A Review on Modified Solar Stills with Thermal Energy Storage and Fins

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ABSTRACT: The daily distillate water production of the single basin conventional solar still is limited. In this aspect, many research works are being carried out to enhance the productivity of the solar still. In the present work, theoretical performance and experimental analysis of a conventional solar still, fin type solar still, solar pond integrated with fin type solar still are reviewed. The addition of the fins in the mini solar pond was definitely a positive in improving the thermal performance of the single basin solar still by increasing the overall water collection over 24 h. When fins were attached at the basin of a still, the heat transfer rate from basin to water is increased. This paper contains the literature survey which gives the techniques to implementation of thermal storage materials and fins in a solar still.

Keywords: solar still, thermal storage materials, fins.

1. INTRODUCTION

Due to rapid population growth and industrial developments, the need of quantum of drinking water increased. So far the only possible way of getting drinking water is from rivers, lakes, wells, etc., which must be purified as they may contain harmful microorganisms and mineral contents. And the purification process involves namely sand filtration, chlorination and boiling. India is almost having 18% of total world population and only 4% of water source is available for serving the Indian community. However, due to the growth in population, urbanization and industrial needs, the demand for water is rapidly increasing. The decrease in annual per capita of water available is from 6042 m^3 during 1947–1545 m^3 in 2011, whereas, during 2001 the total annual per capita of water available is only 1816 m^3. From the latest survey, this water availability will be reduced to 1340 m^3 by 2025and 1140 m^3 by the end of 2050. Moreover, the utilization of groundwater source is 431 billion cubic meter as a major source for drinking and domestic purpose and nearly 690 billion cubic meter of surface water as a major source for irrigation purpose.

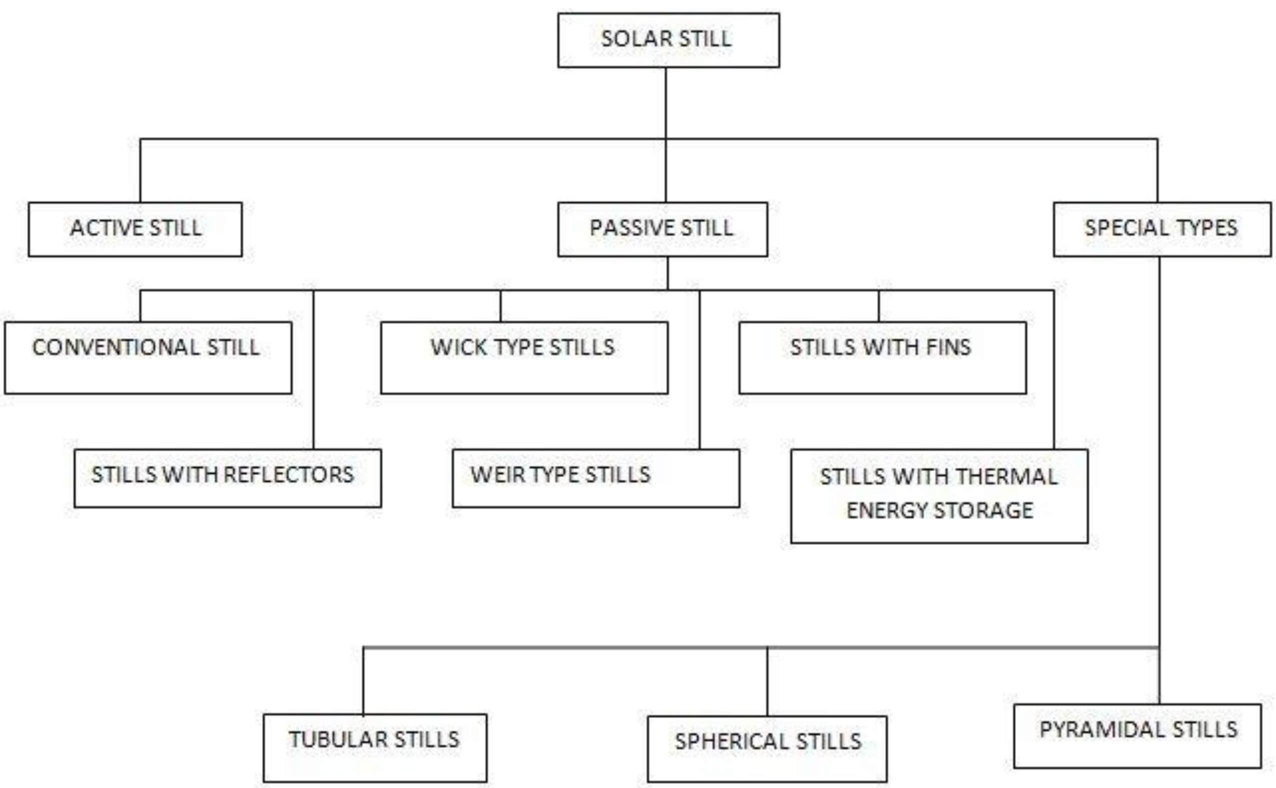
Sources from Indian ministry of water resources, United Nations, UNICEF reported that nearly 90% of the water discharged from rivers does not meet the environmental norms. And nearly 65% of rainfall goes into the sea as waste [1]. Beyond domestic and industrial sector, the next major user of water is the agricultural sector [2]. Several techniques are available for getting fresh water. Major techniques include thermal and membrane process. As the name implies, thermal desalination process requires heat to convert the saline water into steam, and the steam or vapour is condensed to get fresh water. Fossil fuels are used in the thermal process, and this makes the system uneconomical [3]. Solar desalination is subdivided into two major categories namely direct and indirect desalination. Direct desalination system collects the solar energy and converts the saline water into distillate water directly, whereas, in indirect desalination system, energy will be collected by additional solar thermal collectors integrated to a solar still [4]. Desalination through the membrane is a process of getting freshwater from waste or salt water and filtering into useful one by using electrical energy. Fouling effect and salt deposition on the membrane surface makes the maintenance of the process complicated. Almost it consumes 20% of electrical energy for the conversion of salt water to drinking water by pumping water into the perforated membrane. The evolution of using renewable energy has been identified during the 19th century and thus basin type solar stills were designed and fabricated to get fresh water from saline water using solar energy. Solar desalination appears to be the easiest and cheapest method of producing potable water.

For a very small scale of getting fresh potable water, solar desalination appears to the best method. Majorly many review papers have concentrated only on the prospective design configuration. Basin type solar still is one of the breakthroughs of the 20th century where many types of research are carried out to augment the fresh water production. For augmentation purpose, many used coupling methodologies with solar ponds which is an economical thermal energy storage unit [5]. Basin type solar still is the most traditional and conventional method of getting fresh water utilizing solar energy. Saline water washed into the basin, and an inclined glass cover is placed over the basin. Solar radiation heats up the water inside the basin to make it evaporate from the top layer. The evaporated vapour inside the still rejects its latent heat through the cover for condensation to attain thermal equilibrium with surroundings. Since the cover is inclined, the condensed water making a droplet on the cover, the droplets slides through it to the distillate collector due to the smooth cover surface [2]. Also, there is a fact that the water forming larger droplets falls back into the basin itself due to its weight and gravity.

Several researches are carried out to augment the performance of single basin solar still in the 20th century. During the 21st century, many authors identified the change in geometry of the basin. Various integrations are made on the solar still for economical viability [4][6]. There are several factors identified from the basin type solar still and discussed in brief by several researchers. Moreover, the efficiency of the solar still depends upon various important parameters such as Tilt angle of cover plate, depth of water, feed water flow rate, cover plate temperature, orientation of solar still, convective heat transfer from cover plate and side walls, design of structures and shapes, solar tracking, coating and external enhancement like heat pipe and coolers. Several researches were made on solar still with geometrical variations [4], multiple basins [7], increasing the surface area of water [8], techniques for improving the yield of stepped solar still [9], factors affecting the solar still performance [10] and condensation on passive solar still [11]. This paper completely reviews the different enhancement methodology that is used for improving the yield of fresh water from the active solar still. From the review, it was identified that the efficiency of solar still with collector based system depends on the flow rate of water inside the tube surface of the collector, minimum heat loss with outside atmosphere, type of tube and absorber material, and convective heat transfer coefficient between water-Tube-basin water.

