A Study of Double Basin Solar Still: A Review

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Abstract— The device used to produce fresh water from saline water with the use of solar energy is commonly known as solar still. The productivity of simple solar still (conventional still) is nearly 1 - 2 L/m2/day. Many researchers and scientists have performed experiments on different designs of solar still to improve their performance. Double basin solar still is one of the design of solar still having higher productivity 30-40 % than conventional solar still. Productivity and efficiency of this types of solar still can be further increased by using evacuated tube collector, internal heat exchanger, and wick materials used with it. This review article describe the attempts by different researchers to increase the productivity of double basin solar still. A double basin solar still is consist of two basin still in which one basin is mounted on another. The main benefit of using this system is that the amount of latent heat energy of vapour which is condensed at lower surface of inclined glass cover in lower basin is used in heating the upper layer of water rather than heat loss to the ambient.

Key words: Solar Still, Solar Desalination, Double Basin Still, Distillate Output

I. INTRODUCTION

Water is fundamental need for living on earth. As 71 % of earth's surface is bounded with water but most of existing resources are not suitable for human activity. Humans are dependent on lakes, rivers, ponds and underground water reservoir. Most of the available resources of water are get polluted by disposal of toxic and harmful chemical by industrial wastages. These resources are used by domestic as well as for agriculture purpose [1]. There are many health related and waterborne diseases like diarrhea, typhoid fever, pyria etc. India has approx. 16 % of world's population (2nd largest country in population) but have only 4-5 % of its people get fresh water supply [2]. In many developing countries more than 85 % of illness are recorded due to unavailability of fresh drinking water. By 2025, nearly 60 % world's population will have major drinking water deficiency [3]. Availability of fresh water resources are decreasing at faster rate than increasing population, industrial and agriculture demand, also it is uneconomical to transport of fresh water to far off regions. The substitute solution for this growing demand is desalination of existing impure water. Solar desalination is the process of eliminating salts and minerals from impure water by heating it with the use of solar radiation. Solar energy is existing at universally and have cost free so, utilization of this in solar distillation is best solution.

II. SOLAR STILL

Solar stills are used to produce fresh water from brackish water. Depending upon the number of basin used in a solar still, it can be classified as single, double and multi basin types. Basin is the area which absorbs the solar heat radiation come to pass in solar still. In single basin solar still the efficiency is less as compared to multi basin still. Many researchers have performed experimental work on solar still to increase its productivity, this review article focuses on the experimental and numerical study performed on double basin solar still by different researchers. In the next section brief summary about different basin types solar still are classified.

III. SINGLE BASIN SOLAR STILL

A single basin solar still is a device in which one basin is used to produce potable water from saline water using solar energy. Impure water is placed in basin which absorb solar radiation after passing through glass surface. The water gets evaporates and condensed at the inner surface of inclined glass cover. The water get collected from the condensate channel at outlet of solar still. Conventional solar still is shown in Fig. 1.

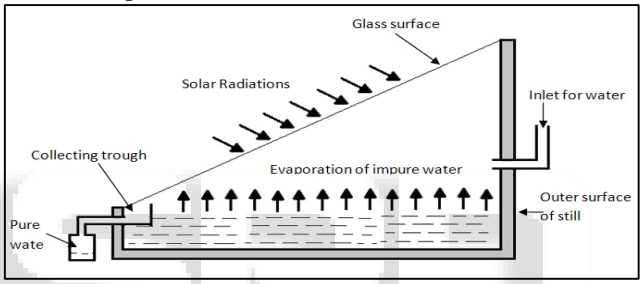

Fig. 1: Schematic Diagram of Conventional Solar Still [4]

Some of the research conducted on single basin solar still are explained as below:

Hamzeh et al. [5] explained the performance of solar still with different sizes of sponge cubes as shown in Fig. 2. The design factor for sponge cubes was also studied.

