International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2020.33721

Volume 6, Issue 4
April - 2020

Performance Evaluation of a Double Slope Concrete Cascade Solar Stills

S. Aliyu[1*] and A. S. Abubakar[1]

[1] Department of Physics

Usmanu Danfodiyo University

Sokoto, Nigeria

ABSTRACT

The availability of drinking water is one of the major challenges faced by our modern society. There are certain locations where fresh drinking water is scarce, but brackish or saline water are available. The available water resources have been used to provide a clean, safe and reliable drinking water with metal basin solar stills using solar energy. The issue of rusting associated with the metal basin solar still constitutes a major problem. A concrete cascade double slope solar still was constructed and tested alongside a conventional metal basin solar still of the same dimensions. The performance tests compared the glass cover and basin water temperatures, as well as the yields of the two stills recorded at 30minutes interval, for seven days. The highest average daily glass temperatures for metal and concrete basin stills of 54.1 °C and 40.5 °C were recorded respectively for the metal basin and concrete cascade solar stills, at an average highest global solar radiation of 867.3W/m^2 and an ambient temperature of 35.1 °C. The highest average daily water temperatures of 58.3 °C and 51.1 °C occurred respectively for the metal basin and concrete cascade stills at the same time under the same atmospheric conditions. The average daily cumulative yields of the metal basin and concrete cascade solar stills were found to be 707.1 mL 577.4 mL respectively. The results show that the conventional metal basin solar still recorded a higher yield, but the concrete cascade solar still has overcome the rusting problem. There is, therefore, a compromise of 18.3% higher yield or a longer span working solar still without rusting.

Keywords: *Double Slope Concrete Cascade, global solar radiation, Solar energy.*

1. INTRODUCTION

Many scientists have worked on various aspects of solar water heating and distillation technology throughout the world. Solar stills of different designs have been proposed and investigated with a view to get greater distillate output. Solar energy is capable to harness directly or indirectly for water heating, distillation, drying, cooking [1]. Due to the continuously increasing demand of fresh water, there is a need for devising a means of providing clean and healthy water for human, animals and industrial consumptions. Rather than use of expensive non-renewable energy resources to meet this demand, solar energy can be harnessed to power simple distillers. Solar distillation is an affordable and reliable source for potable water that is often ignored or underutilized. Solar distillation has the advantage of cost saving over other types of distillation [2].

Muhammad *et al*., (2017), designed, constructed and tested solar still-solar water heater hybrid system for small scale application [3]. The research was assessed with the use of a flat plate collector type solar water heater coupled with a single slope solar still alongside a conventional type single slope solar still of the same dimensions under the same atmospheric conditions for seven days. The average cumulative yield of distilled water obtained from solar still-solar water heater hybrid system was found to be 440ml and that of conventional single slope solar still was 155ml.

Panchal *et al*., (2011), studied the effect of coupling single slope solar still with evacuated heat pipe collector. Productivity of coupled solar still was found 30% higher than uncoupled still [4].

Shobha *et al.,* (2012), developed a hybrid system solar still coupled to an evacuated tube collector type solar water heater. The ETC model solar water heater was coupled to a solar still and the performance study was conducted at various timings with different operating conditions with various water depths and various water samples. The productivity of solar still increases from

* corresponding author: sani.aliyu@udusok.edu.ng

39 to 59% with hybrid unit when operated from 8am to 5pm. The efficiency for 1cm water depth ranged from 43 to 52%, for 1.5cm ranged from 39 to 48% and for 2cm it ranged from 32 to 41% for hybrid solar still operated during the daytime. Hence it was concluded that the efficiency of the still increases with increase in water depth [5].

Syed *et al.,* (2014), studied the performance of a single basin solar still coupled with evacuated tubes to increase the daily productivity of solar still with less heat losses. The performance of an ordinary still was compared with the still coupled with evacuated tubes. It was found that the daily productivity has increased to 50.2% by introducing the evacuated tubes [6].

