INVESTIGATING THE PERFORMANCE OF A SOLAR COLLECTOR WITH PLASTIC BOTTLES AS GLAZING COVER

M.B. Abdullahi[1*], M. Oyinlola[2], A. Ahmed[1], M.B. Balogun[1]

[1] Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Kaduna, Nigeria.

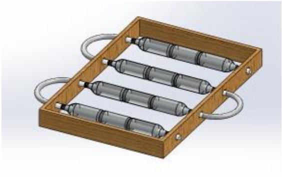
[2]Institute of Energy and Sustainable Development, De Montfort University, Leicester, UK LE1 9BH

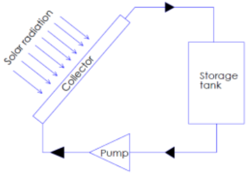
Introduction

Conventional flat plate collectors have found widespread use in both domestic and industrial applications. Despite the high potential of solar collectors in locations with enormous solar energy resource, one major factor limiting its uptake, most especially in low-income communities of sub-Saharan Africa, is its high initial cost. The replacement of flat glazing cover with transparent Polyethylene Terephthalate (PET) plastic bottles has been identified as one way of minimising cost. PET bottles constitute a significant percentage of the waste stream and can be upcycled at no cost. This also contributes to reducing plastic waste in the environment. The idea of using plastic bottles as transparent covers was initially conceived by Jose Alano in 2002. Since then researchers have carried out investigations on modified versions of this design. Studies carried out by Baschir (2018), Jorge (2015), Nizamuddin (2018) among others have shown that high output temperatures within the range of 45°C to 55°C are achievable. Water at this temperature range is suitably warm enough for domestic applications such as bathing and washing. This main innovation of this study is the use of locally available materials and semi skilled artisans to develop a simple and low cost solar water heater that can be used in low income communities.

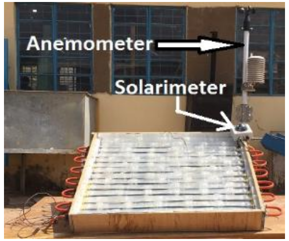
Methodology

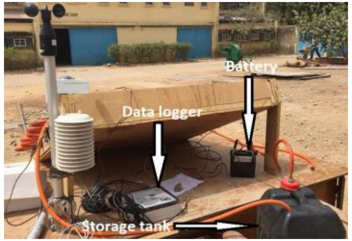
The set up consists of 13 rows of 15mm diameter copper pipes, 1700mm long passing through the centre of 630mm diameter PET bottles. The copper pipes are coated with matte black paint to maximize radiation absorption. This resulted in a total aperture area of 1.194m2. The pipes are connected at the protruding ends using insulated rubber hose pipes such that water flows in a serpentine direction. The whole assembly is then housed in a wooden frame with aluminium foil spread underneath to serve as diffuse reflectors to enhance solar radiation absorbed by the pipes. Water is continuously circulated with the aid of a 12V DC pump at a flow rate of 0.04kg/s. The setup was exposed to solar radiation while temperatures at various points were continuously measured and recorded. The useful gain was calculated using the equation: $Q_u = \dot{m}C_p(T_o - T_i)$





Parameters	Values
Collector area (m^2)	1.194
Collector tilt angle (°)	21
Number of rows	13
Diameter of copper tubes (m)	0.015
Diameter of plastic bottle (m)	0.063
Mass flow rate of water (kg/s)	0.043



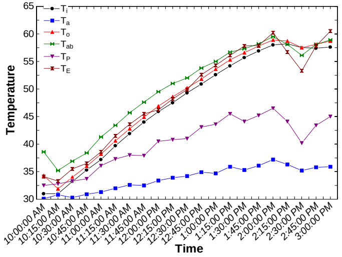


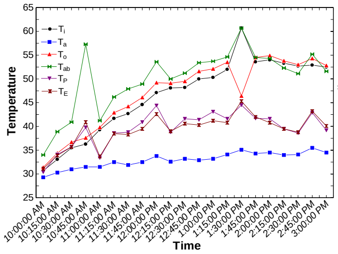
Performance evaluation was carried at the workshop section of the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria. During the test period, solar radiation intensity and wind speed were measured using a solarimeter, anemometer respectively. Also, ambient, absorber, storage, collector inlet and outlet temperatures were measured using Type T thermocouples. The GP2 data logger was configured to record all readings at intervals of one minute. The solar collector was positioned in the north-south direction at a tilt angle of 21° towards the south. The experiment was carried out for five hours daily from 10:00am to 3:00pm on the 4th, 5th and 6th of March, 2020. Measurement system was calibrated before the experiment using handheld devices, which showed temperature s within 0.3 C

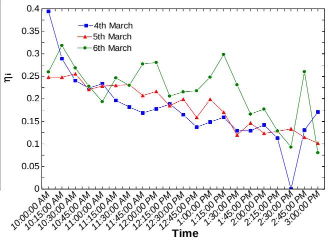
$$\eta_i = F_R(\tau\alpha) - c_1 \frac{T_i - T_a}{G_T}$$

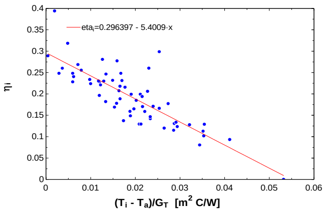
Results Discussion and Conclusion

The instantaneous efficiencies were evaluated It is observed that the efficiencies decrease with increasing temperature. This is as a result of increasing heat loss from the PET bottle due to enclosed air. Unlike the evacuated tube collectors, the PET bottles accommodate a significant amount of air which promotes heat loss by convection from the absorber surface. A thermal performance curve was obtained using data from the 3 experimental days. The equation of the least square fit is given as displayed in the graph. It can be seen from the equations that the collector has an intercept efficiency of approximately 0.3 which is significantly lower than expected, however, considering the low production and running cost, it is still a viable option for low income communities.









References

Baschir H. (2018). *Investigating the performance of a Flat-plate Collector made from Plastic Bottles.* Unpublished M.Sc dissertation submitted at Institute of Engineering and Sustainable Development, De Montfort University.

Duffie, J.A. and Beckman, W.A (2013). *Solar engineering of thermal processes*, 2nd Edition, Toronto :John Wiley & Sons.

Jorge T. (2015). *Feasibility overview of a solar water heater made of polyethylene terephthalate bottles for rural areas in Guatemala.* Institute of Science and Technology for Development, Rafael Landivar University.

Nizamuddin, P. (2018). *Developing a plastic bottle solar thermal flat plate collector*. Leicester, United Kingdom: Institute of Engineering and Sustainable Development, De Montfort University.