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Full Length Research Paper

Efficacy of solar water disinfection for well waters: Case study of Ibadan slums, Nigeria

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The study was carried out to assess the efficacy of solar radiation as a disinfection method for well waters in some communities in the south east local government area of Ibadan metropolis, Nigeria. Well water sampling and quality tests were done during the dry season and parameters such as total solids, suspended solids, total hardness and coli form count were determined using various laboratory methods. Solar disinfection techniques were used and parameters such as volume of water, hours of exposure, colour of container and turbidity were considered. Data collected were analyzed using statistical packages, results are expressed in percentages, frequencies and representation. A 100% coli form count reduction was achieved for 4 and 5 L water samples in 7 L container. 7 h and above of exposure to sunlight were found to be ideal in reducing the coli form count. The degree of disinfection was relatively higher with white (97.9%) and black (98.4%) containers as compared to brown (95%) and blue (82%) containers. With increasing turbidity, solar radiation efficacy decreases. The experiments were found to provide satisfactory and viable performance compared to WHO drinking water standard with MPN count to be 7.2 per 100 ml for 7 h of exposure and 1.4 per 100 ml 8 h of exposure compared to 2478 per 100 ml before the solar disinfection exercise.

Key words: Well waters, solar radiation, disinfection, Ibadan.

INTRODUCTION

The United Nation Development Programme (UNDP) (1990) refers to water as the source of life. Water usage forms the backbone of the world's economy because of its importance in all man's activities apart from his physiological functioning, which was estimated to be 6 L/head/day (Sangodoyin, 1987).

Surface water is generally composed of dissolved solids from ground water overflows, surface run-off, turbidity, organic matter as well as pathogenic organisms because surface water originates partly from either outflows or rainwater run-offs, which would have flowed over the ground.

Groundwater is also a valued fresh water resource and constitutes about two-third of the fresh water reserves of the world (Chilton, 1992).

Quality of drinking water is of highest importance and this depends on source and level of contamination or pollution. About 80% of diseases in the tropics for example, cholera, typhoid, diarrhea and dysentery are as a result of water source contamination. The human population being covered by the water source also influences the level or extent of pollution and contamination. Nigeria's population as at 1992 stood at 90.1 million and expected to be 152.2 millions by the year 2010, with an annual water resource per capital pf 1,000 m^3 and 67% of the population are without safe drinking water (Green, 1992). Ibadan in Nigeria with population of about 966,631 (1991 National Census) has slums, which are highly dense areas such as Odinjo, Agugu, Beere, Oje and Ayeye. Although the entire city of Ibadan lacks a steady supply of potable water, the urban slums people suffer from infections and epidemics.

In the improvement of water quality through low-cost treatment processes for reducing the incidence of water

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borne diseases, the following methods had been experimented.

Container storage

Sangodoyin et al. (1988) observed experimentally that 7 days of storage can kill about 90% of coli form in water which is reasonably clear and on which ultra-violent light is incident deeply. The storage facilities also lead to improvement in turbidity.

Pot chlorination

This refers to the disinfection of well water by placing a vessel containing a mixture of chlorine powder and sand in the well (Hofkesi, 1981). 1.5 kg of chlorine will provide satisfactory disinfection for one week. Others include, boiling which is a safe and effective way of pathogen elimination if carried out properly. The water is boiled for a recommended period of 10 min.

Disinfection

Disinfection is simply the killing of potentially harmful organisms. Its objective is to obtain microbiologically clean water, which contains no pathogenic organisms and is free from biological forms that may be harmful to human health (Kootapep, 1980). Chemical disinfections employ the use of chemical called disinfecting agents, for example chlorine, ozone, potassium permanganate and chlorine dioxide.

