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Performance Evaluation of Solar Radiation as Alternative Disinfection Technique for Well Waters in Ibadan, Nigeria

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Abstract: A solar radiation technique was used as a means of disinfection for well waters in parts of Ibadan comprising 8 zones. The zones are Idi-arere, Oke-odo, Oja'ba, Labo, Kudeti, Kobomoje, Bode and Molete. Structured questionnaires were administered to the dwellers of randomly selected houses in the area with (40) shallow-hand dug wells under the zones resulting into 120 respondents, mostly women to obtain baseline information on their general attitude to water use and the overall sanitary features of their wells. Water samples were also taken from the selected wells and analyzed to determine their physiochemical and bacteriological characteristics. A 100 % coliform count reduction was achieved for 4 and 5 L water samples in 7 L container. Seven hours or more of exposure to sunlight was found to be ideal in reducing the coliform count. The degree of disinfection was relatively higher with white (97.9%) and black (98.4%) containers when compared with brown (95%) and blue (82%) containers. With increasing turbidity, the solar radiation efficiency decreases. Ultra Violet Radiation (UVR) was discovered to be the actual disinfection agent rather than the heating effect due to temperature increase. The temperature range of between 23 and 46°C for ambient and between 25 and 45°C for water samples were found to be ideal for the exercise. The experiment provided satisfactory and viable performance when compared with the WHO standard with MPN count found to be 7.2 per 100 mL for 7 h of exposure compared to 2478 per 100 mL before the solar disinfection exercise. Solar disinfection in a tropical country like Nigeria is affordable and can be used by people irrespective of their educational background. This will also reduce the rate of infections and deaths as a result of water related infections especially in this part of the world.

Key words: Solar radiation, well waters, disinfection, Ibadan, Nigeria

INTRODUCTION

The quality of drinking water for a healthy living is of highest importance to the consumers and this depends on the source and level of contamination or pollution (Akinbile, 2004). The WHO (1995) estimated that over 80% of illnesses in developing nations are water related. Over five million babies die needlessly each year from the combined effects of unsafe water supplies and inadequate or non-existent sanitation (Rosegrant *et al*., 2002). The population of people being covered by the water resource also influences the level or extent of pollution and contamination. Nigeria, with a population of over 123 million as at the year 2000, has a projected population growth of about 204.5 million in 2025 at the annual natural increase of 2.8% (PRB, 2001). The country with an annual water resource *per capita* of 1,000 m^3 and 67% of the population (as at 2000) are without safe drinking water (Akinbile, 2004). A water source is said to be polluted when its quality is degraded as a result of man's activities to the extent that it becomes less suitable for its intended use. The degree of pollution will depend on the efficiency of the waste disposal methods, safety of land use pattern, density of disposal systems in an area, composition of waste and a number of other site specific information (Sangodoyin, 1993).

Ibadan, the ancient and capital city of Oyo state, is the most populous black city in sub-Saharan Africa with a population of about 1,375,539 persons as at June 2000 (PRB, 2001). The city is in the southwestern part of Nigeria, predominantly Yoruba speaking areas. Due to this population density, prevailing presence of slums in highly dense areas such as Odinjo, Beere, Molete, Kudeti, Ogunpa and Ayeeye becomes inevitable. Although the entire city lacks a steady supply of piped water, Government's efforts notwithstanding, the urban slums people suffer from severe infections and epidemics. This is because, while the residents of high income and low

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density areas such as Bodija, Ring road, Jericho, Oluyole and academic areas as the university of Ibadan residence can afford to sink deep wells (boreholes), the urban slums residents use polluted wells, streams, rivers and water from commercial vendors (also known as pure water) for their day-to-day activities. Some residents' in these highly populated areas use chlorination, cloth/thin membrane filtration and water boiling as disinfectant methods to prevent infections. The difficulties associated with these methods are the non-availability and high cost of chemicals, low level of literacy and clear disregard for the instructional directives on the correct usage of chemicals for treatment. Others include high cost of maintenance, cost of filters and also boiling water using wood which is not encouraged due to the effects of deforestation on the environment. There is the need therefore for low cost appropriate (method) technologies for water treatment as alternative source which the urban slum residents' will depend on. It should be simple to use and must be easy to maintain by the intended users at the level of their socio-economic status. Some works carried out in Bangladesh revealed that solar disinfection might be a cheaper, efficient and appropriate option especially in the tropics (Baldi, 1988; Sommer, 1996).

The objective of this study therefore, is to assess the efficacy of solar radiation as a means of providing potable water supply for the low income earners and densely populated areas of Ibadan, Nigeria. This will be achieved by obtaining baseline information on the type of water facilities and source, sanitary features, assessing the chemical and bacteriological qualities of well waters used by the people of the selected regions.