Furthermore, a detailed economic analysis was carried out to analyze the payback period of the collector based system. The following sections discuss the various methods used by previous researchers for improving the yield and possible conclusions are arrived.

2. CLASSIFICATION OF SOLAR STILL



2.1 ACTIVE SOLAR STILL

ACTIVE SOLAR DESIGN

Active solar systems use external sources of energy like power blowers, pumps and other types of equipment to collect store and convert solar energy. Once energy from the sun is absorbed, it is stored for later use.

While small systems are used to furnish electricity for heating and cooling systems in homes and other buildings, large systems can furnish power for entire communities.

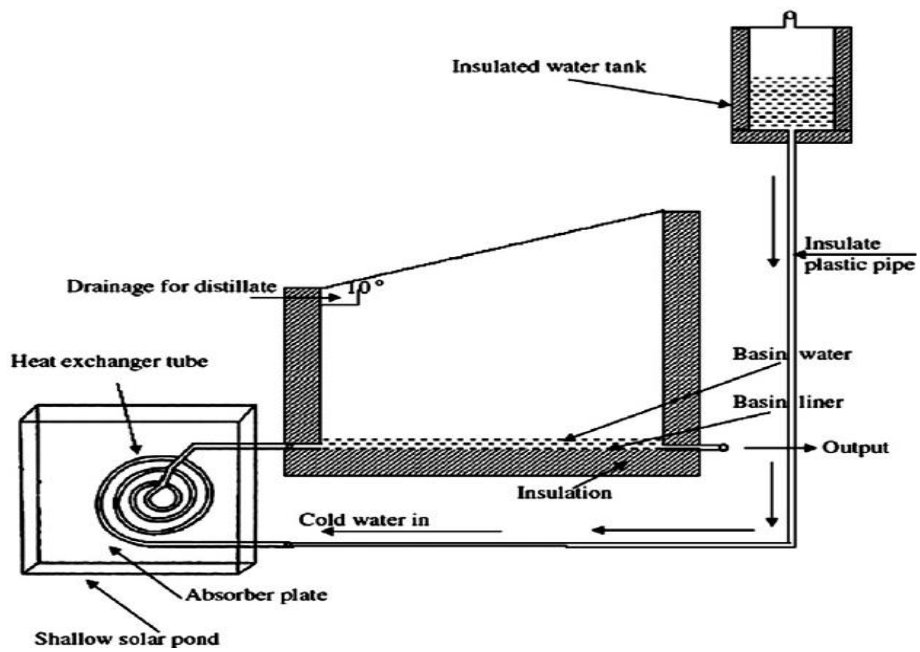


Fig.1. Schematic diagram of single basin solar still coupled with the shallow solar [12]

ACTIVE SOLAR COLLECTORS

Solar collectors are complex than passive collectors in both design and mechanism. It consists of flat-plate PV panels that are usually mounted and remain stationary, although some are designed to track the sun throughout the course of the day. In some active solar still designs, multiple panels are connected together to form modules. Active solar collectors contain either air or a liquid as a conductor. In active system, those that use air are referred to as Air Collectors, while liquid based types are called Hydronic Collectors. The advanced design of these collectors makes an active solar heating system the most effective in terms of reducing reliance on traditional energy resources.

2.2 PASSIVE SOLAR STILL

PASSIVE SOLAR DESIGN

A passive solar system always does not involve mechanical devices or the use of conventional energy sources, beyond that it controls the needs to regulate dampers and other controls if any. Classic examples of basic passive solar still structures are greenhouses and solariums as the sun's rays pass through the glass windows where the interior absorbs and retains the heat. Modelling this concept in your home can cut heating costs by half compared to heating the same home by traditional means without the use of passive solar.

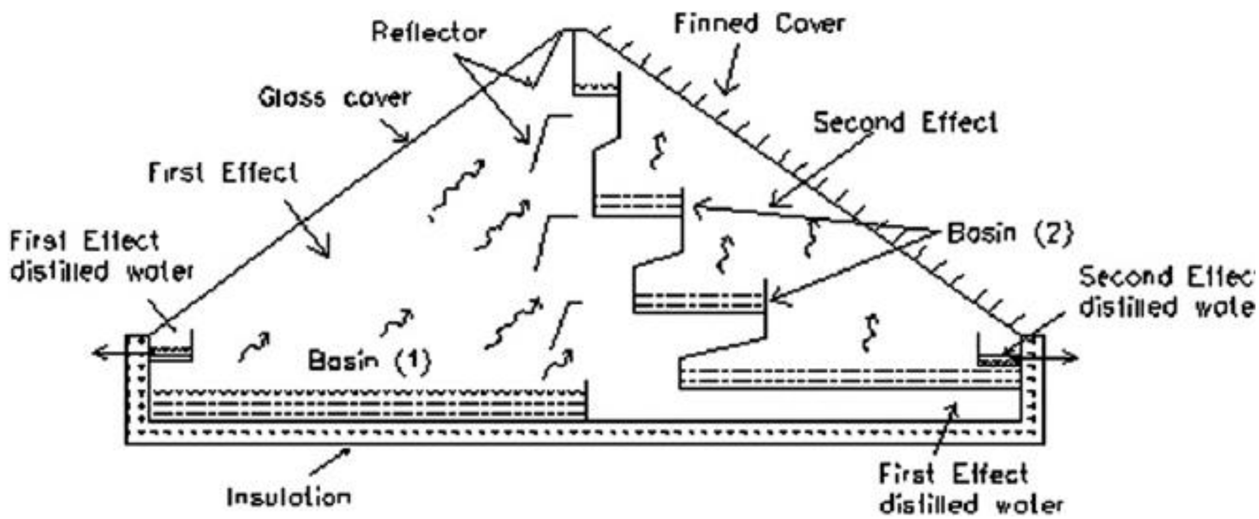


Fig.2. Schematic diagram of passive solar still [13]

PASSIVE SOLAR COLLECTORS

The passive solar system relies on south-facing windows as collectors to capture maximum solar energy, although some systems may also use supplemental PV panels. In most case, the goal system of this is to redistribute the energy collected according to a fundamental law of thermodynamics, which states that heat moves from warm to cool areas and surfaces. The simplest method of transferring the heat from passive solar collectors is through convection. To illustrate, think of a sunroom with windows on a southern wall. As the sun's rays travel through the glass, the heat is directed into that room. The heat then rises to area where the air is cooler, including others rooms beyond and above.

2.2.1 Conventional Solar still

Conventional Solar Stills (CSS) are the oldest, economical and simple devices used for purifying brackish or salt water. They are selected due to their simplicity and passive nature, no requirement to hard maintenance or skilled persons, low space requirement, which results in reduced operating and maintenance costs.

The main limitation of the CSS is its low productivity compared with modern desalination processes that use mechanical, electrical and thermal techniques such as Thermal Vapour Compression (TVC), Electro Dialysis (ED), Multistage Flash (MSF), Multi-Effect Distillation (MED), Humidification & Dehumidification (HDH) and Reverse Osmosis (RO) by Murugavel et al., [14]. Knowing that the daily yield from a single slope basin type solar still may vary from 0.5 to 2.5 kg/m^2 and its efficiency is usually about 5–40% by Dev and Tiwari [15], These drawbacks of CSS have incited researchers to develop other advanced distillers by building multiple-effect solar stills which involved complicated design simultaneously. However, a more efficient way to improve CSS performances, has to be done by converting the passive solar still into an active solar still, using an external heat source is shown in fig.3, the variation of daily yield and solar still efficiency with water mass for the fixed number of collectors and mass flow rate of water. It is found that for the fixed numbers of PV/T collectors the daily yield and daily solar still efficiency decreases by approx. 46% when water mass increases from 50 kg to 200 kg by Gaur and Tiwari [16], 2010.

