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Full Length Research Article

FABRICATION AND CHARACTERIZATION OF A SLANTING-TYPE SOLAR WATER DISTILLATION KIT

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ABSTRACT
Supply of portable water is a major problem in underdeveloped as well as in some developing countries. Distillation is one of many processes that can be used for water purification and solar energy can be a source of energy for solar stills. We fabricated a slanting-type solar water distillation kit which was tested outdoor under the meteorological conditions of Imo State University, Owerri, Nigeria. The system includes four major components; a wooden basin of surface area 0.16 m^2, an absorber surface, a slanting glass roof and a condensate channel. Very cheap locally available materials were used to fabricate the solar still. The solar still produced an average of 0.09 m^3 of distilled water per day, and this study was performed in the month of November, 2015. Though the condensate was small compared to average human need as is peculiar to many solar stills, the output can be increased by fabricating solar still of larger surface area. Also, since the materials are cheap and readily available, one can fabricate as many solar distillation kits as possible to tackle the daily demand of potable water.

Keywords: Imo State, potable water, solar energy, water distillation.

INTRODUCTION
Along with food and air, portable water is a basic necessity for human beings. Most of our earth surface is covered by water; however, less than 1% of total available water is fresh water which is most available in lakes, rivers and underground (Bhattacharyya, 2013). Natural surface water bodies like rivers and streams are subjected to pollution comprising of organic and inorganic constituents (Unnisa & Khalilullah, 2004; Shraddha *et al.*, 2011; Tenthani *et al*., 2012; Ozuomba *et al*., 2012). The problems of ground water quality are much more acute in the areas which are densely populated, thickly industrialized and have shallow groundwater tables (Sehar *et al.*, 2011; Gupta *et al.*, 2013). 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 (Ozuomba *et al.*, 2012). Water is extremely essential for survival of all living organisms. Over one billion people worldwide have no access to safe drinking water (Peter *et al.*, 2006; Sehar *et al.*, 2011). Ideally, drinking water should not contain any micro-organism known to be pathogenic or any bacteria indicative of faecal pollution (Peter *et al.*, 2006). Water free of salinity, organic and inorganic substances, chlorination by products, free of plants, animal wastes and bacteria contamination is known as potable water (Chessbrough, 1994; Haider *et al*., 2002; Medugu & Ndatuwong, 2009).

Distillation is one of many processes that can be used for water purification and solar radiation can be the source of heat energy (Aybar *et al*., 2005; Tripathi & Tiwari, 2005; Chen & Ho, 2010). Conventional distillation processes such as multi-effect fresh evaporation, thin film distillation, reverse osmosis and electrodialysis are energy intensive techniques and are not feasible for large fresh water demands (Medugu & Ndatuwong, 2009). Therefore, solar distillation seems to be a promising method and an alternative method for providing safe drinking water. Solar distillation is a highly promising and environment friendly technology (Bhattacharyya, 2013; Gupta, 2013). A solar still operates on the same principle as that of rain formation: water from the ocean evaporates, then cools, condenses, and returns to earth as rainwater (Tenthani *et al*., 2012). When water evaporates, only pure water vapour is formed while contaminants are left behind in the still basin and the distillate flows to the collection gutter by gravity. 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 (Chafik, 2002; Rodriguez *et al*., 2002; Reali, 2006; Xuyun *et al*., 2009; Mehta *et al*., 2011). Generally, solar still systems have the advantage of low operating and maintenance costs and the shortcoming of low thermal efficiencies (Xuyun *et al*., 2009; Gupta *et al*., 2013; Mehta *et al*., 2011).
The research work was undertaken to investigate the performance of a slanting-type solar water distillation (SSWD) kit. The SSWD system, which replicates the natural process of evaporation and condensation was fabricated from cheap and local materials. A wooden box covered with black polyethylene absorber surface formed the water tank. The water basin has a slanting top onto which a glass sheet was gently placed to form the glass roof. 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 Awomamma Station of Njaba River, located at Oru East Local Government Area, Imo State, Nigeria. The estimate of daily production of potable water by the distillation kit was achieved and the variation of incident solar radiation was studied. The characterization of our distillation kit was carried out in the month of November, 2015 under the actual environmental conditions of Imo State University, Owerri, Nigeria.

