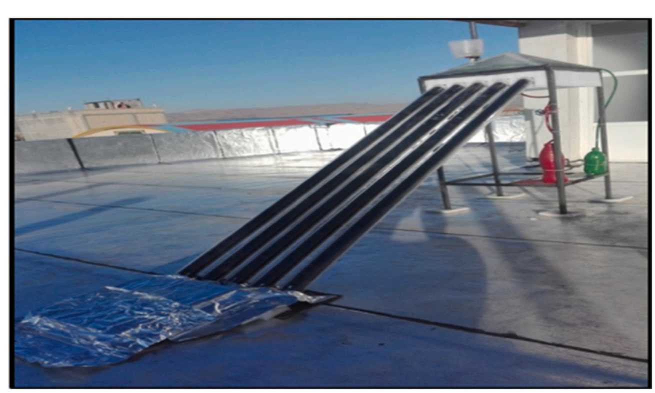

Fig. 4. Fabricated pyramid solar still with heat pipe collector [75].

radiation intensity and then release it to the basin water during periods of low radiation intensity. In addition, a cooled glass cover reduces vapour condensation and so improves the still's production. In compared to typical pyramid solar stills, they found that modified

Fig. 5. Experimental setup of pyramid and conventional solar still [77].

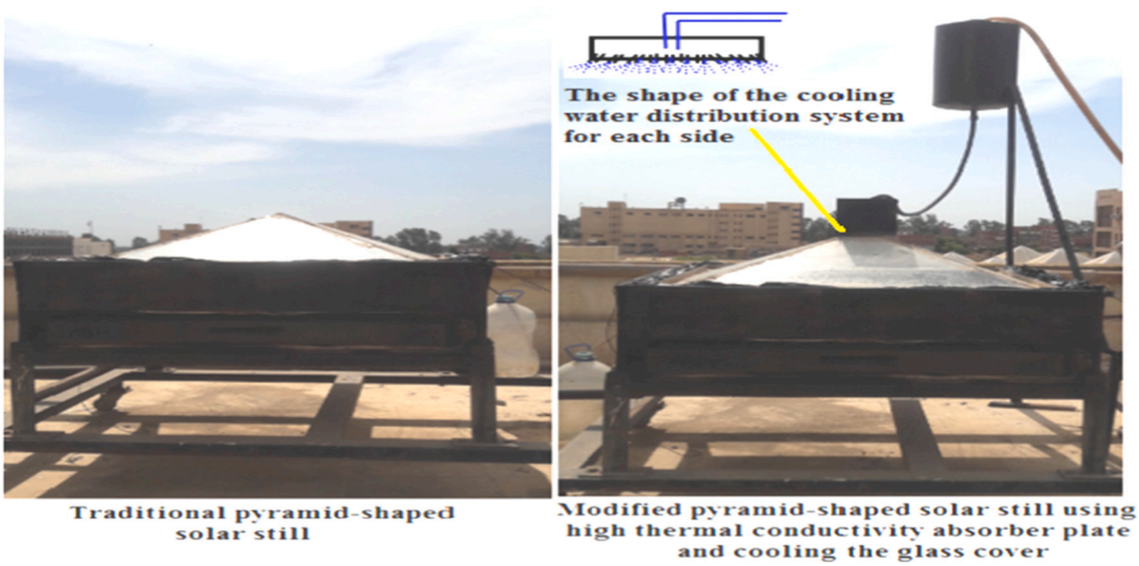

Fig. 6. Photographic image of both solar pyramids [78].

pyramid solar stills have daily production and efficiency ranges of 105.9% to 107% and 97.2% to 98.9%, respectively. The daily productivity of both stills is stated to be between 9 and 9.19 l/m^2 for the modified still and 4.37 and 4.43 l/m^2 for the conventional still, according to the authors. They came to the conclusion that employing graphite material and a cooled glass cover improved the output of the pyramid solar still. Hamdan et al. [79] in Ammanas, investigated the performance of single, double, and triple solar stills with basin sizes of 0.96 × 0.96 m and cover inclinations of 45°. They discovered that triple basin had a peak daily efficiency of 44%, double basin had a peak daily efficiency of 42%, and single basin had a peak daily efficiency of 32%. Fath et al. [80] in Aswan, made a comparison between pyramid-shaped solar still and single-slope solar still (south of Egypt).They have reported that the simple solar still radiation absorption range were lower than the pyramid solar still. Also, authors have observed that the glass angle of 50^o delivered maximum productivity. In the experimentation, authors found the productivity of 2.6 l per day approximately similar for both the setup. Based on the analysis, they obtained 30% and 33% efficiency for the conventional solar still and pyramid solar still. From this research, it is understood that the pyramid solar still may be a best replacement for conventional solar still.

Kabeel [81], by designing and building a concave shaped pyramid solar still, attempted to boost the evaporation rate and productivity. The basin covered with jute material and upper cover as a pyramid shape with inclination angle 45° as shown in Fig. 7. From experimentation, author found that the typical distillate yield was 4.1 l/m^2/day for pyramid solar still and conventional solar still was 2.1 l/m^2/day. The researcher claimed that the evaporative surface was increased by using wick material in the basin, which resulted in improved productivity of solar still. For the pyramid solar still, the immediate efficiency and average daily efficiency were found to be 45% and 30%, respectively. Wassouf et al. [82] prepared design and fabrication of two pyramid-shaped replicas as shown in Fig. 8. The primary model is square shaped PVC(poly vinyl chloride) pyramid solar still with basin area of 0.2 m^2. Similarly, PVC long prism solar still was constructed with basin area of 0.6 m^2. Both solar stills were constructed using light weight material (PVC) and extrusion manufacturing process. During the experimentation authors observed that the typical efficiency and distillate yield increased by 49.9% and 0.5 l/day for square pyramid solar still and 35.8% and 0.9 L/day for long prism solar still.