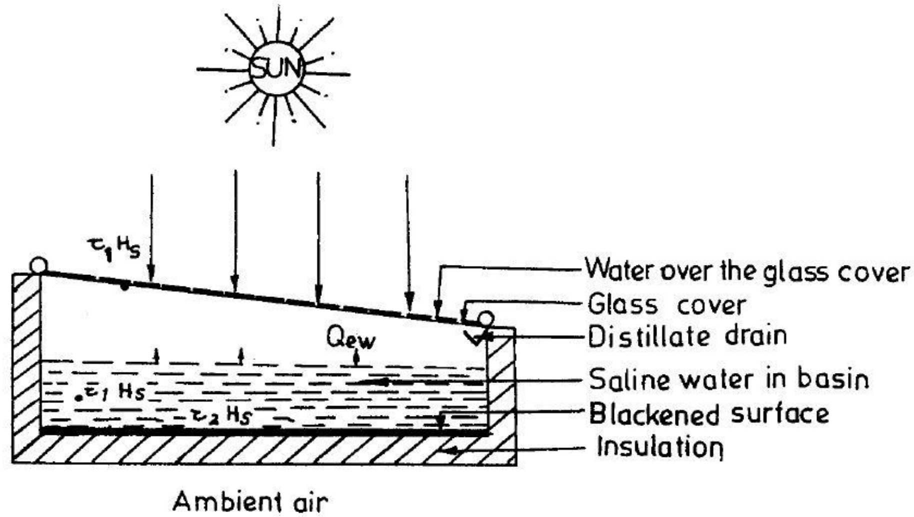


Fig.3. Schematic diagram of a Single Basin Single Slope Solar Still [17]

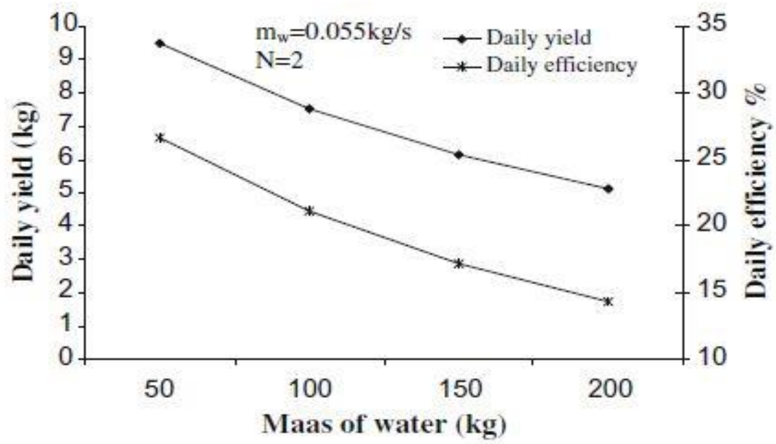
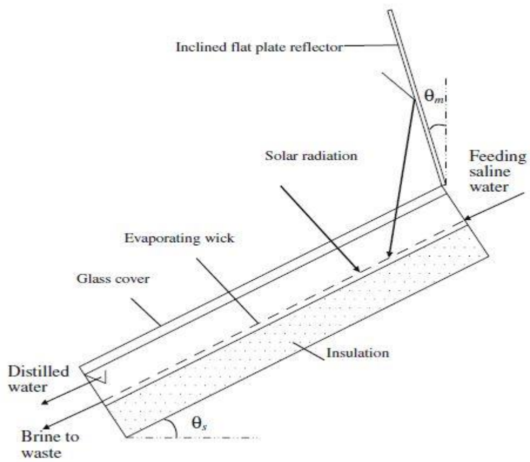


Fig.4. Variation of daily yield and efficiency with water mass [16]

2.2.2 Solar Still with Solar Reflectors:

Solar still with reflectors is also one of the methods to increase the productivity of still where Internal reflectors are useful tools to concentrate and redirect solar radiation. They are recommended when sunlight is weak or the local temperature is relatively low. External reflectors are preferred to be used to change the direction of solar beams to improve the flexibility of the absorber plate configuration such as vertical solar absorber plate which is helpful in recovering vapour latent heat of condensation. External and/or internal reflectors are recommended when sunlight is frail or the local temperature is moderately low. Tamimi [18] studied experimentally the performance of a single-slope single-basin solar still with mirrors installed on the side walls of a still. He concluded that using mirrors increases the basin efficiency throughout the whole day. El-Swify and Metias [19] used mathematical modelling and conducted experiments to find out the effect of IR on the back and side walls of a single slope still with its back wall acting as an additional condenser. They mentioned that the distillate increase of 82.6% and 22% can be obtained by installing reflectors in the winter and summer respectively. A theoretical analysis was used by Tanaka and Nakatake [20] to study the effect of a vertical flat plate ER on the productivity of a TWSS and showed an average increase of 9% a year. Another theoretical analysis of a top ER with TWSS on a winter was investigated by Tanaka and

Nakatake [21].Their results indicated that the productivity of a still with an inclined reflector would be around 15% or 27% over that with a vertical reflector when the reflector's length is a half of or the same as the still's length.



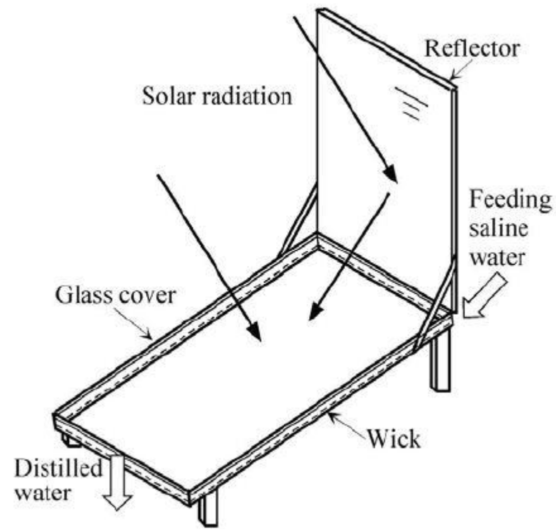


Fig.5. Schematic diagram of a solar still with reflector [20] **Fig.6.** Schematic diagram of a solar still with reflector [21]

2.2.3 Wick type Solar still:

Wick-type collector–evaporator is generally inclined in nature. However, a few attempts were addressed to improve the solar still thermal performances using vertical wick materials. An attempt has been found by Saktivel et al. [22] to improve the CSS productivity by a jute-cloth attached against the back-wall of the single slope solar still. Their experimental results show that the daily productivity of their modified still is only 3.9 kg/m^2.

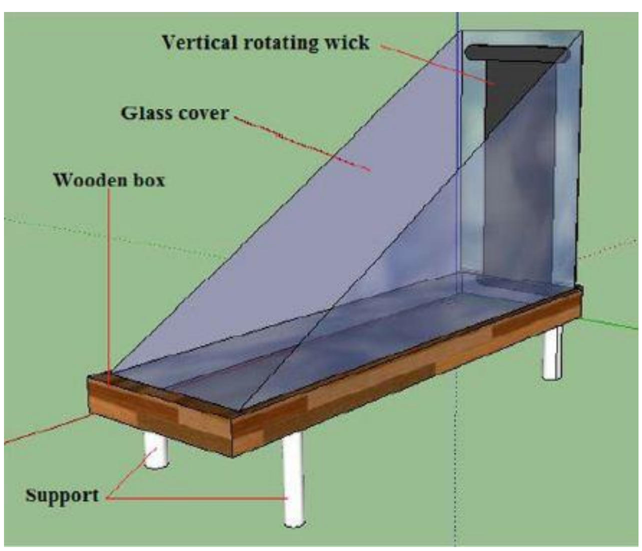


Fig.7. Schematic diagram of the proposed solar still [23]

In the scope of this work, a new concept is proposed to improve the basin type solar still daily productivity using a Vertical Rotating Wick (VRW). The idea is based upon integrating a rotating black jute cloth belt against the back-wall of the single slope solar still in order to increase the evaporation rate without changing the still layout and its operating principle. The VRW acts as an additional internal collector evaporation area, allowing more evaporation and contributing to increasing the still productivity. This design allows getting a compact solar still with reduced cost, low maintenance, and space requirement. A set of experimental tests was conducted by Haddad et.al [23] to evaluate the Vertical Rotating wick (VRW) in improving the performance of the still. The comparison with the conventional solar still (without VRW) shows that the distillate output of the modified still (with VRW) was increased by about 14.72 in summer and by 51.1% in winter.