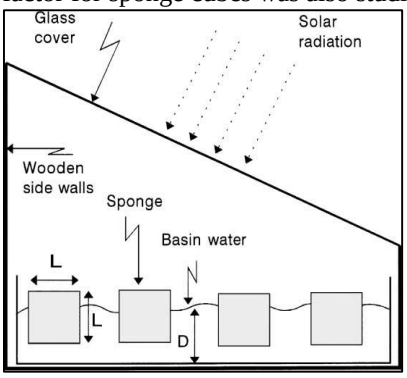

Fig. 2: Schematic Diagram of Solar Still with Sponge Cubes [5]

It was concluded that there is about 273% increase in the productivity of solar still when combination of sponge cubes was 6×6 cm size, placed at 7cm water depth in basin. Murugavel and Srithar [6] studied the effect produce by different wick materials (black cotton cloth, jute cloth and sponge cubes) on the performance of solar still. Still with rectangular aluminium fins covered with cotton cloth and arranged in length wise direction was concluded effective. The maximum distillate of 3.49 kg/m^2/day was found with the uses of light black cotton cloth. Experimental studies of effect

produced by porous fins (prepared by blackened old cotton rags) on the productivity of the solar still was explained by Srivastava and Agrawal [7] Solar still used with porous fins in basin is shown in Fig. 3. It was concluded that distillate output of 7.5 kg/m2/day was obtained by solar still, when black ended old cotton rags were partially dipped in the basin water of solar still.

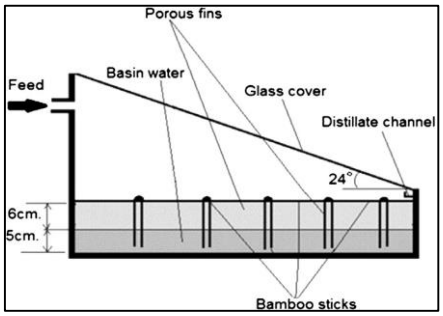

Fig. 3: Schematic Diagram of Solar Still Used with Porous Fins in Basin [7]

Tabrizi and Shark [8] explained the effect of sandy heat reservoir below the basin of a solar still. Sand as a heat reservoir was used below the basin due to its cheap cost and availability. Solar still with sandy heat reservoir is shown in Fig. 4.

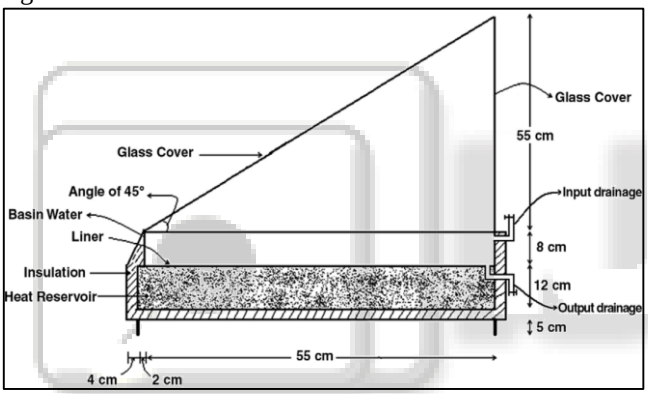

Fig. 4: Schematic Diagram of Solar Still with Sandy as Heat Reservoir [8]

A distillate yield of nearly 3000 cm3/m2/day was obtained. An increase of 75% in productivity was recorded as compare to simple solar still. Zerrouki et al. [9] explained a numerical simulation for a capillary film solar still coupled with solar still. They joined capillary solar still and conventional solar still in series. An increase in production rate due to coupling of capillary film solar still with conventional solar still was nearly 54-83%.

IV. DOUBLE BASIN SOLAR STILL

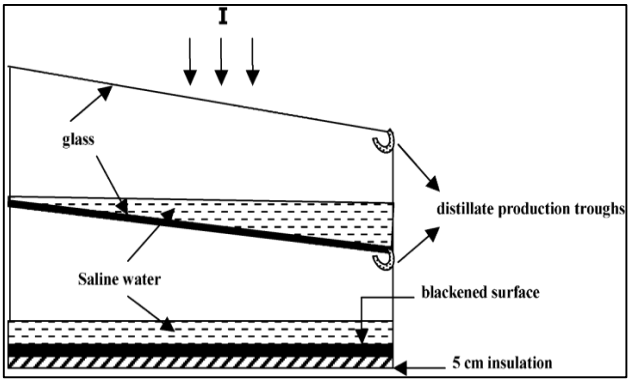

Fig. 5: Schematic Diagram of Simple Double Basin [10]

A double basin solar still is a device which consist of two basin still in which one basin is mounted on another. The working process of this system is same like simple solar still but it has more productivity than single basin solar still. Simple double basin solar still is shown in Fig. 5.

The main benefits of this system is that latent heat energy of vapour, condensing at lower surface of glass cover in lower basin used in heating upper layer of water rather than heat loss to the ambient.

