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A possibility to combat the intake of poor quality drinking water by Nigerians using a locally fabricated solar water distillation kit

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ABSTRACT

Nigeria is blessed with abundant solar energy and potable water shortage is one of her major challenges. A roof-type solar water distillation (RSWD) system was fabricated from local materials and tested under actual environmental conditions of Urualla, an ancient town in the Eastern part of Nigeria. The system includes four major components; a rectangular wooden basin, an absorber surface, a glass roof and a condensate channel. The RSWD system is very cheap and has no moving parts. Hence, the cost of maintenance is almost free coupled with free source of energy. The RSWD of surface area 0.5m^2 was able to produce an average of 0.4m^3 of distilled water per day. Though the condensate was small compared to human need as is peculiar to many solar stills, the efficiency can be increased by fabricating RSWDs of larger surface area. Also, since the materials are cheap and readily available, one can fabricate as many RSWDs as possible to tackle the daily demand of potable water.

Keywords: Nigeria, potable water, solar energy, water distillation.

INTRODUCTION

Water is the most common and widespread chemical compound in nature which is a major constituent of all living creatures [1-3]. The quality of water is of great importance as it is commonly consumed and used by households. Natural surface water bodies like rivers and streams are subjected to pollution comprising of organic and inorganic constituents [4,5]. The problems of ground water quality are much more acute in the areas which are densely populated, thickly industrialized and have shallow groundwater tables [6]. The rapid growth of urban areas in Nigeria has affected surface and ground water quality due to over exploitation of resources and improper waste disposal practices. Potable water shortage is expected to be one of the major worldwide challenges in the near future [7-9].

Water is extremely essential for survival of all living organisms. Over one billion people worldwide have no access to safe drinking water [6,10-13]. Water quality is a vital concern for mankind since it is directly linked with human welfare. Ideally, drinking water should not contain any micro organism known to be pathogenic or any bacteria indicative of faecal pollution [6]. Water free of salinity, organic and inorganic substances, chlorination by products, free of plants, animal wastes and bacteria contamination is known as potable water [14-17]. Because of the high dependence of man on water, the World Health Organization (WHO) has formulated standards for drinking water quality [6,18].

There is an urgent need for clean, pure drinking water in Nigeria. Pure water is also needed in some industries, hospitals, and schools. Often water sources are brackish (i.e., containing dissolved salts) and/or contain harmful bacteria and therefore cannot be used for drinking [19]. Distillation is one of many processes that can be used for water purification and solar radiation can be the source of heat energy [7,19,20]. In this process, water is evaporated, thus separating water vapour from dissolved substances, and is then condensed as pure water [2,19,21]. Solar still distillation is a natural phenomenon on earth [19]. Solar energy heats water in the seas and lakes, evaporates it, and condenses it as clouds to return to earth as rainwater. Among the many factors considered in the design and fabrication of a solar water distillation system are cost implication and efficiency. As a supporting technique for water purification, various types of solar stills have been developed and are being applied worldwide [22-24]. Generally, solar still systems have the advantage of low operating and maintenance costs and the shortcoming of low thermal efficiencies [25].

The present study was undertaken to investigate the efficacy of a roof-type solar water distillation (RSWD) kit. The RSWD system, which replicates the natural process of evaporation and condensation was fabricated from cheap and local materials [2]. A wooden rectangular box covered with black polyethylene absorber surface was the water tank. A glass roof was designed to rest onto the water tank. Beneath the glass roof was a gutter or condensate channel for driving out distilled water. The heating and evaporation took place on the absorber surface, while condensing process took place on the glass roof. The water sample was collected from Njaba River and an estimate of daily production of potable water was achieved.

MATERIALS AND METHODS

A schematic diagram of an RSWD water basin whose interior has been covered with black polyethylene is shown in Figure 1. The 91cm x 56cm rectangular water tank is 22cm deep. The water tap is for discharging of untreated water sample should the need arise. The condensate channel was made of aluminium sheets, while the wooden frame that formed the water basin also served as thermal insulator.

Figure 2 shows the glass roof, outlets for distilled water and RSWD stand. Two sheets of glass, about 90.8cm long, 61.2cm wide and 3mm thick were rightly placed to form the glass roof. Each of the two edges of the glass roof was covered with a triangular glass sheet of two equal sides and a base of 57.8cm. A 2-in-1 chemmer fast epoxy glue was used to hold the glass roof in place.