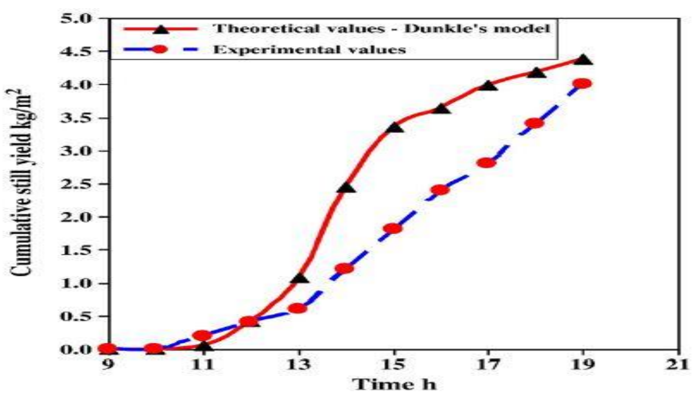


Fig.8 Comparison of theoretical cumulative still yield with the experimental still yield [22]

2.2.4 Weir type Solar still:

A weir-type solar still is designed and constructed, it is an inclined type still, which consists of a weir-shaped absorber plate, cover/condensing glass, distillate collection trough, water circulation system and support structure. The still is well insulated to minimize any heat loss from the bottom and sides of the unit. The smaller arrows in the figure show the water flow direction in the still. The average productivity of the still is approximately 5.5 l/m^2/day. The productivity of the conventional basin-type still measured at the same location and time period is also measured [24] James D, et al. The average productivity of the conventional basin-type still is approximately 4.5l/m^2/day. This amounts to a 20% gain in the productivity for the proposed still compared with basin type.

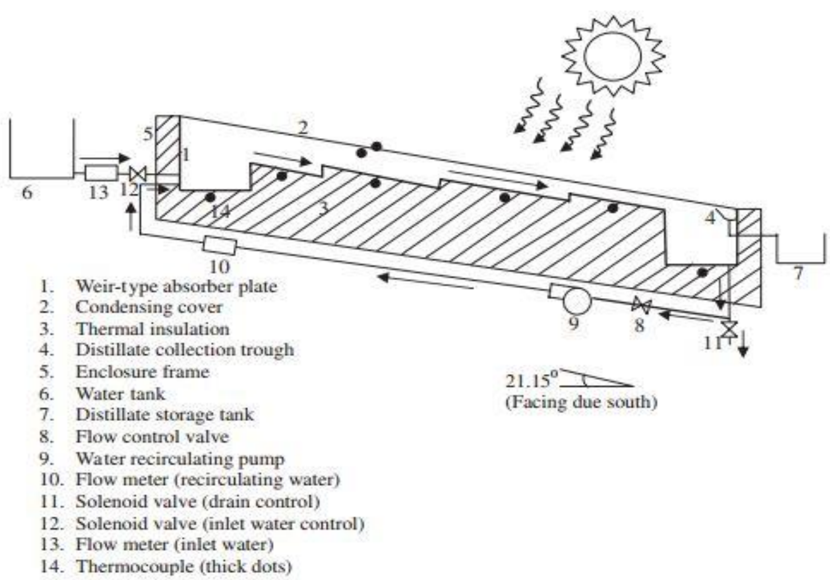


Fig.9. Schematic diagram Weir type solar still [25]

2.2.5 Solar still with Fins:

To augment the evaporation rate solar still incorporated with fins of square, circular, pin etc. Fins are acting as an extended surface, the temperature of the water increases and so increase the productivity rate.

Velmurugan et al. [26] integrated a mini solar pond with single basin solar still for enhancing the productivity of the still from salt water. The productivity was increased by 57.8% when the solar pond was integrated with the single basin solar still. Various techniques like using the sponge, black rubber, sand and pebble in the basin plate are also tried to augment the productivity of a single basin solar still. The performances are compared with the conventional basin solar still.

Kamel Rabhi et al.,[27] Gafsa-Tunisia made a comparative study and conclude that cumulative water production gain of 41.95%,23.39% and 11% implying an hourly gain of 12.9%,9.7% and 3.1% recorded for pin fin absorber coupled with condenser respectively with conventional still (fig 7.d)

Gain of 32.18% is recorded for still with condenser compared to conventional still (fig 7.b) Simple pin fin absorber gains only 14.53% compared to conventional still(fig 7.c)

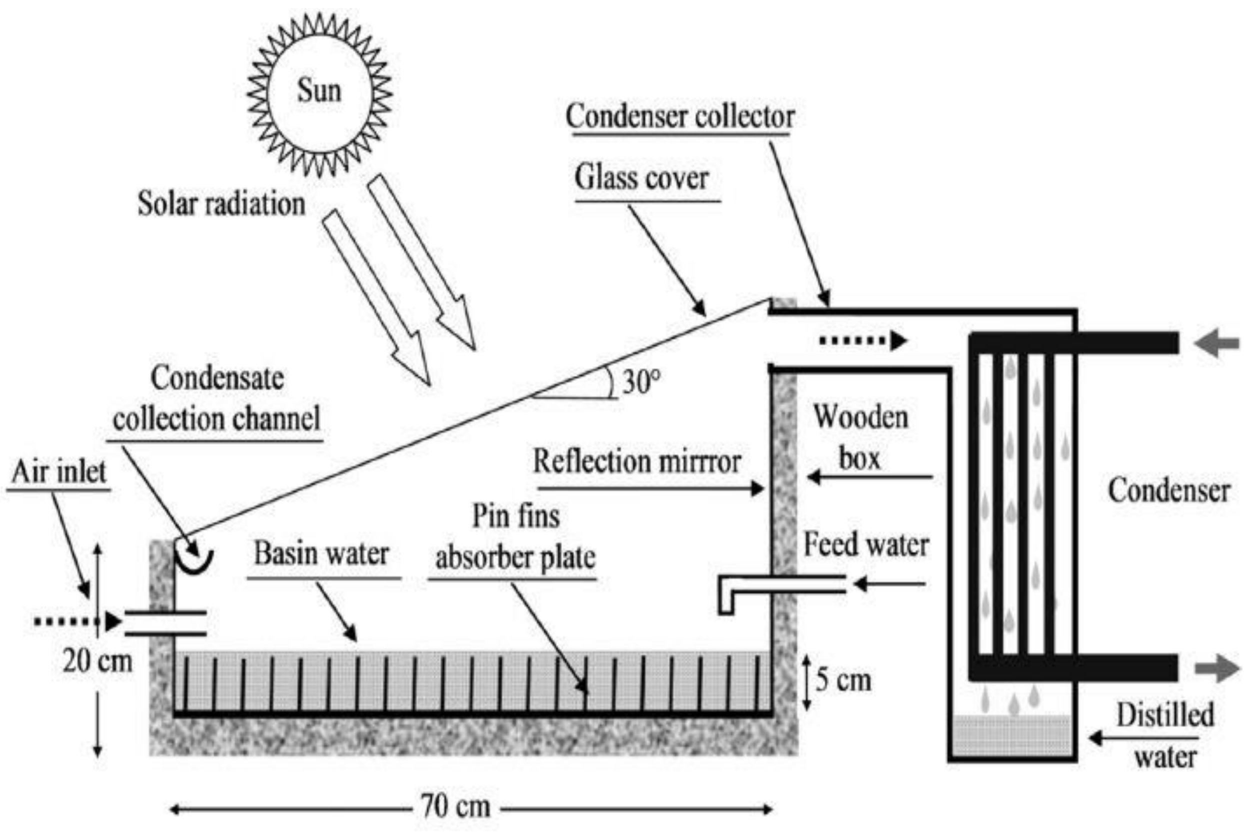


Fig.10. Schematic diagram of a solar still with fins [27]

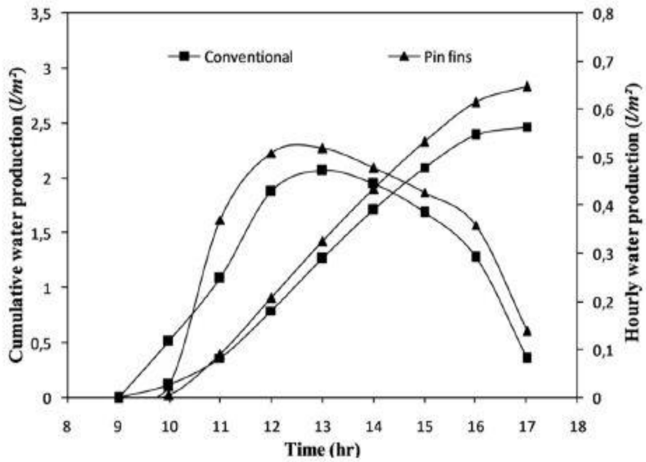


Fig.11. Evolutions of the water production for the conventional still and the still with pin fins absorber [27]