Fig. 7. Concave wick material pyramid solar still [81].

Fig. 8. Triangular-prism and square pyramid solar still [82].

Mahian and Kianifar [83] studied that the performance of pyramid solar still with basin area 0.9 m^2. It is designed and constructed in Mashhad, Iran. Inside the basin they attached a DC fan to supply continuous turbulent flow of water vapour within the still. Experiments were conducted and analyzed under free and forced convection modes. They have reported that various parameters like air velocity, depth of water level in the basin and insulation thickness involved in improving the performance of solar still. Also, authors obtained that the effects of air velocity and Reynolds number increase the daily yield up to 56%. Kianifer et al. [84] designed, constructed and compared the exergy efficiency for active and passive pyramid solar stills. The experiment was carried out during two different climatic conditions for analysing the effect of incident radiation and water depth on exergy efficiency. The production and exergy efficiency of solar stills on a daily basis under varying conditions and water levels are depicted in Fig. 9. The greatest daily distillate yield recorded in a hot climate for an active system was 3.14 l/m^2 at an 8 cm water depth and 3.04 l/m^2 at a 4 cm water depth during the trial. In passive system, the highest distillate yield recorded in hot climate was 2.72 l/m^2 at 8 cm water depth and 2.56 l/m^2 at 4 cm water depth. Also they suggested, the higher incident radiation increases the daily distillate output of solar still. Authors have concluded that the active pyramid solar still has the increased daily distillate output and it is 15–20% higher than that of the passive system. Also, summer and winter exergy efficiencies are higher for smaller water depths, according to the findings.

Taamneh and Taamneh [85] constructed and built a square pyramid solar still with a basin size of 0.95 m^2 as illustrated in Fig. 10. For the varied seasons of Jordan, the still's performance was investigated in active and passive ways. For active system, the solar photovoltaic panel was attached with small fan to boost the evaporation rate inside the solar still. Distillate yield productivity was found to be 2.99 l/day on a daily basis. Also the active pyramid solar still productivity was 25% more than the conventional system in clean water production. The authors suggested that, the efficiency of solar still is improved by integrating fan in the still and also, they mentioned that it was one of the feasible and cost effective methods. Arunkumar et al. [86] designed, constructed and conducted test on various designs of solar still. The pyramid solar still was fabricated with a collector area of 1.21 m^2 at the water depth of 0.05 mm. Authors found that the productivity of four faced triangular shape solar still was 3.3 l/m^2. The results obtained in the pyramid solar still is higher when compared to the double basin, concentrator coupled single basin and spherical solar stills. Also authors recorded that the daily distillate output was 6.928 l/m^2 when tubular still was integrated with pyramid still. They came to the conclusion that the productivity of a pyramid solar still coupled system outperforms other stills which is understood from Fig. 11.

Eze and Ojike [87] compared pyramid shaped and rectangle shaped solar stills under Nigerian climatic circumstances. Based on the results, authors concluded that the rectangular solar still shows higher efficiency than pyramid solar still. Kalaivani and Radhakrishnan [88] constructed pyramid solar still with stainless steel basin of area 0.5625 m^2 and top cover with acrylic sheet of thickness 3 mm and inclination angle 10°. Authors considered various properties of the still and evaluated performance of the still. The daily distillate output and overall efficiency ranged from 2.76 l to 2.8 l and 16.16% to 18.22%, respectively, according to the findings. Hassan and Algarni [89] have constructed and tested three similar square pyramid solar stills with basin area of 0.25 m^2 and a top cover slope angle of 45°. The experiments were conducted under various environmental conditions of Syria. For evaluation of solar still, three different water levels were maintained in each models of the still. During the experimentation authors observed that the typical daily distillates for three different water depths were 3.92 l/m^2, 3.12 l/m^2 and 2.41 l/m^2 respectively. Furthermore, the authors discovered that lower the water depth within the basin, the higher the distilled yield. Sathyamurthy et al. [90] investigated the performance of a triangular pyramid solar still with various parameters in the environmental conditions of Chennai, India. The tests were carried out at various water levels within the basin. From the experimental results, authors concluded that the daily productivity of distillate output for various water depths (lower to higher levels) were found to be 4.3 l/m^2, 2.3 l/m^2, 1.2 l/m^2, 0.9 l/m^2 and 0.5 l/m^2 respectively. Also, the still production increased from 8 to 15 when the air velocity range was extended by 3 m/s to 4.5 m/s. Sathyamurthy et al. [91], as indicated in Fig. 12, tested the performance of the still with and without active material (PCM). They used paraffin as the PCM and the heat reservoir was combined with the still. Supported by the experimentation, authors claimed that with PCM, daily yield was obtained as 4.3 l and it was 20% higher than that of the still without PCM. From the comparative study, authors have found that the daily efficiency for the still with PCM and without PCM was 53% and 45% respectively. Senthilrajan et al. [92] combined a biomass heat source with a pyramid solar still to improve the performance of the latter. Experiment was conducted for varying water levels in the basin with three different modes for different climatic conditions of Ramanathapuram, Tamilnadu. Based on the performance test, it was found that the still productivity increased by 84%, 69% and 61% for three different modes than the conventional still.

Prakash et al. [93] created a square-shaped pyramid solar still with corrugated wick material inside the basin to increase the production of solar stills. In this experiment, authors observed that the distillate output is 17.68% higher than the standard non-wick still. Also, authors found that the daily yield of 4.82 l and 50.25% effectiveness for developed still.

