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Comparative analysis of indoor and outdoor tests on solar still

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ABSTRACT

Solar still is a device utilized for converting saline or brackish water into potable water by use of heat energy of solar irradiation. In solar still, solar radiations after passing through the glass cover heats the water in a basin for producing potable water after condensation. In this present research paper, a novel approach is shown to corroborate the effects of outdoor test of a solar still by introducing an indoor test (lab testing). For the indoor and outdoor testing purpose, two numbers of single slope, single basin solar stills were fabricated using locally available materials of the same area. Outdoor solar still remains exposed to the sun for producing potable water, whereas indoor solar still is inbuilt made with 1,000 W heater for the purpose of heating the water. A series of experiments on outdoor and indoor tests were carried out at constant 1 cm water depth at Sal Technical Campus, Ahmedabad (latitude angle 23°03′N & longitude angle 72°40′E) Gujarat during July to December 2015. For the validation of outdoor test parameters like water temperature, inner glass cover temperature, distillate output, temperature controlled room with variations of ambient temperature, wind speed to simulate the actual conditions of outdoor tests. For the six months of research work, it has found that, the distillate output of 500 and 480 ml was obtained for outdoor test and indoor test during continuous 6 h of the test. Also, water and inner glass cover temperatures have also found good agreement like distillate output.

Keywords: Solar still; Indoor test; Outdoor test; Distillate output

1. Introduction

In many small communities/towns, arid and semi-arid regions, the natural supply of fresh water is a massive difficulty in comparison to the available saline water. In such a places solar distillation is a feasible alternative for providing clean water. Solar distillation is one of the easiest methods that break up the sweet water from impure water with the use of solar energy which is inexhaustible also it is an environmentally clean sources of energy and freely available in all divisions of earth in sufficient quantities and device used for this desalination process is termed as solar still. But due to lower productivity and efficiency of solar still yet it is not used on a large scale. Various investigations have been performed by many researchers and scientist and are ongoing to enhance the performances of a solar still.

El-Bialy [1] performed an experimental analysis to investigate the issue of different floating absorber plate like Mica, Aluminum, Stainless steel and Copper on single basin single slope, solar still and concludes that greater production is obtained with low thermal conductivity material such as isinglass. Vimal Dimri et al. [2] have conducted an experimental and theoretical analysis to inspect the performance of a solar still coupled with flat plate collector. Experimental and theoretical investigation have been conducted out by Velmurugan and Srithar [3] for a solar still integrated with a mini solar pond with sponge cubes as energy absorbing material. It has been concluded from the results that the output of a solar still coupled with a mini solar pond with energy storage material is 57.8%

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higher that simple still. Panchal and Shah [4] reported that, the solar still with 4 mm glass cover thickness increased distillate output of a solar still compared with 5 and 6 mm for Indian climate conditions. Nafey et al. [5] reported that productivity of simple solar still increases with the use of absorbing materials like rubber mat and black gravel. Akash et al. [6] have studied the issue of water depth on the performance of double slope, single basin solar still and concludes that productivity decrease with increasing water depth. Abu-Khader et al. [7] have performed an experiments on single slope, single basin solar still with energy absorbing material like coated and uncoated metallic wiry sponges and black volcanic rocks. They showed that black rocks within still gave output 20% more than conventional still. Panchal [8] made double basin solar still with vacuum tubes from locally available materials and tested in climate conditions of Mehsana, Gujarat and found that, it is best solar still for getting higher distillate output. An attempt has been made by Kalidasa and Elango [9] to investigate different water depth under insulated and uninsulated condition on double slope, single basin and double basin solar still. They show that double basin still gave output 17.28% and 8.12% for insulated and un-insulated stills compared to single basin still. Increment in surface temperature of the water also enhances distillate output. Hence, Panchal and Shah [10] put floating plates and found the higher distillate output compared with conventional solar still. Kalidasa Murugavel et al. [11] have studied the effect of different energy storage materials like quartzite rock, red brick pieces, cement concrete pieces, iron scraps, washed stones. Panchal et al. [12] have done experimental and simulation analysis of the single slope, single basin still and found that the results of the experiment and ANSYS CFX simulation results are nearly obtained. Panchal and Shah [13] found that, energy storage materials show remarkable effect to store the excess solar energy during sunshine hours and increment distillate output during off-sunshine hours. Khalifa et al. [14] performed an indoor test to investigate the effect of different water depth on single slope single basin solar still. Marwah and Khalifa [15] compared indoor tests to find effect of water depth inside the solar still and found that, least water depth increased distillate output of a solar still. Marwah and halifa [16] also conducted indoor tests on solar still to see the effect of wind speed on the performance of a solar still. They found that, increasing wind speed enhances the distillate output of a solar still and higher wind speeds adversely affect the performance of a solar still. Mashlay et al. [17] assessed the performance of a solar desalination system approach for ZLD under hyper arid environment and found that, more studies are required for the continuous pilot production system, modeling for commercial production, in addition to full economic evaluation of the system.