Physical disinfection solar disinfection

Solar water disinfection (SODIS) popularized by Prof. Aftim Acra of the American University of Beirut in Lebanon is a technique in which small quantities of drinking water is disinfected by exposure to solar radiation (Acra et al., 1990). The technique makes use of either the batch process in which discrete units of water are exposed in various containers like plastic bowls and bottles or continuous flow systems in which an attempt is made to maintain a uniform flow of water and solar intensity at all points of the system (Acra et al., 1990). It was observed that with a 95 min exposure to sunlight in Beirut, between 0900 and 1400 h, a 99.9% reduction of the faecal coliforms was achieved with 300 min being required for 99.9% inactivation of the total bacteria. The minimum exposure time vary with location for reasons related to solar intensity which in turn varies with latitude of geographical location, season (dry or wet), cloud coverage, atmospheric pollution, solar altitude and elevation above sea level (Acra, 1990). Some other work carried out in developing countries like Bangladesh revealed that solar disinfection might be a cheaper, efficient and appropriate option especially in the tropics (Sommer et al., 1997). Thus, the study is to assess the effectiveness of solar radiation as a method of providing potable water for highly dense areas of Ibadan city.

MATERIALS AND METHOD

Study area

The city of Ibadan under study is located on the longitude 3° 58' E and latitude 7°22' N. The altitude general ranges from 15 to 21 m above mean sea level. The City has two distinct seasons namely: dry season (October to March) and wet season (April to September) (Alawode, 2000). The population in the city with an ever-increasing rate in commercial and industrial activities is also increasing with average water demand. The four Ibadan inland local government areas (LGAs) have a population of about 966,631 and South East LGA of the study location is the third largest with a population of 272,865 (112,144 – male, 115.721 – female). This is about 29% of the total population. Molete, Kudeti, Idi-arere and Oja-oba others like Labo, Kobomoje, Oke-odo and Bode are all located within the study area and having public water wells were surveyed.

Well water sampling

A total of 40 shallow well water samples were collected in the South East Local Government area of Ibadan city. The samples were collected in 1 L plastic bottles in the morning and taken to the laboratory for the physiochemical and bacteriological qualities. Some of these same samples were later used in the field for assessing the efficacy of solar radiation.

Laboratory analysis

The collected samples were taken to the laboratory for analysis with much emphasis on the bacteriological quality and also physiochemical quality analyses.

Solar radiation experiment

In order to confirm whether the MPN reduction is a result of ultraviolet rays from solar radiation or from heat, an experiment was conducted. 5 L samples of well water were taken into sets of plastic bowls, covered with plastic covers and one set was exposed to solar radiation outside and the other set kept inside a closed cupboard. Also, an experiment to find out the effect of high level of particle matter on the efficacy of solar radiation was carried out. Varying amounts of kaolin were added to increase the turbidity of the water samples in the range of 90 to 960 mg/L. The sample bowls were exposed for 8 h and the coli form counts were determined.

Data analysis

Data collected were analysed using T- test statistical technique. Results are expressed in percentages, frequencies and graphical representation.

