Experimental Investigation on Single Slope Solar Still with Toughened Glass as Basin Material

S. Saravanan[1], N. Krishna Mohan[2]
[1, 2] Department of Mechanical Engineering
[1, 2] Annamalai University, Chidambaram, India

Abstract- *In this work two identical single slope solar stills with different basin material i) G.I sheet, ii) Toughened Glass with basin area of 1 m2 has been fabricated and tested for sea water distillation. The results show that the still with Toughened glass as basin material is more productive and overcome the basic problems such as scaling, degradation of absorber material. The distillates collected from the solar stills are also tested for its quality parameters such as pH, Turbidity, Total Dissolved Solids (TDS). The test results reveal that the product water quality found to be within the standard ranges, the odor and taste of distillate water from toughened glass as basin material is acceptable.*

Keywords- Solar still, Efficiency, Distillate water, degradation of absorber material, Odor, Toughened glass, G.I Sheet.

I. INTRODUCTION

The shortages of clean potable water in arid, remote and coastal areas are on the rise. The shortage of clean potable water is common and seems to be also an emerging problem in many countries, especially in developing countries. Water from rivers, lakes, sea and underground reservoirs are not advisable for direct drinking purpose, because they have higher amount of salt and harmful organisms.

Solar distillation is the use of solar energy to evaporate water and collect its condensate leaving behind all impurities such as inorganic material and chemicals within the same closed system. Unlike other forms of water purification it can turn salt or brackish water into fresh drinking water. People have found many ways to desalinate, the process for removing salt from seawater and brackish water. Solar distillation is one of the cheapest methods.

Malik et al, [1] studied experimentally single basin solar still, convert the brackish water into potable water. Srithar et al, [2] studied experimentally open type FRP solar flat plate collector to treat tannery effluent into potable water. Nafety et al, [3] studied experimentally the use of black rubber or black gravel materials within a single sloped solar still as a storage medium to improve the still productivity. Nijmeh et al, [4] studied the effect of using various absorbing materials on the productivity of a single basin solar still. The materials used to enhance the absorptivity of water for solar radiation include dissolved salts, violet dye, and charcoal. The salts were potassium permanganate and potassium dichromate. They found that the addition of potassium permanganate resulted in 26% improvements in efficiency. The best result was obtained using violet dye with an increase in efficiency of about 29%. Tripathi et al, [5] studied basin water depth is having significant effect on productivity. Investigations show that the water depth is inversely proportional to the productivity of the still. Akash et al. [6] examined the effect of various cover tilt angles of 15°, 25°, 35°, 45° and 55° on solar still with and the optimum tilt angle for water production was found to be 35°. Also the authors studied the effect of the salinity of water on solar distillation, and concluded that the distilled water production decreased with salinity. Omar [7] conducted performance test on single slope solar still and concluded that (a) the increase in either ambient temperature and/or the solar intensity can lead to an increase in the solar productivity, (b) as the water depth decreases from 3.5 cm to 2 cm, the productivity increases by 25.7 %, (c) The maximum efficiency occurs in early afternoon due to the high solar radiation at this time, (d) the overall heat loss coefficient increases until it reaches the maximum in the afternoon due to higher solar intensity and ambient temperature and finally, (e) the proposed mathematical model gave good match with experimental results.

Velmurugan and Srithar [8] investigated the properties of raw effluent, settled effluent and distilled water produced by a single basin solar still integrated with an effluent settling tank. The physical (turbidity, total dissolved solids) and chemical analyses (pH, alkalinity, total hardness, calcium, magnesium, potassium, sodium, iron, manganese, ammonia, nitrate, chloride, fluoride, sulphate, phosphate, BOD and COD) were performed in India. It was found that the minerals present in the desalinated water sample were very low. According to the Indian guidelines some minerals were added to improve the water quality. The cost of the minerals per liter of water was about Rs. 0.28 ($0.0056), i.e. $5.6/m^3.

Many investigations have been conducted over the years with various basin materials. Phadatare and Verma [9] conducted an experiments with Plexiglas still and found that the maximum distillated output is 2.1 lit / m^2 / day at a water depth of 2 cm in still basin and Tiwari et al. [10] found that, double slope FRP multi wick solar still is more economical and efficient than a simple one

Amimul Ahsan [11] tested with a simple solar still with wide range of water samples (e.g. seawater, pond water, and arsenic contaminated groundwater and synthetic saline water). The experiments confirm that the solar still can produce potable water from source water of very poor quality.

