Methods of Performance enhancement in solar still distillation: A Review

Uday Kumar Prajapati[1], Bhupendra Gupta[2], Jyoti Bhalavi[3]

[1]Research Scholar, M.E. (Heat Power Engineering)
[2]Assistant Professor, Department of Mechanical Engineering
[3]Assistant Professor, Department of Industrial and production Engineering
Jabalpur Engineering College, Gokalpur, Jabalpur (M.P.) - 482011, India

***Abstract*: Fresh water is becoming scarce with time, leading to severe water crisis in many parts of the world. Growing demands of freshwater resources are creating an urgent need to develop self-sustained system to meet the demand of fresh water. Among the available purification technologies, solar distillation process proves to be a suitable solution for resolving this existing crisis. The sun's energy heat increases the rate of evaporation. As the water evaporates, water vapor rises and condenses on the glass surface for collection. Among the various methods of purification of water solar distillation is more prominent. The distillation is one of the important methods of getting pure water from brackish water using solar energy. An experimental work is conducted on a double slope single basin solar still. So in this paper, the characteristics and working principles of double slope still introduced and the current researches in the field are described from the viewpoint of experimental tests, theoretical analyses as well as practical application.**

***Keywords*: Solar still, desalination, solar energy, purification, technologies.**

Introduction:

Solar desalination is the process of converting the impure saline water into potable drinking water using solar energy. The solar desalination methods have been used by the mankind for thousands of years. In fact, solar stills were the first method which was used on a small scale to convert impure saline water to potable water. Water is one of the most important constituent for the sustenance of mankind. Water crisis will be a serious challenge in near future with increasing the global warming in the world. Even though water is one of the most abundant resources on the earth and the earth contains about 1.4 billion km^3 of water i.e. around 70% of surface area; in which 97.5% is salty. From the remaining fresh water, only 0.5% is available and accessible to support all life on earth. It is useful for many purposes like agriculture, irrigation and domestic purposes like cooking and so on. Fresh water is the most important issues of health hazard in today's world.
The schematic diagram and working operation of a Double slope solar still as shown in fig 1 and fig 2 respectively. Solar still presents specific advantages to be used in these areas due to its easier construction, minimum skills of operation and maintenance requirements, and friendliness to the environment. The clean free energy and friendly to the environment are two major advantages which strengthen the use of solar stills. The main disadvantage of solar stills is the low yield of freshwater in comparison with the other desalination systems. The production capacity for a simple type still is only between 2–5 L/m^2/day. This makes the solar stills uneconomical compared to the other conventional desalination systems.

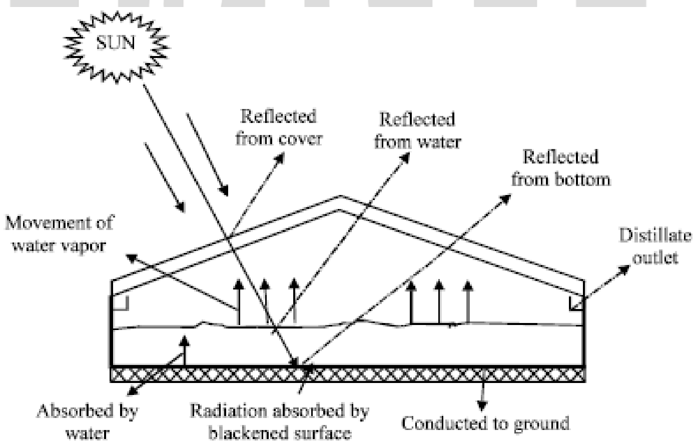

Fig 1: Block diagram of double slope solar still.