MATERIALS AND METHODS
A schematic diagram of an SSWD system whose interior has been covered with black polyethylene is shown in Figure 1.The water basin which also functions as the heating chamber has a

surface area of 0.16 m^2. A glass sheet of length 0.760 m and width 0.382 m was gently placed on the slanting surface of the water tank to obtain the glass roof. The water tap can be used to discharge untreated water sample.

Figure 2 shows the inlet for impure water, the outlet for distilled water and the SSWD stand of height 0.695 m. The condensate channel was made of aluminium sheets, while the wooden frame that formed the water basin also served as thermal insulator. A piece of black leather was used to cover the edges of the glass roof to avoid contaminants like rain water which may drip into the condensation channel. The Top Bond adhesive was used to glue the leather onto the glass and wood surfaces. The parameters of the solar still are given in Table I.

Fig. 1. Front view of the slanting-type solar water distillation (SSWD) kit

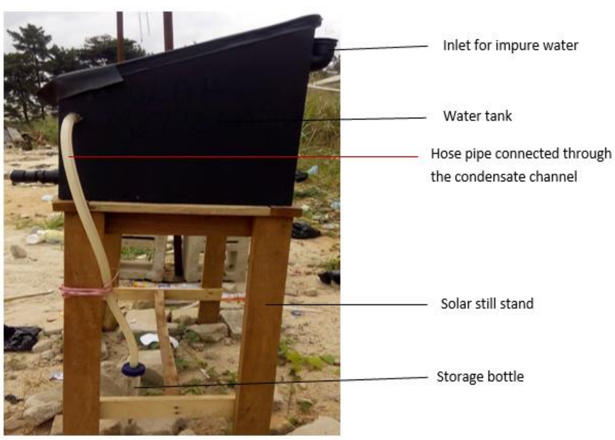

Fig. 2. Side view of the slanting-type solar water distillation (SSWD) kit

Table I. Design parameters of the SSWD kit

Parameter	**Value**
Area of collecting surface	0.i60 m^2
Area of basin	0.160 m^2
Tilt angle of glass roof	23^0
Thickness of glass cover	0.003 m
Height of backs wall of basin	0.398 m
Height of front wall of basin	0.245 m
Width of basin	0.360 m
Height of tank stand	0.695 m

Incident solar radiation passes through the glass cover and is mostly absorbed by the blackened liner of the basin. The untreated water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The heated water evaporates from the basin and condenses on the inside of the glass cover. Condensed water trickles down the inclined glass cover to the interior collection trough and out through a hose pipe to a storage bottle.

The volume of distilled water produced hourly by the SSWD kit was measured for seven consecutive days. Hourly measurement of volume and temperature was carried out for seven days at Imo State University, Owerri, Nigeria. The hourly ambient temperature (T_{ext}) was measured using a copper/constantan thermocouple. The corresponding internal temperature (T_{int}) of the SSWD kit was also obtained.

RESULTS AND DISCUSSION

Table II shows the dependence of output on the temperature. The total volume of water collected per day is represented by V_{pd}, while the average ambient and internal temperatures of the still are represented by T_{ExAv} and T_{InAv}, respectively. Generally, the quantity of distilled water produced depends on temperature. The maximum daily production of 0.115 m^3 was recorded on Day 3 and the average ambient temperature recorded on that day was 30.86 ^{0}C. Total volume of pure water produced within the seven days was 0.63m^3. Hence our 0.16 m^2 distillation kit was able to produce an average of 0.09 m^3 of drinking water per day. It was also observed that a comparable high volume of distilled water usually collects towards evening as atmospheric temperature decreases.

Table II. Relationship between volume of distillate and temperature

Day	T_{ExAv} (^{0}C)	T_{InAv} (^{0}C)	V_{pd} x 10^{-3} (m^3)
1	31.27	45.45	110.00
2	27.32	34.41	65.00
3	30.86	43.41	115.00
4	31.82	46.68	87.00
5	27.09	34.50	67.00
6	31.91	46.77	77.00
7	33.36	47.82	107.00

The variation of the atmospheric temperature with the internal temperature of the SSWD is shown below (Figure 3 to Figure 9). The values of the internal temperature of the still are always higher than the ambient temperature, with high temperature differences recorded between 11am and 3pm. This is an evidence of the effect of the heating chamber (water tank) and the absorber surface (black liner). The highest value of internal temperature recorded was 58 ^{0}C when the external temperature was 36 ^{0}C. This occurred on the fourth day by 2 pm.