Figure 1. The rectangular water tank on top of RSWD stand

Figure 2. The glass roof on top of the rectangular water tank

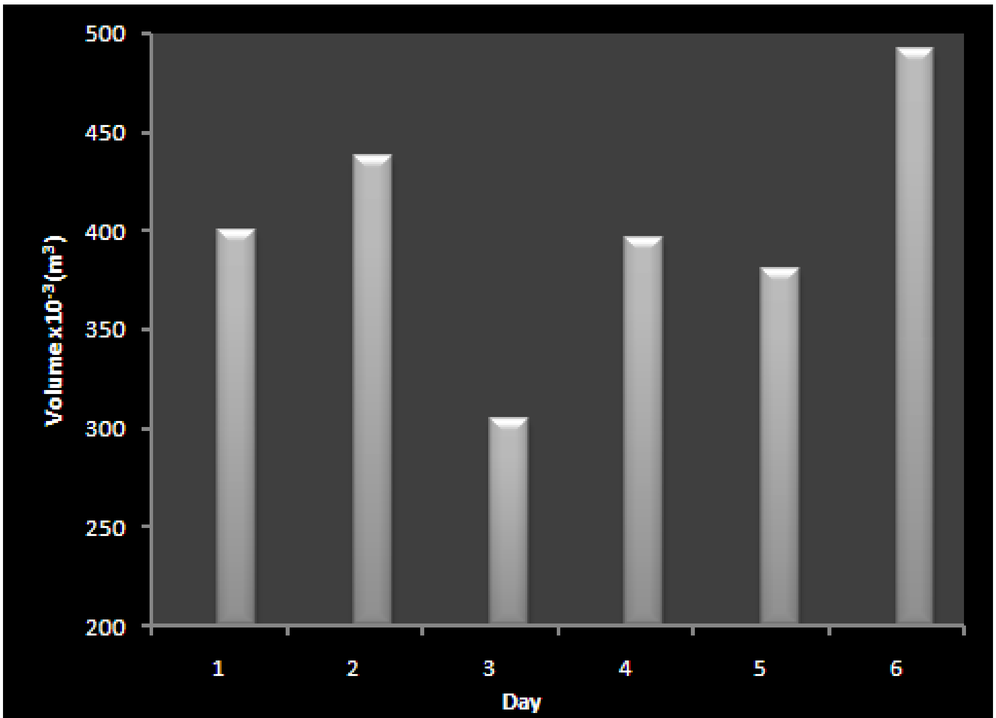

Figure 3. Volume of water that flowed per day within six days

Solar energy warms the absorber surface and some of the water evaporates and condenses on the glass roof. The condensate flows into the condensate channel and is taken out through a hose pipe. The volume of distilled water produced hourly by the RSWD kit was measured for six consecutive days. The water sample was obtained from Awomamma station of Njaba river. Njaba river is located in the Eastern part of Nigeria. Hourly measurement of volume and temperature was carried out for six days at Urualla, one of the ancient communities in the Eastern part of Nigeria. The hourly external (atmospheric) temperature (T_{ext}) was measured using a copper/constantan thermocouple. The corresponding internal temperature (T_{int}) of the RSWD kit was obtained by inserting the reference point of the thermocouple through inlet 2.

RESULTS AND DISCUSSION

Figure 3 shows the volume of distilled water produced per day within the six days (2nd to 7th January, 2012). The highest volume of distilled water produced per day was $492x10^{-3}m^3$ while the least was $305x10^{-3}m^3$. Total volume of pure water produced within the six days was $2.4m^3$. Hence, the $0.5m^2$ distillation kit was able to produce an average of $0.4m^3$ drinking water per day. It was also observed that a comparable high volume of distilled water usually collects towards evening as atmospheric temperature decreases.

The variation of atmospheric temperature with the internal temperature of the RSWD is shown below (Figure 4 to Figure 9). The values of external and internal temperature are almost the same at dawn and this phenomenon also occurs at dusk. Meanwhile, as incident solar radiation increases, the internal temperature increases correspondingly by an appreciable high margin. The highest value of internal temperature recorded was 52^0C when the external temperature was 36^0C. This occurred on the fifth day by 2pm.

