# AN EXPERIMENTAL INVESTIGATION INTO THE PERFORMANCE OF A GI BASIN PASSIVE SOLAR STILL USING HORIZONTAL MESH AND VERTICAL MESH

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## Abstract

*Potable Water or Pure Drinking Water is essential to mankind and it is difficult to obtain fresh water at many places . The conventional methods available to purify Water are costly. Solar Energy is freely available and can be used as a very cheap option to purify Water through Solar Distillation, by using Solar Stills . The conventional Single Basin Passive Solar Still or Plain Basin Galvanized Iron (GI) Solar Still can be used to purify Water but the main problem is that the per square metre distillate output is less. Many methods have been used to increase the output of GI Basin Solar Still. Horizontal or Vertical Mesh made of GI can be used in the Basin of Solar Still to increase the distillate output. Outdoor Experiments were conducted at Nagpur, Maharashtra ,India (21.15ᴼN, 79.09ᴼE) for GI Basin Plain (Without Mesh) Solar Still, With Horizontal Mesh and With Vertical Mesh in the months of May-June and September-October. It was found that both the Mesh increase the distillate output considerably, in which the Horizontal Mesh gives an appreciable increase in the Average Distillate Output (about 400ml per day) and an increase of about 6% in the Average Distillation Efficiency whereas the Vertical Mesh gives a significant increase in the Average Distillate Output (about 1000ml per day) with an increase of about 13% in the Average Distillation Efficiency. The Vertical Mesh is very cheap and the payback period for the Vertical Mesh is hardly 3 months. Thus , the GI Basin Solar Still with Vertical Mesh gives a higher output and can be helpful in obtaining pure drinking water for communities , both cheaply and effectively.*

**Key Words** *: GI Basin Solar Still, Distillate Output, Average Efficiency, Horizontal Mesh, Vertical Mesh*

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## 1. INTRODUCTION

The demand for fresh water is growing everyday in the world. There are many methods of obtaining pure/fresh water and Solar Distillation is one of them. Solar distillation is an easy, small scale & cost effective technique for providing safe water at homes or in small communities. Various types of Solar Stills can be used for solar distillation and the simplest and most economical still is the conventional basin type solar still. In this communication the performance of a conventional basin type Passive Solar Still is evaluated when a Horizontal Mesh or Vertical Mesh is inserted in the Basin of Passive Solar Still.

Solar Still essentially consists of a blackened basin of GI metal sheet of 1m x 1m size . This basin is covered by glass at an angle of $15^0$ (say). Brackish or saline or used water is filled in this basin and the Still is placed under the Sun. The water in the blackened basin evaporates & gets condensed on the inner side of glass cover . Finally the condensed water rolls down on the inner side of glass cover , gets collected in the basin channel and comes out through pipe as pure/ distilled water. This type of operation of still is passive and one still gives an output of about 2/3 liters per day during Sunny days or typical Summer Season. These stills can be coupled with similar 1m x 1m stills in order to increase the output and thereby the drinking water needs of families and even the community. The output of this Solar Still can be increased by various modifications and in this communication we have discussed the performance enhancement of the Solar Still by use of Horizontal or Vertical GI Mesh in the Basin.

## 2. LITERATURE REVIEW

A Single Basin Solar Still as shown in Fig 1 consists of a Galvanised Iron (GI) basin (1m*1m size ) on which a plain glass is fixed . The basin has a short front side and a slightly bigger back side thereby giving an angle of say 15 degree to the other two sides and to the glass fixed over it. The basin is painted black from inside and the basin is made airtight after fixing the glass over it. A small inlet pipe is fixed on the back wall of Basin and a outlet pipe is fixed on the front basin wall. Brackish or impure Water is poured inside the Basin from the Inlet pipe in small quantity ,say 20 litres thereby giving a shallow depth of say 2cms to the water inside the basin. The Still is kept exposed to Sun and the Solar Radiations falling on the Still cause the Water inside the Basin to get heated at a temperature ($T_w$) and eventually to get evaporated. This evaporated water or water vapour gets condensed on the inside glass cover because of lower glass cover temperature ($T_g$). The condensed water then trickles down on the inside surface of glass because of slope of glass and gets collected in the channel of front side. The collected water in the channel finally gets out through the outlet pipe as distillate output (mew).
The performance of a basin type Solar Still (ie distillate output ($m_{ew}$) / yield per day) depends upon $T_w$ (water

temperature) and $T_g$ ( inner glass temperature). All the attempts to improve the distillate output are essentially focused on increasing evaporation of water and thereby $T_w$ and increasing condensation of water by reducing $T_g$ . Research has been done earlier by various researchers with the following parameters and their effect on the Solar Still performance was studied :