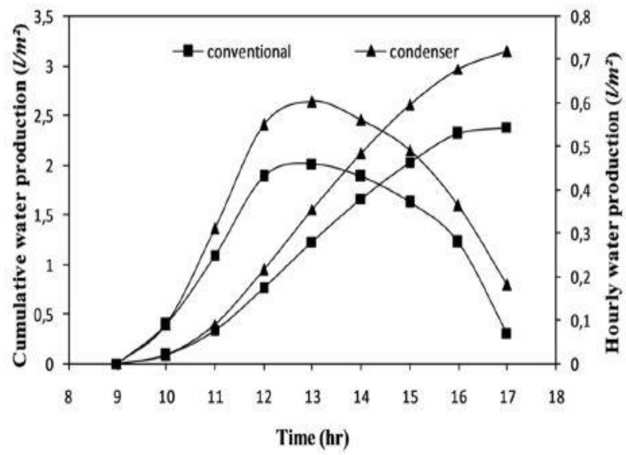


Fig.12. Evolutions of the water production for the conventional still and the still with condenser [27]

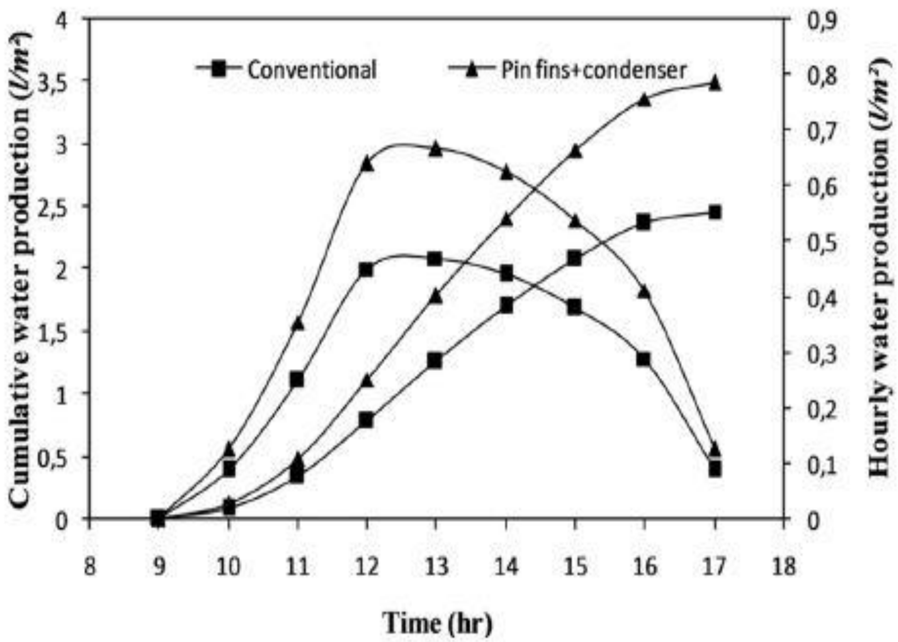
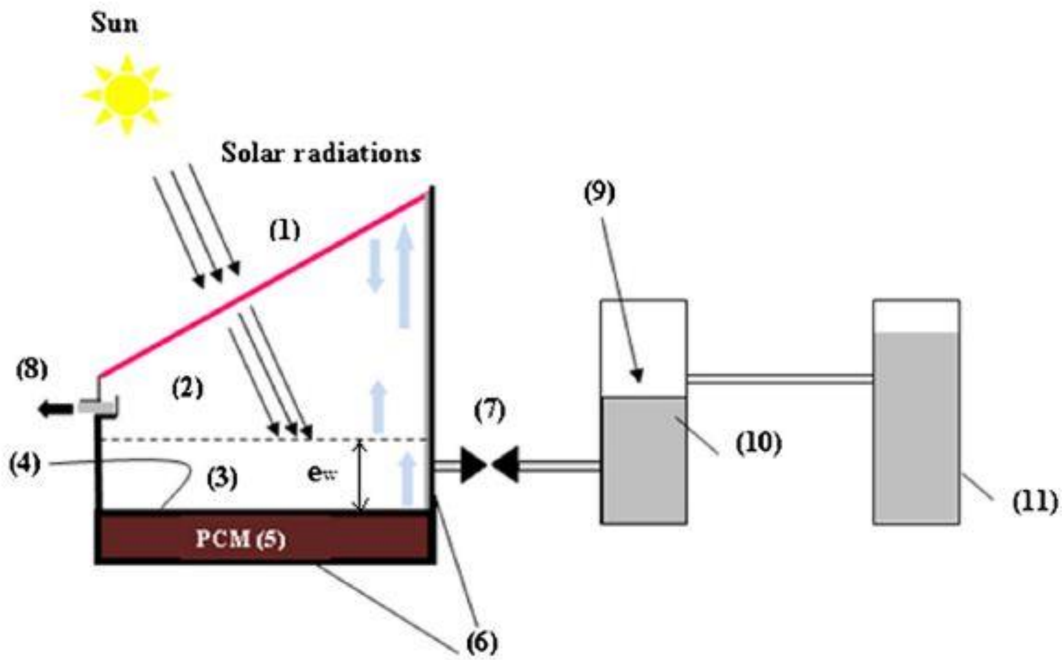


Fig.13. Evolutions of the water production for the conventional still and the still with pin fins absorber and condenser. [27]

2.2.6 Solar still with Thermal Energy Storage (TES)

Ranjan and his collaborators [28] performed the exergy analysis of a single-effect, single-slope horizontal passive solar still under the climatic condition of India. It has been shown that energy and exergy efficiencies are 30.42 and 4.93% respectively. Also, exergy destruction has been evaluated in the process of each component and the global exergy efficiency of the solar still is estimated as 23.14%.

To improve the productivity of a solar still, Dashtban and Tabrizi [29] have been investigated theoretically the thermal analysis of a weir type cascade solar still integrated with PCM as well as without PCM storage system. In this research work, the paraffin wax was used as a heat storage system which keeps the operating temperature of the still high enough to produce distilled water during the lack of sunshine, particularly at night. Also, Ansari et al. [30] examined the desalination of the brackish water using a passive solar still combined with a heat energy storage system. Phase change materials (PCMs) are used to store energy in the process of changing the aggregate state from solid to liquid. Sathishkumar et al. designed and tested a compact regenerator which can be coupled to solar still to get enhanced productivity [31].



(1) Condensing glass cover
(2) Mixture of heated air and steam
(3) Basin;
(4) Basin liner (absorber)
(5) Storage medium (PCM)
(6) Thermal insulation
(7) Non-return valve;
(8) Outlet of distilled water;
(9) Floating water level switch
(10) Feed tank
(11) Brackish water reservoir

Fig.14. Schematic diagram of a solar still with TCM [30]

2.3 SOLAR STILLS OF SPECIAL DESIGNS:

Many optimizations by means of changing the design of solar still to improve the performance of the solar still. In this aspects, spherical and tubular have been discussed here.

2.3.1 Tubular:

A tubular solar still (TSS) is a very old technique which employs the same distillation principle of the conventional basin solar still type but differs in shape (cylindrical).

Kumar et.al [32] conducted an experiment on tubular multi-wick solar still and it was investigated. The results show that the tubular multi-wick solar still can yield 13% more than that of the conventional multi- wick solar still and 8% more than that of a simple tubular solar still.