Some of the research focused on double basin solar stills are described as below:

A double basin solar still was designed and tested by Malik [11] he used a transparent material sheet which is placed in middle of the basin and glass cover. The base of transparent sheet act as another basin liner of upper basin in solar still. The solar intensity was absorbed by water in upper basin whereas the lower basin uses the upward heat loss from lower basin of solar still. This system act as combination two simple solar stills which are placed at one another. Double basin solar still has required lesser area in comparison of two single basin. El-Sebaii et. al. [12] explain and analysis the effect produced on the daily output of solar still by increasing number of basin. It was concluded that the higher output given by double basin still in day hours, whereas the triple and quadruple basin still gives most output during the night. Sodha et. al. [13] experimentally analysis double basin solar still. A double basin solar still and single basin solar still of equal basin area (0.8 m × 0.9 m) was fabricated and tested at same climate condition. Single basin solar still and double basin solar still is shown in Fig. 6. The outer glass cover of solar still was tilted at 10^o with the sides of solar still. Another glass sheet with a slope of 7^o at 0.10 m height from the lower basin. It was observed that productivity of both stills was increases with increases in thickness of insulation up to 4 cm,

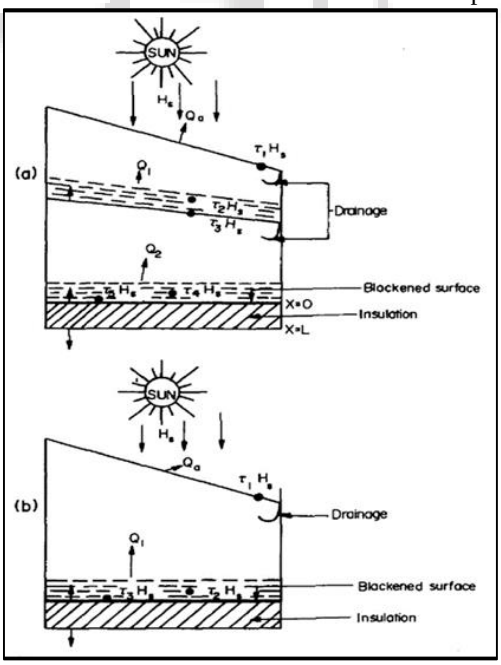

Fig. 6: Experimental view of (a) Single Basin Solar Still and (b) Double Basin Solar Still [13]

After this productivity increases slowly. The productivity given by double basin solar still was nearly 36 % higher than single basin. Al-Karaghouli et. al. [14] experimental study given by double basin solar still and single basin solar still. Two solar still having same basin area

(0.45 m2) were fabricated and tested for 5-month period (Feb. - June). Single basin and double basin solar still is shown in Fig. 7.

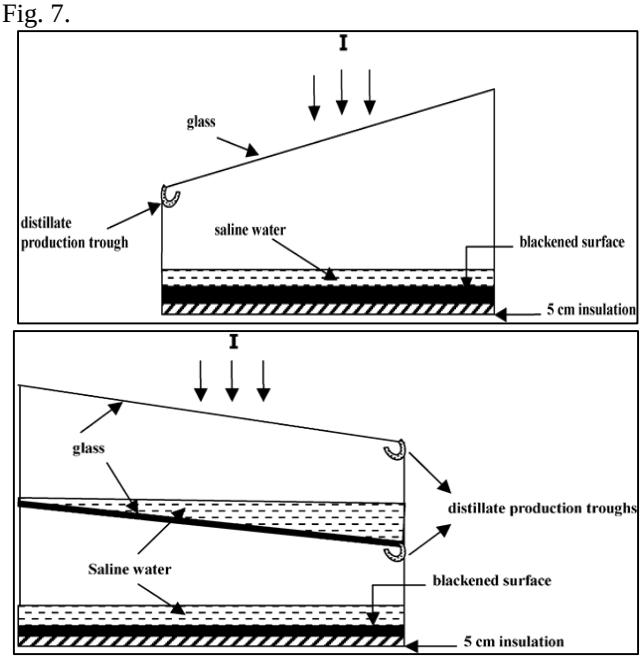

Fig. 7: Schematic Diagram of Simple Single Basin and Double Basin Solar Still with Same Basin Area [14]

The performance given by both stills were measured with insulation and without insulation. Daily average distillate water production (ml) was observed as: [14]

