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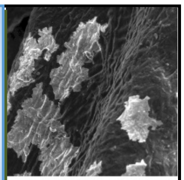

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Households Water Purification Using Solar Water Disinfection (SODIS) in Gombe Metropolis, Gombe State, Nigeria

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ABSTRACT

Assessment of water quality has been an important issue nowadays as the available water supply is severely polluted and can be the cause of waterborne diseases like cholera, diarrhea and dysentery. Solar disinfection (SODIS) is an efficient, low technology and cost-effective method for inactivation of pathogenic microorganisms in low-income communities where clean drinking water is limited or absent. The study was designed to assess the information about sanitation behavior at the household level using a structured questionnaire and to provide cost-effective method for its treatment. The result of the bacteriological analysis shows that all the water samples were found to harbour coliforms organisms in numbers greater than the required WHO/FAO/NSDWQ standards. The isolated organisms were identified to be *Enterobacter aerogenes,* species. SODIS was proven to be a more environmentally friendly and low-cost method to disinfect water against the conventional methods of water treatment that require high technology and it is time-consuming. In addition, the chemical used in the treatment process might be toxic. Providing the community with simple water treatment techniques using the SODIS method, and intensive health education and sanitation practices for the community are highly recommended.

INTRODUCTION

Solar water disinfection (SODIS) is a treatment process in which water is exposed to sunlight over time. Solar water disinfection is another way by which drinking water can be disinfected [1]. It's a point of water treatment method [2,3]. Solar water disinfection is a low cost method for disinfecting water for drinking, relatively easy to understand and to implement, and it is environmentally friendly [4,1,5]. It is a low cost method for killing pathogens present in drinking water using sunlight only [6,7].

The SODIS process is generally performed in transparent plastic bottles [8,9]. Plastic bags and glass bottles can also be used for this process. Glass bottles of some types of glass may function, but window glass and some other glasses screen out most UV radiation, which is essential for SODIS under most conditions [8]. In addition, plastic bags and glass are less durable than plastic bottles, and plastic bottles are easily available in developing countries [10].

Recycled polyethylene terephthalate (PET) bottles are mostly used for solar water disinfection [11]. Another reason why PET bottles are highly suitable for solar water disinfection is the nearly perfect depth of the bottles. There is a 50% decrease in UV radiations at depth of 10 cm [12,13], yet as much depth of water as possible that allows for UV transmittance is desirable. PET bottles are considered better than PVC (polyvinyl chloride) as they contain less additive (UV stabilizers), which reduces the chances of migration of any additives into the water [14].

Public water supplies in developing countries often fail to produce and distribute safe water for consumption. Even if safe water is provided at the source, transport, storage and handling of water often lead to secondary contamination before consumption. Point of- use water treatment methods are therefore gaining increased significance with regard to reducing the global diarrhoea burden [16,18]. Studies have shown that PET bottles are safe for SODIS water treatment under the normal SODIS process [19,20]. It is also recommended that the bottles be replaced after every 6 months to minimize the effects of bottle ageing [21].

In Nigeria, less than one-third of urban and rural dwellers have access to piped water supply connections in their yards for drinking, and those with piped water may still experience unreliable, poor quality service [22]. Most households rely on public standpipes and non-piped water supplies, such as hand dug wells, boreholes, springs and water vendors [23].

The sources of water abound ranging from rainwater, stream or river water to ground water. Some of these water harbour both feacal and non-feacal coliforms which are indicators of pathogenic contamination. Therefore, the treatment and purification of water is paramount and serves as link in controlling disease transmission in water. Some bacterial and protozoans' pathogens can survive in water and infect humans e.g. *Vibrio vulnificus, V. parahaemolyticus* etc.

Most water requires some treatment before use; even water from deep wells or springs. The extent of treatment depends on the source of the water. Appropriate technology options in water treatment include both community-scale and household-scale point-of-use (POU) designs Millennium Development Goal (MDG), 2016). Only a few large urban areas such as Christchurch, New Zealand have access to sufficiently pure water of sufficient volume that no treatment of the raw water is required [5].

Solar disinfection (SODIS) is an efficient, low technology and cost-effective method for inactivation of pathogenic microorganisms in low-income communities where clean drinking water providing is limited or absent [24]. The use of sunlight for supplying healthy water is not a new phenomenon. It has been demonstrated that solar disinfection inactivates microorganism by direct exposure is volume independent economic process and avoids production of hazardous by-products of chemically driven technologies [25].