For comparison purpose of actual observations of solar stills, researchers have done two methods like theoretical analysis based on energy balance equations and CFD analysis based on simulation results. But nobody has ever tried for the comparison of actual observations of solar still based on indoor tests. Hence the major aim of this present research work is to compare results of outdoor tests with indoor tests.

2. The experimental setup

The experiments (outdoor test and indoor test) were Performed by Sal Technical Campus, Ahmedabad (latitude angle 23°03′N & longitude angle 72°40′E), Gujarat in December month of 2015.2D line diagram and isometric view of a solar still is shown in Figs. 1 and 2, respectively. Solar still is fabricated by 2 mm thick galvanized iron plate. The basin area of solar still for Experimental purpose is 0.5 × 0.5 m to absorb the more solar radiation heat the whole structure is coated with black paint. The basin is enclosed with 4 mm thick ordinary glass. To build up the assembly vapour leakage proof silicon sealant is applied. All the sides of still covered by 30 mm thick glass wool as an insulation to prevent the heat losses. An Electrical heater is built to furnish warmth to the basin water for Evaporation instead of solar radiation in indoor test. Electrical heater (Fig. 3) of size 46 × 46 cm is fabricated which is located under the drainage area. Winding of a fiber lead wire of 2.93 Ω/m is done over the 0.4 mm thick mica plate (middle) which is then put between two other

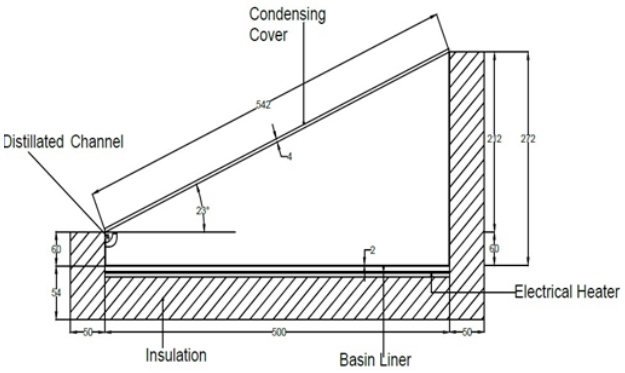

Fig. 1. 2-D line diagram of Solar still for indoor test and outdoor test.

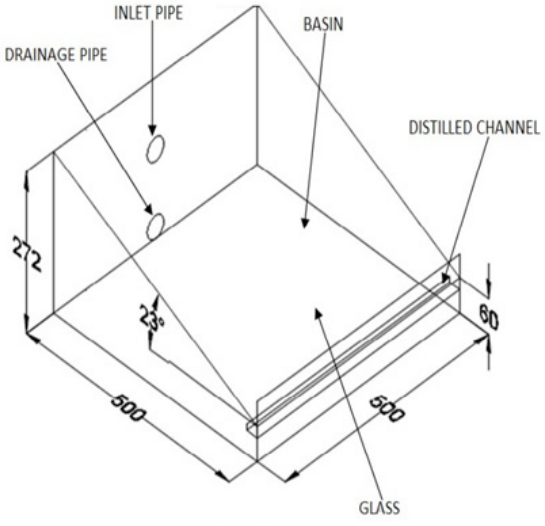

Fig. 2. Isometric view of Solar still.

plates of mica of the same dimensions. The whole assembly is covered by M.S plate to prevent the inflation of mica. A Variac 220 v is used to determine the input voltage and corresponding current is measured by digital clamp meter. Wind velocity is modulated by a fan similar to the outdoor wind. K type thermocouple wires were used to measure water and inner side glass cover temperature. Measurement of distillate, water temperature, inner side glass cover temperature, potential difference and current were done at an interval of one hour during 10 am to 4 pm. Fig. 4 shows the experimental setup of the indoor and outdoor test. Table 1 shows the measuring instruments used in this research work with accuracy and range.