Month	Single without sides insulated	Single with sides insulated	Double without sides insulated	Double with sides insulated
February	655	720	834	1045
March	745	765	936	1340
April	810	890	1045	1420
May	945	1010	1180	1630
June	1105	1280	1410	1760

Table 1: Performance given by both stills were measured

It was concluded that double basin solar still gives nearly 40 % higher productivity than single basin soar still. Their efficiency were also observed as: [14]

Month	Single without side insulated	Single with side insulated	Double without side insulated	Double with side insulated
February	19.2	21.1	24.4	30.6
March	20.9	21.4	26.2	37.5
April	22.1	24.2	28.5	38.7
May	24.9	26.6	31.1	42.9
June	27.5	31.8	35.1	43.8

Table 2: Performance given by both stills were measured

It was concluded that higher efficiency given by double basin solar still was 43.8 % during the month of June. Rajaseenivasan and Kalidasamurgavel [15] investigate theoretically and experimentally performance of double slope double basin and double slope single basin solar still as shown in Fig. 8.

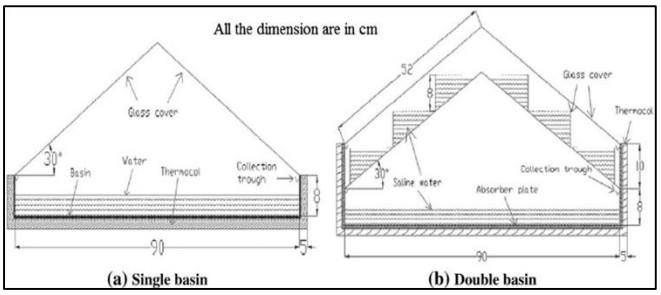

Fig. 8: Experimental view of (a) Double Slope Single Basin Solar Still and (b) Double Slope Double Basin Solar Still. [15]

It was concluded that the variation between experimental and theoretical result was nearly 10 % and productivity of double basin was observed 85 % higher than single basin at same climate condition. The productivity of solar still increases with decreases in water mass in basin, also productivity given by lower basin was higher than upper basin. It was observed that maximum water production was nearly 2.99 L/day (4.75 L/m2/day) by double basin solar still. Bapeshwararao et. al. [16] explained the effect of water flowing over upper glass cover of double basin solar still. Effect of water flowing over glass cover of double basin solar still is shown in Fig. 9.

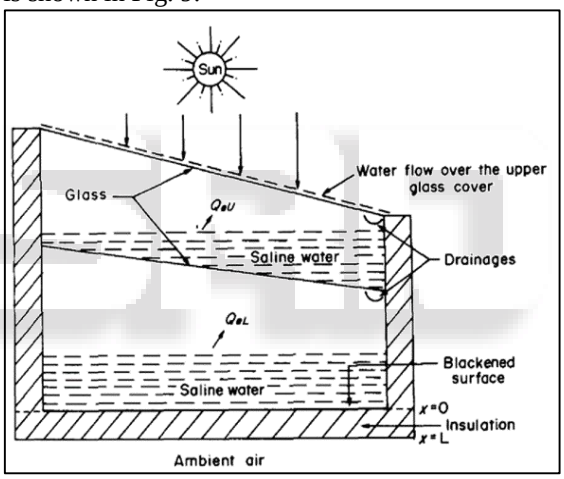

Fig. 9: Experimental view of Water Flowing over Glass Cover of Double Basin Solar Still. [16]

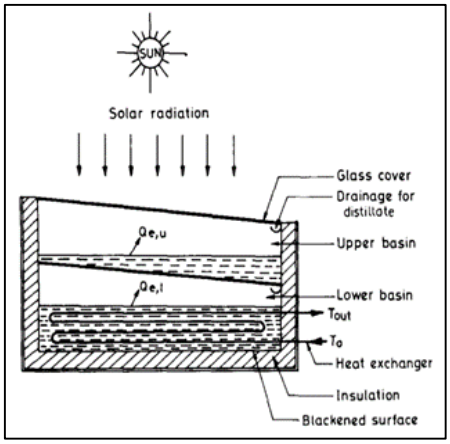

Fig. 10: Schematic Diagram of Double Basin Solar Still with Heat Exchanger [18]

It was observed that the temperature of flowing water at the surface of glass cover was nearly equal to temperature of glass cover and there was increase in productivity of solar still. Tiwari et.al. [17] experimental

studies of water flowing over the glass cover and connecting flat plate collector on the performance of solar still. The productivity was found nearly 50 % higher than normal double basin still. Kumar et.al. [18] explained the performance of double basin solar still integrated with heat exchanger. Double basin solar still with heat exchanger is shown in Fig. 10. A heat exchanger was inserted inside lower basin of solar still. It was found that with the use of heat exchanger the output by system increased. The efficiency of system increased up to (20-25) % when hot fluid inlet at temperature of 40°C passed through heat exchanger.

