Bacteriological and Physicochemical Assessment of Water from Student Hostels of Osun State University, Main Campus, Osogbo, Southwest Nigeria

Joshua B. Owolabi[1*],

Janet O. Olaitan[2],

Ademola A. Alao[2],

Adebukola. K. Deile[2],

Oluwabusayo O. Ige[2]

&

Julius K. Oloke[3].

[1]Department of Biological Sciences,
School of Natural & Applied Sciences,
College of Science & Technology,
Covenant University,
Ota, Ogun State, Nigeria.

[2]Department of Biological Sciences,
College of Sciences, Engineering & Technology
Osun State University,
Osogbo, Osun State, Nigeria.

[3]Ladoke Akintola University of Technology,
Ogbomoso, Oyo State, Nigeria

*E-mail: joshua.owolabi@covenantuniversity.edu.ng

Abstract: *This study was conducted to investigate the potability of 15 samples of water, three each from boreholes (BH1-BH3) and hand-dug wells (HD1-HD3), and nine brands of sachet water (SW1-SW9) that were regularly patronized by the students of Osun State University, main campus, residing in private hostels in Osogbo metropolis. The objective of the study was to determine the quality of such water samples. Borehole and well water samples from selected areas and samples of sachet water regularly vended by different manufacturers and vendors were collected, and subjected to physical, chemical and bacteriological analysis. For physical and chemical analysis Wagtech's photometer plus chemical reagents were used. Total heterotrophic bacteria, total coliforms, and feacal coliforms in the water samples were obtained using, respectively, the pour plate method, membrane filtration and growth on MacConkey* *agar as well as Eosin Methylene Blue agar. The results showed that all of the samples of sachet water exhibited values of physical / organoleptic parameters, inorganic constituents, and mean coliform and E. coli counts per 100 ml below the WHO/SON maximum permissible levels; and were therefore, considered safe for drinking. There were slightly elevated levels of iron in water samples from the borehole category, BH2 and BH3 with no known health impacts. This is because iron is an essential element in human nutrition. Taste is not usually noticeable at iron concentrations below 0.3 mg/l. Although iron concentrations of 1–3 mg/l can be acceptable for people drinking well-water, no health-based guideline value for iron has been proposed. However, there were slightly elevated nitrate levels in samples from hand-dug wells, HD1 and HD3, suggesting that these water sources were not safe for consumption by infants under three months old. In addition, evidence of feacal coliform in water samples from hand-dug wells HD1 and HD2 suggest that they were not safe for human drinking. It is recommended that water from hand dug wells should be boiled before consumption to ensure public health and safety.*

Introduction

Water is essential to sustain life, and a satisfactory supply must be made available to consumers. Potable water is water pure enough to be consumed or used with low risk of immediate or long term harm. Like other developing countries, the issue of access to potable water is very important in Nigeria, where 48% (about 67 million Nigerians) depend on surface water for domestic use, 57% (79 million) use hand dug wells, 20% (27.8 million) harvest rain, 14% (19.5 million) have access to pipe borne water, and 14% have access to borehole water sources (FGN, 2007). The quality and quantity of pipe borne water for drinking is deteriorating in the country due to inadequacy of treatment plants, direct discharge of untreated sewage into rivers and streams, and inefficient management of piped water distribution system (UNEP, 2001; Aderibigbe *et al*., 2008; Gbadegesin and Olorunfemi, 2007). Although, the importance and use of groundwater has increased significantly during the last decades in urban and rural areas of the country (Adekunle *et al*., 2007), contamination from natural and human activities is affecting this vital resource (Adetunde *et al*., 2011; Ishaku *et al*., 2011). A recent local intervention, drinking water sold in polythene sachets, though readily available and affordable, has generated public health concerns about purity due to the questionable integrity of the production environments and contamination from improper vendor handling (Adekunle *et al.*, 2004; Dada, 2008).

Water which is not safe to drink can carry pathogenic microbes and heavy metals. Globally, about 80% of all diseases and death in developing countries are water-related as a result of polluted water (Ayeni *et al*., 2011, Aderibigbe *et al*., 2008). The numbers of water-borne disease outbreaks that have been reported in

Nigeria demonstrate that transmission of pathogens by drinking water remains a significant cause of illness (Nwidu *et al*., 2008). Although, the symptoms of gastrointestinal disorders (nausea, diarrhea, vomiting and abdominal pain) are usually mild and generally last a few days to a week and only a small percentage of those affected will visit a health facility, there is untold impact on human productivity.