RESULTS

Regarding the depth of water column in the wells, a

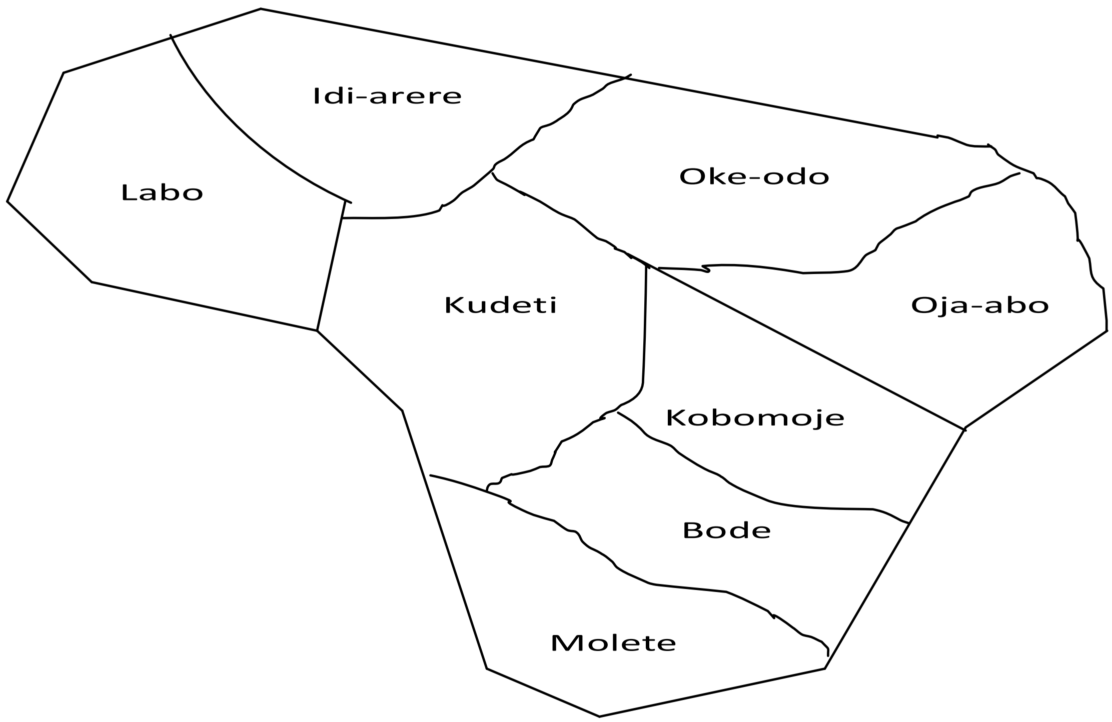

Figure 1. Sketch of the study area (Ibadan South East LGA) showing the zones.

majority of 78 (65%) were below 2 m, 24 (20%) were > 2 m and less than 6 m, 13 (10.8%) were > 6 m and less than 8 m and the remaining (54.2%) were > 8 m (and above).

DISCUSSION

Well water quality in the study area

A total number of 40 wells were sampled in the study area (Figure 1) during the dry season. Physiochemical and bacteriological (coli form count) characteristics were determined. The range of values of the characteristics, their mean and standard deviations are presented in Table 1. The results indicate that the quality of most of the water samples were within WHO standard except for the bacteriological quality as indicated by the coli form number. The coli forms were high in all the examined wells and total solids values above the WHO standard.

Solar radiation experiments

The solar radiation experiments were conducted by taking the well water in containers and various parameters were studied. These include the colour of container and cover, quantity (volume) of water used and time of exposure to solar radiation. The coli form number before and after the exposure was used as an index in evaluating the efficacy of solar radiation. One of the well waters was used as a control for further experiment using solar radiation (Figure 2 to 7).

Effect of quantity (volume) of water

Varying volumes of well water were taken in plastic bowls of 7 L capacity and were exposed to solar radiation on a flat-cemented surface. At the end of 8 h exposure to solar radiation, the samples were taken and the coli form counts were measured. The ambient and water temperatures were recorded at 0.90 h, 13.0 h (1.0 pm) and 17.0 h (5.0pm), that is at interval of 4 h. The result indicated about 98 to 100% reduction in the coli form count, for example with 2 litre volume, 99.6% reduction and with 3 litre, the % reduction dropped to 98.6% (about 1%) but with 4 and 5 litres volume, the % reduction increased to almost 99% optimum. Therefore, for a better and efficient result in solar disinfection, a volume of 4-5 litres is recommended based on the findings (Fig. 6a).

Effect of number of hours of exposure

The samples of water (5 L) taken in 7 L bowls were also exposed to solar radiation. At hourly intervals, 100 ml samples were collected from each of the bowls and examined for coli form count using the MPN count. The results indicated that solar radiation for 7 h and above were found to be ideal in reducing the coli form count,

Table 1. T-test on the effect of heat from solar radiation on the disinfection process.

	Group statistics			
	N	Mean	Std. Deviation	Std. Error mean
MPN count container kept in sunlight	4	329.50	384.63	192.31
container kept in wooden cupboard.		438.50	395.14	197.57

Table 1(b). Independent samples test.

	Levene's test for quality of variance		T-test for equality of means						
								95% confidence interval of the difference	
	F	Sig.	t	df	2 tailed	Mean difference	Std. error difference	Lower	Upper
MPN count equal variance	.002	.965	-.395	6	.706	-109.00	275.65	-783.65	565.65
assumed equal variance			-.395	5.996	.706	-109.00	275.72	-783.77	565.65