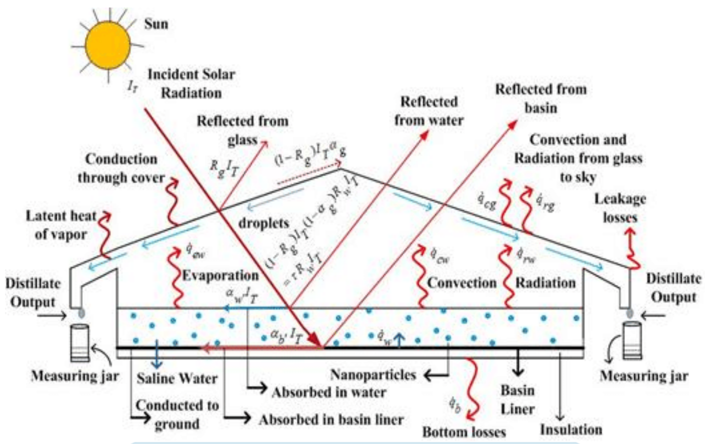

Fig 2: Working mechanism of double slope solar still

Existing research effort:

Many of the researchers work in the field of solar still and optimized the different parameters. Researcher mainly used solar energy to convert the saline water into the pure water. To increase heat storage capacity different kind of working phase change materials used. Many people uses the Nano composites particles of metal like titanium oxide, copper oxide, Aluminum oxide and many others to increase heat transfer rate, some of the work is mention hear in the below section:

1. **Mr. A. Prabakaran (2018) [1]:** An experimental study was conducted to improve the productivity of single basin single slope solar still with thermal energy storage. Two types of solar still were designed and fabricated, in order to study the performance of each still. The first one is a conventional type and the second one is a modified solar still which has squared fins and thermal energy storage material. The performance of two different solar still were tested under two cases. In the first case conventional solar still is compared with modified solar still which has square fins placed in the basin of solar still. In the second case conventional solar still is compared with modified solar still in which square fins packed with thermal energy storage material The result show that the modified still has improved the productivity by 41%,61%, than the conventional solar still under same climate conditions for the first and second case respectively.

2. **Miqdam Tariq Chaichan (2018) [2]:** In this paper Nano particles were dispersed in paraffin wax (as a phase change material) to increase the thermal conductivity of the latter compared to the base material. The mixing of Nano particles with the wax changes the thermos-physical properties of the used wax. The thermos-physical properties as density, viscosity, and thermal conductivity showed increasing values in contrast to the specific heat where it reduced relatively. In this three distillers were made to study the effect of adding these Nano particles to simple solar distillers. The first of which was without any modification and the second had paraffin wax as additional material. In the third distiller, combination of paraffin wax with a nano-Al_2O_3 spread on it that was used to promote thermal conductivity. They observed that the addition of Nano particles to paraffin wax increased significantly the rate of heat transfer, resulting in higher yields of the solar distiller. Paraffin wax addition caused an increase in the daily distillation yield up to 10.38% while the addition of nano-Al_2O_3 to paraffin wax improved distillate yield up to 60.53% compared to the simple distiller yield due to continuous distillation after the sunset.

3. **Nader Rahba (2018) [3]:** In this study, two types of solar stills, triangular and tubular one, had been experimentally tested under a real weather condition. Following the same procedure, the experiments were carried out over seven typical winter days and the effects of solar radiation and ambient temperature on water productivity and total efficiency of the stills has been experimentally investigated. Furthermore, to understand the detail structures of the air flow inside the enclosures, the fluid flow has been numerically simulated using computational fluid dynamics. Having the details of the fluid flow, the values of local entropy generation in the chamber have been obtained. The results indicated that the tubular still showed a better performance by 20% compared to the triangular one. The results of numerical simulation showed that the greater strength of the recirculating zones and the lower entropy generation are the main reasons to have a better water production in the tubular still.

4. **A. Muthu Manokar (2017) [4]:** In this paper researcher presents a comparative study of single basin single slope aluminum finned acrylic solar still and single basin single slope galvanized iron solar still. By using acrylic sheet as casing as it has very low thermal conductivity, it reduces the loss of heat from the still basin to the bottom which leads to increase in the rate of evaporation of water. The daily productivity of single basin single slope acrylic solar still is 660ml/0.25m^2/day and galvanized iron solar still is 585 ml/ 0.25m^2/day.