Effect of flat plate collector in natural mode and force mode was explained by Yadav [19] in natural circulation mode flow of water between collectors and still is due to density gradient whereas in force mode a pump is required to run flow of water between collectors and still. Simple double basin solar still, double basin solar still in free mode and double basin solar still in force mode are shown in Fig. 11.

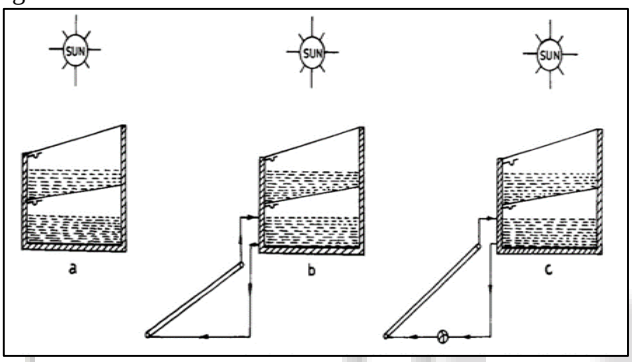

Fig. 11: Experimental unit of (a) Double Basin Solar Still, (b) Double Basin Solar Still in Free Mode and (c) Double Basin Solar Still in Force Mode [19]

It was found that the efficiency of higher temperature distillation system was lower than conventional system. The performance of force mode was found better than natural mode. The productivity and efficiency given by lower basin decreases with increases in water depth in basin. The temperature of basin water could be increased further by increasing the area of collector plate but efficiency of system decreases with increases in area of solar collector. The performance of inverted absorber solar still with different water depth was studied by Suneja et. al. [20] as shown in Fig. 12.

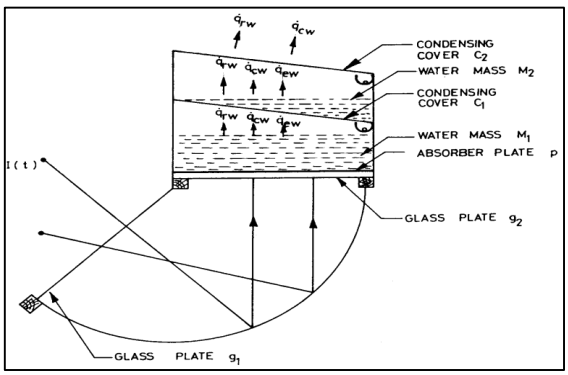

Fig. 12: Experimental view of Double Basin Solar Still connecting with Inverted Absorber [20]

A double basin solar still with an invert absorber was fabricated and studied at different climate condition. It was observed that productivity of system increases with increase in water depth inside lower basin for constant water level in the upper basin. Also increasing water inlet temperature 22 °C to 35 °C the productivity of system increased by about 10 %. Cappelletti [21] explained the performance of double basin solar still. A V- shape transparent cover has been used for upper basin. Double basin solar still is shown in Fig. 13. The distillate water collect at centre of basin. The efficiency of system was observed to be 16 %.

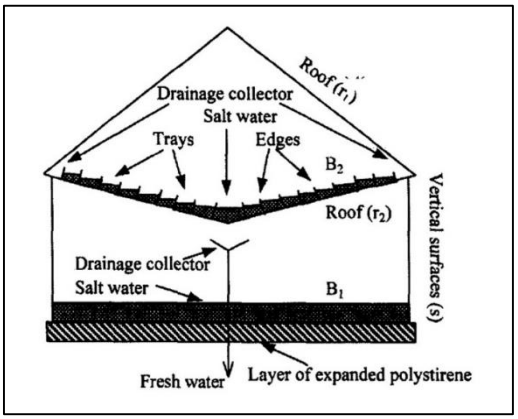

Fig. 13: Schematic Diagram of V-Shape Double Basin Solar Still [21]

Al-Hinai et. al. [22] explained the double basin solar still and compare its performance with single basin solar still. The system has been operated and tested at different climate conditions. Double basin solar still is shown in Fig.14. It was found that maximum distillate output given by single basin still was nearly 4.15 kg/m^2/day and 6 kg/m^2/day for double basin solar still.