1. To increase absorption of radiation by basin water by addition of absorbing materials like black dye, charcoal pieces, etc.[1-5],
2. Determination of optimum water depth and glass cover angle, thickness, etc. [6-8],
3. Effect of insulation and its optimum thickness[9],
4. Effect of wind velocity[10- 11],
5. Effect of climatic parameters like solar radiation, ambient temperature, etc.[12],
6. Effect of orientation of Solar Still [13],
7. Effect of wicks in solar stills, use of multibasin, multieffect solar stills, etc.[14-24],
8. Various materials for Solar Stills and novel designs with different cover shapes , different types of basins, effect of reflectors , etc [25-39],
9. Thermal analysis and modeling of Solar Stills [40-56].

It has been observed by us that the evaporation of basin water and eventually the output can be increased by introduction of GI strip meshes in the basin. This improved the distillate output and gave a percentage increase in efficiency by about 25% in the experiments conducted by us. Such type of work has not been reported by any researcher so far.

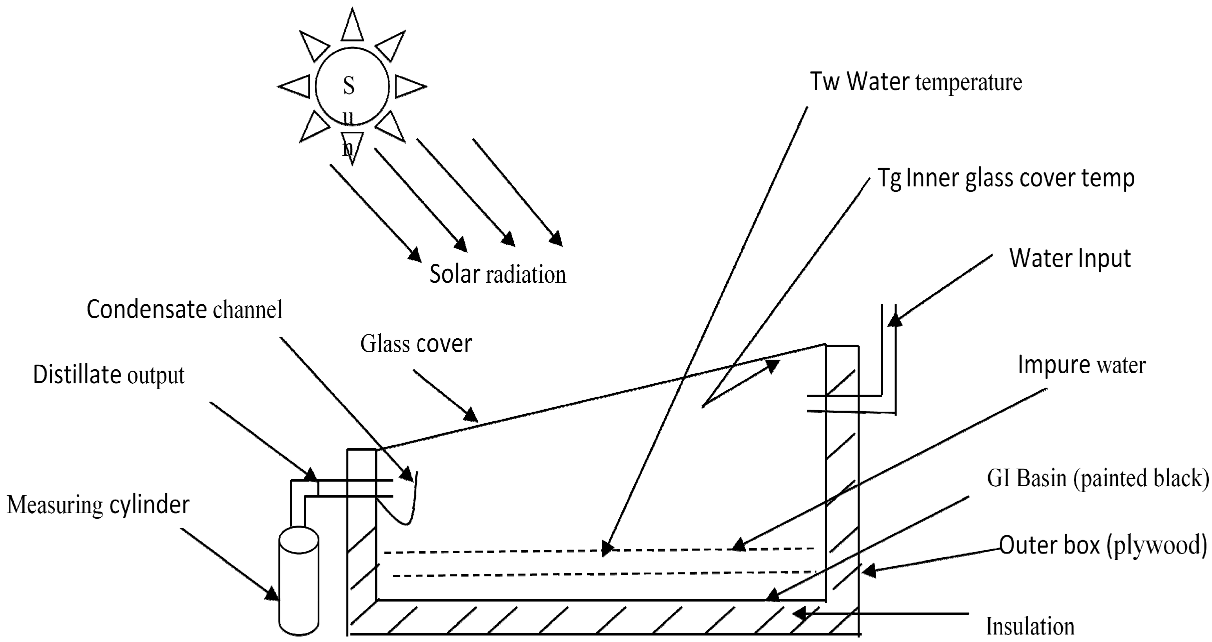



**Fig.1:**A typical conventional Solar Still

## 3. EXPERIMENTAL SETUP

The experimental still has the following dimensions, as shown in **Fig 2**.

1.Basin – base size , 1m x 1m base, front height 0.15m, rear height 0.418m, basin material – GI .
2.Condensing cover – size 1m x 1m, thickness 0.005m, material- glass.
3.Insulation – sawdust, thickness- 0.05m
4.Outer box – plywood
5.Inlet and outlet pipes – pvc
6.Stand for solar still – MS angle stand, height – 0.6m

The glass cover angle is kept at $15^0$ and the water depth 0.02m respt. Mesh is having 0.05m height of strips in one direction and 0.04m height of the perpendicular strips inserted in it , length – 1m, thickness – 0.001m (22 gauge of GI) , and spacing between mesh strips – 0.1m. **Fig 3** shows the Plain Basin & Basin with Horizontal / Vertical Mesh of the Solar Still. A photograph of GI Basin with Vertical Mesh is shown in **Fig. 4**.