5. **S. Shanmugan (2017) [5]:** Belongings of incorporating (Al_2O_3) Nano particles of wick materials in the solar still of a PCM charity in the basin for TES organization have been probed in this study. It is an innovative organization of techniques by a drip button to decant saline water drop by drop on absorbing materials in the basin. It (summer and winter) has been established with the dripping of saline water on altered absorbing materials like CW, FWCW, JW and FWJW as the basin liner. Diurnal variations of drip button temperature, T_g, T_b, T_w and mass of the output have been verified. Vitality equilibrium equations for the moist air inside the still,

glass cover and wick material have been solved to get the analytical expressions for the instantaneous efficiency of the anticipated structure. Diagram of Experimental analysis of single basin still with different fin absorbing material is shown in fig 3. The numerical calculations have been authenticated with the experimental annotations for a (S & W) few typical days from January 2016 to January 2017. With the heat extraction performance, the yield of wick materials with a single basin solar still by a PCM and Nano particles (S & W) as FWCW is 7.460 & 4.120 kg/m^2 day, respectively.

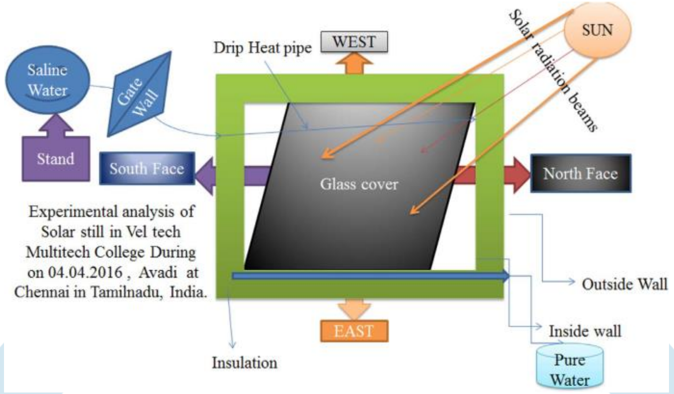

Fig 3: Experimental analysis of single basin still with different fin absorbing material [3]

6. **S. Joe Patrick Gnanaraj et.al (2017) [6]:** during the analysis attempt was made to optimize the performance of double basin solar still. The dimension of the lower basin was 100 × 140 cm2 and the dimension of the upper basin was 100 × 100 cm^2. So the lower basin was 100 × 20 cm^2 glass cover in both the sides of the still to receive direct sunlight. They uses external energy sources such as reflectors, flat plate collector and mini solar pond. The productivity of single basin still, double basin still with no external modifications, double basin still with reflectors, double basin still with reflectors coupled with flat plate collector and mini solar pond was 2745, 4333, 5650 and 6249 ML/day respectively. The productivity of double basin still, double basin still with reflectors and double basin still integrated with flat plate collector and mini solar pond was 57.83%, 105.8% and 127.65% respectively higher than the single basin still. These modifications increased the performance of lower basin and upper basin. But the relative contribution of lower basin improved from 29.75% to 35.22% and to 40.6%.

7. **Ibrahem Altarawneh ET. Al (2017) [7]:** In this research work, the annual performance of single basin single slope, double slope and pyramidal shaped solar stills has been investigated experimentally and theoretically. Fig 4 shows single basin single slope solar still. Experiments were performed in Ma'an area in Jordan throughout the year from January 2015 to December 2015 on clear days using solar stills with different orientations and different tilt angles of 15°, 30° and 45°. And the mathematical models of solar radiation and solar desalination were developed to simulate the availability of solar radiation and the performance of the solar stills. The average basin area was found to be of 0.64 m^2 and 0.82 m^2 in January and July, respectively. Annual optimal tilt angles of 30.3°, 45°, and 65° were suggested for south oriented single slope, double slope and pyramidal shaped solar stills, respectively. Under optimal settings, the single slope solar still was found to be the best system with improvement in productivity of about 28%. On a seasonal basis, a south oriented double slope solar still with tilt angle of 35° was found to perform, slightly, better than the other stills in summer.