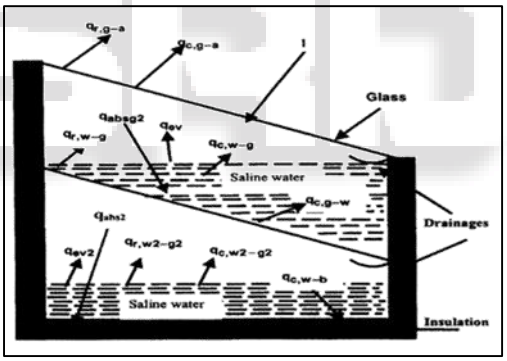

Fig. 14: Experimental Unit of Double Basin Solar Still [22]

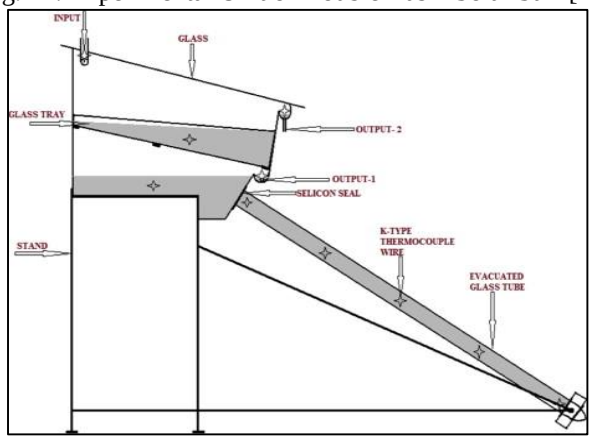

Fig. 15: Schematic Diagram of Double Basin Solar Still Coupled with ETC [25]

Gupta et. al. [23] studied the effect of hot inlet water in double basin solar still. The productivity of still increases with increase in temperature of inlet hot water. Elango [24] studied different water depth from 1 to 5 cm under both

insulated and uninsulated conditions. The experiment results shows that at 1 cm water depth, there was 17.38 % increase in productivity given by double basin solar still. Panchal [25,26] studied the distillate output given by double basin solar still with vacuum tubes. Double basin solar still coupled with evacuated tubes collector is shown in Fig. 15.

It was concluded that distillate output was increased to 56% with addition of vacuum tubes and 65% when vacuum tubes and black granite gravel are used in the basin of solar still. The distillate output of system was nearly 8 kg/m^2/day. Deshmukh et. al. [27] studied the performance given by double basin solar still integrated with ETC and reflector. They concluded that there is an increase of 62.1 % in daily out put than simple basin solar still.

V. CONCLUSIONS

As a results of the above reviews of double basin solar still, the following conclusions have been inferred:

- The main benefits of double basin solar still system over single basin system is that latent heat energy of vapours, condensing at lower surface of glass cover in lower basin used in heating upper layer of water rather to loss in ambient
- Double basin solar still has required less area in comparison of two single basin.
- The number of basin used does not have more than three further this does not have significant effect on productivity during day hours.
- The distillate output given by double basin solar still have 30-40 % more than single basin.
- The yield of double basin double slope solar still have 85 % more than single basin double slope. Also yield of lower basin was higher than upper basin solar still.
- The productivity of double basin solar still was increased up to 56 % when Vacuum tubes are connected with lower basin of solar still.
- The yield of double basin solar still increases up to 50 % when water is flowing over the upper glass cover.
- Using of heat exchanger in lower basin of solar still and supply water at 40ºC inlet in heat exchanger increases the efficiency up to 20–25 %.
- Distillate output of solar still increases with increases in thickness of insulation up to 4 cm.
- The productivity of still increases with increase in temperature of inlet hot water in basin.
- The temperature of lower basin water could be increased by increasing in area of solar collector but efficiency of the system decreases with increases in area of solar collector.
- Inverted absorber solar still have higher production due to reduction in bottom loss and with increasing water temperature 22ºC - 35ºC the productivity of system increased by about 10 %.
- There is 273% increase in the productivity of solar still, when combination of sponge cubes was: 6×6 cm sizes placed at 7cm water level in basin.
- Sand as a heat reservoir can be used below the solar still due to its cheap cost and availability. An increase of 75 % in productivity was recorded as compare to simple solar still.

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