Osun State University is a non-residential institution of higher learning with six campuses distributed across Osun State, Southwest of Nigeria. The main campus of the University is situated in Oke Baale area of Osogbo, the state capital. Students live in private hostels near the main campus and other communities in the metropolis. The water supplies from the Ministry of Water Resources and Rural Development, Osun State Water Corporation (OSWC), and the Rural Water Environmental Sanitation Agency (RUWESA) are inadequate for the growing population and at best epileptic in most Osogbo communities (OSWC, 2008). As a consequence of pipe borne water shortage, the Osun State University students depend on water from boreholes, hand-dug wells and water vended in sachets. From a public health perspective, there is a need to ascertain the quality of water accessible to the university student hostels to avoid or reduce incidence of contaminated water-related health hazards. Based on this, the study was undertaken to assess the physical, chemical, and bacteriological properties of the water sources used by the students of Osun State University main campus. The study is relevant in assuring whether the quality of the water sources meet regulatory standards and is significant because potable water is essential to life.

Materials and Methods

Study Area

The study was conducted in Osogbo, a commercial and industrial city (located 7°46′ North 4°34′East with an area of 47km sq), and the capital of Osun State, Nigeria. Specifically, private hostels at Oke Baale, Abe Obi, Kasmo, and Ogo Oluwa communities of Osogbo occupied by the students of Osun State University, main campus, were used in the present study.

Water Collection

A total of 15 samples of water, three each from hand dug-wells and boreholes, and nine brands of sachet water vended by different manufacturers and vendors were collected between December 2011 and February 2012, during the dry season of the year when the problem of water access and supply was very acute. Three replicates were collected per source. Well water sample was collected directly from each well by means of a sterile plastic container fitted with a weight at the base; taking care to avoid contamination by surface scum. The outlet of each borehole was disinfected using cotton wool soaked in 70% (v/v) ethanol and was allowed to run for at least five minutes before taking the sample into a sterile plastic container. The samples of sachet water were purchased from the retailers of the brands regularly patronized by the students. The water samples were transported to the laboratory in insulated containers with ice, stored in a refrigerator at a temperature at 4^0C, and analyzed within twenty four hours of collection.

Physicochemical Analysis

The water samples collected were analysed for pH, temperature, odour, colour, taste, turbidity, electrical conductivity, total dissolved solids, total alkalinity, total hardness, chloride, nitrate and selected trace metals.

Determination of pH

The pH of the water samples was determined using the Wagtech pH meter. 10 ml of each of the samples was poured into a sterile beaker and the anode of the pH meter was dipped into it and readings were obtained when it was stable.

Measurement of Temperature

This was conducted *in situ* at the site of sample collection using a mercury-in glass thermometer.

Determination of Colour, Odour and Taste

A 20 mL volume of each water sample was poured into a clean beaker. The sample was then shaken vigorously to check for any frothing and allowed to settle. Colour was determined through visual examination and then odours were determined through the sensation of smell. Taste tests for consumer acceptability were performed on the water samples. Small volumes of each sample was tasted with the tongue and then immediately rinsed with distilled water (taste free) after each sample, and the results were recorded accordingly.

Determination of Turbidity

A two part calibrated turbidity tube was used, with calibrations from 5-25 turbidity units. The joined tubes were held over a white paper, while slowly pouring the water sample into the tube until the black cross at the bottom was no longer visible. At this point the reading was taken from the side of the tube as the turbidity value of the water sample.

Determination of Electrical Conductivity

A 20 mL volume of each water sample was poured into a clean beaker at room temperature. The Wagtech electrode was placed in the sample, and following stirring the electrical conductivity value was determined after the meter became stable.

Determination of Total Alkalinity

10 ml of water sample was put in curvet; alkaphot tablet was added, crushed and mixed until all particles have dissolved. Optical density reading was taken at 570 nm wavelength on a Wagtech photometer.

Determination of Total Dissolved Solids

The total dissolved solids were determined by submersing the Wagtech probe into 100 ml of each water sample following which the readings were recorded.