The objective of this work is to study effect of basin material made of toughened glass on the productivity of the solar still and compare with the G.I basin material solar still and to analyses the distillate water quality.

II. SYSTEM DESCRIPTION

Single slope solar still with two different basin material are fabricated as shown in Fig.1 and 2. The bottom of solar still is insulated with an insulation material glass wool, provided in order to restrict the heat transfer from basin to the atmosphere. The thickness of the glass wool is 0.02 m. above the glass wool the basins are placed. one basin material is choosen as Galvanised Iron (G.I) sheet of 20 SWG and the G.I sheet inner surface is coated with black paint for effective absorption of solar radiation. Another basin material a clear toughened glass plate with a thickness of 0.004 m and the outer surface of the glass basin is frosted and coated with black paint for effective absorption of solar radiation. The glass cover plate is provided on the top portion of solar still. The thickness of glass cover plate is 0.004 m. All the four sides of solar still are insulated with an insulation material like thermocole, provided in order to restrict the heat transfer from basin to the atmosphere. The thickness of the thermocole is 0.01m. Each of the single slope solar still basin area is 1 m2. Slope of glass cover is 15o. An Eppley pyranometer is used to measure the solar radiation. A digital Anemometer is used to measure wind speed. Copper-constantan thermo couples are used for temperature measurements. Glass cover plate top and bottom side temperature, absorber plate temperature, water temperature, and vapour temperature are measured with the help of digital temperature indicator. The experiments were conducted and measurements were made. Photographic view of experimental setup is shown in Fig. 3. This experimental setup was designed, installed and tested in the Energy Laboratory, Department of Mechanical Engineering, Annamalai University, Annamalai Nagar, Tamil Nadu, India (11.3921° N latitude and 79.7147° E longitude).

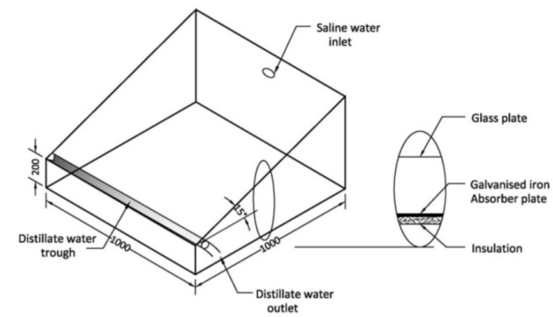

Fig. 1 Line diagram of Galvanised Iron basin still

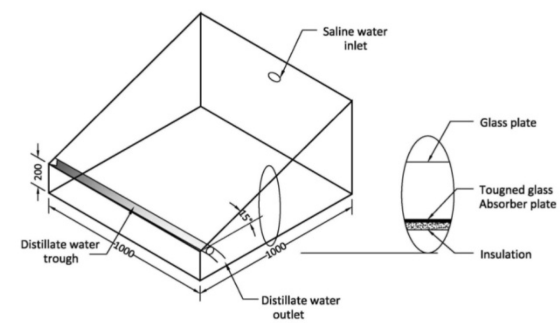

Fig. 2 Line diagram of toughened glass basin still

Fig. 3 photograsphic view of Experimental set up of Solar stills with basin area of 1 m^2

III. RESULT AND DISCUSSION

Fig.4 shows the variation of solar intensity for one of the experimental day .The intensity increases and reaches a maximum around mid day then decreases.

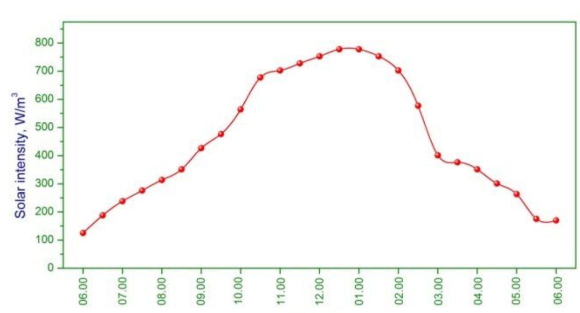

Fig. 4 Variation of solar intensity for the experimental day

Fig. 5 shows the cumulative productivity at a depth of 0.01m for both stills. It was higher in the toughened glass as basin material compared to G.I basin material. The absorption of solar intensity is higher for toughened glass coated with black paint when compared to G.I basin, that gives higher productivity.