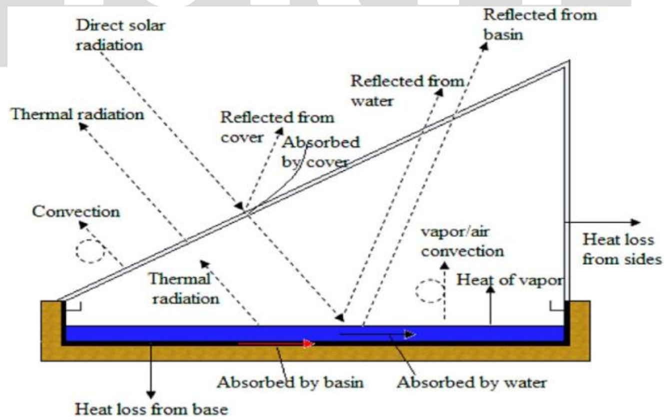

Fig 4: Energy flux in a typical single basin, single slope solar still.

8. **A. Muthu Manokara (2016) [8]:** Scarceness for water exists in many countries even though three fourth of the earth is covered by water. The reason behind this is the rapid enlargement of industry and populace worldwide. Solar still is the only efficient solution for water trouble in hot climatic conditional areas where there is scarcity of water and electricity. Solar still is a very simple solar device that is used for converting the available salted water into potable water. This paper presents a comparative study of single basin single slope aluminums finned acrylic solar still and single basin single slope galvanized iron solar still. By using

acrylic sheet as casing as it has very low thermal conductivity, it reduces the loss of heat from the still basin to the bottom which leads to increase in the rate of evaporation of water. The daily productivity of single basin single slope acrylic solar still is 660ML/0.25M2/day and galvanized iron solar still is 585 ML/ 0.25M2

9. **Hasan Mousa (2016) [9]:** In this paper study of detailed modelling of water desalination involving PCM that stores energy during day time and emits it during night time is theoretically investigated. The effect of various parameters such as the PCM type through its melting point, PCM quantity, feed-water flow rate, and solar irradiation on the productivity of the unit expressed as the amount of fresh water produced per day is theoretically investigated. The results showed that the presence of PCM with 40 ºC melting point maintains higher water temperatures after sunset but negatively affects the productivity. Decreasing the feed flow rate from 10 L/hr. to 1 L/hr. improved the fresh water productivity by 49%. When the maximum solar intensity increased from 400 to 1000 W/m^2, the fresh water productivity increased from 0.75 L/day to 2.1 L/day. In the presence of PCM and at certain solar irradiation intensity the productivity can be improved by using PCM of higher melting point and reducing water feed flow rate.

10. **Chendake A.D. (2015) [10]:** Here in this work the sun's energy is used to heat the water and increases the rate of evaporation. As the water evaporates, water vapor rises and condenses on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The purpose of this research is to design a water distillation system that can purify water from nearly any source. The designed model produces 1.6 liters of pure water from 12 liters of dirty water during eight hours. The TDS in the pure water was 30 ppm. The efficiency was 22.33 % at water depth of 0.02 m.

11. **T. A. Babalola (2015) [11]:** As the increasing demand for potable water, researchers have developed various technologies to meet this target. In this research, the productivity of water by a double slope solar still was determined by varying the water depth and surrounding temperature for nine days in the premises of Lagos State University, Ojo, Nigeria at 6.5ºN, 3.35ºE. It was observed that at a depth of 2.0cm the maximum output of
The solar still was obtained and a maximum efficiency of 25.3%.