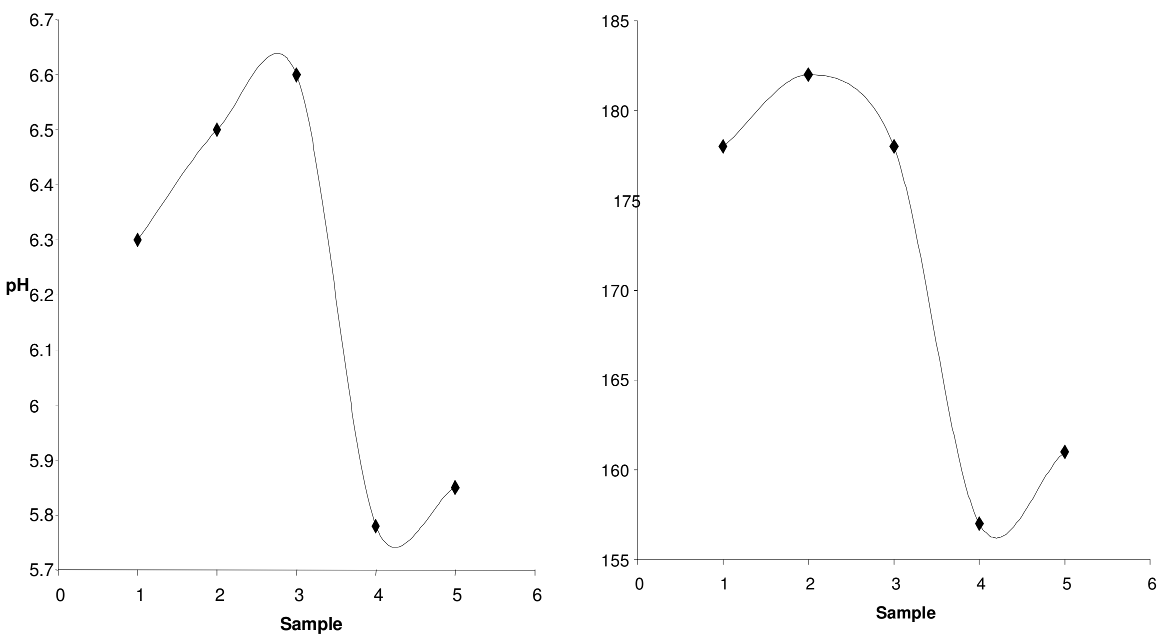

Figure 2. Characteristics of well water used as control for the solar disinfection process.

thus ensuring the desired disinfection (Figure 6b).

Effect of colour of container

Samples of water (5 L) were taken in plastic containers with different colours; White, brown, blue and black (and control which was covered with black plastic material to prevent passage of sunlight). They were exposed to solar radiation for varying hours and the coli form counts were determined. The results (Figure 7) indicate that black and white colours appeared to be relatively efficient in the removal of coli form.

Effect of heat form solar radiation on the disinfection process

After the experiment described, the coli form counts were determined at the end of 24 , 48 and 72 h respectively. The results (Table 2) indicate that there was some coli form reduction though not as high as reached during

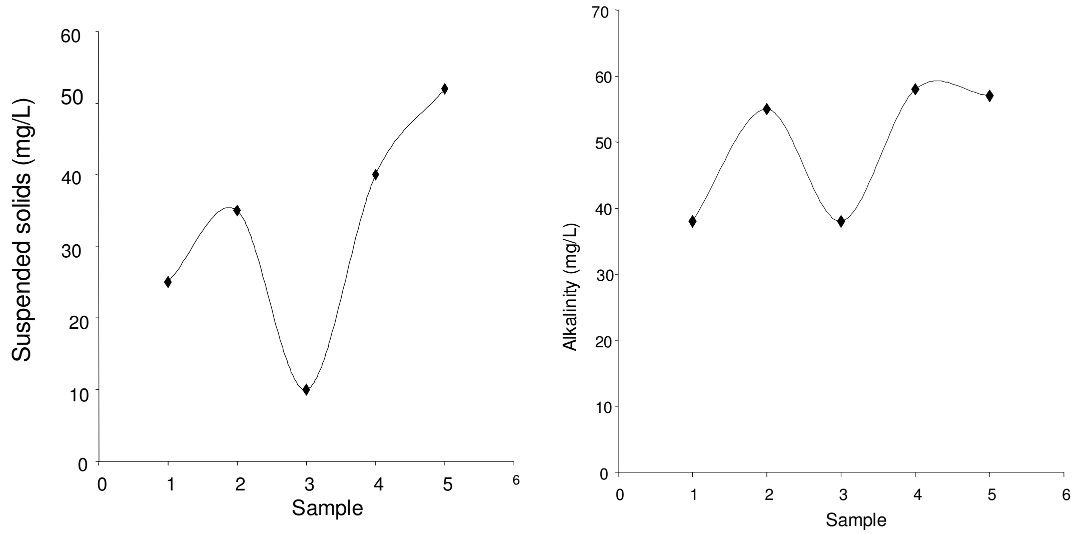

Figure 3. Characteristics of well water used as control for the solar disinfection process.