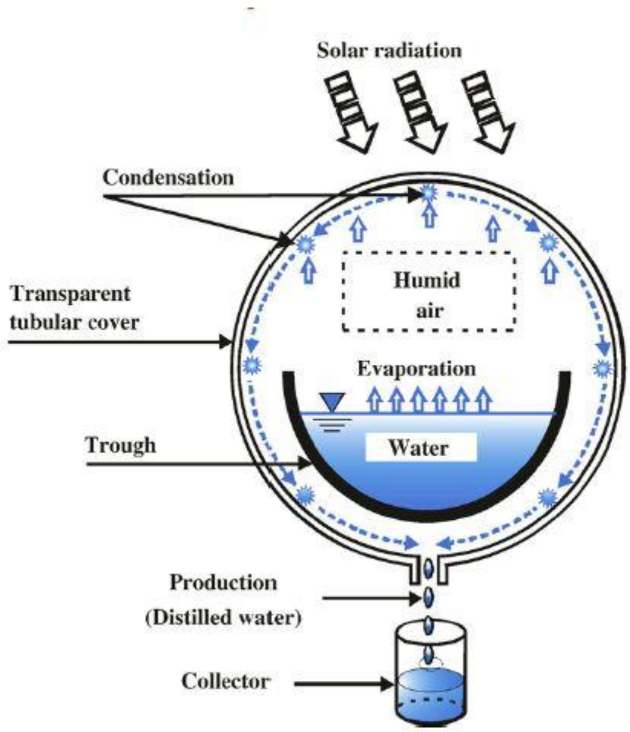


Fig.15. Schematic diagram of a tubular design solar still [32]

A new TSS design was proposed by Ahsan et al. [33] to enhance the design, maintenance, and economy. The new design has a frame assembled with six galvanized iron (GI) pipes (longitudinal) six GI rings (transverse) to hold a polythene film as a transparent cover of the TSS instead of the old vinyl chloride rigid sheet cover. Results show a reduction in productivity because of the pipe's geometry which obstructed the way of some droplets. The hourly productivity of TSS is schematically shown in fig.9. Zheng et al. [34] performed an experiment to compare single, double and triple-effect TSSs. The performance ratio (PR) of the three experiments were 0.75, 1.4 and 1.7 respectively. Recently Xie et al. [35] proposed a five-effect modular MED system (86 L/day capacity) composed of arrayed TSS on a matrix. Results showed more than 70% energy utilization efficiency.

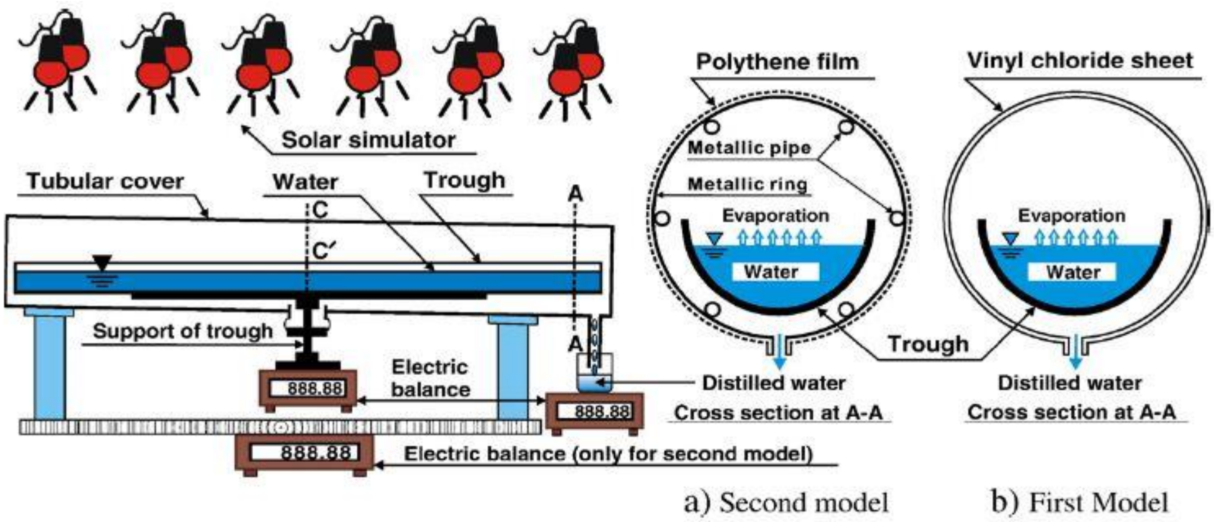


Fig.16. Schematic diagram of a tubular design solar still [32]

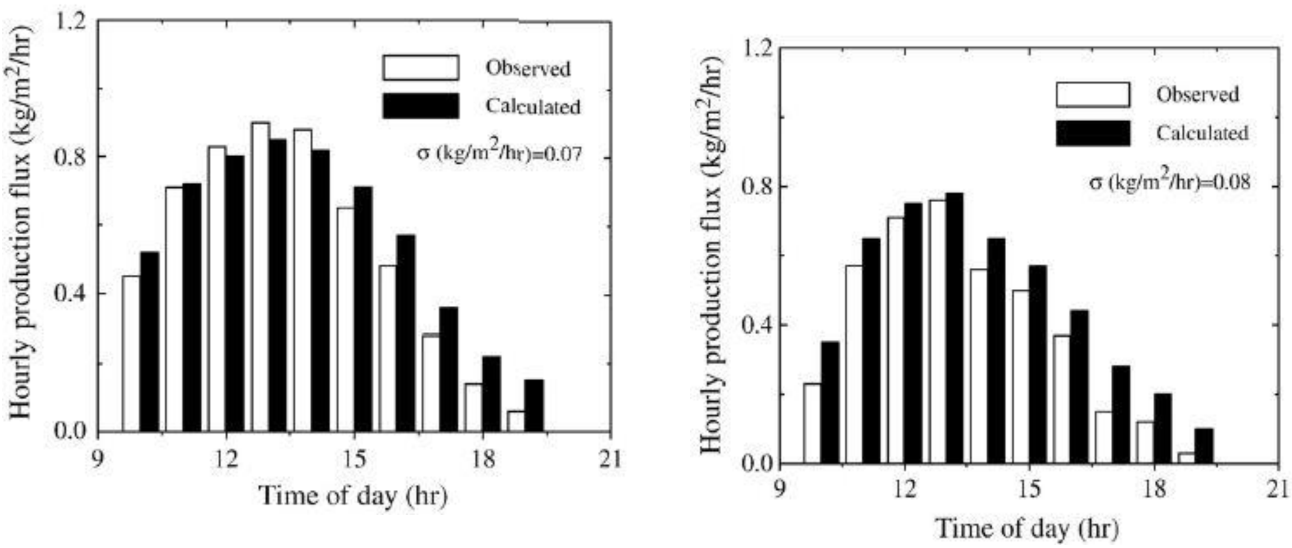


Fig.17. Schematic diagram of a tubular still hourly productivity [32]

2.3.2 Spherical:

A mathematical model for the prediction of thermal performance of the spherical type solar still was presented by Dhiman [36]. This still consists of a spherical glass cover which is fitted with a blackened metallic plate horizontally at its centre. The water gets condensed along the inner surface of the glass cover and fresh water is collected in a trough located at the bottom of the still. Their results showed an increase of 30% efficiency compared to that of conventional solar still.

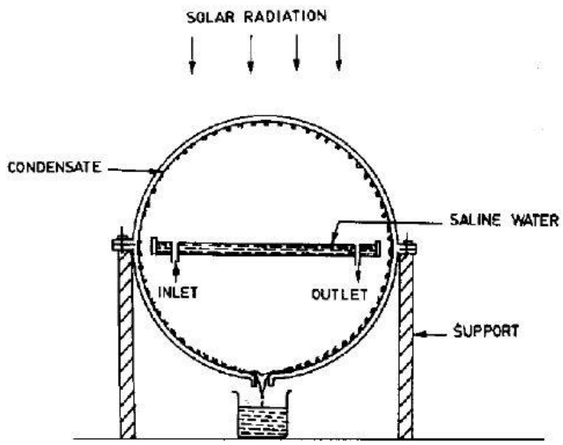


Fig.18. Schematic diagram of a spherical design solar still [35]

2.3.4 Pyramidal:

Ibrahim Altarawneh and et al., [37] investigated an annual performance of pyramidal shaped, double slope and single slope single basin solar stills experimentally and theoretically. Nine different glass covers are used, these are pyramidal shaped (15°, 30°, and 45°), double sloped (15°, 30°, and 45°), single sloped (15°, 30°, and 45°). The productivity difference is shown below in a graphical manner. Therefore finally concluded that the productivity of the pyramidal shaped solar still was lower than the others during all seasons.