Fig. 3. Actual photograph of electrical heater.

Fig. 4. (a) Photograph of indoor test setup. (b) Photograph of outdoor test setup.

Table 1
List of measuring instruments with accuracy and range

Sr. No	Instrument	Accuracy	Range
1	Solarimeter	±1 W/m^2	0–4,000 W/m^2
2	Anemometer	±0.1 m/s	0–30 m/s
3	Digital temp. Indicator	±1°C	0°C to 400°C
4	Digital thermometer	±0.1°C	–10°C to +45°C
5	Digital clamp meter	±0.1 Ã	2 to 400 Ã
6	Multimeter	±0.1	0–1,000 V
7	Graduated flask	10 ml	500 ml
8	TDS meter	±2%	9,990 PPM (mg/L)

3. Result and discussion

Outdoor test and Indoor test were carried out at 11/12/15 and 19/12/15, respectively. Readings were taken at an interval of one hour during 10 am to 4 pm for both the test. Figs. 5–9 illustrate the results of outdoor test and indoor test.

Fig. 5 shows the variation of solar Insolation with time recorded on 11/12/15. Solar intensity gradually increases from 10 am to 1 pm and then after the decrease. The maximum amount of solar insolation is obtained during the period of 12 to 2 pm in outdoor test. The solar insolation recorded at an hourly time interval in outdoor is applied to the still in indoor test through electrical heater which is kept below the basin.

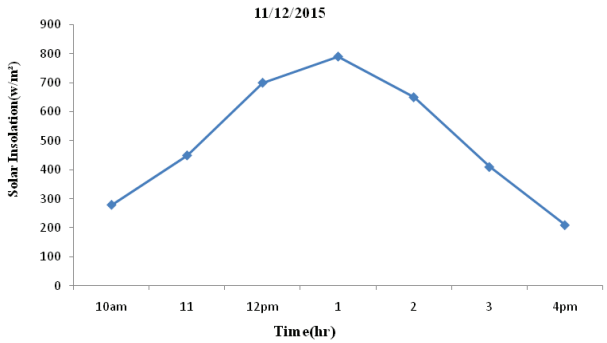

Fig. 5. Variation of solar insolation vs. time.

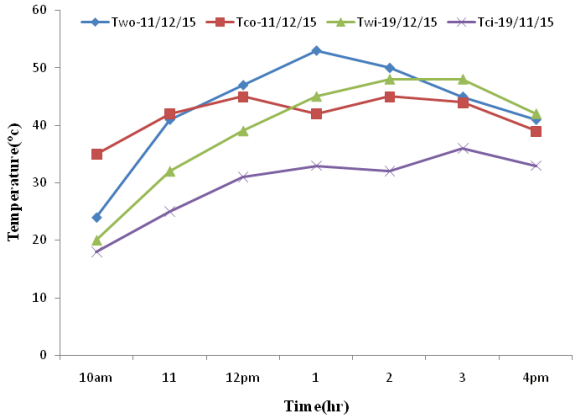

Fig. 6. Comparisons of basin water and inner side glass cover temperature.

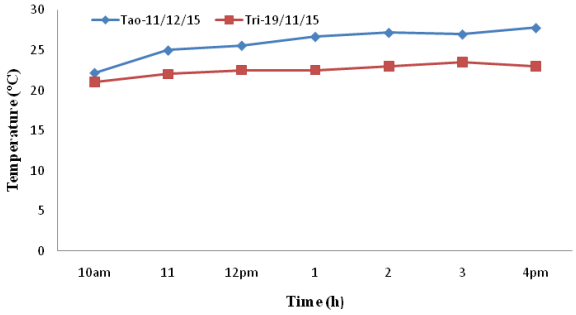

Fig. 7. Variation of ambient and room temperature vs. time.