The values of external and internal temperatures were almost the same at dawn and this phenomenon also occurred at dusk. Meanwhile, as incident solar radiation increases, the internal temperature increases correspondingly by an appreciable high margin.

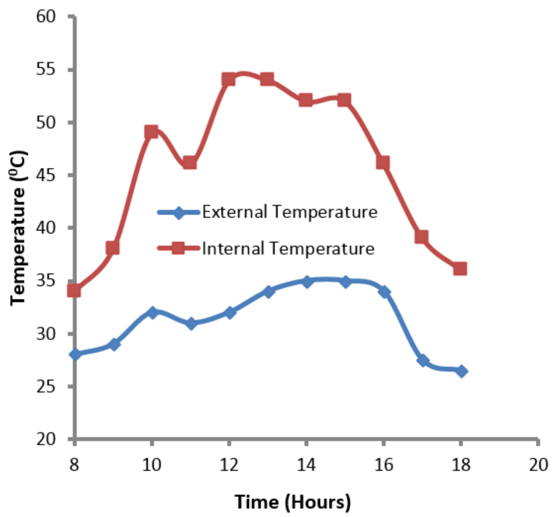

Fig. 3: Hourly variation of external and internal temperatures (Day 1)

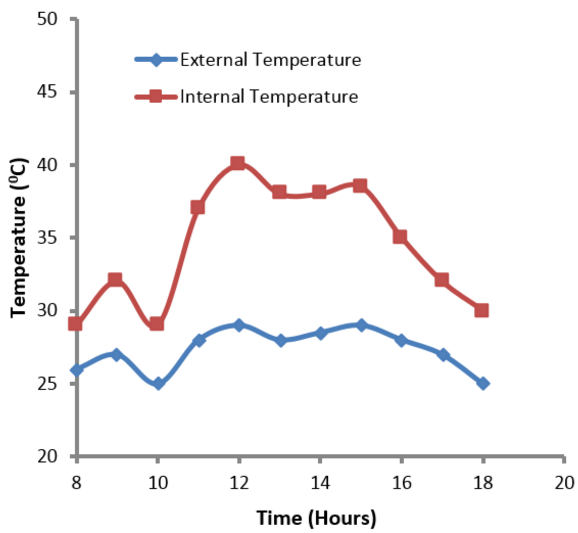

Fig. 4. Hourly variation of external and internal temperatures (Day 2)

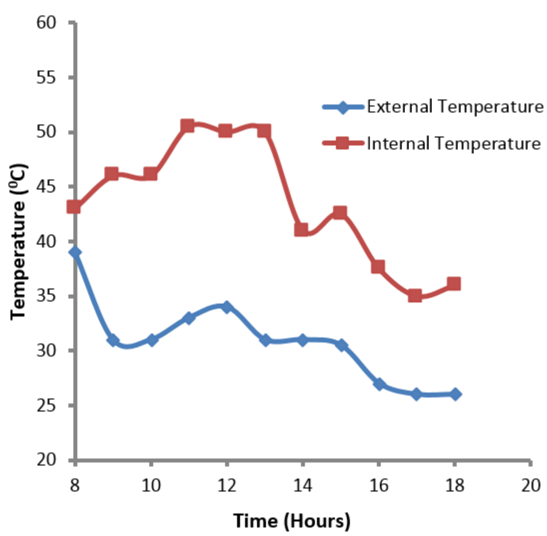

Fig. 5. Hourly variation of external and internal temperatures (Day 3)

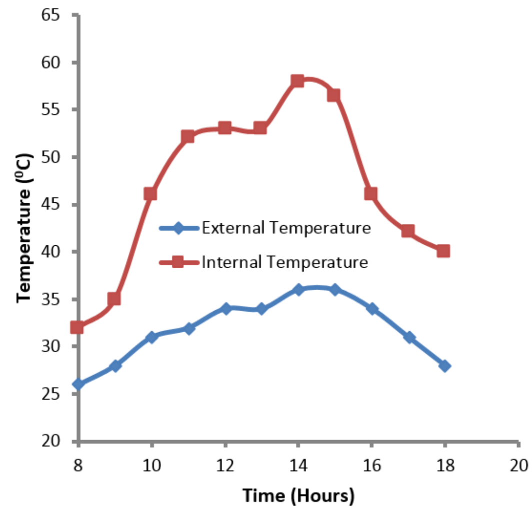

Fig. 6: Hourly variation of external and internal temperatures (Day 4)