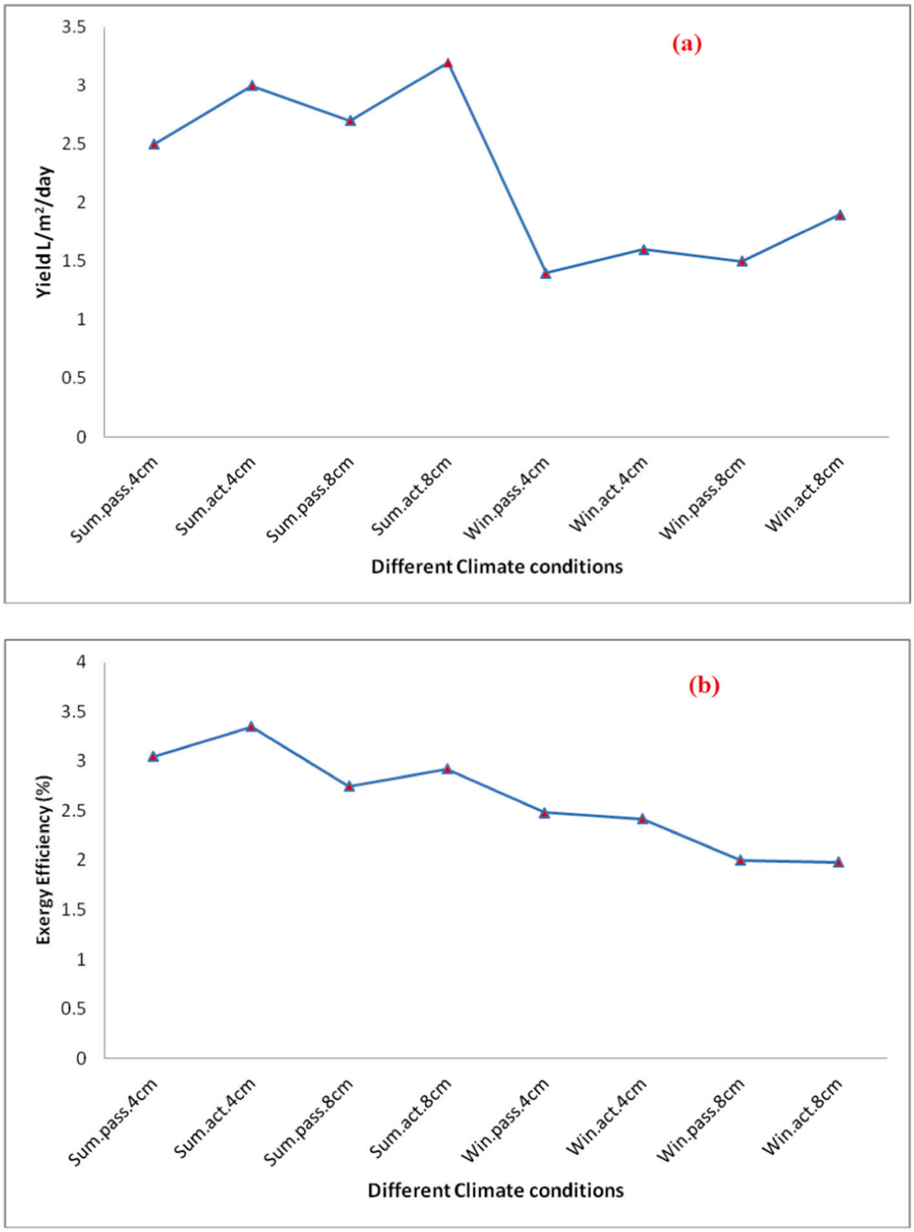

Fig. 9. (a) Daily productivity and (b) exergy efficiency for different conditions [84].

Kabeel et al. [94] designed and constructed three pyramid solar stills with different condensing surface slope angles like 30.47°, 40° and 50° at Tanta City-Egypt. The experiment was carried out in a basin with a 2 cm water level. The distillate yield for three different glass inclination (30.47°, 40°, and 50°) solar stills was calculated as 4.3 l/m^2, 3.5 l/m^2, and 2.93 l/m^2, respectively, based on the experimental results. For the above latitude angles, authors found that the still productivity of distillate output decreases as inclination of glass cover angle increases. The comparison of different boundaries like area, slope angle, radiation intensity, depth of water, temperature of water, wind speed, productivity of distillate output, still efficiency and enhancement techniques for various pyramid solar still results are shown in Table 3.

The significant point to be noted from Table 2 is that the efficiency of PSS without any attachments and modifications is above 40%. PCM based PSS ensured the improvement in efficiency which is found to be above 50%. PCM based PSS along with fin attachments have higher yield compared to normal PSS. Very few authors from India have worked on performance improvement of PSS and there is a large research gap with respect to usage of nano particles in basin bed and levels of contaminated water. New avenues on treatment of textile effluent using PSS and modified PSS need to be explored.

Beik et al. [96] designed and constructed the two modes (passive and active) of modified setups as shown in Fig. 13 and performed experimental and theoretical analysis on MSSPSS. Authors estimated that 2358 l of clean water can be produced per annum. Also, they have reported that the performance of MSSPSS will be based on the temperature difference between water and glass.

Shanmugapriya et al. [97] investigated the thermo-physical mode of acrylic pyramid solar panels with and without Zn^{2+} replaced Cr_2O_3 nanoparticles as shown in Fig. 14. The experiments were conducted under five modes of operations. The productivity yield of solar still with 7.5 mol% Zn^{2+} doped Cr_2O_3 nanomaterial is increased to a greater level due to improved solar radiation absorption when compared to other modes of operations.