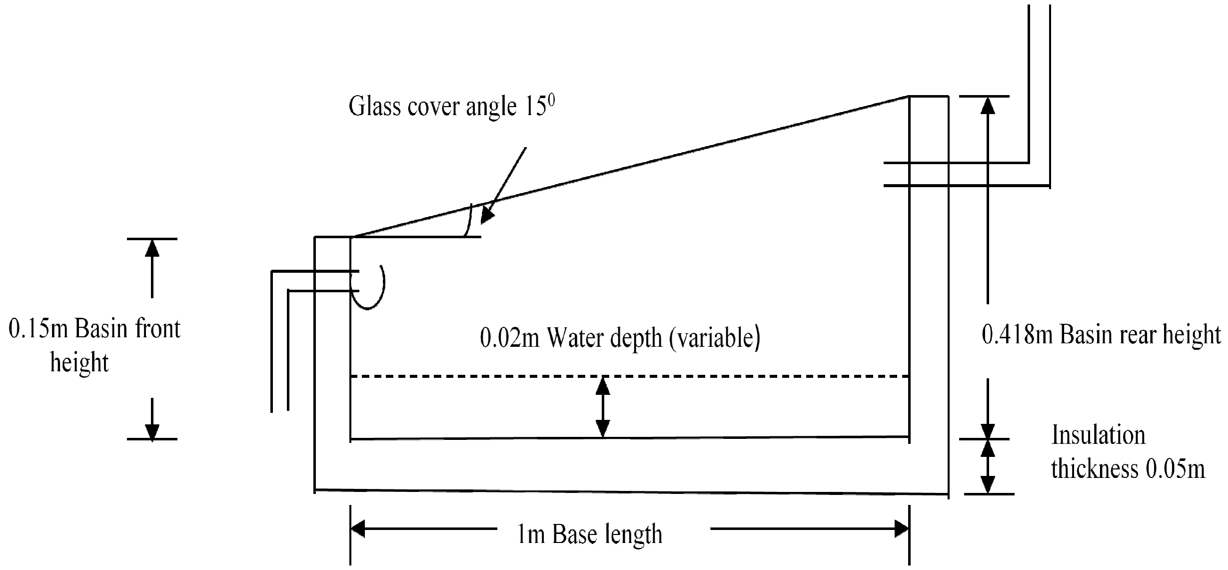



**Fig .2:**Design Specifications of Experimental still

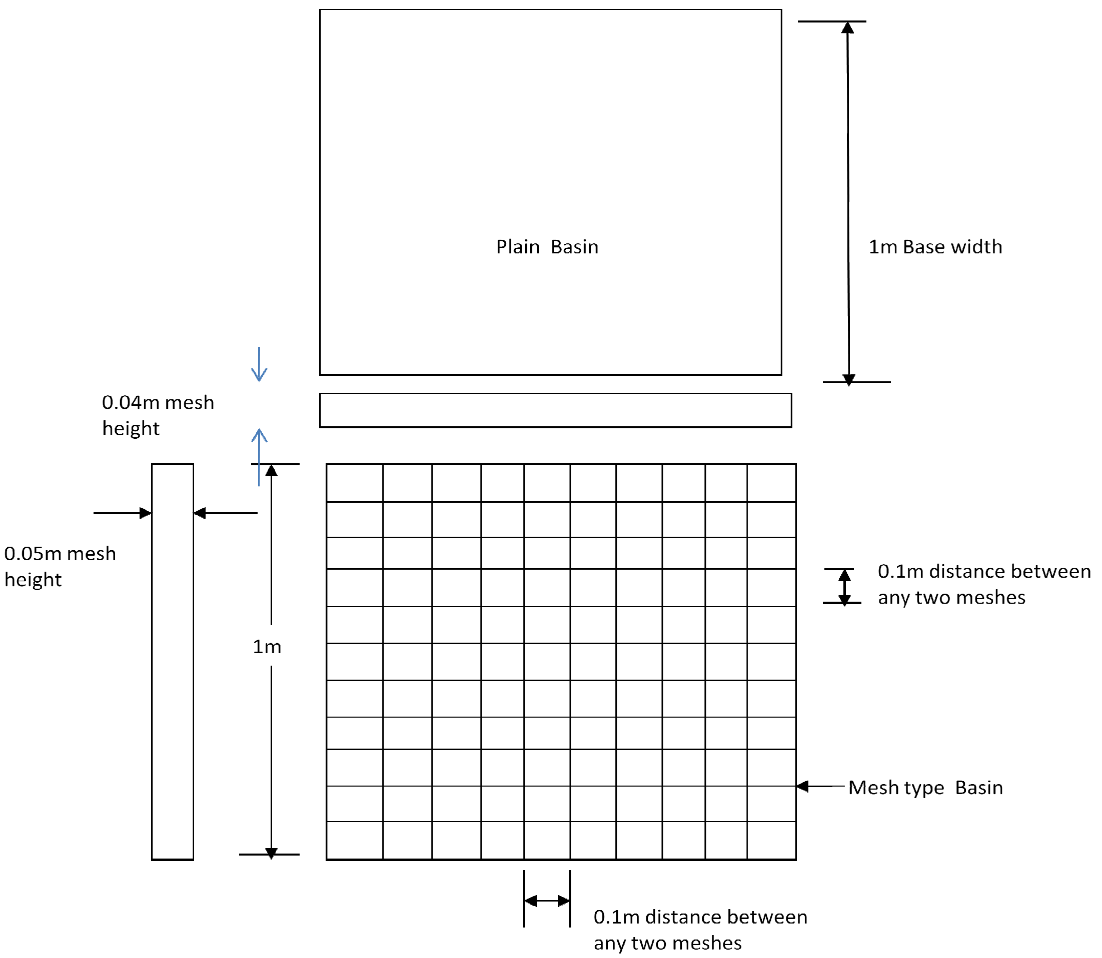



**Fig.3:** Plain Basin and Basin with Horizontal / Vertical Mesh

**Fig.4:**GI Basin with Vertical Mesh

## 4. EXPERIMENTAL PROCEDURE

### 4.1 Instrumentation:

The following measurements were taken during the course of experiment:

1.Temperatures of the basin water $T_w$, inside of glass cover $T_g$, ambient, ,etc were measured by thermocouples and digital temperature indicator. These thermocouples were calibrated with Zeal thermometer.

2.Distillate output (ml) was measured by measuring cylinder.

3.Solar insolation (I, in W/m$^2$) (radiations falling on the Solar still) were measured with a Solarimeter .

4.Wind speed in m/sec was measured using Anemometer.

5.These readings were taken from sunrise to sunset with hourly intervals.