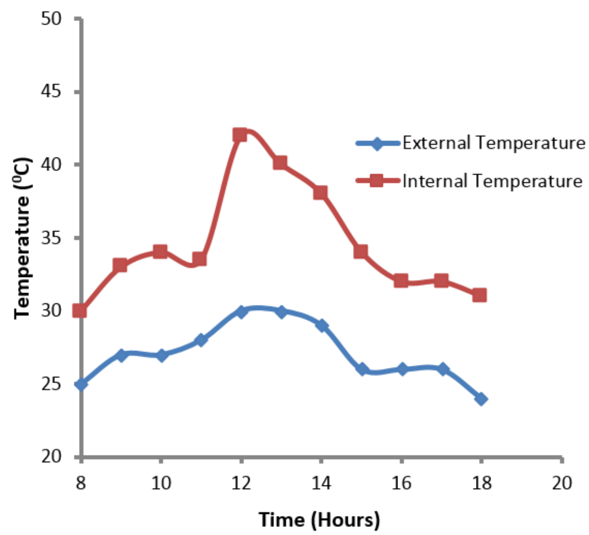

Fig. 7. Hourly variation of external and internal temperatures (Day 5)

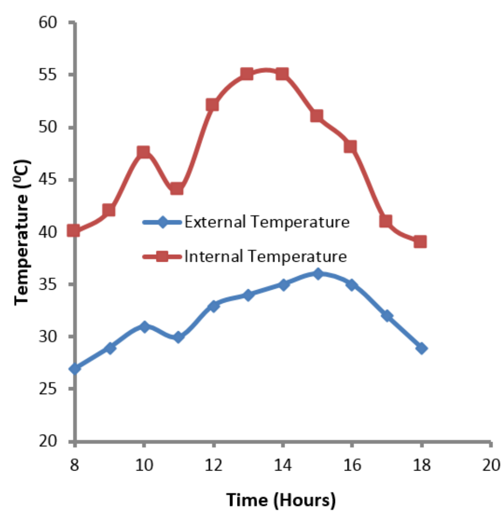

Fig. 8. Hourly variation of external and internal temperatures (Day 6)

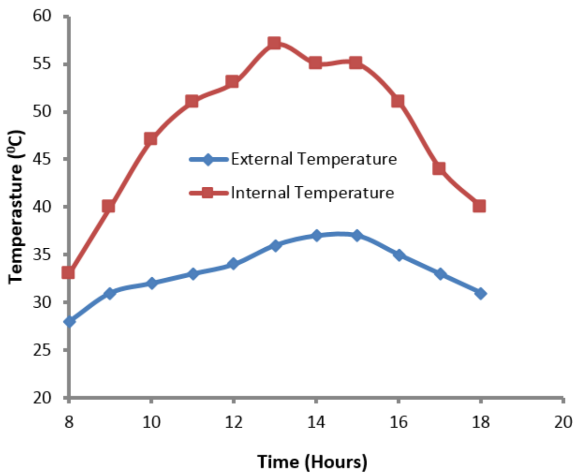

Fig. 9. Hourly variation of external and internal temperatures (Day 7)

Conclusion

We successfully fabricated a slanting-type solar water distillation (SSWD) system which was tested under the actual environmental conditions of Imo State University, Owerri, Nigeria. The system includes four major components; a wooden basin (heating chamber), an absorber surface (black liner), a slanting glass roof, and a condensate channel. The SSWD kit of surface area 0.16 m^2 was able to produce an average of 0.09 m^3 of potable water per day. Actually, this quantity is small when compared to daily need of drinking water, but the volume of distilled water can be increased by fabricating a SSWD of larger surface area. Increase in slanting angle will equally increase the efficiency of the still. Also, since the SSWD can be fabricated with cheap and readily available materials, one can fabricate a good number of the system to meet daily demand of potable water. The comparatively high level of internal temperatures is as well necessary for the purification process. Like every other solar installation, SSWD system is safe to the environment and has low operating and maintenance costs.

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