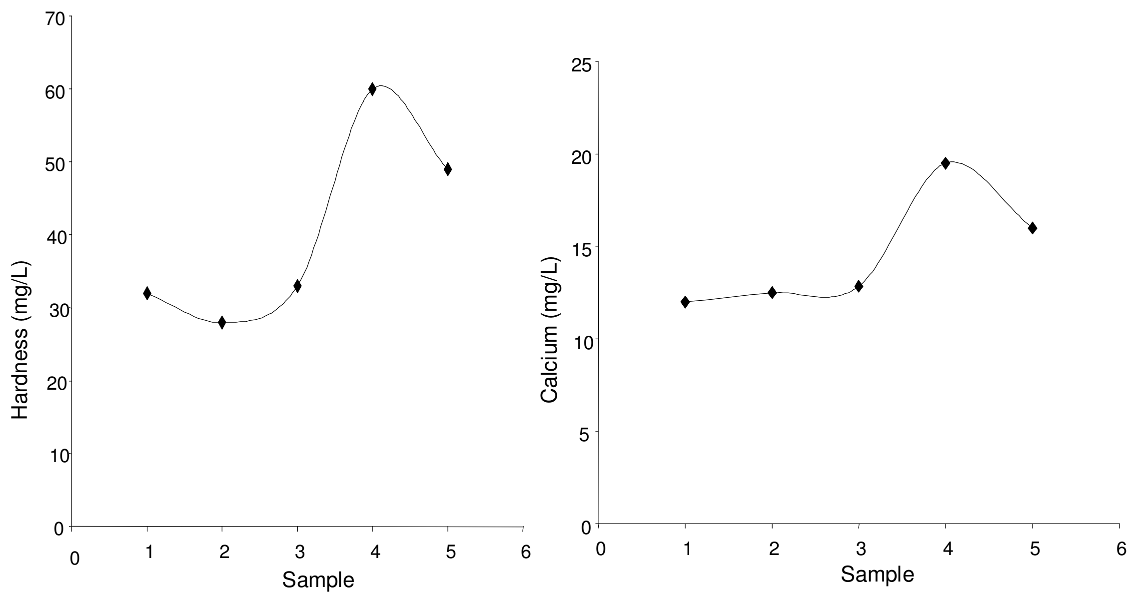

Figure 4. Characteristics of well water used as control for the solar disinfection.

solar radiation experiments earlier described. Some reduction observed may be due to natural death rates of coli form.

Effect of particle matter in water on the solar disinfection process

Though the particle matter or turbidity of most of the well waters in the study area were within the acceptable limits, an experiment conducted to determine the effect of high level of particle matter on the efficacy of solar radiation described previously. Indicate that with increasing turbidity, the efficacy of solar radiation decreased (Table 3 and 4).

Conclusions

The solar radiation water disinfection method used in this study using the coli form count index showed that white and black coloured containers were most efficient than