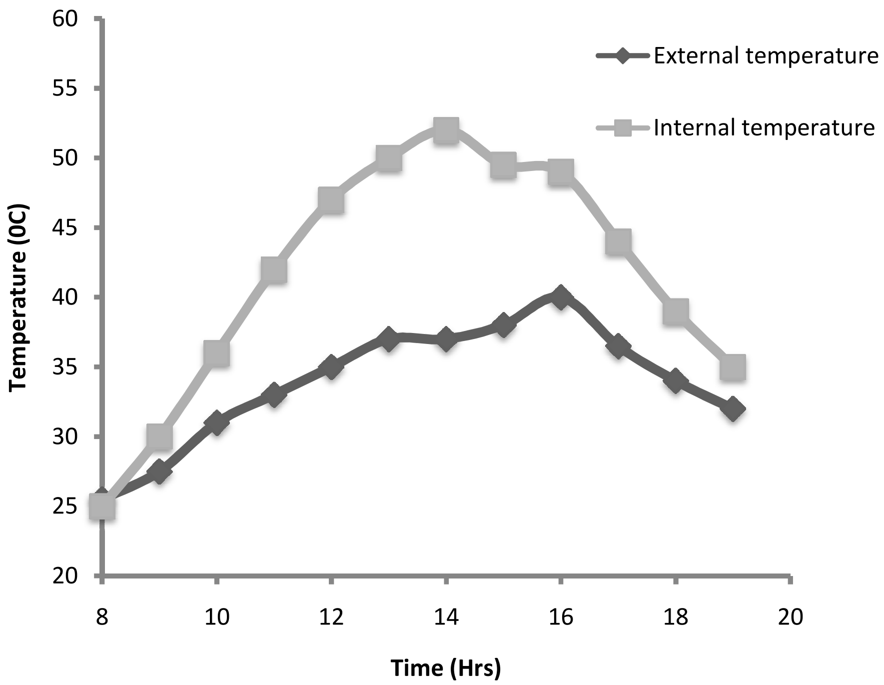

Figure 4. Hourly variation of external and internal temperature (Day 1)

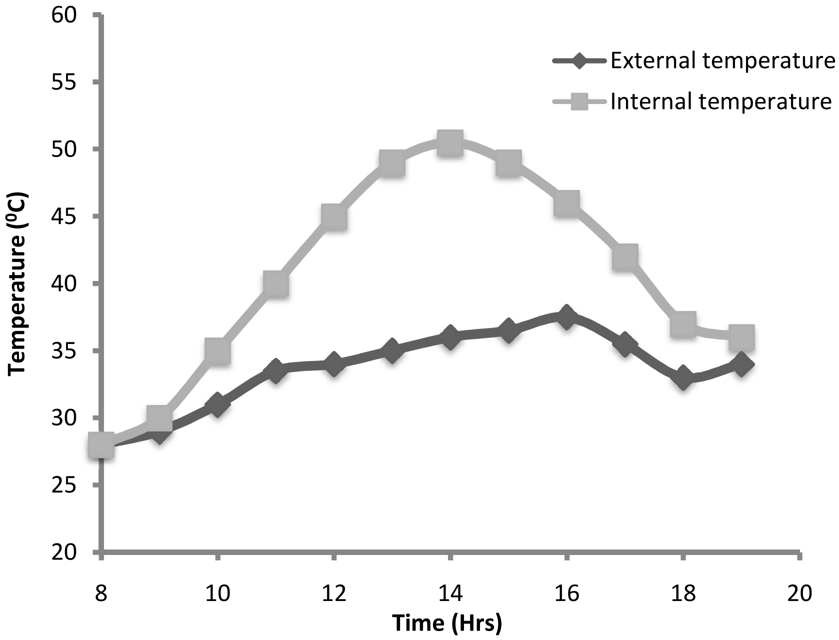

Figure 5. Hourly variation of external and internal temperature (Day 2)