Distillation using sunlight (solar) is an attractive application. The basin type of solar still is simple in design, manufacture and operation (Muhammad *et al*., 2017). The design of a particular solar still system is responsible for changes in its performance (Shobha *et al.,* 2012). Therefore, it is very important for researchers in the field of renewable energy to develop new ideas of technology to improve the performance and efficiency of solar thermal devices in a way that is affordable. This paper therefore presents an approach of developing concrete cascade solar still thereby testing its performance alongside a conventional metal basin solar still of same dimensions under the same metrological conditions.

2. CONSTRUCTION

Numerous materials were involved in the development of the two different types of solar stills, some of which include: Metal sheets, GI pipes, glass sheets, triangular iron bar, cement blocks, sharp and smooth sands, cement, gravels, iron rods, silicon rubber sealant etc. Some of the major components are discussed below in more details.

2.1 Metal Basin Solar Still

The metal basin solar still was constructed in a rectangular box shape with an area of 155cm x 74cm and average height of 97cm. An inlet pipe was fixed at the rear side of the still to supply brackish water and another pipe fixed at the bottom side of the basin which is used to drain out the dirty water after distillation. A plane transparent glass sheet was used to make the roof of the still basin which was made to slant from the top to the two sides of the still walls. The space between the glass cover and the body of the still was sealed using a silicon rubber sealant to make it air-tight. The distilled water that condenses on the glass roof from inside the still basin was set to be collected by means of a collection trough which was fixed at the lower edge of the glass cover from both sides. The distilled water coming out was set to pass through a rubber pipes attached to the end of the collection troughs and collected in a measuring cylinder. Narrow holes were drilled in the body of the still to be able fix thermocouple wires for the measurement of still inner temperatures (Figure 1 & 2).

Pate 1: Metal basin Solar still

2.2 Concrete Cascade Solar Still

The concrete cascade solar still was constructed in the same design, size and shape with the metal basin solar still. In this case, the still basin was constructed with concrete and painted black from inside to maximize absorption of solar radiation. The same set-up as in the metal basin still was made to the concrete cascade still.

DOI: 10.31695/IJASRE.2020.33721

Pate 2: Concrete cascade solar still

2.3 Experimental Set-up

The experiment was started each day at 8:00 am to 6:00 pm and readings were recorded. The Solar distillation was started by introducing 50L of brackish water into each of the metal basin and concrete cascade solar stills. The top of the assembly was covered with a roof of glass which allows solar radiation to pass through it, but does not let thermal radiation (emanating from the interiors including the water) from outgoing. At the end of the roof, a v-trough provided at each sides which collected the distilled water. The whole assembly was kept in an open sun. The solar radiation passed through the top cover, got absorbed predominantly by the black painted surface in metal basin and the concrete cascade solar stills and also some extent by the water mass. As a result, the evaporation of water took place filling the inside air by water vapor and leaving the dirt or salt behind. The inside humidity increased and condensation took place on the underside of the top cover, which is sloped gently on both sides to allow condensed water trickle down into the v-trough, from where it descends down to the measuring cylinder through the attached rubber pipes. Readings of distillate volume and temperatures for the still walls, water, inner air and glass cover were recorded at 30minutes interval each day for seven days. The average daily temperatures and yields were determined.