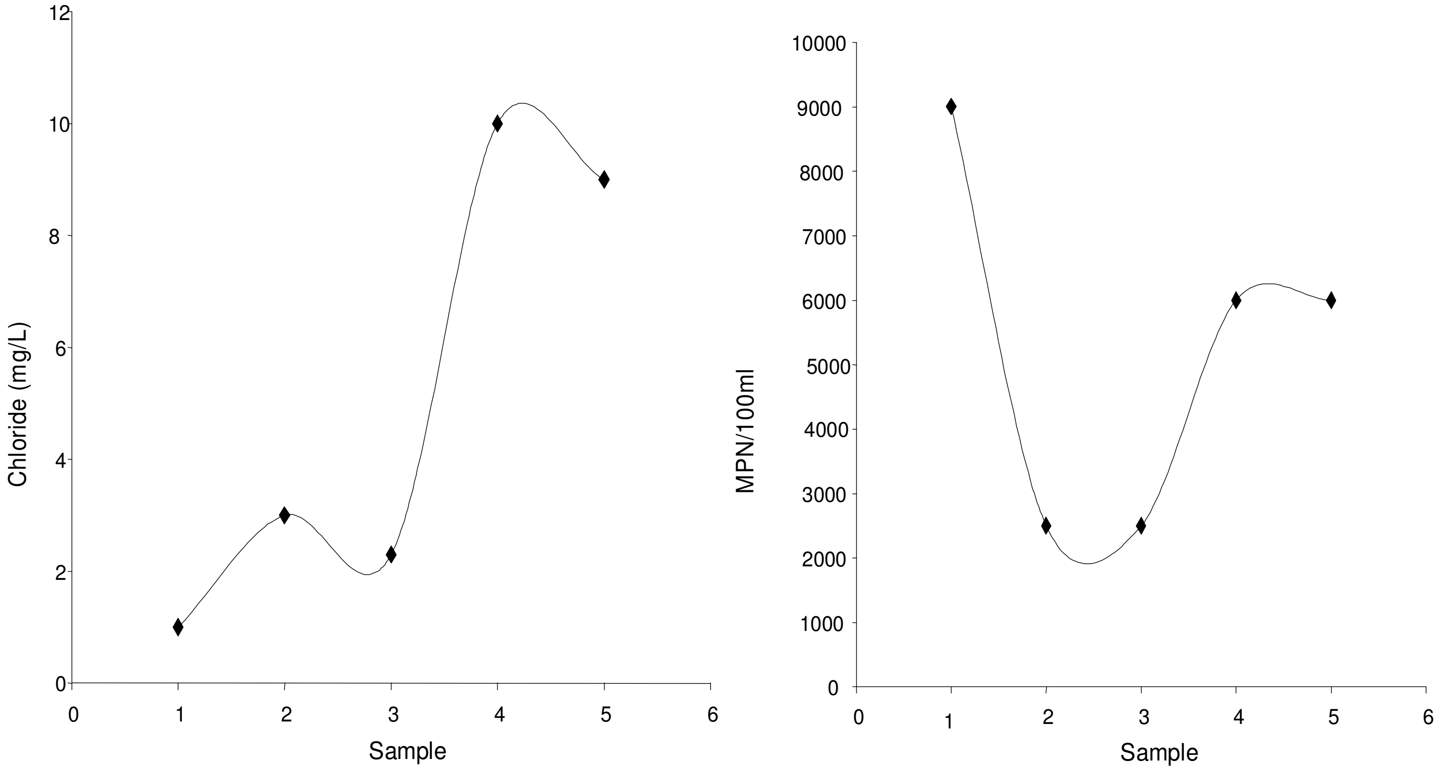

Figure 5. Characteristics of well water used as control for the solar disinfection.