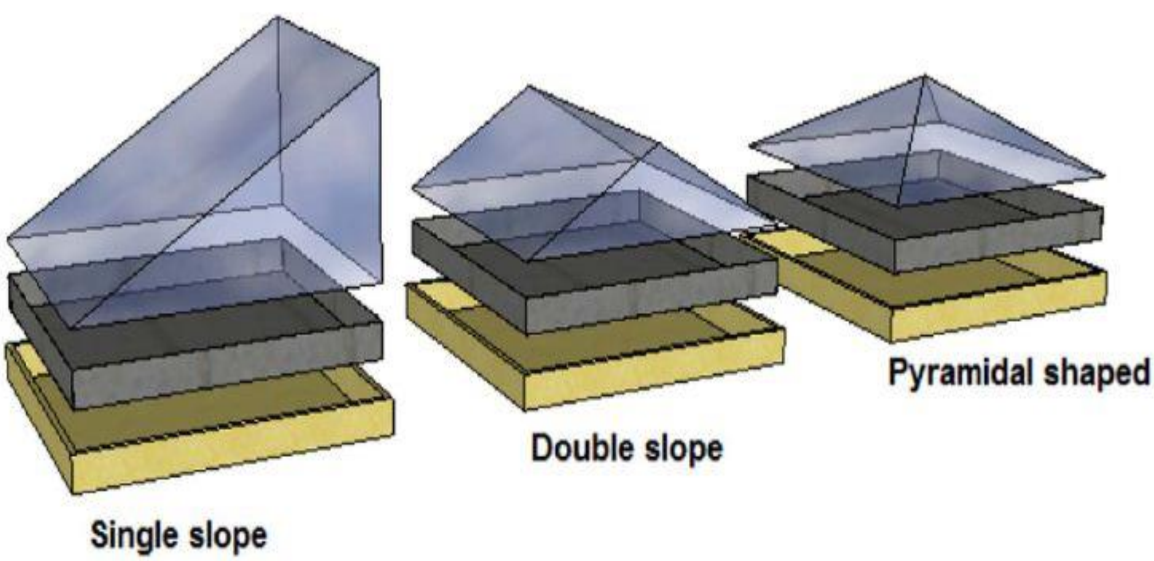


Fig.19. Schematic diagram of a pyramidal design solar still [36]

Tab.1. Schematic table for a pyramidal design solar still [36]

Still Type	Season	South	East/West	North
Single slope	Winter	50.56°	54.41°	0.00
	Spring	25.00°	25.85°	15.05°
	Summer	14.35°	19.29°	16.66°
	Autumn	43.48°	32.60°	15.31°
	Annual	30.31°	27.28°	14.95°
Double Slope	Winter	> 70°	> 70°	> 70°
	Spring	31.94°	49.45°	31.94°
	Summer	34.92°	50.65°	34.92°
	Autumn	> 70°	> 70°	> 70°
	Annual	45.00°	55.52°	45.00°
Pyramidal	Winter	> 70°	> 70°	> 70°
	Spring	50.15°	50.15°	50.15°
	Summer	49.35°	49.35°	49.35°
	Autumn	> 70°	> 70°	> 70°
	Annual	65.00°	65.00°	65.00°

Optimum settings Orientation: South, Tilt angel: 30.31°, Still configuration: Single Slope

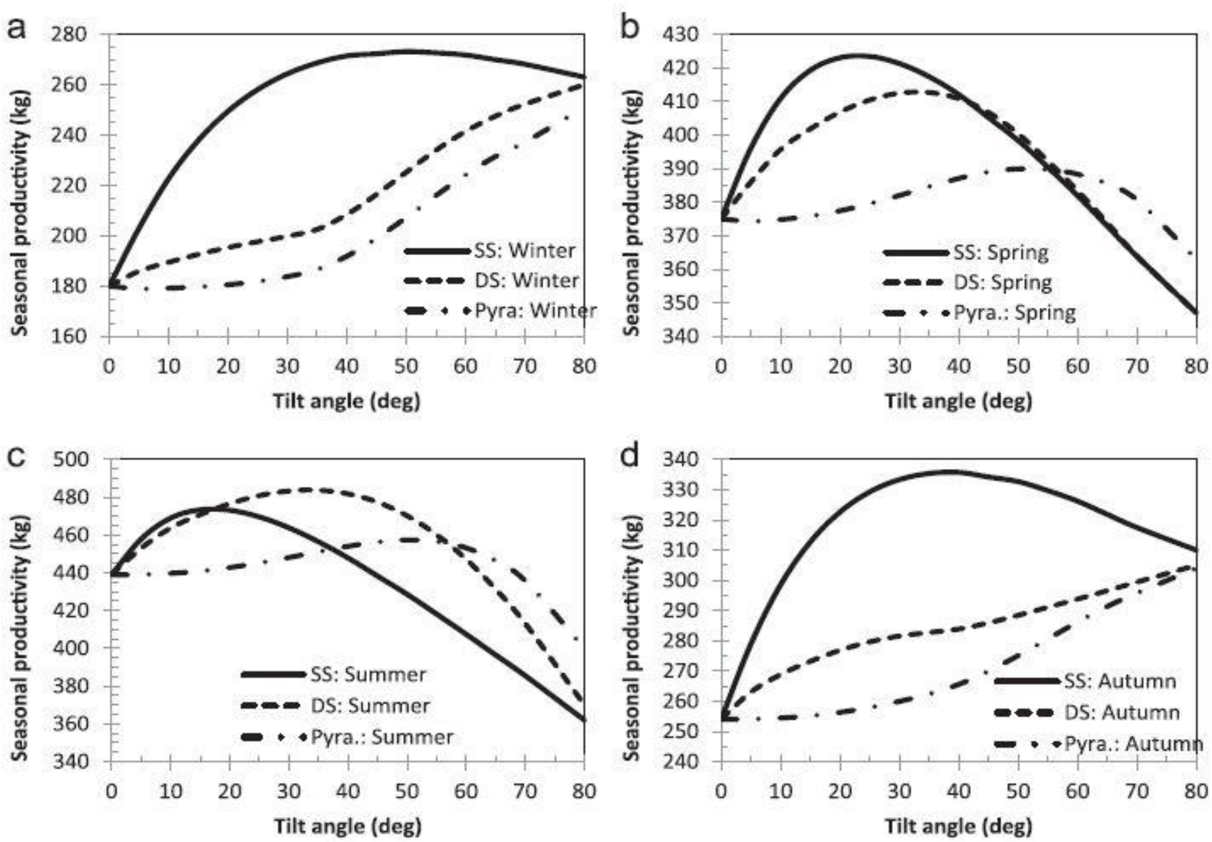


Fig.20. Schematic diagram for a pyramidal design solar still seasonal productivity [36]

COMPARISON TABLE

Table 2 Comparison of the effects due to the modifications in solar stills.

SI. no	Author's and place	Modifications/ Apparatus used	Specifications	Month / Year	Effects / Observations
1	Sakthivel et al.[38] Coimbatore, India	Jute cloth placed in vertical position	Basin area=1m x 0.5m Still cover=0.003mthick Daily yield=3.9 kg/m2	Jan.– Aug. 2006	Productivity is 20% more than conventional still. Maximum efficiency of the still is 52%.
2	Kabeel [39] Egypt	Black wick is placed on concave absorber surface	Basin area=1.2m x 1.2m Basin material=galvanized steel Insulation=glass wool Glass cover=3 mm thick	June– July 2007	Productivityis4l/m^2 and efficiency is45%
3	M. Appadurai et al.[40] Tuticorin, India	Conventional single slope solar still and mini solar pond integrated with fin type.	Basin area=1 m x 1 m Basin material=galvanized steel Insulation=wooden box Glass cover=5 mm thick	July- Nov 2014	Fin type single basin solar still have increased the water collection gain of around 47%,45.5%,50% at different water levels
4	Kamel Rabhi et al.,[27] Gafsa-Tunisia	Comparative study carried out between the modified solar still with pin fins absorber and conventional still.	Basin area=1 m x 1 m Basin material=galvanized steel Insulation=wooden box Glass angle=30º	Jan 2016	A cumulative water production gain of 41.95%,23.39% and 11% implying an hourly gain of 12.9%,9.7% and 3.1% recorded for pin fin absorber coupled with condenser respectively the conventional still. The gain of 32.18% is recorded for still with condenser compared to conventional still. Simple pin fin absorber gains only 14.53% compared to conventional still.
5	T. Rajaseenivasan et al.,[41] Madurai, India	Comparative study carried out between the solar still with circular and square fins integrated at basin	Basin area=1 m x 1 m Basin material=mild steel Insulation=wooden box Glass cover=4 mm thick	July- Dec 2015	Daily productivity of the still increases by 26.3 and 36.7% for circular and square finned stills and it changes to 36 and 45.8% for fins covered with wick materials.