3. RESULTS

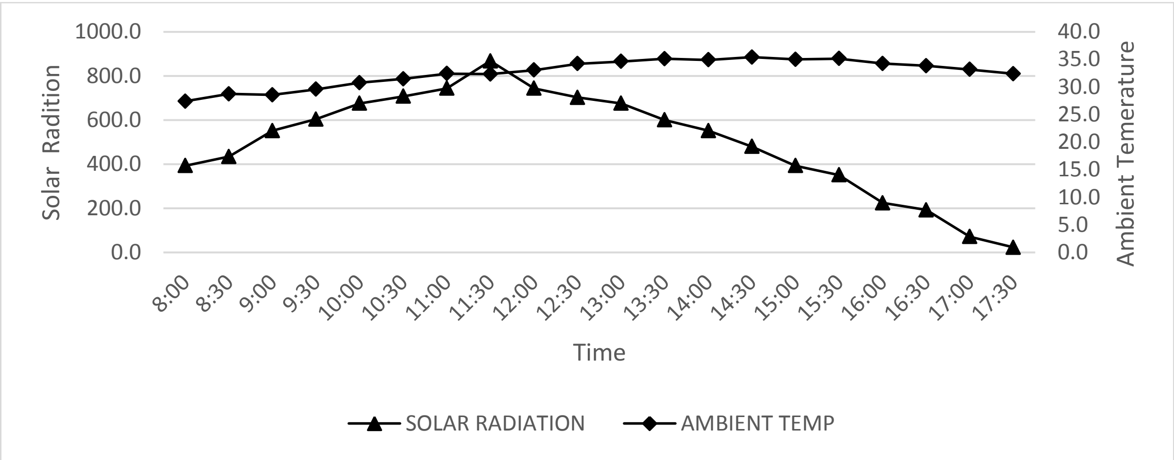

Figure 1: Variation in the Average Daily Solar Radiation and Ambient temperature.

DOI: 10.31695/IJASRE.2020.33721

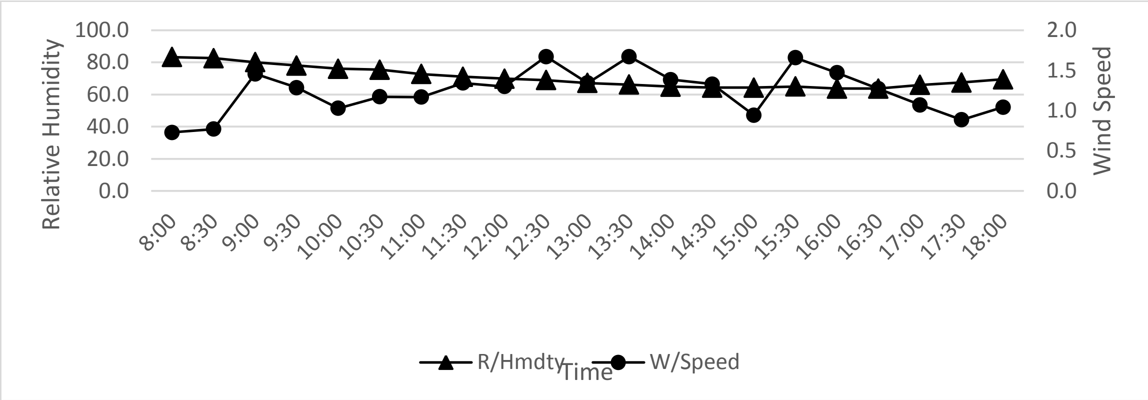

Figure 2: Variation in the Averages of Relative humidity and Wind speed.

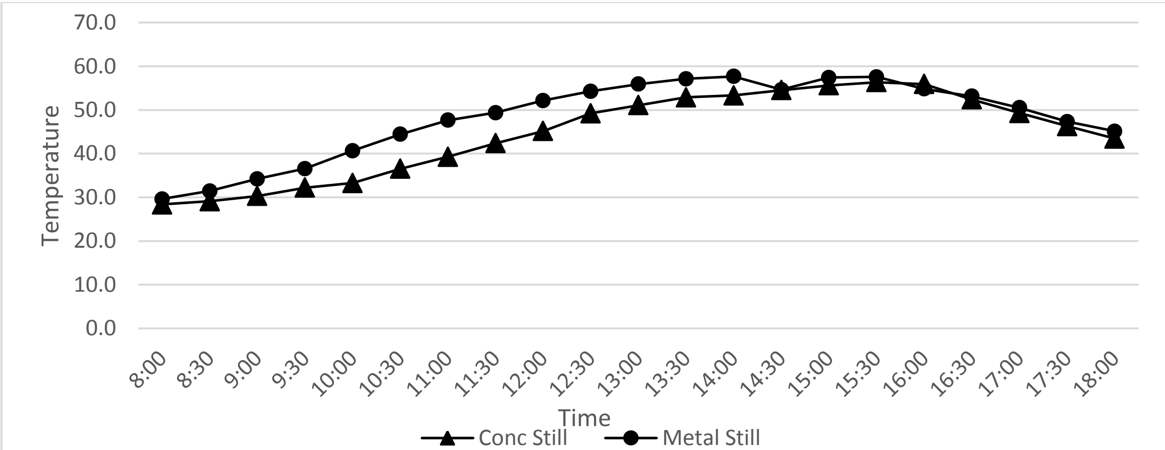

Figure 3: Variation in the Average wall temperatures for both concrete cascade and metal basin solar stills.