MATERIALS AND METHODS

Study area: Ibadan, the area under study is located on longitude 3°58^{1}E and latitude 7°22^{1}N. The altitude generally ranges from 15 to 21 m above the mean sea level. There are isolated ridges and peaks with the latter sometimes rising to 280 m above the mean sea level. The city has two distinct seasons namely: The dry season (October to March) and the wet season (April to September) (Akinbile, 2004). The population of Ibadan is 966,631 (1991 national census) with an ever increasing rate in commercial and industrial activities and decrease in average water available. Ibadan south east local government, the study location is the third largest with a population of 272,865 (112,144- male and 115,721- female). This is about 29% of the total population. (Table 1).

The towns located within the study area are Molete, Kudeti, Bode and Oja'ba. Others are Labo, Kobomoje, Idi-arere and Oke-odo. The public water wells were surveyed and sampled. The people have no predominant occupation, while some are into petty trading, transportation business, few are into government (civil service) work as low-middle cadre officers and others are with no known occupation.

Table 1: Population of Ibadan municipal city

S/N	Local govt areas	Male	Female	Total
1	Ibadan North West	72,849	75,270	146,759
2	Ibadan North East	133,609	139,390	272,979
3	*Ibadan South East	112,144	115,721	272,865
4	Ibadan South West	137,084	136,944	274,028
	Total	455,686	466,325	966,631

*Local Government Area under consideration. Source: 1991 Census (National Population Commission, Ibadan)

Data collection and analysis: Data was collected using structured questionnaires to obtain information on water source and points, well type, pollution distance and type, sanitary features of the wells, water treatment and water related health risks. Analysis of the sampled wells water for physiochemical and bacteriological characteristics were also carried out on the samples from a total of 40 shallow wells in the local government area. The analysis covered the pH, total solids, suspended solids, alkalinity, hardness and chloride content using various but convectional laboratory methods. Multiple fermentation tube technique using McConkey method was used to estimate the number of specific organisms in the well water samples under micro-biological analysis. Some of the samples were also used in the field for assessing the efficacy of solar radiation as a disinfection technique. The final data analysis was done using statistical packages and their results expressed in percentages. Parameters such as the volume of water, hours of exposure, colour of container and turbidity were also determined.

RESULTS AND DISCUSSION

On the demographic characteristics of the area, results of the questionnaire survey indicated that about 123 households living around the water well points were interviewed, 118 respondents were women between the ages of 16 to 65 years which is about 98.3% while the remaining were boys of ages 10 to 16 years. Each household occupants range between 5 to 20 and less than 18 litre/day was used for drinking amongst the 120 respondents. Seventy percent of the respondents i.e., 84 of them had low-income unskilled jobs such as trading, tailoring, food vendors, water hawking and so on while others were either unemployed or have medium to high income jobs. As for the water source and usage, most of the respondents depend heavily on shallow wells all through the year. Eighty five percent of the respondents

Table 2: Sources of water and usage

Source/ usage	Drinking	Cooking	Washing	Sanitary	Bathing
Shallow well	102 (85%)	102(85%)	92 (76.7%)	72 (60%)	81(67.5%)
Rainwater	5 (4.2%)	5(4.2%)	19 (15.5%)	21(17.5%)	25(20.8%)
Public Tap	8 (6.7%)	8(6.7%)	2 (1.6%)	7 (5.8%)	7 (5.8%)
Pond	2 (1.6%)	2(1.6%)	6 (5%)	19 (15.8%)	4 (3.3%)
Commercial vendor	3 (2.5%)	3(2.5%)	1 (0.8%)	1 (0.8%)	3 (2.5%)
Total	120 (100%)	120 (100%)	120 (100%)	120 (100%)	120(100%)

X(Y %) X = no of respondents, Y = % of total respondents

Table 3: Age of water wells in use

Age Distribution (in years)	Frequency	(%)
Less than 5	51	42.5
Between 6 and 10	49	40.8
Between 11 and 15	11	9.17
Greater than 16	9	7.5
Total	120	100

were dependent on wells for drinking, while the remaining 15% depends on other sources such as public tap, pond and water from commercial vendors for drinking (Table 2). The same water sources were also being used for cooking and other domestic purposes as well as sanitary activities. On well location, 78 (65%) respondents has the well inside their compounds, 38 (31%) have it outside meaning that the well is shared while the remaining 4 (4%) respondents did not respond. As for the age of the well, 51 (42.5%) respondents had dug their wells in the last 5 years, 49 (40.8%) in the last 5-10 years, 11 (9.17%) in the last 11-15 years and others had their wells dug with ages greater than 16 years (Table 3). As for the local methods of treating the well waters, it was discovered that 54 respondents (45%) boil their water before consumption, 27 respondents (22.5%) use alum ($Al_2(SO_4).14H_20$) before use, 5 (4.2 %) make use of filter membrane, 13 (10.8%) use chlorination while the remaining 17.5%, that is 21 respondents did not indicate any methods of treatment (Table 4). This may mean that they do not treat water before use. Pertaining to the sanitary features, quite an average number of the respondents had wells with a permissible level of sanitary features such as linings, apron, cover and others. However, one or more sanitary features were absent from most wells (Table 5).