SI. no	Author's and place	Modifications/ Apparatus used	Specifications	Month/ Year	Effects / Observations
6	Rattanapol Panomwan Na Ayuthaya et al.,[42] Bangkok Thailand	Modified Still at the outdoor conditions and indoor conditions	Basin area=0.7 m x 0.7 m Basin material=GI steel Insulation=wooden box Glass angle=14º	Feb-Aug 2012	In order to increase the performance at the outdoor conditions, a basin solar still was integrated with a set of fin-plate fitting in the still basin for distillation of a 10%v/v Alcohol solution. It was found that the productivity of the modified solar still was increased by 15.5%, Compared to that of a conventional still.
7	Z.M. Omara et al.,[43] Egypt	Corrugated solar still compared with a conventional solar still	Basin area=1 m x 1 m Basin material=Iron sheet(1.5 mm thick) Insulation=saw dust followed by wooden box Glass cover=3 mm thick	Jan-May 2011	The integrated fins at the base of the solar still gives an average of 40% increase in the amount of distilled water produced compared with a conventional solar still, while using the corrugated plate as the base productivity increases by about 21% compared with a conventional still.
8	V. Velmurugan et al.,[44] Madurai India	Comparison made on solar still with wick type ,sponges and fins	Basin area=1 m x 1 m Basin material=GI steel Insulation=saw dust Glass angle=10º	Feb-July 2008	It was found that 29.6% productivity increased when wick type solar still was used, 15.3% productivity increased when sponges were used and 45.5% increased when fins were used.
9	W.M. Alai et al.,[45] Egypt	Modified by means of pin fins and comparison takes places	Basin area=1.25 m x 0.8 m Basin material=Aluminum Insulation=saw dust Glass cover=4 mm thick Glass angle=17º	June-Oct 2015	Enhancement of the still productivity and efficiency is proven when pin-finned wick is applied. More than 23% increase in system productivity is attained when pin finned wick is applied. Fluctuation of solar radiation limits the improvement in system Productivity to 11.53% when using wick surface.
10	A.A. El Sebaii et al.,[46] Egypt	Made a comparative study between finned-basin liner still (FBLS) and conventiona l still	Basin area=1 m x 1 m Basin material=G.I. sheet Insulation=insulating foam Glass cover=4 mm thick Glass angle=17º	Mar-Aug 2016	The measured daily productivity of the conventional and finned basin liner solar stills are 4.235 and 5.065 (kg/m^{2}day) respectively, with a relative percentage improvement ratio of 16.39 %.The average annual productivity for the CS and FBLS stills are found to be 1467.4 and 1898.8 (L/m^2).

SI. no	Author's and place	Modifications/ Apparatus used	Specifications	Month/ Year	Effects / Observations
12	Hitesh Panchal et al., [48] Rajasthan, India	Various methods applied to solar still for enhancement of distillate output	Basin area=1 m x 1 m Basin material=G.I. sheet Insulation=wooden box Glass cover=4 mm thick	2017	Attachment of fins found increment in distillate output due to enhancement in the surface area of water inside the basin. It is a characteristic of each storage material to store the excess heat during day time due to pore holes inside it and then release during off sunshine or absence of solar energy for increment in distillate output compared with conventional solar still.
13	P. Naveen kumar et al.,[49] Chennai, India	Experiments are carried out for three solar stills namely, pyramid solar still, inclined solar still and triangular pyramidal solar still incorporated to an Inclined solar still.	Inclined solar still: Basin area=0.65m x 0.65m Basin material=mild steel Insulation=Thermocol sheets Glass cover=4 mm thick Glass angle=30º Inclined solar still with triangular pyramidal solar still: Basin area=0.5m x 0.5m Basin material=mild steel Insulation= thermocol sheets Glass cover=4 mm thick Glass angle=13º Triangular pyramidal solar still: Basin area=0.5m x 0.5m Basin material=mild steel Insulation=thermocol sheets Glass cover=4 mm thick Glass angle=13º	June-Aug 2017	The productivity of solar still is strongly influenced by various parameters such as solar intensity, basin area, depth of water. Also the productivity of fresh water increases when depth of water is reduced. To preheat the feed water, inclined solar still is used as a solar energy collector thereby the productivity of solar stills are enhanced. The maximum yield obtained from triangular pyramidal solar still integrated to an inclined solar still was about 7.52 kg/m^2 Inclined solar still integrated with pyramid solar still produced 79.05% higher productivity than the conventional solar still
14	M.H. Sellami et al.,[50] Algeria	Experiments are carried out to improve the yield of a solar still by improving absorber performance through the use of an added inner heat storage system. Recovering the absorber surface with layers of blackened sponge	Four small-scale solar powered distillation pilot units were set up and operated.	2017	The results obtained showed that a 0.5cm sponge thickness increased the yield by 57.77 % i.e. 58%, relative to the baseline case (i.e. with no blackened sponge added).In contrast, a sponge thickness of 1.0cm resulted in a yield improvement of only23.03 %, whereas a sponge thickness of 1.5cm resulted in a decreased yield of 29.95 % i.e. 30% (relative to the baseline case).

SI. no	Author's and place	Modifications/ Apparatus used	Specifications	Month/ Year	Effects / Observations
15	R. Samuel Hansen et al.,[25] Tirunelveli, India	A comparative analysis in productivity and efficiency was also made for the conventional inclined still and the new hybrid integrated solar still with and without hot water storage tank	Inclined solar desalination system: Basin area=1m x 1m Basin material=G.I. sheet Insulation= thermocol Glass cover=4 mm thick Single basin solar desalination system: Basin area=1 m x 1 m Basin material=G.I. sheet Insulation=thermocol Glass cover=4 mm thick	2017	Based on the experimental Analysis, it was observed that for the conventional inclined still, 25.75% productivity increased, when it is coupled with fin shaped absorber and 74.5% productivity increased, when it is integrated with basin still. The overall productivity (distillate output) in the integrated still with fin shaped absorber configuration was 5210 ml/day and the efficiency of the integrated desalination system with hot water thermal storage was 46.9%.

3. CONCLUSION

Table 2 summarizes the comparison of the effects due to the modifications in the solar stills. A detailed review is made on the researches done on improving the productivity of the solar stills and the following conclusions are arrived;

- The use of water absorbing materials like jute cloth, wick and charcoal cloth increases the area of absorption and thereby increases the productivity of the stills.
- The use of finned plate, corrugated plate and floating thermocol insulation in the still basin also increases the performance of the solar stills.
- Maintaining minimum water depth in the basin increases the productivity of the solar stills. The increase in the depth of water decreases the still productivity.
- The inlet water may be preheated to increase the productivity of the solar stills. The evaporation and condensation rate for preheated water is more compared to the ordinary water. The water may be preheated by integrating the still with a flat plate collector, solar pond and heat pipe.
- The heat energy from the sun may be stored using sand, absorbing materials and PCM. The stills can produce distillate during off-shine hours. Paraffin wax and stearic acid may be used as PCM.
- Maintaining vacuum conditions in the still improve the productivity.
- The performance of the still with double basin is comparatively high than the single basin stills.
- The use of hemispherical plastic cover, reflectors and condensers and other types such as weir type stills, stills with humidification–dehumidification process, multi-effect distillation can improve the productivity.
- Stills with thermoelectric cooling, hybrid type stills, inclined stills, stills using packed layer and rotating shaft, photo catalyst, etc enhances the productivity.

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