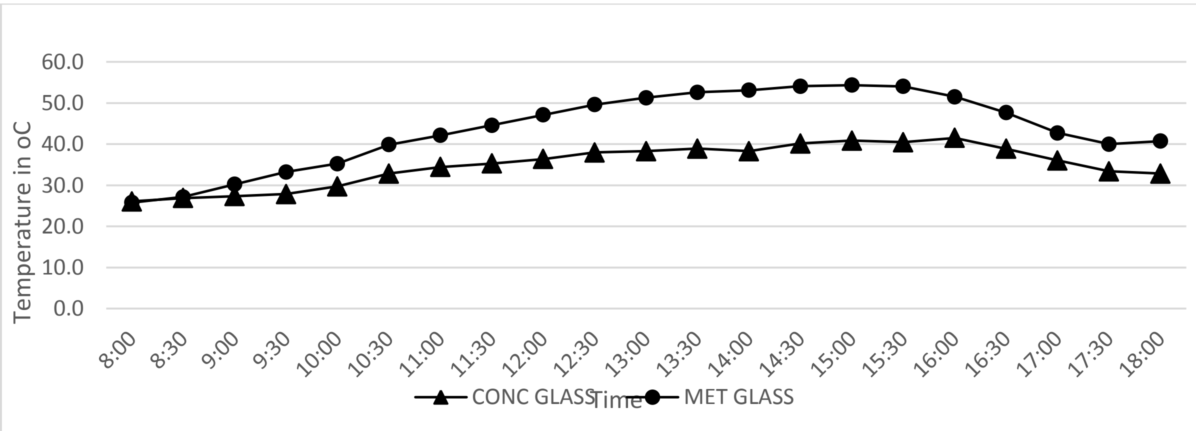

Figure 4: Variation in the Average Glass temperature for both concrete cascade and metal basin solar stills.

DOI: 10.31695/IJASRE.2020.33721

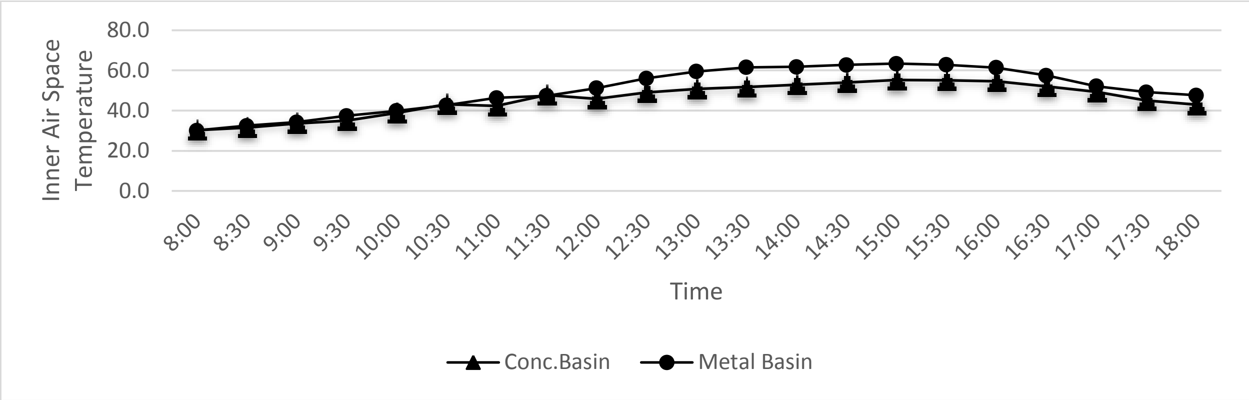

Figure 5: Variation in average daily inner air temperature for both concrete cascade and metal basin solar stills.