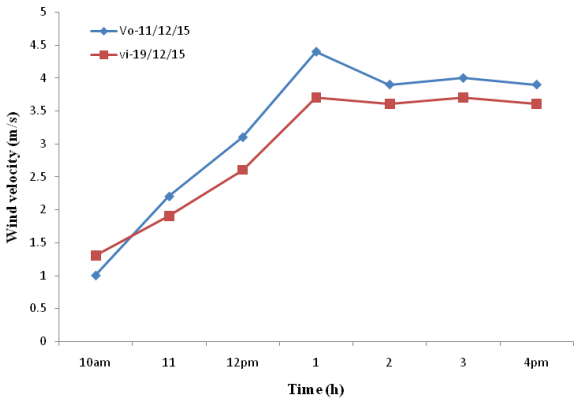

Fig. 8. Variation of wind velocity vs. time.

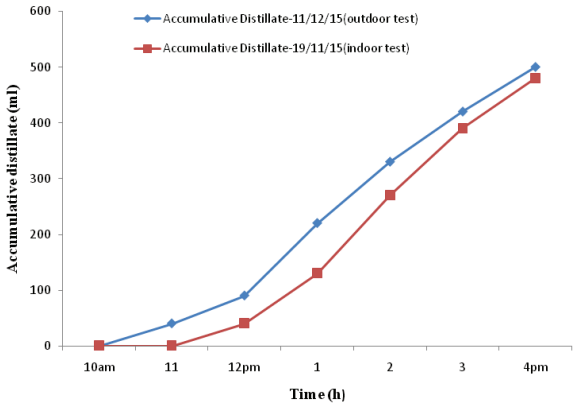

Fig. 9. Comparison of cumulative distillate output of indoor and outdoor test.

Fig. 6 shows the comparisons of basin water and inner side glass cover temperature for the indoor and outdoor test. Minimum and maximum basin water Temperature of 24°C and 53°C was observed during outdoor test and 20°C to 48°C is observed during the indoor test. Inner side glass cover temperature in the range of 35°C to 45°C is noticed during outdoor test and 18°C to 36°C is noticed during the indoor test. Mainly basin water and inner side glass cover temperature difference are responsible for the performance of the still.

It is seen from the graph that, the positive temperature difference of basin water and inner side glass cover increases during afternoon hours, where in indoor test it is gradually increased from starting because necessary heat is supplied from the bottom through the heater. It is a main reason the increment during afternoon hours.

Fig. 7 shows the variation of ambient and room temperature with Respect to time. In this present experiment, the temperature variation room was used to simulate the actual conditions. It is clearly seen that, the room temperature is nearly constant for to simulate the actual atmospheric temperature during the continuous 6 h of the experiment. It has been also observed that due to constant room temperature, it slightly affects the output of still.

Fig. 8 shows the variation of wind velocity vs. time. It has been well explained by Velmurugan and Srithar [3] that, the wind velocity has a significant effect on the performance of still. As the wind speed Increases production of distilled water increases. It has been observed from the graph that wind speed is increasing from 10 am to 1 pm and then after slightly decrease also maximum distillates is noticed during higher wind speed for both the test.

Fig. 9 represents the comparisons of cumulative distilled water collection with time for both the test. It has been observed from the Fig. 9 in indoor test distilled water production gradually increasing with increasing solar radiation intensity and vice versa. Whereas, in indoor test distilled water production starts after some period because necessary heat to the basin water for evaporation is obtained through heater which takes longer time to heat up.

4. Conclusion

The following points were concluded the present research work:

- 2.5 L brackish water is poured in the solar still at starting of experiments and maintained for every 1 h of experiments. It has reported cumulative distillate of 500 and 480 ml during outdoor test and indoor test, respectively during continuous 6 h of the test.
- It has been seen from the graphs that room temperature affects the performance of indoor test still.
- Results of outdoor test and an indoor test are in good agreement.
- It has found good agreement in cumulative distillate output during indoor and outdoor tests.

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