A total number of 40 wells (5 wells each in 8 zones, Fig. 1) were sampled in the study area while physiochemical and bacteriological (coliform count) characteristics were determined. The results indicated that the quality of most of the water samples were within the WHO standard (Table 6) except for the bacteriological quality as indicated by the coliform number. The coliforms were high in all the examined wells, with exceptionally high values in few ones especially in zones C and D (Table 6). Akinbile (2004) remarked that the presence of coliform bacteria in the water samples may also signify the presence of *Escherichia coli* (*E. coli*), a disease

Table 4: Local water treatment methods practiced by the respondents

Method	No of respondents	(%)
Boiling	54	45
Addition of alum ($AL_2(SO_4)_3.14H_20$)	27	22.5
Chlorination	13	10.8
Filter membrane	5	4.2
No treatment	21	17.5
Total	120	100

Table 5: Sanitary features of the wells used by the respondents

	Present		Absent	
Sanitary features	No	(%)	No	(%)
Well Lining	76	63.3	44	36.7
Apron	68	56.7	52	43.3
Cover	103	89.2	6	5
Broken cover	9	7.5	2	1.7
Bucket for drawing water	66	55	54	45
Waste material around the well	62	51.7	53	44.2
Animals around the well	49	40.8	70	58.3

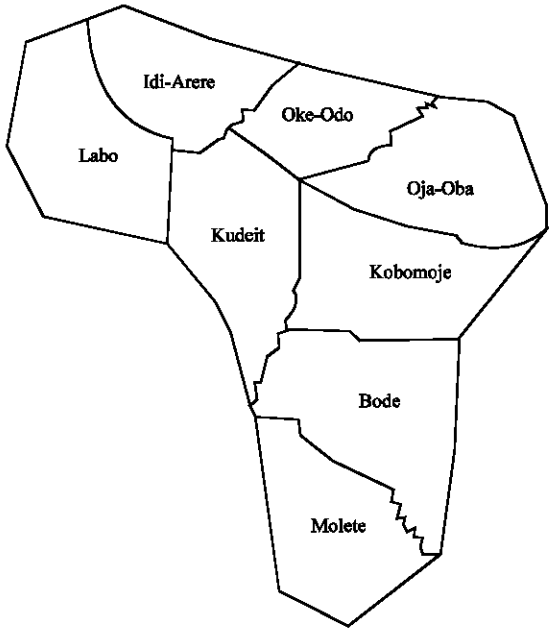

Fig. 1: Sketch of the study area (Ibadan South East LGA) showing the zones

producing-organisms that produce diseases such as cholera, typhoid, dysentery which are injurious to human health. Three of the wells had a total solids value above the WHO standard and this may be due to the quantity of wastes generated in the area without adequate disposal mechanisms which may lead to indiscriminate disposal and subsequently high rate of pollution or contamination of the wells. Various parameters such as the colour of container and cover, quantity (volume) of water and time of exposure to solar radiation were known in the experiment to determine the efficacy of solar radiation as an effective and cheap disinfectant. The coliform number

Table 6: Physiochemical characteristics of the well waters quality in the study area

S/N	Location	pH	Total solids	Total alkalinity	Total hardness	Calcium	Magnesium	MPN per 100 mL
1	Zone A	6.6	800	105	145	15	9	400
2	Zone B	6.3	350	50	30	12	7	300
3	Zone C	6.7	200	38	19	12	8	2,350
4	Zone D	6.5	700	62	50	10	6	1,100
5	Zone E	6.9	150	117	105	28	17	750
6	Zone F	6.7	600	79	45	35	22	450
7	Zone G	6.1	200	45	100	4	3	700
8	Zone H	5.8	300	50	58	10	6	700