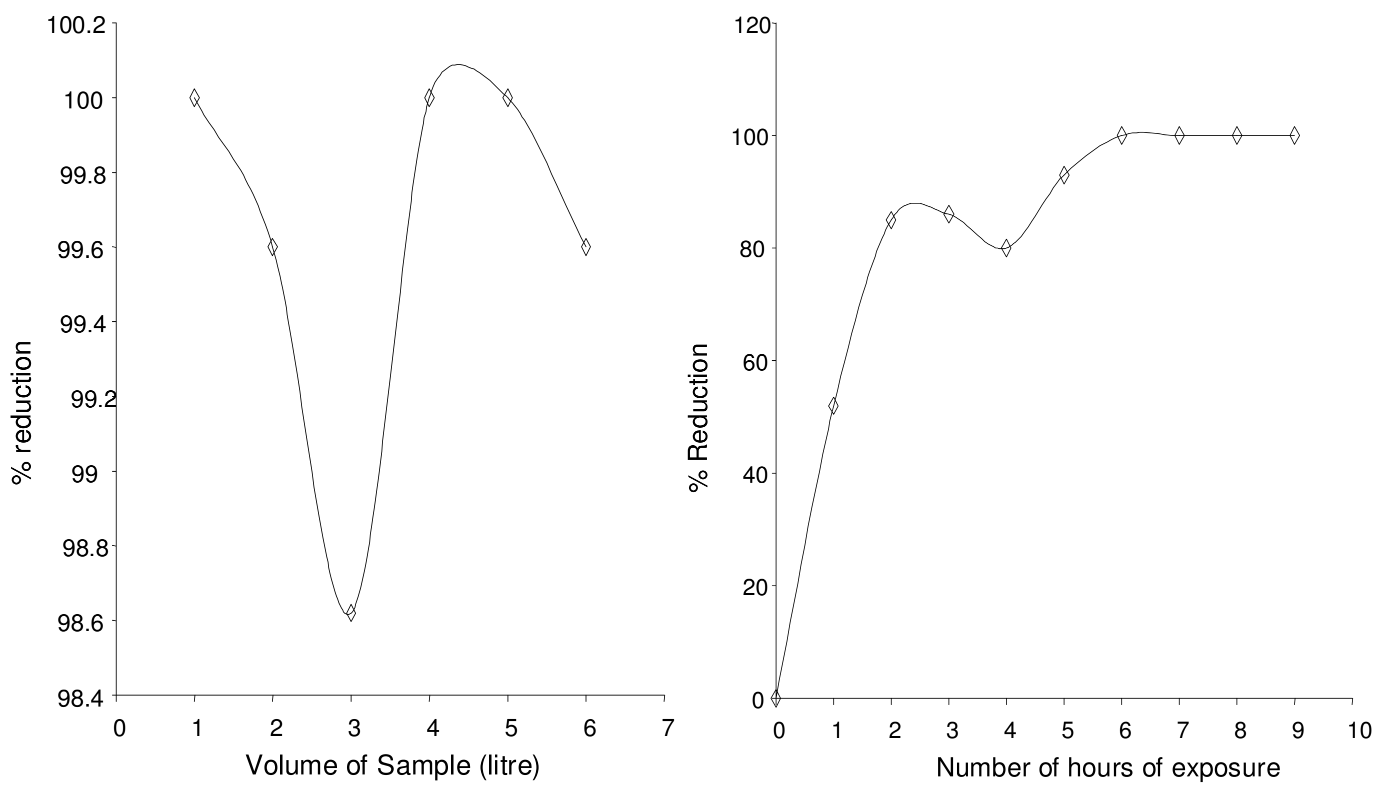

Figure 6 (a). Effect of volume of water on efficacy of solar disinfection. **(b)** Effect of number of hours of exposure to solar radiation.