Essa et al. [98], proposed a novel pyramid solar distiller as in Fig. 15 with wick operating technique. The cords wick pyramid solar still

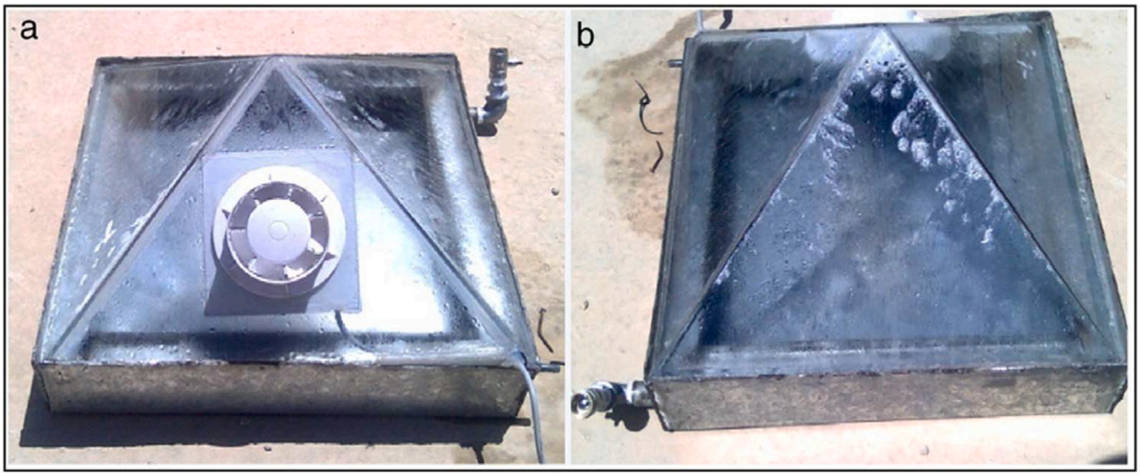

Fig. 10. Active and passive pyramid solar Still [85].

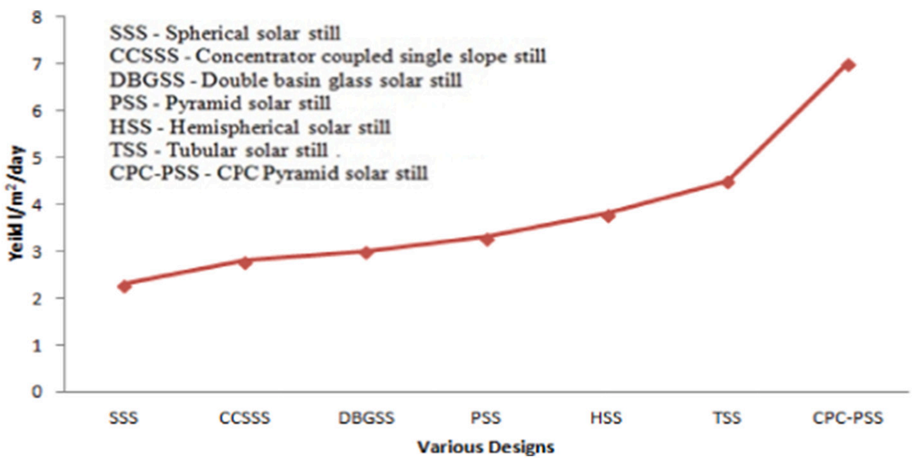

Fig. 11. Productivity of various solar still [86].

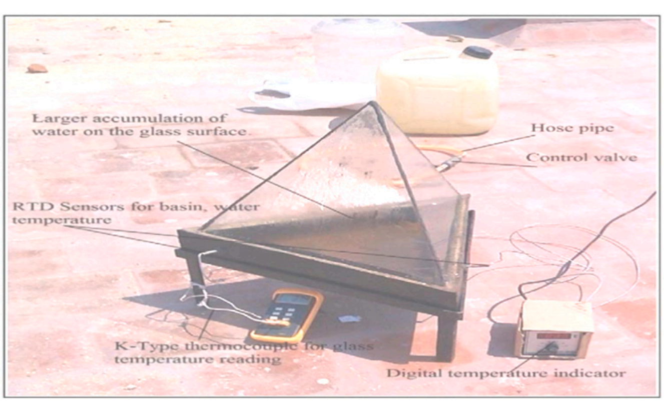

Fig. 12. Triangular pyramid solar still [91].

(CWPSS) featured a parallel upper basin liner with several cracks that were 3.0 cm higher than the original basin liner. The coated jute liner with wick cords dangled from the liner gaps to pull water out of the basin and maintained the wick surface wet all of the time through capillary action. The greatest performance of CWPSS was achieved when using the mirrors and fan at 35 wick cords, with an efficiency of 53% and a productivity increase of 195% over a conventional solar still.

Prasad et al. [99] tested and compared the performance of a triangular solar still with that of a conventional basin solar still. With a 0.25m^2 area, the solar basin and absorber are constructed of glass with a polyethylene cover. The temperature of the water inside the TBSS was similarly higher than that of the CBSS, according to the testing data. The CBSS and TBSS daily yields were determined to as 2.7 and 3.2 kg/m^2, respectively. In addition, the TBSS's daily efficiency was 11.36% higher than the CBSS's. Prakash and Jayaprakash [100] designed and constructed a unique multi basin stepped PSS as shown in Fig. 16. The pyramid solar still has four basins, each with a different area that steadily decreases as it approaches the condensing glass surface. As the surface area of the evaporating surface confronting the condensing glass was lowered by the stepped basins, the thermal capacity was reduced. The suggested pyramid solar desalination system has an average efficiency of 50.85%, with a distillate production of 3.25 l/day, considering night time collection.

Elgendi et al. [101] suggested a comprehensive design of a solar still unit with an automatic feedwater regulator system that was user-friendly and kept the brine level at ideal level. Subramanian et al. [102] designed, structured and integrated a modified PSS with flat plate collector. The pyramid solar still and low-cost solar flat plate collector were subjected to experimental and theoretical research. The average solar still produces 1.61 l of water per day. The modified pyramid solar still has a production capacity of 2.25 l. Because the redesigned pyramid solar still has less water and glass distance, it has a 50% increase in productivity. When combined with a low-cost solar flat plate collector, the modified pyramid solar still produces 3.1 l of water. Because of the

Table 3
A comparison of different aspects in improving the performance of a pyramid solar still.