12. **T. Elango (2015) [12]:** This paper presents a new approach to increase the productivity of the solar still by using glass as the basin material. Single and double basin double slope solar stills (as shown in fig 5 & 6) of same basin area were manufactured by using glass. And they were performing the experiments by varying the water depths from 1 to 5 cm under both insulated and un-insulated conditions. They observe that the production of single basin is more than the double basin during the heating period and double basin is more during the cooling period. The performance of the double basin double slope solar still was higher than the single basin double slope solar still under insulated and un-insulated conditions. The productivity of the stills was more at the lowest water depth of 1 cm. At 1 cm water depth, double basin insulated and un-insulated stills gave 17.38% and 8.12% higher production than the single basin still.

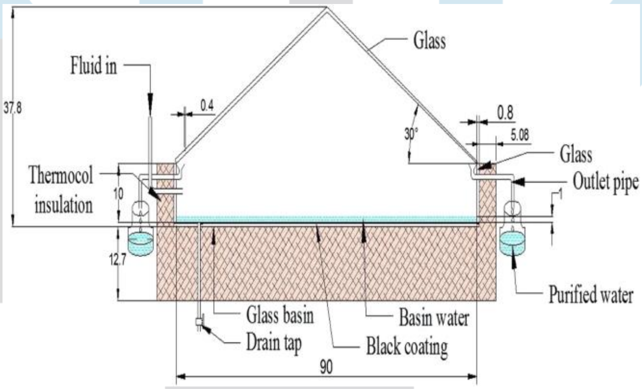

Fig. 5: Schematic diagram of a single basin double slope glass based solar still.

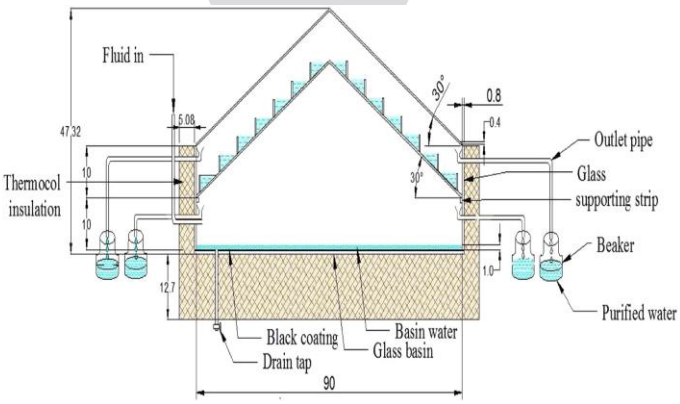

Fig. 6: Schematic diagram of a double basin double slope glass based solar still.

13. **T. Rajaseenivasan (2013) [13]:** In his research paper a new approach to enhance the productivity of a solar still by introducing an additional basin in the double slope solar still. Single basin and double basin double slope solar still shown in fig 7 & 8.The author modelled two solar stills, single basin double slope and double basin double slope with the same basin area and tested at Kovilpatti (9° 11′N, 77° 52′E), Tamil Nadu, and India. They performed experiments with various depths of water, different wick materials, porous material and energy storing material. They observed in double basin still, a mass of water in upper basin is constant for all experiments. For both stills, water production decreases with increase of water depth. The production rate is higher for both the stills, when mild steel pieces are used as storing material in the basin. For the same basin condition, double basin still production is 85% more than single basin still.