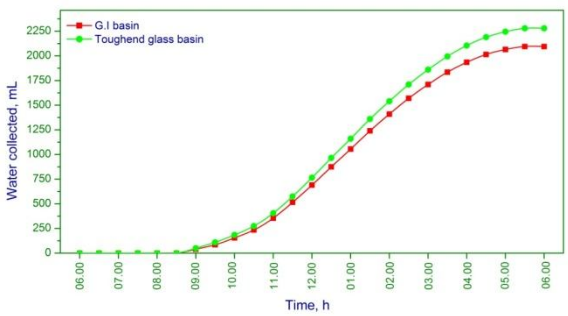

Fig. 5 Variation of cumulative productivity of water for the experimental day

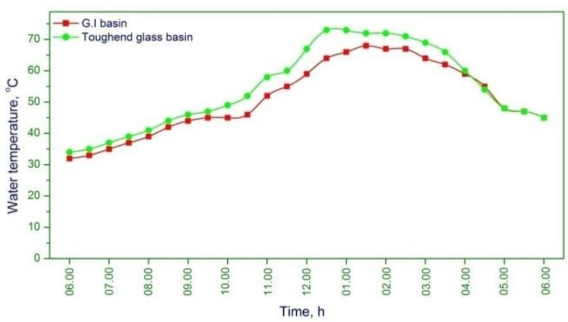

Fig. 6 Variation of water temperature

Fig. 6 shows the basin water temperature inside the solar stills with respect to time. Water temperature in the toughened glass basin increases and reaches a maximum temperature of around 73 °C. While the G.I basin records a maximum temperature of around 68°C. The productivity increases in toughened glass as basin material because water temperature is more when compared to G.I basin material.

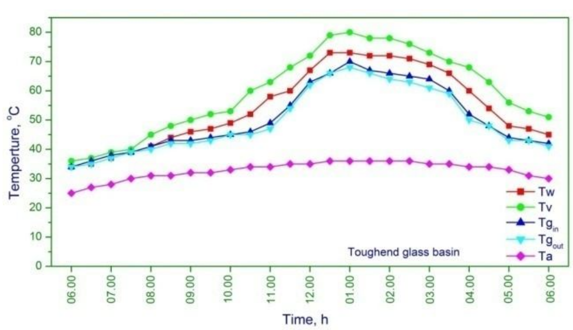

Fig. 7 Variations of the temperatures of toughened glass still

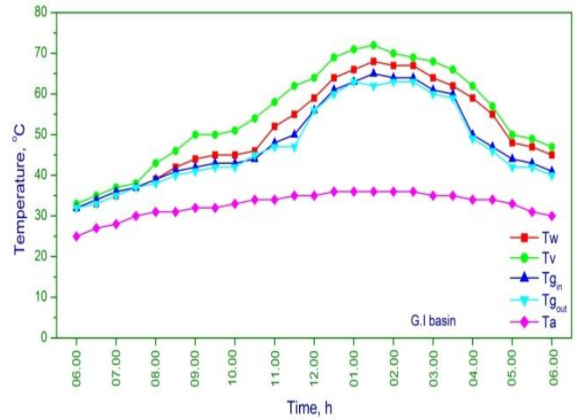

Fig. 8 Variations of the temperatures of G.I still

Figs. 7 and 8 show that the cover glass inner temperature (Tg_{in}), and outer temperature (Tg_{out}), vapor temperature(Tv), basin water temperature (Tw), ambient temperature (Ta), for toughened glass as basin material and G I basin material. For both the still, cover glass temperature is less than the vapour temperature, it causes condensation of vapour on the inner surface of the glass.

Figs. 9, 10, 11 and 12 shows the photographic view of both the stills after distillation of sea water. Figs. 9, 10 show the scale formed in the toughened glass as basin material and which can be easily removed by wiping with cloth. Fig.11 shows the scale formed in the G I basin material and which cannot be removed as it adheres to the paint surface. Fig. 12 shows the degree of degradation of G.I basin material after two months use of still.