S-no	Reference	Location	Area (m^2)	Slope angle (deg)	Solar intensity (W/m^2) or (MJ/m^2) per day	Water depth (m)	Basin water temperature (°C)	Wind speed (m/s)	Maximum/average productivity (l/m^2) or (kg/m^2) or (ml/m^2) per day	Still efficiency (%)	Inference
1	Kabeel et al. [74]	Egypt	0.64	–	1065	0.02	–	–	8.1	–	101% for still with fins and PCM, 99.5% for still with fins
2	Rasoul et al. [75]	Iran	0.25	35	10,000	0.08	59.2	–	MPSS: 6.97 CPSS: 3.3	–	Modified pyramid still increases 211% than conventional pyramid still
3	Manokar et al. [76]	India	–	–	1000	0.01 to 0.035	–	3	Insulation: 3.72 not insulation: 3.27	by insulation: 28.5% not insulation: 26.17%	19.46% for PSS with insulation and 8.26% for without insulation than conventional still at 0.01 water depth
4	Kumar et al. [77]	India	0.5 &0.42	30	–	0.02	50	–	TPSS+CPSS: 7.52 TPSS: 4.2	–	79.05%
5	Kabeel et al. [78]	Egypt	0.56	30.47	1050	–	MPSS: 84 CPSS: 78	–	–	–	97.2 to 98.9%
6	Hamdan et al. [79]	Jordan	0.92	45	–	–	–	–	–	44%	–
7	Fath et al. [80]	Egypt	–	50	25	–	–	–	2.6	30%	–
8	Kabeel [81]	Egypt	–	–	–	–	–	–	PSS: 4.1 CSS: 2.1	PSS: 45% & CSS: 30%	195%
9	Wassouf et al. [82]	Australia	0.2 & 0.6	–	13.3	–	–	–	PSS: 0.47 CSS: 0.92	PSS: 49.9% & CSS: 35.8%	–
10	Mahian and Kianifar [83]	Iran	0.9	–	–	–	–	10	–	–	PSS with fan 56% higher than without fan
11	Kianifer et al. [84]	Iran	0.9	36	960	0.04 to 0.08	–	–	Active: 3.14, 3.05 Passive: 2.72, 2.56	–	15 to 20%
12	Taamneh and Taamneh [85]	Jordan	0.95	–	1060	–	–	–	2.99	40.20%	25%
13	Arunkumar et al. [86]	–	1.21	–	–	0.05	–	–	6.928 & 3.3	–	–
14	Eze and Ojike [87]	Nigeria	–	22	–	–	–	–	0.2	36.80%	–
15	Kalaivani et al. [88]	India	1	10	386.46 to 1002.39	–	70.5	–	2.75 to 2.805	17.84 to 18.25%	–
16	Al-Hassan and Algarni [89]	Syria	0.25	45	–	3 L, 6 L & 9 L	–	10.9	3.924 at 3	–	–
17	Sathyamurthy et al. [90]	India	–	13	2000	0.02, 0.06 & 0.08	74	1.5 to 4.5	4.7 at 0.02	–	8 to 15.5%
18	Sathyamurthy et al. [91]	India	–	–	–	–	–	–	4.3	PCM: 53% not PCM: 45%	with PCM 20% higher than without PCM
19	Senthil Rajan et al. [92]	India	0.6642	30	–	0.02 to 0.04	75	–	–	–	84%
20	Prakash et al. [93]	–	–	–	–	–	–	–	4.82	50%	18%
21	Kabeel et al. [94]	Egypt	0.64	A: 30.47 B: 40C: 50	–	0.02	A: 78, B: 75C: 74.4	–	A: 4, B: 3.5C: 2.93	–	System A 41% and 18% higher than System C and System B
22	Ganesh et al. [95]	India	1	15	1100	0.04	55	0.5 to 3	A: 2.1 B: 4	A: 21.93% B: 28.89%	Integrated system shows better result than still alone

greater inlet water temperature and shorter water-to-glass distance, distillate output has increased by 60%.

Nayi and Modi [103] used thermal storage material in the basin as an effort to improve the distillate yield of a SBSPSS. The tests were carried out using two similar stills in the same climate, one containing small pieces of black granite as a heat storage medium and the other without. The influence of brackish water level on the performance of stills was tested with and without thermal storage. At water depths of 30 mm and 20 mm, respectively, yields of 1.43 l/m^2 and 1.38 l/m^2 were obtained for the still with thermal storage as compared to the still without thermal storage. The still with thermal storage produced a higher yield at a water depth of 30 mm than the still without thermal storage, which produced a higher yield at a water depth of 20 mm than the still with thermal storage. For the still with thermal storage, the daily average efficiency was reached at a water depth of 30 mm, which was higher than that at 20 mm.

Al-Madhhachi and Smaisim [104] have constructed and evaluated a SPSS during 4 seasons in Al Kufa, Iraq as shown in Fig. 17. The trials