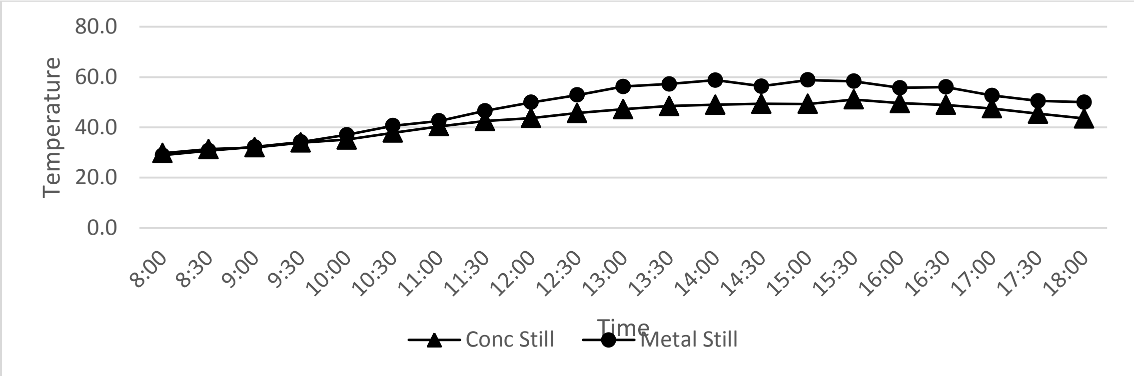

Figure 6: Variation in average daily water temperature for both concrete cascade and metal basin solar stills.

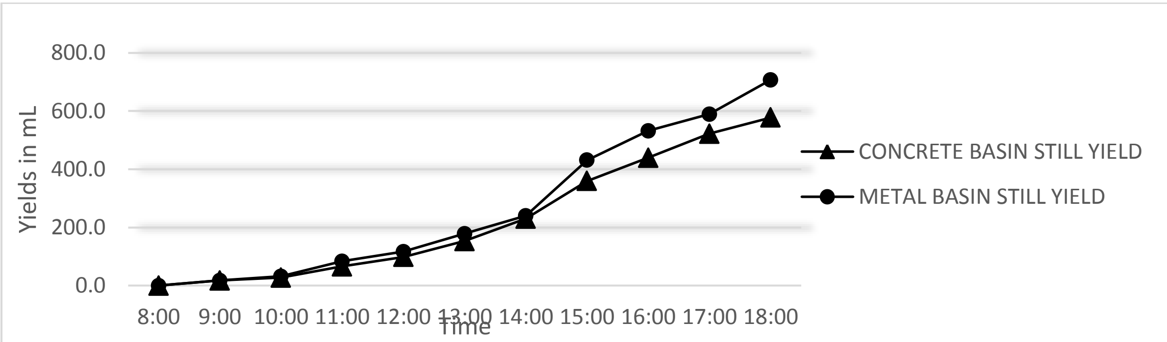

Figure 9: Average Daily Cumulative Distillate Yields for both concrete and metal basin stills.

4. DISCUSSION

Figure 1 depicts the average daily solar radiation and ambient temperature. The figure shows that there was enough global solar radiation (up to 800W/m^2) to bring about ambient temperature, which is a good condition for better performance of the solar stills. The solar radiation reached its peak (867.3W/m^2) and the ambient temperature attained its peak (35.5^{o}C). The concrete cascade solar still yield was found to attain its maximum yield at the same time the solar radiation attained the maximum value. Figure 2 represents the variation in the average relative humidity and wind speed with time. It shows how the relative humidity was high in the morning and slowly goes down in the afternoon and rises again in the evening time. The highest relative humidity value (83.3%) was recorded, the lowest yield at the same time. The wind speed was observed to be low and fluctuating throughout. The maximum wind speed (1.7m/s) which almost correspond d to the time the maximum yield was obtained. This is because the wind speed helps to cool the glass cover temperature which aids the condensation process to produce more distilled water. Figure 3 shows the comparison between the average wall temperatures of the concrete cascade and metal basin solar stills. The wall of metal basin still with the maximum temperature of 57.7^{o}C was found to be higher than the concrete still wall temperature with the