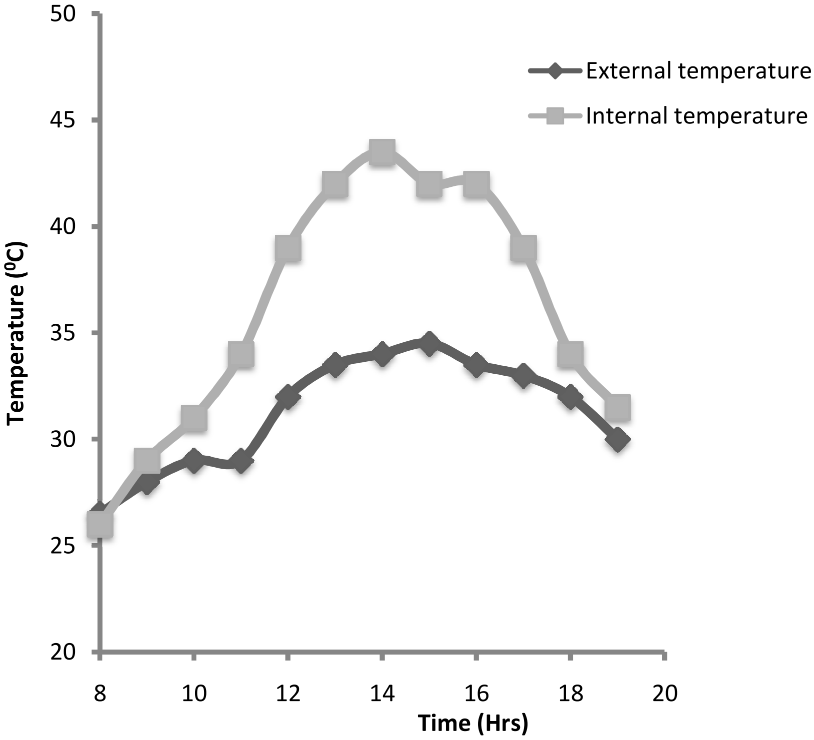

Figure 6. Hourly variation of external and internal temperature (Day 3)

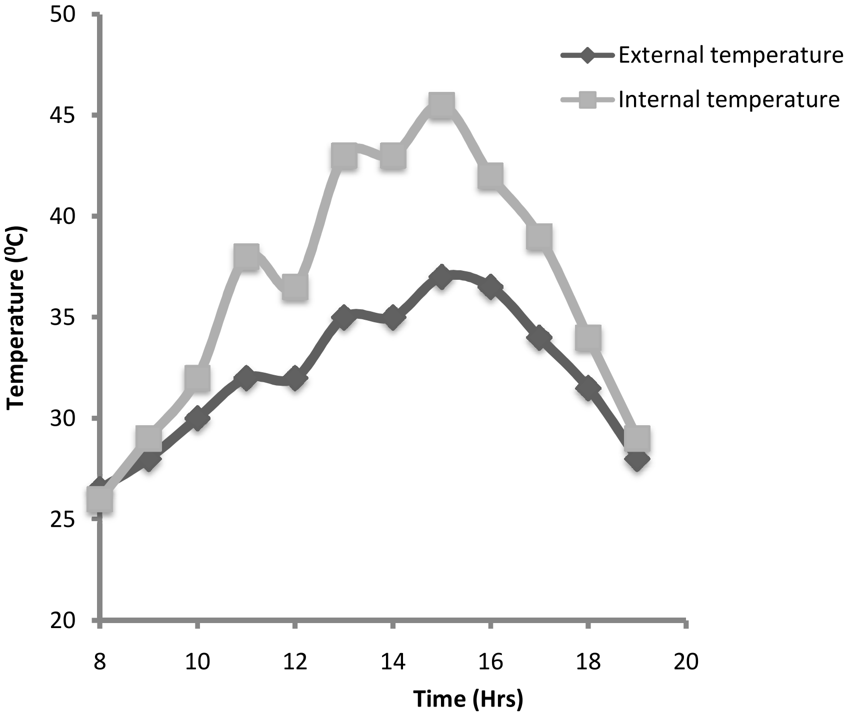

Figure 7. Hourly variation of external and internal temperature (Day 4)