All units are in mg L^{-1} except in pH and MPN

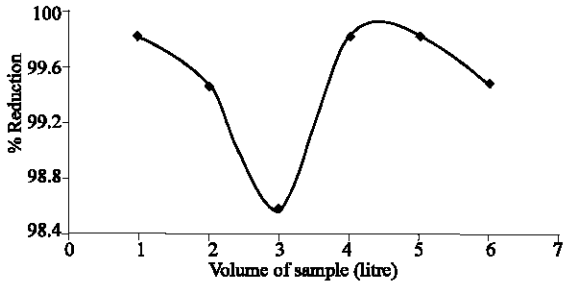

Fig. 2: Effect of volume of water on efficacy of solar disinfection

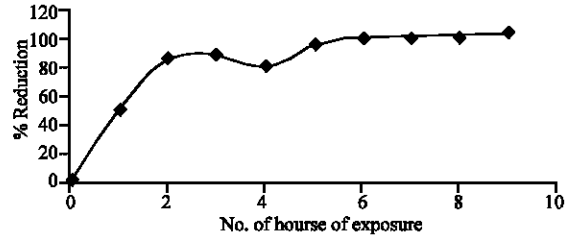

Fig. 3: Effect of number of hourse of exposure to solar radiation

before and after the exposure was used as an index for evaluating the efficacy of the experiment. Varying volumes of well water samples were taken in plastic containers of 7 capacity and were exposed to solar radiation for (8) h just as the ambient and water temperatures were recorded at a four hourly intervals (0900,1300 and 1700 h). After 8 h exposure, coliform counts were measured in all the samples exposed. The results indicated significant reduction in coliform count but no significant difference in the coliform reduction for varying volumes (Fig. 2). However, repeating the above experiment for a 5 litre of water taken in 7 litre bowls and examining 100 mL samples from each of the bowls for coliform count using the MPN count at hourly intervals, the results indicated that solar radiation in 7 h and above were found to be ideal in reducing the coliform count, thus ensuring the desired disinfection (Fig. 3).

As for the effects of colour of the container, the results indicated that black and white coloured containers

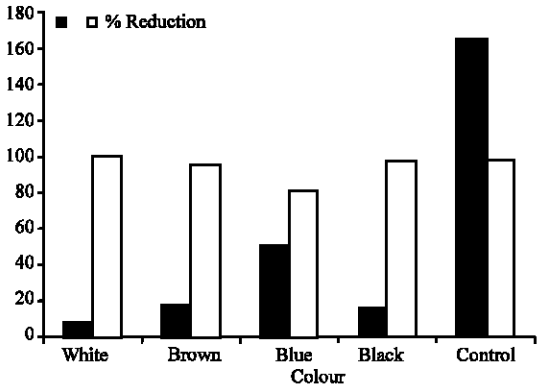

Fig. 4: Effect of colour container on efficacy of solar disinfection

appeared to be relatively efficient in the removal of coliform (Fig. 4). Five litre water samples were taken in white, brown, blue and black containers and were exposed to solar radiation for 8 h and coliform count determined. Considering the turbidity effect on disinfection process, even though the turbidity of most well waters in the study area were within the acceptable limits, the results of the experiment conducted to determine the effects of high level particle matter on the efficacy of solar radiation indicate that increasing turbidity decreases the efficiency of solar radiation

CONCLUSION

The absence of treated pipe borne water in sufficient quantities to Ibadan inhabitants particularly to people in the south east local government area which is a densely populated area had caused untold hardship and severe health-related problems on the people of the area. The dwellers had relied heavily on polluted waters such as rivers, streams and shallow wells for survival in spite of unhygienic sanitary practices, indiscriminate dumping of refuse near such water sources, citing major pollution sources like pit latrines near wells and general poor sanitation. There is no doubt that water plays a major role in the development of any community and its availability adequately both in terms of quantity and quality is essential for the survival of man (Akinbile, 2004).

For this study, the performance evaluation of solar radiation as an alternative technique for disinfection of waters in Ibadan south east areas was carried out. It was observed that for a high efficiency of the technique, it should be carried out in batches of 5 L containers for a period of 7 to 8 h for reduction of coliform to acceptable limits. Using the coliform count index, it was also concluded that white and black coloured containers were mostly efficient when compared with the other colours for highest performance of the system. This colouring index was based on the premise that the exposed transparent portion allows solar radiation through the water, whilst the black portion limits re-radiation and also keeps the temperature high making use of the synergetic effect of ultra violet rays and heat (Sommers, 1996). The ultra violet rays were found to be the active germicidal agent and not the temperature in the reduction of the coliform. There was a negative correlation between turbidity and efficacy of disinfection meaning that increase in the degree of disorderliness of water decreases the efficiency of the technique.

RECOMMENDATIONS

The recommendations are as follows:

- Small volume of water sample should be exposed in a bigger capacity of large surface area container for better and faster disinfection. For example, 5 L of water sample in a 7 L container is adequate. It has been proved that smaller volumes may be more reliably disinfected.
- The design of solar radiation equipment (solar cells and accessories) be initiated to improve (or standardize) this technique so as to adopt the system in the water packaging industry.
- The government should encourage the use of solar power as an emerging alternative to various energy-dependent sectors of the economy in order to reduce it's over dependence on the erratic supply form the already existing systems which is causing heavy losses each day.

The areas of further research however are that since the study was carried out in dry season, similar study should be conducted in wet season to confirm the efficacy of the technique. Another area is taking care of some pollutants that are airborne which will have tremendous negative impact on the water samples when exposed in sunlight for solar disinfection.

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