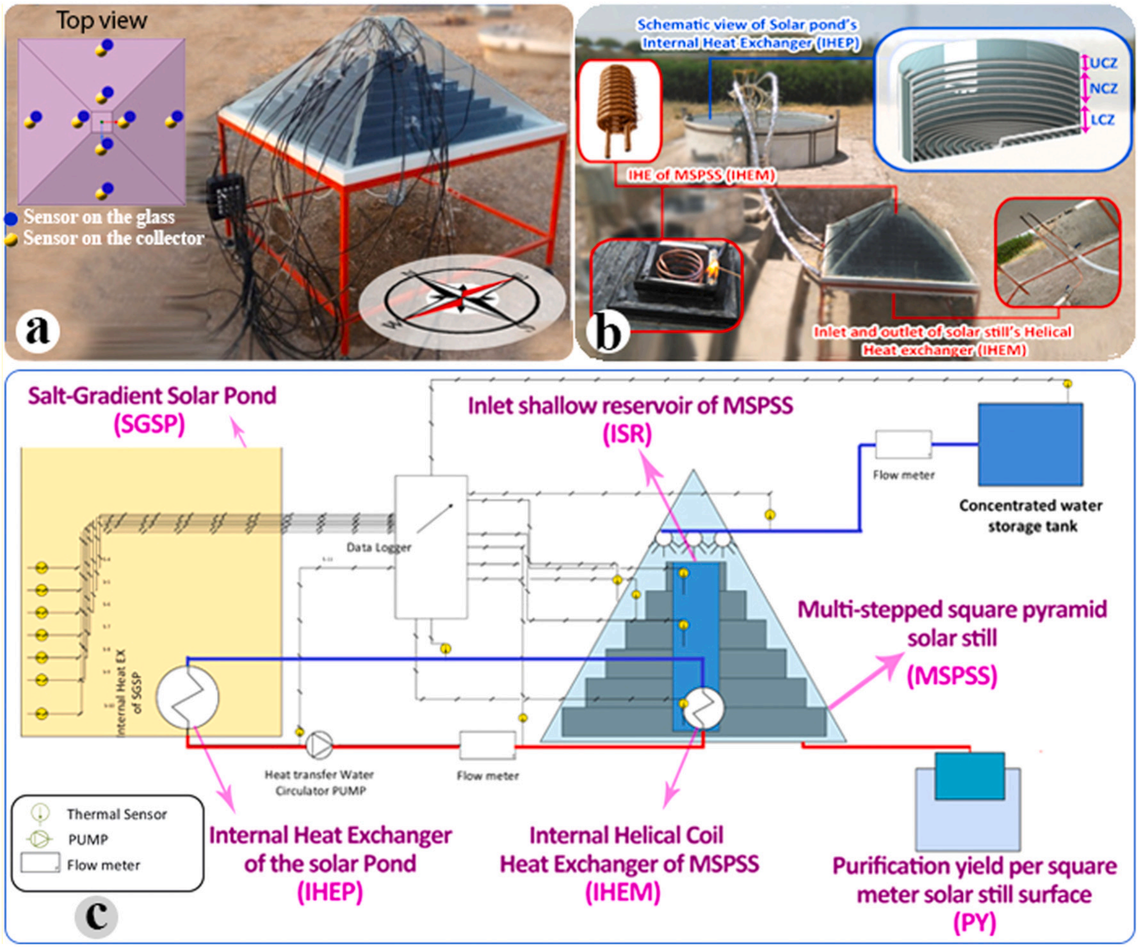

Fig. 13. a) Function of MSSPSS, b) integration of SGSP with MSSPSS, and c) layout of the pre-heating diagram [96].

Fig. 14. Experimental setup of pyramid solar still [97].

were carried out over the course of four seasons to evaluate the differences in still temperatures. According to the data, the designed still produces 2.2 l/m^2 of water on a daily basis. In comparison to other experimental solar stills, the results demonstrate that the developed still's efficiency has increased to 60%. Also, it was illustrated that the manufacturing and distribution of portable solar still has a reasonable

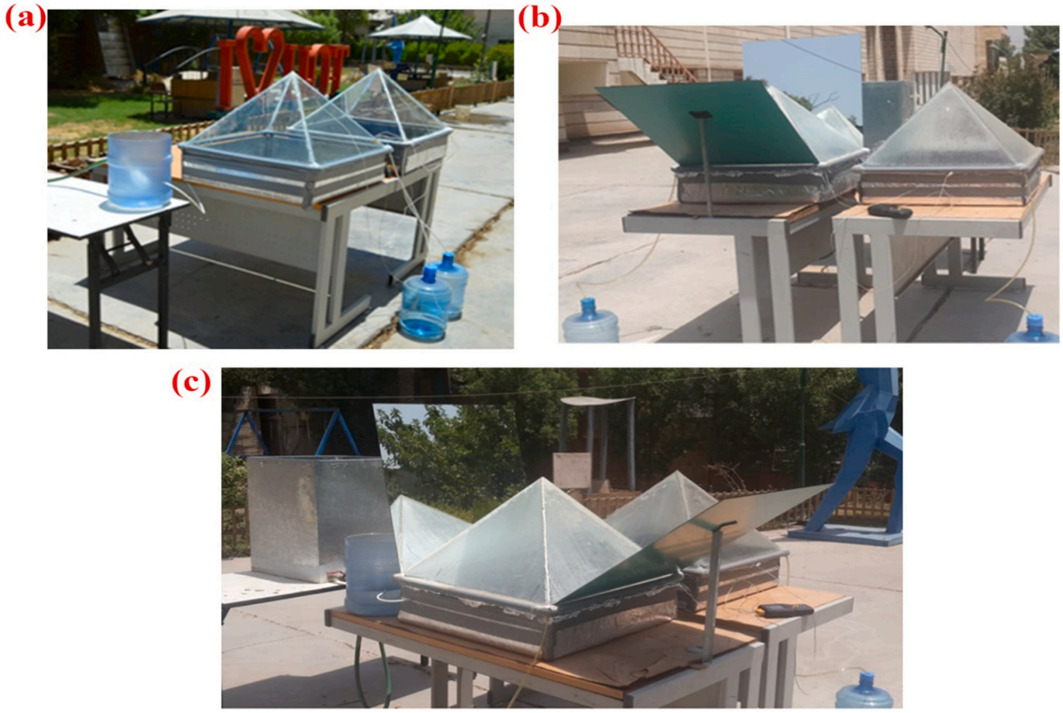

Fig. 15. Experimental test-rig (a) solar stills without mirrors, (b) solar stills with mirrors, and (c) experimental setup [98].

Fig. 16. Experimental setup of the multiple basin stepped pyramid solar still [100].

environmental impact in terms of air acidification and water eutrophication over a 20-year period.