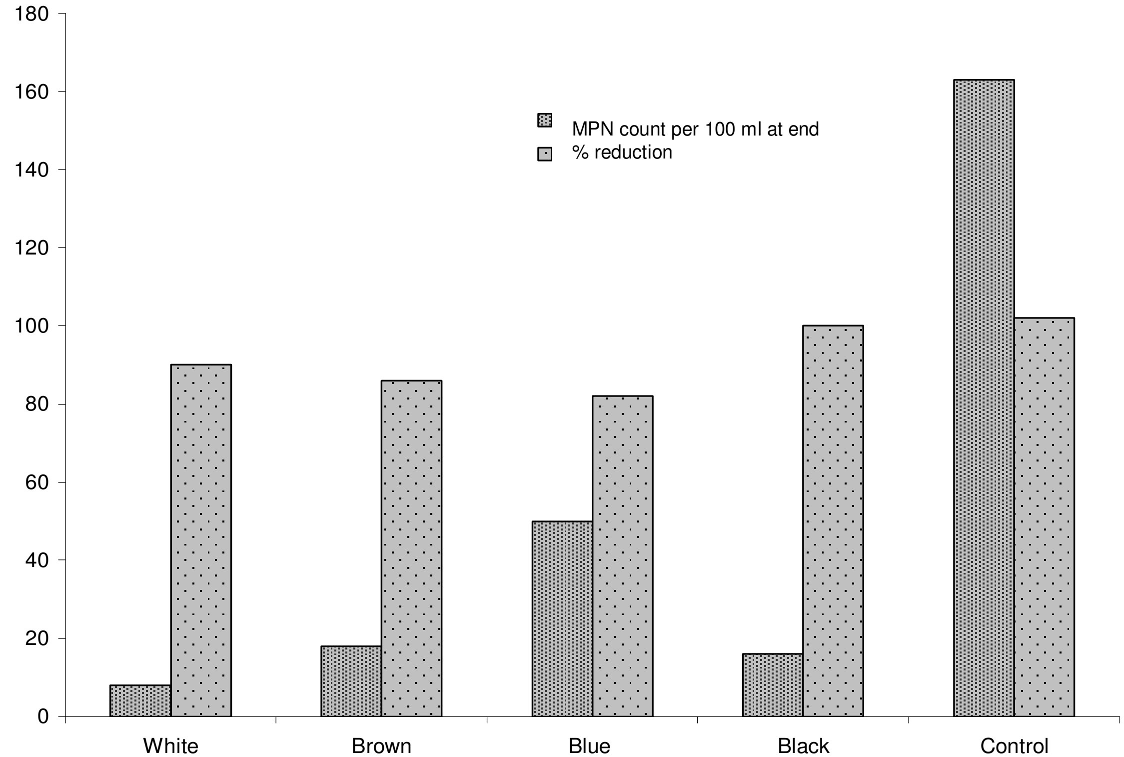

Figure 7. Effect of colour of container on efficacy on solar disinfection.

Table 2. Effect of heat from solar radiation on the disinfection process.

Container covered with black plastic wrapper and kept in sunlight						Container covered with black plastic wrapper and kept in sunlight		
Outside mean temp. (°C)	**Inside mean temp. (°C)**	**Outside water temp. (°C)**	**Inside water temp. (°C)**	**MPN (per 100 ml) count**	**Reduction (%)**	**MPN (per 100 ml) count at start**	**Reduction (%)**	**Time of measurement (h)**
30	28	31	30	902	0.00	1024	0.00	0
28	28	31	30	206	77.2	328	68.00	24
32	28	33	29	107	88.2	184	82.00	48
31	28	32	29	103	88.6	218	78.70	72

Coliform counts were done at 0, 24, 48 and 72 h.

Table 3. Effect of particulate matter in water on the solar disinfection.

Turbidity (Mg/l)	Ambient temperature (Ta°C)			Water temperature (Tw°C)			MPN count per 100 ml at start	MPN count per 100 ml at the end	Reduction (%)
	At 09.00 h	At 13.00 h	At 17.00 h	At 09.00 h	At 13.00 h	At 17.00 h			
0.934	26	30.5	32	32	36	36	5400	7	99.9
100.0	26	30.5	32	32	36	36.5	5400	21	99.6
186.7	26	30.5	32	32	36	36.5	5400	49	99.1
240.0	26	30.5	32	32	36.5	36.5	5400	33	99.4
533.4	26	30.5	32	32	36.5	36.5	5400	170	99.9
746.8	26	30.5	32	32	37	37	5400	130	97.6
960.1	26	30.5	32	32	37	37	5400	220	95.9

Table 4. Effect of turbidity in water on the disinfection process.

Turbidity (Mg/l)	MPN (per 100 ml) at start	MPN count (per 100 ml) at the end h	Reduction (%)
Sample 1	130	4	97.5
Sample 2	330	130	60.6
Sample 3	490	240	51.0

Water samples (5 L) each with varying natural turbidities were exposed for 8 h.

than other colours and that disinfection should be carried out in batches of 5 L samples for a period of 7 to 8 h for reduction of coli forms to acceptable limits. Ultra violet rays were found to be the active germicidal agent and not temperature in the reduction of the coli form. There is a negative correlation between turbidity and efficacy of infection. Also in the study, it was not discovered that the efficiency of infection decreased with turbidity although a small degree of turbidity (<25 NTU) does not affect the disinfection.

RECOMMENDATIONS

The following are recommended for disinfection process using solar radiation.

1. Small volumes of water sample should be exposed in bigger capacity larger surface area.
2. Container for better and faster disinfection. For example, 5 L of water sample in a 7 L container is adequate.
3. Where the water is turbid, such should be allowed to settle for 3 to 5 h before exposure to sunlight to reduce turbidity (Wegelin, 1994; Sangodoyin et al., 1998).
4. Since this study was done during the dry season, a similar study should be conducted during the rainy season to further know its effectiveness.

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