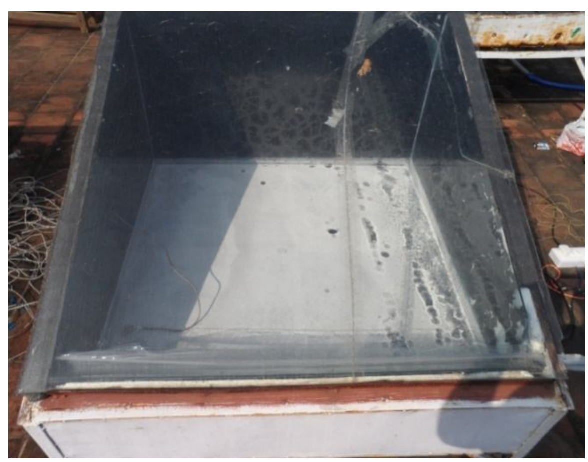

Fig. 9 Photographic view of scaling on toughened glass basin material of Solar Still

Fig.10 Photographic view of after removing the scale on toughened glass basin material of Solar Still

Fig. 11 Photographic view of after removing the scale on Galvanised Iron basin material

Fig.12 Photographic view of Galvanised Iron basin material after degrad

The following sea water quality parameters, e.g. pH, Turbidity, TDS, calcium, magnesium, chloride, sulphate, iron etc., for the feed and product water were obtained. These obtained parameters of the product water were then compared with drinking water standards are tabulated in Table 1. It was found that pH, Turbidity, TDS for both the sill is on par with the standard value and the minerals present in the desalinated water sample for both the still were very low. According to the Indian standards [12] some minerals were added to improve the water quality.

Odor and taste of distillate water from the G I basin material is unacceptable because the paint in the inside basin is in direct contact with the feed water while heating which inherits false odor and taste on the distilled water. Odor and taste of distillate water from the toughened glass basin material is acceptable because the paint on the outside surface of the basin is not in contact with the feed water.

Table 1 Result of physical and chemical testing on sea water (G.I sheet & Glass plate)

Sl. No	**Parameter**	**Requirement As Per BIS (IS :10500:1991)**	**Permissible Limit In Absence of Alternate Source**	**Result**		
				Sea Water	**Distilled Sea Water (GI Sheet)**	**Distilled Sea Water (Glass Still)**
1	Colour (TCU)	5	25	<5	<10	<5
2	Odour	Unobjectable	Unobjectable	Unobjectable	Objectable	Unobjectable
3	Conductivity	-	-	48900 μs/Cm	27 μs/Cm	72 μs/Cm
4	Turbidity, NTU	5	10	<0.1	0.5	0.5
5	pH Value	6.5 To 8.5	-	8.07	7.6	7.9
6	Total Dissolved Solids	500 mg/L	2000 mg/L	29600	18	48
7	Total Hardness (As $CaCO_3$)	300 mg/L	600 mg/L	6040	8	16

8	Carbonate Hardness (As $CaCO_3$)	-	-	140	7	26
9	Non Carbonate Hardness (As $CaCO_3$)	-	-	5900	1	Nil
10	Phenopthenlein Alkalinity (As $CaCO_3$)	-	-	Nil	Nil	Nil
11	Methyl Orange Alkalinity (As $CaCO_3$)	200 mg/L	600 mg/L	140	7	18
12	Calcium Hardness (As $CaCO_3$)	-	-	3200	4	8
13	Magnesium Hardness (As $CaCO_3$)	-	-	2840	4	8
14	Chloride(As Cl)	250 mg/L	1000 mg/L	19994	9	19
15	Sulphate (As SO_4)	200 mg/L	400 mg/L	1210	1.6	3.8
16	Iron (As Fe)	0.3 mg/L	1 mg/L	0.12	0.16	<0.01
17	Nitrate (As NO_3)	-	-	14.6	0.24	0.08
18	Silica (As SiO_2)	-	-	34	6	6

IV. CONCLUSION

The performance of a single slope solar still with different basin materials was experimentally investigated and the water quality before and after distillation are tested. Toughened glass basin has more productivity of 2.325 liters/day compare with G I basin have productivity of 2.135 liters/day.

In solar still basin material overcomes the problems such as scaling on the black surface. It cannot degrade when in contact with sea water and hot sun. It must not leave a bad taste and odor in the distilled water. Toughened glass as basin material overcomes the above problem.

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