### 4.2 Experimental Observations:

The readings were taken in the months of May, June and September, October for several days from 7am to 7pm and the nocturnal output was also noted. Experiments were conducted in actual field conditions at Nagpur, Maharashtra ,India (21.15ºN, 79.09ºE) & data of output(yield mew) and temperatures($T_w$, $T_g$, $T_v$, etc) were recorded apart from climatic data of $T_a$, I & V. The Input quantity of Water was kept at 20 litres or the depth of Water in the Basin was 0.02 m. A Sample Table of Readings for a typical day (15 Sept) for Solar Still with plain basin is shown in **Table 1**. A Graphical variation of Water and Inner Glass Temperature, Wind Speed, Solar Insolation and Distillate Output with respect to Time of the day is also shown below for the typical day (15 Sept) in **Fig 5** to **Fig 8**, below. The Summary of Experimental Observations is shown in **Table 2** and it's Graphical Description is shown in **Chart 1** & **Chart 2**.

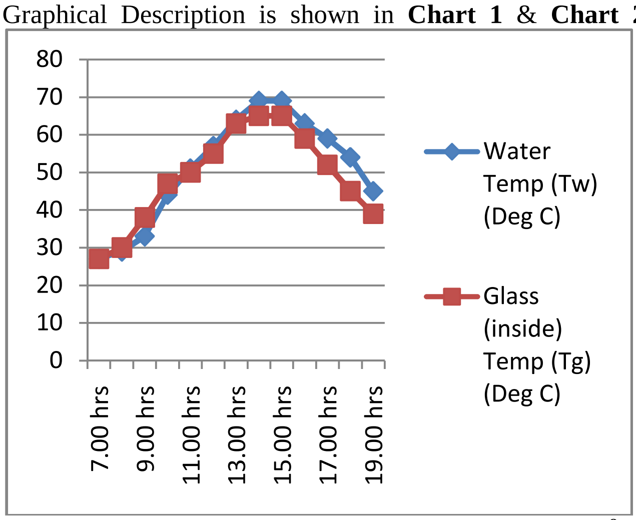



**Fig. 5:**Variation of Water and Inner Glass Temperature ($^o$C) vs Time for GI Solar Still with Plain Basin (Without Mesh) for a Typical Day (15 Sept)