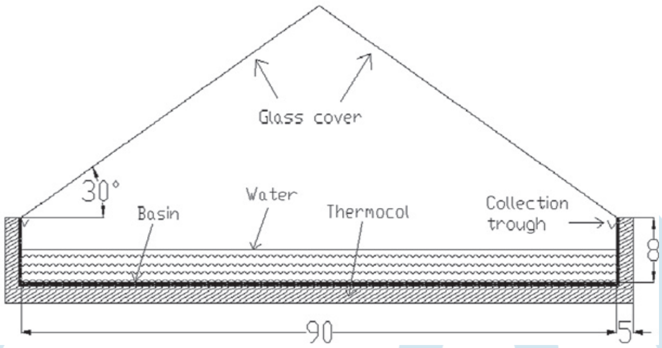

Fig 7: Single basin

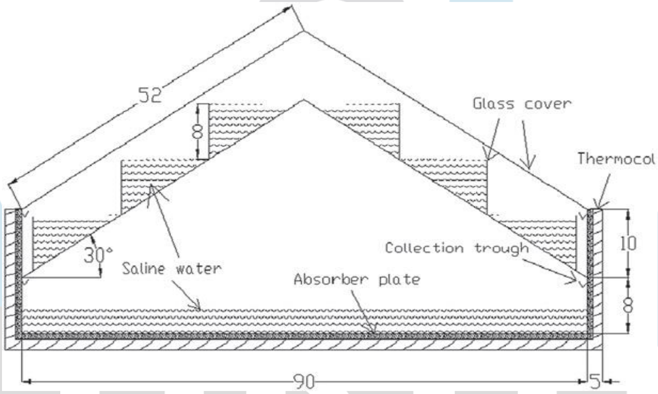

Fig 8: Double basin

14. **Gajendra Singh (2011) [14]:** Here in this work researcher design and fabricate a modified photovoltaic thermal (PVT) double slope active solar still for remote locations. They installed the system at the campus of KIET, Ghaziabad (India) and systems performance has been experimentally evaluated under field conditions in natural and forced circulation mode (series and parallel).they has been used Photovoltaic operated DC water pump between solar still and photovoltaic (PV) integrated flat plate collector to re-circulate the water through the collectors and transfer it to the solar still. The production rate has been accelerated to 1.4 times than the single slope hybrid (PVT) active solar still and obtained highest (7.54 kg/day) for the parallel configuration in forced mode in the month of October, 2010. The daily average energy efficiency of the solar still was obtained as 17.4%.

15. **K. Kalidasa Murugavel ET. al (2010) [15]:** In this research author modelled a single basin double slope solar still with an inner basin size 2.08 m X 0.84 m X 0.075 m and that of the outer basin size 2.3 m X 1m X 0.25 m with mild steel plate and tested with a layer of water and different sensible heat storage materials like quartzite rock, red brick pieces, cement concrete pieces, washed stones and iron scraps. And fig 9 shows photographic view of single basin double slope solar still. It was found that, the still with 3/4 inches sized quartzite rock is the effective basin material. The variations in solar incidence angle and transmittance of the covers are also considered in this work. The theoretical values are compared with actual values. The theoretical Water and glass temperatures and the theoretical production rate are having higher deviation with actual. Therefore, another thermal model developed for this still is applied to validate the results accurately. It was found that, the theoretical production rate using thermal model agrees well with experimental.

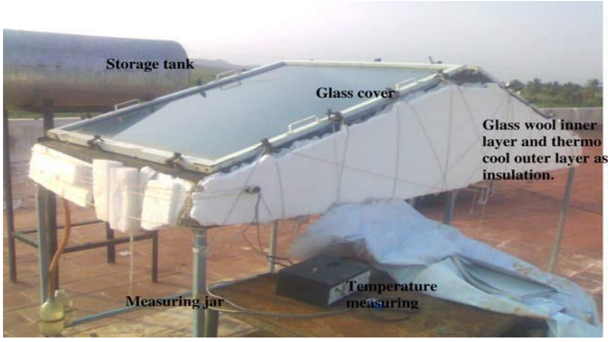

Fig. 9: Photographic view of single basin double slope solar still.