Since strong synergy between optical and thermal inactivation has been observed at temperatures >45ºC [26], a number of enhancement methods have been attempted by accelerating the rate of thermal inactivation of organisms through the use of absorptive materials and painting PET bottles black [13], in order to aid in the absorption of solar radiation. In most cases the water temperatures necessary to reach a synergistic effect between sunlight and temperature are not reached during exposure in bottles in practice.

Induced water temperatures remain for long periods of time within the "preferred" growth temperatures for enteric bacteria (25–40°C). Thermal enhancement has been achieved by: (i) painting sections of the bottles with black paint [27]; (ii) circulating water over a black surface in an enclosed casing which was transparent to UV-A light [28]; (iii) using a solar collector attached to a double glass envelope container [29]. Solar reflectors can also increase the temperature of water but not to the same extent as the use of absorptive materials or blackening of bottles [30,31,32]. All of these studies have achieved different degrees of success with respect to enhancing the heat transfer to the contaminated water. Solar disinfection is very well suited for rural communities of low income in developing countries, which do not have access to standard water purification systems, do not boil or chlorinate the water, and are only interested in treating the water required for their daily consumption [33,34].

Given the fact that borehole water is the commonest source of water to the poor urban communities. It was recorded for the past seven (7) years from 2012 to 2019, diarrhea cases among children less than five (5) years of age in Gombe and recently, there was cholera outbreak within Gombe metropolis, Gombe State and other states across the country [35], due to the inadequacy for water treatment at the household level. This study will provide a best method with a great potential to improve water sanitation among users.

MATERIALS AND METHODS

SODIS treatment involves modifying 2-liter polyethylene terephthalate (PET) bottle which is inexpensive materials that are cost effective, easily available and low maintenance, and they require very little technical knowledge to actually use. The water samples were filled into transparent PET bottles of up to 2 L volume was exposed to full sunlight for 6h at >45 ºC, while two days of consecutive exposure needed under more than 50% cloudy skies. The PET bottles were wrapped with black plastic sheets [8].

Presumptive Test

Total Coliform loads were enumerated by Most Probable Number method as described by [14]. Coliform count was obtained using two tube assay. Presumptive test was carried out using MacConkey broth. The 1st and 2nd sets of one and five tubes had sterile 1x50 mL and 5x10 mL double strength broth respectively. All tubes contain inverted Durham tubes before sterilization. The two set of tubes received 50 mL and 10 mL of water samples respectively using sterile pipette.

The tubes were incubated at 37 ºC for 24 h for estimate of the Coliforms and examined for acid and gas production. Acid production was determined by change in colour of the MacConkey broth from pale yellow to creamy and gas production was checked for by entrapment of gas in the Durham tubes [14].

Complete Test

The positive MacConkey broth test tube was inoculated onto the prepared Eosin Methylene Blue agar plates via pour plate technique, in a Petri dish using a sterile wire loop for picking and streaking on the media in the Petri dish. The inoculated plates were incubated for 24 h at 37 ºC for growth. Some typical colonies with metallic green sheen were observed indicating the presence of *Enterobacter aerogenes* on the Petri dish [14].

RESULTS

Water samples taken directly from borehole taps, reservoir tanks and Jerry cans in this study yielded coliforms in the presumptive test. Presumptive test (total coliform count) of water samples revealed the positive result in all set of tubes which indicates the presence of feacal coliforms. Complete test using EMB agar revealed Coliforms produce colonies with a greenish metallic sheen which indicate the presence of *Enterobacter aerogenes* in the water samples (**Fig. 1**). **Table 1** indicated the most probable number (MPN) before the application of SODIS which indicated high population of bacteria in the water samples. There was a drastic decrease in the population of bacteria in the water samples after the application of SODIS method (**Table 2**).

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Fig. 1. Colonies formation after presumptive test.

Table 1. Most probable number (MPN) of water sample before application of SODIS (treatment).