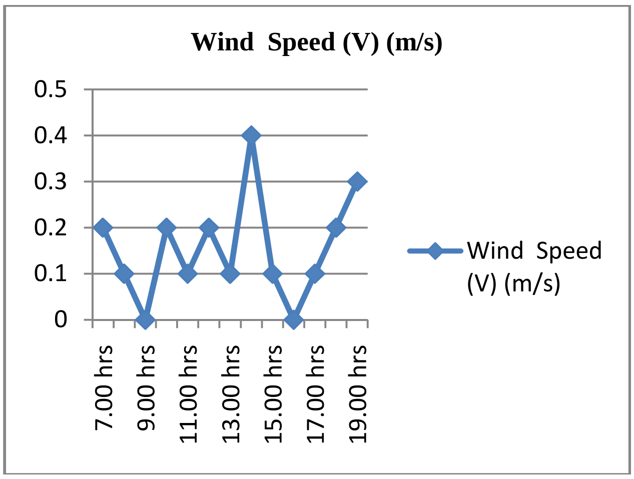



**Fig.6:**Variation of Wind Speed vs Time for GI Solar Still with Plain Basin (Without Mesh) for a Typical Day (15 Sept)

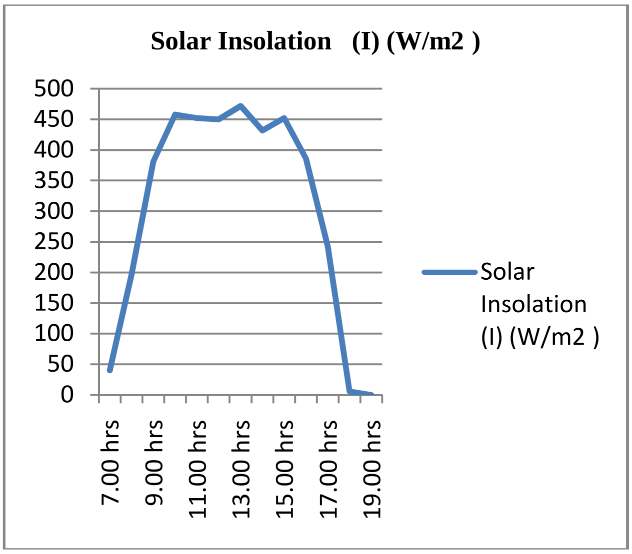



**Fig.7:**Variation of Solar Insolation vs Time for GI Solar Still with Plain Basin (Without Mesh) for a Typical Day (15 Sept)

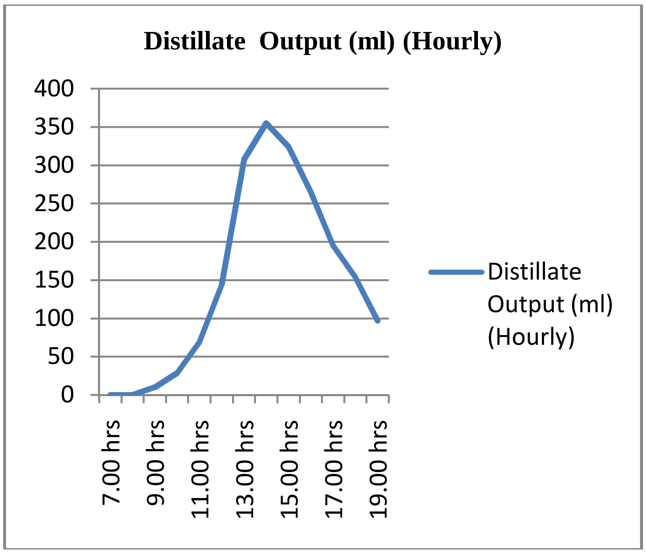



**Fig.8:**Variation of Distillate Output vs Time for GI Solar Still with Plain Basin (Without Mesh) for a Typical Day (15 Sept)

**Table 1:**Experimental Observations for a Plain GI Basin (Without Mesh) Solar Still for a Typical Day (15 Sept) at Nagpur , Maharashtra, India (21.15°N, 79.09°E).