Alawee et al. [105] proposed a novel change to the pyramid solar still's structure coupled with 4 rotating cylinders into the basin as shown in Fig. 18. Three electric heaters were also installed in the basin to increase the temperature of the liquid. Under varying rotating speeds, the performance of the MPSSRC was examined. The complete yields of the MPSSRC without heaters and the standard still were 7.3 l/m^2 per day and 3 l/m^2 per day, with a 143% improvement. Furthermore, the MPSSRC's net distillates with heaters and standard still were 9.1 and 2.9 l/m^2 per day, respectively.

In a pyramid solar still, Elgendi et al. [106] studied water depths ranging from 5 mm to 50 mm. The thermal capacity when the water depth was increased. Lower water depths resulted in larger total yields throughout the course of the day, according to the experiment. Authors found that 90% of the water level has reduced from 50 mm and the accumulated distillate has increased by 37%. Maatki [107], with the help of a novel design of solar still proved the enhancement of heat and mass transfer rates. Also, it was found that the nanofluid concentration is a key parameter for the better performance of solar still.

3. Conclusion

In the competitive world demand for fresh water is higher as

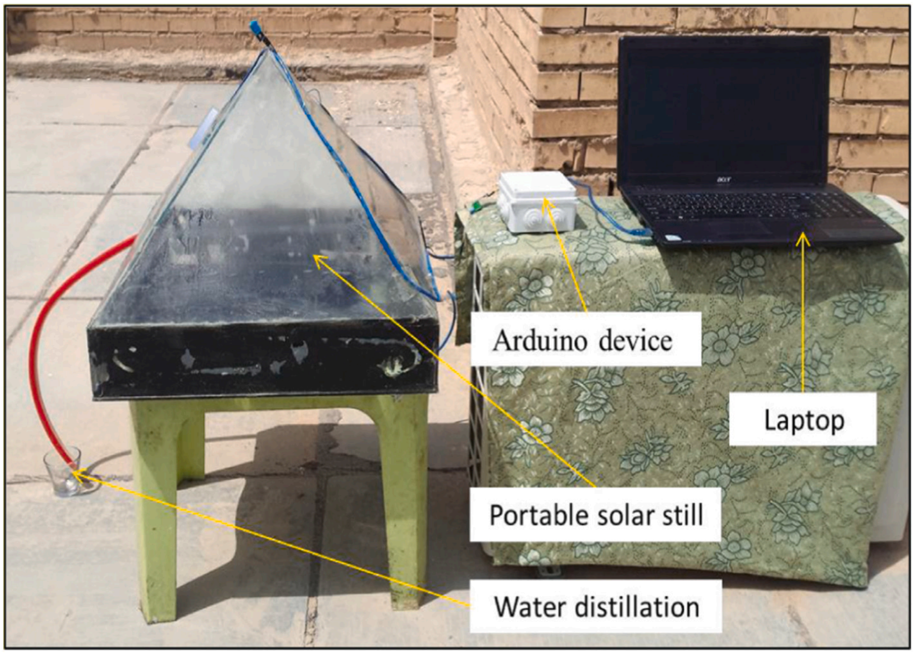

Fig. 17. The experimental setup of the portable square solar still system [104].

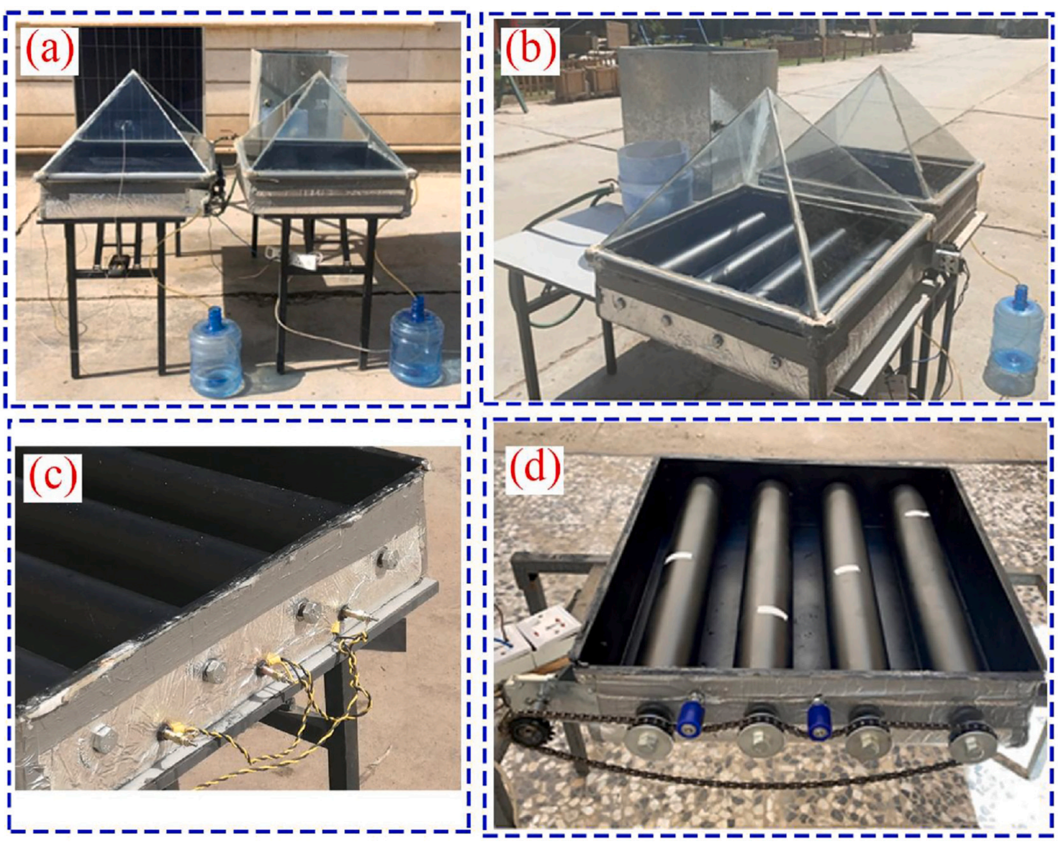

Fig. 18. Experimental setup (a) tested distillers with PV, (b) side view of the distillers, (c) heaters from outside the distiller, and (d) the arrangement of the motor, chains, and pulleys [105].