Samples	1 x 50 mL	5x 10 mL	MPN
A	–	+	16
B	+	+	>18
C	+	+	>18
D	+	+	>18
E	+	+	>18

Note: A = Pantami, B = Bolari, C = Herwagana, D = Hammadu kafi, E = Checheniya
+ = positive, – = negative

Fig. 2 shows the field application of SODIS in treating the water samples with sunlight as an eco-friendly, harmless to users, and the most cost-effective technology at temperature 51ºC revealed that the water is safe to drink as all the samples were found negative, there was no any coliforms formed in the presumptive test (**Table 2**). This shows the effectiveness of SODIS method for household water treatment for inactivation of microorganism. This result revealed that the water can be consumed directly from the bottle to avoid recontamination.

Table 2. Microbial Analysis, Most probable number (MPN) of the water sample after application of SODIS (treatment).

Samples	1 x 50 mL	5x 10 mL	MPN
A	–	–	<1
B	–	–	<1
C	–	–	<1
D	–	–	<1
E	–	–	<1

Note: A = Pantami, B = Bolari, C = Herwagana, D = Hammadu kafi, E = Checheniya
+ = positive, – = negative

(a) (b)

Fig. 2. Application of SODIS in household water purification. (a) Unwrapped and (b) wrapped with black plastic sheet.

DISCUSSION

SODIS method for household water treatment is effective as this study that uses 2 L capacity transparent PET bottles for the treatment of the water samples which was expose to direct sunlight for 6 hours, 2 consecutive days for cloudy condition. Since strong synergy between optical and thermal inactivation has been observed at temperatures >45 ºC [26], a number of enhancement methods have been attempted by accelerating the rate of thermal inactivation of organisms through the use of absorptive materials and painting PET bottles black [13,27], in order to aid in the absorption of solar radiation. In most cases the water temperatures necessary to reach a synergistic effect between sunlight and temperature are not reached during exposure in bottles in practice.

Polythene bag was used to enhance and optimize the treatment processes which result the increase in temperature to 51ºC, and lead to prevent solar radiation which aid in the synthesis of photosynthetic activities of algae and to prevent the ageing of the PET bottles, reduce health risks associated with plasticisers and other carcinogenic compounds which may leach from the bottles into the water and serve as the cost-effective absorptive material [36]. The result of this study revealed that all the samples were found negative, there was not any coliforms formed in the presumptive test, which signifies water is safe to drink. This shows the effectiveness of SODIS method for household water treatment for inactivation of microorganism.

The effectiveness of SODIS against microbiological contamination of water was reported as very effective (>99%) on bacteria, somewhat effective (>80%) on viruses, somewhat effective (>80%) on Cryptosporidium (Protozoa), very effective (>99%) on Giardia (Protozoa) and Effective (>90%) on Helminths [5]. The study arrived at the conclusion that SODIS as a method of HWT has a potential role as a diarrheal disease prevention strategy.

This finding is consistent with similar studies conducted in Kenya (44%) [37], Cambodia (50%) [38], and Cameroon (42.5%) [39]. Most of the previous studies, [40-43], positively suggested that SODIS water treatment with natural sunlight is simple to use, eco-friendly, harmless to users, and the most cost-effective technology for developing countries. SODIS is cost-effective for Gombe State and Nigerian poor urban and rural communities as well. For instance, in the study area, a 2-L capacity transparent PET bottle can be bought at a price of ₦10 which is less than (USD 0.10) from the local provision retail shops and can serve an average family for at least 6 months. Many of the households can afford ₦10 which is less than (USD 0.10) to buy 10 such bottles for SODIS treatment of 20 L of drinking-water daily for 6 months.

CONCLUSION

The traditional method used for water treatment require a high cost and time consuming. In addition, the chemical used in the treatment process are toxic and of high cost.
SODIS is an effective method for treating water where fuel or cookers are unavailable or prohibitively expensive. Even where fuel is available, SODIS is a more economical and environmentally friendly option. SODIS water treatment with natural sunlight is simple to use, eco-friendly, harmless to users, and the most cost-effective technology for developing countries, as most of the households can afford ₦10 which is less than (USD 0.10) to buy 10 of such bottles for SODIS treatment of 20 L of drinking-water daily for 6 months. The running costs for SODIS application are greatly outweighed by the economic benefits drawn from improved health as a result of reduced diarrhea incidence, i.e. expenditure for medical care decreases, the economic productivity of adults' increases.

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