Experimental Observations – 15 Sept :Total Distillate Output (7am to 7pm)(12hrs) = 1950ml;Total Nocturnal Distillate Output (7pm to next morning 7am)= 222ml.Total Daily Solar Insolation (7am to 7pm)(12hrs) = 3969 W/m2

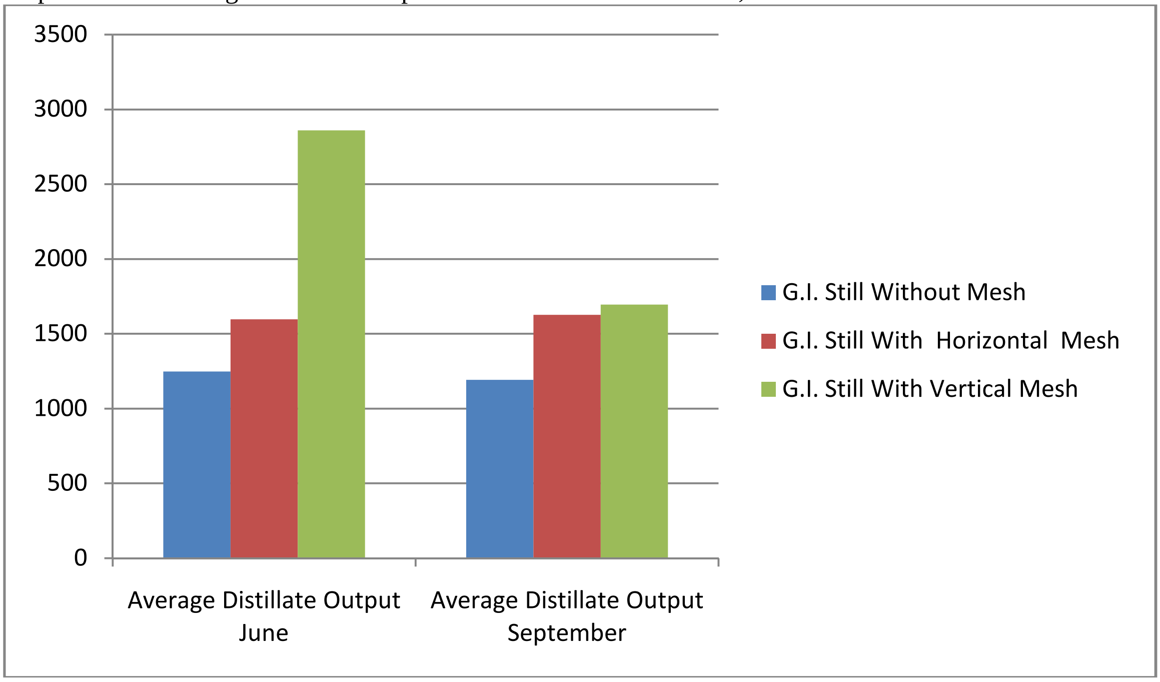
| Sr. No. | Time (in hrs) | Distillate Output (ml) (Hourly) | Ambient Temp (Ta) °C | Basin Temp (Tb) °C | Water Temp (Tw) °C | Vapour Temp (Tv) °C | Glass (inside) Temp (Tg) °C | Wind Speed (V) (m/s) | Solar Insolation (I) ($W/m^2$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.00 hrs | 0 | 25.3 | 28 | 27 | 28 | 27 | 0.2 | 40 |
| 2 | 8.00 hrs | 0 | 27.6 | 30 | 29 | 31 | 30 | 0.1 | 197 |
| 3 | 9.00 hrs | 10 | 29.4 | 34 | 33 | 39 | 38 | 0 | 381 |
| 4 | 10.00 hrs | 29 | 32.4 | 44 | 44 | 55 | 47 | 0.2 | 458 |
| 5 | 11.00 hrs | 69 | 33.7 | 52 | 51 | 59 | 50 | 0.1 | 452 |
| 6 | 12.00 hrs | 144 | 33.9 | 59 | 57 | 67 | 55 | 0.2 | 450 |
| 7 | 13.00 hrs | 308 | 34.2 | 65 | 64 | 73 | 63 | 0.1 | 472 |
| 8 | 14.00 hrs | 355 | 34.4 | 69 | 69 | 74 | 65 | 0.4 | 432 |
| 9 | 15.00 hrs | 324 | 34.2 | 69 | 69 | 79 | 65 | 0.1 | 452 |
| 10 | 16.00hrs | 265 | 33.6 | 63 | 63 | 70 | 59 | 0 | 386 |
| 11 | 17.00 hrs | 195 | 32.8 | 59 | 59 | 60 | 52 | 0.1 | 243 |
| 12 | 18.00 hrs | 154 | 31 | 54 | 54 | 50 | 45 | 0.2 | 6 |
| 13 | 19.00 hrs | 97 | 30.2 | 45 | 45 | 43 | 39 | 0.3 | 0 |