compared to rise in earth's population. Solar distillation provides the simplest choice to meet this demand in minimum period. So, many researchers are targeting the advancement of various designs of solar distillation unit by overcoming the constraints in conventional still. One of the best replacement design is pyramid solar still in all alternative method for them. This paper has reported a detailed study for pyramid solar still. Based on the literature survey on pyramid solar still, subsequent salient points are concluded:

- ✓ Other than conventional solar stills, pyramid-shaped solar stills are one of the most effective ways to produce potable water. For larger condensing area, it reduces the side wall shadow effect within the pyramid solar still. Radiation tracking mechanism isn't required for pyramid solar still.
- ✓ Additionally, in pyramid stills employing PCM with fins, shows enhanced output for day by day yield up to 101.5% and for efficiency up to 99.5% than that of the traditional pyramid solar still.
- ✓ The depth of water within the basin increases over the day, lowering the convective and evaporative heat transfer coefficients in the triangular pyramid solar still.
- ✓ By adding corrugated wick material to the basin of pyramid solar still, the distillate output is 17.68% higher than that of the non-wicked still.
- ✓ For improving the evaporation rate in forced convection method a small DC fan was mounted within the pyramid solar still and it is proved the distillate output improved up to 25%.
- ✓ Lower water level within the basin results in increased exergy efficiency. Condensing area of the pyramid solar still should be larger than evaporative area.
- ✓ Pyramid solar still utilizing the heat from biomass, the productivity of distilled output is ahead of the standard solar still.
- ✓ Coupled system produced 79.05% distillate output at minimum water level, which is greater yield than normal still.
- ✓ For MSSPSS using SGSP in active process, clean water production was increased up to 13% in summer and 9% in night time.
- ✓ The substitution of pure Cr_2O_3 and Zn^{2+} substituted Cr_2O_3 nanoparticles increases the yield rate for the pyramid solar. Also, the improved properties of the substitution that aid in maintaining temperature of the water in the PSS.
- ✓ The increased clean water productivity was greater in the case of TBSS, which was primarily due to its exposure area and condensing cover area with solar radiance.
- ✓ The stepped basin solar still allows for a reduction in heat capacity within the still while increasing evaporation.
- ✓ When combined with a low-cost solar flat plate collector, the modified pyramid solar still production has increased by 60% due to the shorter distance between the water and the glass.
- ✓ The summer and winter exergy efficiencies are higher for decreasing water depth in the case of active pyramid solar still.
- ✓ This review concludes that various parameters like collector design, absorber plate material, insulation thickness and slope angle of glass cover, level of water within the basin, position and orientation of still should be optimized using cost-effective analysis and multi-objective method. It will help to develop the pyramid solar still to commercial level.

4. Scope of further research & recommendations for pyramid solar still

The following recommendations for long-term work would be good for improving the performance of pyramid stills, based on the review.

- ✓ PCM is a crucial substance that improves the distilled output performance in a pyramid solar still. As a result, a pyramid still with PCM and thermionic valve may be created for the distillation of rainfall and river water.
- ✓ Currently single PCM material is used for performance enhancement of distillate output. In future focus may be driven towards design and development of pyramid solar still with PCM mixture that may accustom to increase the energy storage capacity.
- ✓ Developing an adequate mathematical model and numerical solution utilizing software to optimise the performance of a pyramid solar still can save time and money when it comes to assembling distilled product.
- ✓ Various methods like stepped basin, transparent glass cover with different materials and vertical wick material may be employed for improving the effectiveness of pyramid solar still.
- ✓ Photo-thermal process together with nanotechnology may assure to create a possible cost effective water management in future.
- ✓ Absorber plays a crucial role in supplying distilled water from solar stills. Hence, to cut back the economic and ecological cost, recycling the absorber with high strength can be thought off. Based on the numerous researchers' work, this system is established in islands, arid regions, natural disaster places, industrial areas and remote areas to produce fresh water by using solar distillation methods.

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Declaration of competing interest

All authors have no conflict of interest.

Acknowledgement

This publication was supported by Qatar University Internal Grant No. QPH3P-CAM-2021-452, respectively. The findings achieved herein are solely the responsibility of the authors.

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Notations

%: percentage
°C: degree Celsius
cm: centimetre
Cr_2O_3: chromium oxide
h: hour
H_2O: water
kg: kilogram
l: litre
m: meter
MJ: mega Joule
ml: millilitre
mm: millimetre
W: Watt
Zn: zinc

Abbreviations

TE: thermal efficiency
EE: exergy efficiency
PCM: phase change material
Deg: degree
Al: aluminium
GI: galvanized iron
PVC: poly vinyl chloride
DC: direct current
win: winter
sum: summer
pass: passive
Act: active
SSS: simple solar still
CSS: conventional solar still
ETHP-SC: evacuated tube heatpipe solar collector
PSS: pyramid solar still
MSS: modified solar still
CCSSS: concentrator coupled single slope still
DBGSS: double basin glass solar still
HSS: hemispherical solar still
TSS: tubular solar still
CPCPSS: concentric parabolic collector pyramid solar still
MPSS: modified pyramid solar still
CPSS: conventional pyramid solar still
TPSS: triangular pyramid solar still
MSSPSS: multi-side step square pyramid solar still
SGSP: salt gradient solar pond
CWPSS: cords wick pyramid solar still
TBSS: triangular basin solar still
CBSS: conventional basin solar still
SBSPSS: single basin square pyramid solar still
MPSSRC: modified pyramid solar still rotating cylinder
SPSS: square pyramid solar still