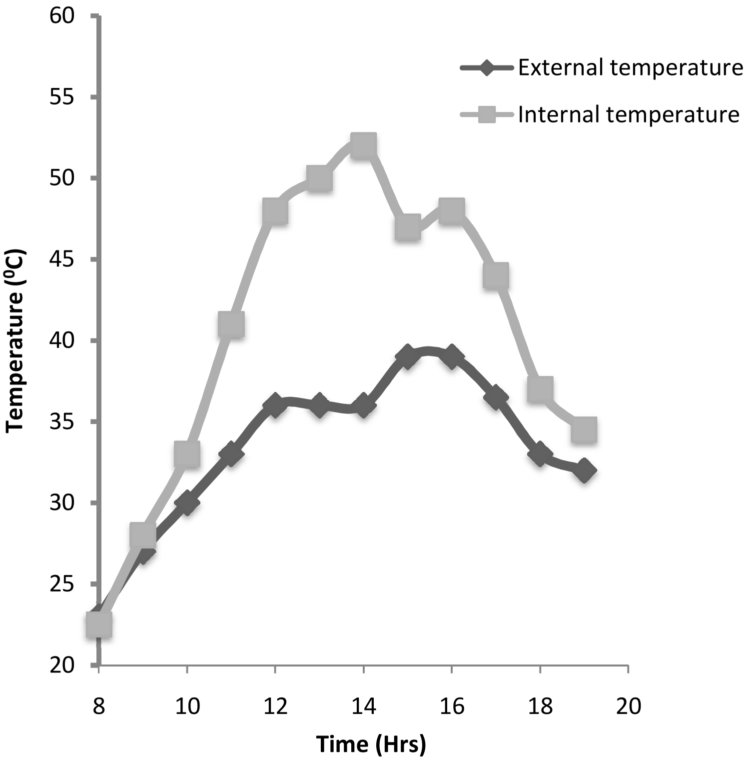

Figure 8. Hourly variation of external and internal temperature (Day 5)

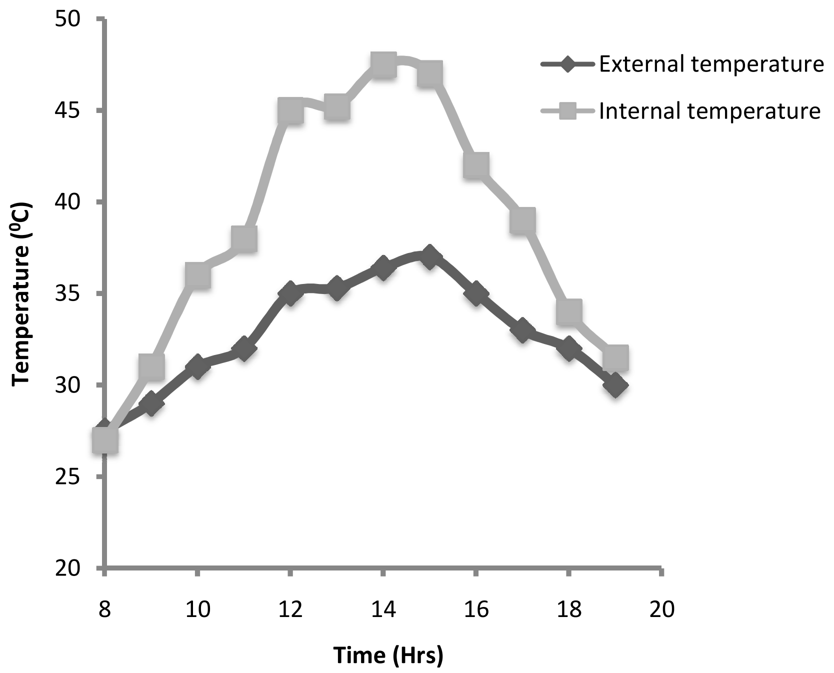

Figure 9. Hourly variation of external and internal temperature (Day 6)

CONCLUSION

A roof-type solar water distillation system was fabricated and tested under actual environmental conditions of Eastern Nigeria. The system includes four major components; a rectangular wooden basin, an absorber surface, a glass roof and a condensate channel. The RSWD of surface area 0.5m^2 was able to produce an average of 0.4m^3 of distilled water per day. Although this quantity is small when compared to daily need of drinking water, the volume of distilled water can be increased by fabricating RSWDs of larger surface area. Also, since the RSWD can be fabricated with cheap and readily available materials, one can fabricate a good number of it to meet daily demand of potable water. It was also observed that the RSWD maintained a comparatively high internal temperature. This is a necessary phenomenon that facilitates the water purification process. Like every other solar installation, RSWD system is environment friendly and has low operating and maintenance costs. Hence, the RSWD is a sure way to combat the prevalent intake of poor quality drinking water by Nigerians.

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