**Table 2:**Summary of Experimental Observations for GI Basin Solar Still Without Mesh (Plain Basin), With Horizontal Mesh and With Vertical Mesh taken at Nagpur , Maharashtra, India (21.15°N, 79.09°E).

| Sr. No. | Date | Type of Experiment | Average Daily Distillate Output ($m_{ew}$ in ml) | Average Daily Total Solar Insolation (I in W/m$^2$) | Calculated Average Efficiency (η) (%) |
|---|---|---|---|---|---|
| 1 | 20 June to 24 June | G.I. Still Without Mesh | 1249 | 4526 | 28.04306 |
| 2 | 6 June to 7 June | G.I. Still With Horizontal Mesh | 1597 | 4947 | 32.91016 |
| 3 | 5 May to 8 May | G.I. Still With Vertical Mesh | 2860 | 6863 | 41.80972 |
| 4 | 9 Sept to 15 Sept | G.I.Still Without Mesh | 1192 | 2700 | 29.72685 |
| | 23 Sept to 1 Oct | G.I.Still With Horizontal Mesh | 1627 | 3298 | 35.47661 |
| 6 | 17 Sept to 21 Sept & 7 Oct to 15 Oct | G.I.Still With Vertical Mesh | 1695 | 3287 | 36.6635 |

**Chart 1:**Comparision of Average Efficiency of Solar Still Without Mesh, With Horizontal Mesh and With Vertical Mesh

**Chart 2:** Comparision of Average Distillate Output of Solar Still Without Mesh, With Horizontal Mesh and With Vertical Mesh




## 5. RESULTS AND DISCUSSION

The Summary of Results shown in Table No 2 clearly indicates that the Solar Still with Horizontal and Vertical Mesh both show an increase in the distillate output and certainly an increase in the average efficiency over the Plain Basin Solar Still.

### 5.1 Solar Still with Horizontal Mesh :

The Solar Still having Horizontal Mesh gives an increase in the average efficiency by upto 6 % and gives an increase of 348 ml in the average distillate output in May/June and thereby a percentage increase of 27.86 % whereas in the month of September/October the average distillate output is increased by 435 ml and a percentage increase of 36.49 % over the Plain Basin ( Without Mesh ) Solar Still. Thus on an average about 400 ml of distillate output is increased daily by using Horizontal Mesh, which is an appericiable increase.

### 5.2 Solar Still with Vertical Mesh :

The Solar Still having Vertical Mesh gives an increase in the average efficiency by upto 13 % and gives an increase of 1611 ml in the average distillate output in May/June and thereby a percentage increase of 128 % whereas in the month of September/October the average distillate output is increased by 503 ml and a percentage increase of 42.19 % over the Plain Basin ( Without Mesh ) Solar Still. Thus on an average about 1000 ml of distillate output is increased daily by using Vertical Mesh which is a very significant increase.

### 5.3 Performance of Vertical Mesh in comparison to Horizontal Mesh:

Although both the Mesh give an increase in distillate output and thereby distillation efficiency over the Plain Basin (Without Mesh) Solar Still , it is the Vertical Mesh which gives a very significant increase. The Mesh work on a simple logic of extended surface for heat transfer .The GI (Galvanized Iron) strip Mesh is painted black like the GI basin and it fits in the GI basin. The black GI strips have very good absorptivity and they are good conductors of heat. So the Mesh absorb maximum radiations falling on them and transfer heat to water surrounding them, thereby raising the Water temperature ($T_w$) and finally the distillate output. Now the most important point is the Mesh is absorbing the Solar radiations which were otherwise falling on Water in the Basin. In a way the Mesh is preventing the Water from getting directly heated and hence it is becoming a cause in reducing the Water temperature. So the Mesh is increasing the heat transfer area but it also blocks some radiations from directly falling on Water and hence the Horizontal Mesh gives lesser output as compared to Vertical Mesh because the Mesh area is same but the Mesh orientation is such that the Horizontal Mesh blocks more radiations from falling directly on Water as compared to Vertical mesh especially when the water depth is low (0.02m) . The fabrication of Mesh is done in such a way that one strip is Vertical with 0.05m height and another strip of 0.04m height is inserted in a slot in the vertical strip at a height of 0.025m from basin. So with 20 litres of water the depth of water is 0.02m and the horizontal strip is at a height of 0.025m which is 0.005m (0.5 cm) above the water surface. Therefore, the advantage of increase in heat transfer area in the case of Horizontal

Mesh is subdued by the fact that it blocks more radiations from falling directly on Water as compared to Vertical Mesh. This explains the reason why Vertical Mesh gives higher output as compared to Horizontal Mesh especially at shallow depth of Input Basin Water.