Table 1: The existing research work and different process parameters

S.no.	Authors Name	Improvement technique	Types	Output Parameter	Parameters used	Analysis Type
1.	Mr. A. Prabakaran (2018)	Fines & PCM	Single slope solar still	Finn enhance eff by 41% Finn with PCM enhance eff by 61% compared to simple solar still	Basin Area $0.5m^2$ Fines $(0.02x0.45x0.08m^3)$	Experimental analysis
2.	Miqdam Tariq Chaichan (2018)	Nano Particles & PCM	Single slope solar still	Efficiency, Thermo-physical properties	4.8 kg of PCM & 48 gram Aluminium oxide	Analytical Analysis
3.	Nader Rahba (2018)	Different types of solar still	Triangular and tubular solar still	Tubular still showed a better performance by 20% compared to the triangular one.	Radius of basin 10 cm	Experimental & Numerical Analysis ,
4.	A. Muthu Manokar (2017)	Al fines	Single slope Al finned acrylic solar still and galvanised iron solar still	Galvanized iron solar still acrylic solar still gives 11.36% higher productivity	Basin Area $0.25m^2$ Fines 15 mm of height	Experimental Analysis
5.	S. Shanmugan (2017)	Nano articles & PCM	Single slope solar still	Efficiency of the still through 59.14% (summer) and 27.13% (winter)	Basin Area $1.69m^2$ Mass of water 12 kg	Theoretical and Experimental Analysis
6.	S. Joe Patrick Gnanaraj et.al (2017)	Reflectors, flat plate collector and mini solar pond	Double basin solar still	Productivity of double basin still, double basin still with reflectors and double basin still integrated with flat plate collector and mini solar pond was 57.83%, 105.8% and 127.65% respectively	lower basin was 100 × 140 cm^2 upper basin was 100 × 100 cm^2	Theoretical and Experimental Analysis
7.	Ibrahem Altarawneh et.al (2017)	Different solar stills	Single basin single slope, double slope and pyramidal shaped solar stills	The single slope solar still was found to be the best system with improvement in productivity of about 28%.	Basin Area 0.82 m^2	Experimental and Theoretical Analysis
8.	Hasan Mousa (2016)	PCM	Solar desalination units	Productivity increased from 0.75 L/day to 2.1 L/day.	m_f =5 L/h, m_{PCM} = 10 kg	Theoretical Analysis

9.	Chendake A.D. (2015)	Double slope	Double Slope Type Solar Distillation Unit	Efficiency is 22.33 % at water depth of 0.02 m.	Basin Area 0.7 m^2	Experimental Analysis
10.	T. A. Babalola (2015)	Depth veriation	Double slope solar still	Maximum efficiency of 25.3% at 2cmm depth of water	Basin Area 0.86 m^2	Theoretical Analysis
11.	T. Elango (2015)	Depth variation	Single and Double basin double slope glass solar stills	At 1 cm water depth, double basin insulated and un-insulated stills gave 17.38% and 8.12% higher production than the single basin still	Basin Area 0.81 m^2	Experimental Analysis
12.	T. Rajaseenivasan (2013)	Water depth	Double basin and single basin solar stills	For the same basin condition, double Basin still production is 85% more than single basin still.	Basin Area 0.81m^2	Experimental Analysis
13.	Gajendra Singh (2011)	Solar cell	Hybrid photovoltaic thermal (PVT) double slope active solar still	Daily average energy efficiency of the solar still is obtained as 17.4%.	Basin Area 2m^2	Experimental and Analytical Analysis
14.	K. Kalidasa Murugavel et.al (2010)	Depth, energy storing materials	Single basin double slope solar still	The still with 3/4 in. sized quartzite Rock is the effective basin material.	Basin Area 2.32m^2	Experimental and Theoretical Analysis

Conclusion:

In the world of competition and energy crises, solar still proves the best option to meet the growing need of potable water, as it utilize the renewable, unlimited, pollution free and free of cost solar energy. So many researches have been carried out in this field for continuous innovative and efficient revolution. This study reviewed some of the general solar still systems used. Different heat recovery and renewable energy methodologies in order to determine the typical double solar still arrangements along with their working temperature range for use in the respective.

The main factors affecting the productivity of a solar still are solar intensity, wind velocity, environmental temperature, water–glass temperature difference, depth of water, temperature of inlet water, absorber plate area and glass cover angle.

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