DOI: 10.31695/IJASRE.2020.33721

maximum temperature of 56.4°C at 15:30. In the early hours there was a remarkable difference between both stills temperatures, this is attributed to the fact that metals have higher thermal conductivity than the concrete. From 14:30 to 16:00 the temperatures were almost the same because metals easily lose heat. Figure 4 depicts the comparison between the glass temperatures of concrete cascade solar still and metal basin solar still. The glass temperature of the metal basin still with the peak (54.4°C) was found to be higher than that of the concrete cascade still with peak of 41.5°C. This may be due to the higher wall temperature and design difference of the stills. Figure 5 shows the graph of variation of the inner air temperature the concrete cascade and metal basin solar. The metal basin still with peak temperature of 63.3°C was higher than the concrete cascade still with a peak temperature of 55.3°C at the same time. Figure 6 depicted the comparison between the average daily cumulative distillate yields for the concrete cascade and metal basin solar stills. The metal basin solar still, having the highest temperature values, the highest yield of 707.1mL against the concrete cascade solar still with 577.4mL. Figure 8 depicted the variation of water temperature for both the concrete cascade and metal basin solar stills. It shows that during the late hours of the experiment (from 1:00 to 18:00hours), the basin water temperature was slightly greater for the two still types. The concrete cascade still attained its peak water temperature (51.1°C) and the metal basin still with the highest water temperature (58.9°C). This shows that the water temperature difference is attributed to the difference in rate at which the different basin types absorb heat. Metal has higher rate of heat absorption and also releases the heat energy faster to the water.

$$H_0: \mu_1 = \mu_2 \quad (1)$$

The statistical significant difference test conducted using the independent samples t-test on SPSS software shows in equation 1 above that there is no significant difference in the means of the two still types yields. The p-value (0.696) obtained is greater than 0.05. the null hypothesis requires that a $P \leq 0.05$ to signify a reasonable difference in the yields. Therefore, the yields of the two types of solar still are not significantly different.

5. CONCLUSION

The experimental results obtained from the thermal performance tests shows that the metal basin solar still performed better than the concrete still considering the difference in their outputs. The highest average glass and water temperatures for metal basin and concrete cascade solar stills were found to be 54.4°C, 58.9°C and 41.5°C and 51.1°C respectively at an average highest global solar radiation 867.3 W/m^2 and ambient temperature of 35.5°C. The average daily cumulative yields of metal basin and concrete cascade solar stills were found to be 707.1 mL and 577.4 mL respectively. This concluded that the conventional metal basin solar recorded a higher yield, but the concrete cascade solar still has overcome the rusting problem. There is therefore a compromise of 18.3% higher yield or a longer span working solar still without rusting.

REFERENCES

1. Kapurkar, P. M. and Kurchania (2013). Performance Evaluation of Fresnel lens Concentrated Solar Water Heater Cum Distillation Unit. *International Journal of Agricultural Engineering*, **6**(1), 71-74.
2. Muhammad, S. B, Aminu S., Umar, S., Aliyu A. S. and Adamu I.U(2017). Design and Construction of Solar Still-Solar Water Heater for Small Scale Application. *Journal of Alternate Energy Sources and Technology*, **8**(2), 11-16
3. Panchal, H. N., Doshi, M., Patel, A., Thakor, K. (2011). Experimental Investigation on Coupling Evacuated Heat Pipe Collector on Single Basin Single Solar Still Productivity. *International Journal of Mechanical Engineering & Technology*, **2**(1), 1-9.
4. Sethi, A. K. and Deviedi, V. K. (2013). Design, Fabrication and performance evaluation of Active Solar Still under forced circulation mode. *Research Journal of Engineering Sciences*. **2**(6), 6-12.
5. Shobha, B. S., Vilas, W., and Rajesh, A. M. (2012). Performance Evaluation of a Solar Still Coupled to an Evacuated Tube Collector Type Solar Water Heater. *International Journal of Innovations in Engineering and Technology*, **1**(1), 72-84.
6. Syed, F. M and Aasim, N. A. (2014). Single Basin Solar Still Performance with Evacuated Tubes Solar Collector. *Journal of Mechanical and Civil Engineering*. 2320-334X,64-70.

DOI: 10.31695/IJASRE.2020.33721