## 6. MATHEMATICAL ANALYSIS

The overall distillation efficiency of the Solar Still is given

by the expression ,

$\eta = ( m_{ew}*L) / (I_T * A_s ) * 100$ (%) ,
where $\eta$ = Overall Thermal Efficiency,
$m_{ew}$ = Total Distillate Output of the Day (in kg) = $\sum m_w$ ,
($m_w$ = Hourly Distillate Output)
L= Latent Heat of Vaporization (J/kg),
$I_T$ = Total Daily Solar Radiation (W/m$^2$) ,
$A_s$ = Basin Area (in m$^2$ ).
The Latent heat of vaporization (L) is temperature dependent and is given by the expression ,
$L = 3.1615 *10^{-6} * [1-(7.616*10^{-4}*T_v)]$ for $T_v > 70^0$ C, and
$L = 2.4935 * 10^6 * [1-9.4779*10^{-4}*T_v + 1.3132*10^{-7}*T_v^2 - 4.7974*10^{-9}*T_v^3]$ for $T_v < 70^0$ C,
where $T_v$ is the Vapour Temperature.

Efficiency is calculated for each day by taking the values from the daily observations as shown in Sample Table 1.
$m_{ew}$ is the total distillate output of the day which is available from the Observation Table. Similarly $I_T$ or the Total Daily Solar Radiation ( in W/m$^2$) is also available from the Table. $A_s$ or the Basin Area is taken as 1 m$^2$. The Latent heat of vaporization (L) is calculated on hourly basis using the Vapour temperature $T_{v,}$ and then the daily average value is used for calculation of efficiency. Similarly efficiency is calculated for each day and the average efficiency for many days for a typical type of experiment is calculated and is shown in the Summary Table 2.

## 7. ECONOMIC ANALYSIS

The GI Basin Solar Still costs about eight thousand rupees including labour charges and the Mesh costs about one thousand rupees, ie the Mesh cost is almost 12.5 % of the Solar Still cost. The average increase in efficiency by Vertical Mesh is about 13 % and the average increase in distillate output by Vertical Mesh is about 1 litre per day.

The cost of Vertical Mesh will therefore be recovered in maximum 3 months or the payback period for Vertical Mesh is 3 months. Similarly the payback period for Horizontal Mesh is about 8 months. So , it is much economical to use Solar Still with Vertical Mesh.

## 8. CONCLUSION

The following conclusions can be drawn from the Experimentation and Analysis :
The drinking water problem can be solved at many places by using the cheap method of Solar Distillation , ie by using Single Basin Passive Solar Stills.

The problem of lesser output or productivity of Single Basin Passive Solar Still can be solved by using Horizontal or Vertical GI Mesh strips in the Basin.

The Horizontal Mesh gives an increase in efficiency by about 6 % and the average increase in the distillate output was about 400ml per day thereby giving a percentage increase in average distillate output by about 32% which is an appreciable increase.

The Vertical Mesh gives an increase in efficiency by about 13 % and the average increase in the distillate output was about 1000ml per day thereby giving a percentage increase in average distillate output by about 85 % which is a very significant increase.

The reason for Vertical Mesh performing better than Horizontal Mesh is that the Vertical mesh inspite of having same surface area as the Horizontal Mesh blocks lesser radiation from falling directly on Basin Water. Therefore the Vertical Mesh gives higher Water temperature ($T_w$) and thereby higher distillate output ($m_{ew}$) and higher distillation efficiency ($\eta$).

Economic Analysis shows that the payback period for Horizontal Mesh is 8 months whereas the payback period for Vertical Mesh is 3 months.

The Solar Still with Vertical Mesh can be used very effectively to increase the distillate output and Distillation efficiency especially for shallow depths of Input Basin Water. Hence it can be recommended to use such type of GI Basin Solar Still with Vertical Mesh to solve the drinking water problem of communities where there is scarcity of potable water.

## NOMENCLATURE

$m_{ew}$ = Distillate Output (ml)

$\eta$ = Distillation Efficiency
I = Solar Insolation (W/m$^2$)
V = Wind Speed (m/s)
$T_w$ = Water Temperature in the Basin ($^o$C)
$T_g$ = Inner Glass Temperature ($^o$C)
$T_v$ = Vapour Temperature ($^o$C)
$T_a$ = Ambient Temperature ($^o$C)
L = Latent heat of Vaporization (J/kg)

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