Determination of Chloride

To fifty ml of the sample 5 drops of a phenolphthalein indicator solution was added and neutralized with 0.1N sulphuric acid to the colorless side of phenolphthalein. One ml of potassium chromate indicator solution was added before titration with standard silver nitrate solution to the pinkish-yellow endpoint. A reagent blank titration was carried out in parallel to the sample titration. Chloride concentration was calculated as follows (APHA, 2005): Chloride, mg/l = [(A-B) (N) (35.45)/V] x 100, where A = Silver nitrate solution, in ml for sample titration; B = Silver nitrate solution, used for blank titration (in ml); N = Normality of the silver nitrate solution; and V = Sample volume in (ml).

Determination of Nitrate

Test tube was filled with sample to 20 ml mark and one level spoonful (~ 15 ml) of nitratest powder (containing zinc dust 60%, and barium sulphate 40%) and one nitratest tablet (ammonium chloride) were added and was shaken for a minute. The tube was allowed to stand for a minute and was inverted 3-4 times to aid flocculation and was allowed to stand for two minutes to ensure complete settlement. The clear solution was dispersed into tube to 10ml mark and one nitricol tablet (sulfanilic acid, acting as the aromatic amine), was added, crushed, and mixed to dissolve, then it was allowed to stand for 10 minutes for colour development and readings were taken on the photometer at 570 nm wavelength.

Determination of Total Hardness

Total hardness was analyzed by titration of 50 ml water sample with standard EDTA

The EDTA was added in drops at pH 10 using Erichrome black T indicator until the colour changed into purple and the hardness was calculated by multiplying the average number of drops of EDTA used for the sample by the calibration factor of 20.

Determination of Iron

A cuvette was filled with each water sample plus 0.25% ortho-phenanthroline solution (1:10 dilution), and optical density was taken at 510 nm wavelength using the Wagtech photometer. From a standard curve, the concentration of iron in the sample was determined**.**

Determination of Zinc

Ten ml of water sample was dispensed in a test tube and one zinc tablet (5-(0-carboyphenyl)- 1-(2-hydroxy -5- sulphophenyl)-3-phenyl-formazan) was added, crushed, mixed to dissolve and was allowed to stand for five minutes and mixed to obtain a complete dissolution of the indicator. The optical density reading at 640 nm wavelength was taken using a Wagtech photometer.

Bacteriological Analysis

Total heterotrophic bacteria in the water samples were obtained using the pour plate method. The enumeration and isolation of coliform bacteria was by the use of the membrane filtration technique (Eckner, 1998; Jagals *et al*., 2000) and growth on MacConkey agar. The presence of Escherichia coli in the water samples was assessed by growth and colour reaction on Eosin Methylene Blue (EMB) agar, together with standard biochemical reactions as described (Barrow and Feltham,1993).

Results

The physicochemical properties of the water samples from boreholes, hand-dug wells and sachet water brands patronized by the students of Osun State University, main campus, residing in private hostels in Osogbo metropolis, examined in this study are as shown in Tables 1 and 2. All the water samples analyzed had similar and acceptable colour, odour and turbidity. The temperature of all the samples were between 26.8 ^{0}C and 29.3 ^{0}C. The pH values of all the samples ranged between 6.1 and 8.4. The electrical conductivity, total dissolved solids and total hardness of all the water samples, ranged, respectively, between 97 and 305 µS/cm, 145 and 455 mg/l, and 84 and 446 mg/l. The total alkalinity was between 20 and 45 mg/l. The levels of zinc and chloride ranged, respectively, between 0.01 and 0.37 mg/l, and 5.0 and 32.0 mg/l while there were no detectable levels of arsenic ions in all the water samples analyzed. The tests for heavy metals such as lead, chromium or cadmium were not carried out in the present study. Two water samples in the borehole category (BH2 and BH3) had high levels of iron of 0.1 mg/l. Similarly, nitrate levels in two of the samples of water from hand-dug wells (HD1 and HD3) were determined to be greater than 50 mg/l.

The bacteriological properties of the water samples examined in this study are as shown in Table 3. Total viable bacterial counts were in the order of 2.5 x 10^1 - 7.0 x 10^1 colony forming units per ml of borehole and branded sachet water samples, and 1.5 x 10^3 - 2 x 10^3 in the water samples from hand-dug wells. Coliform counts per 100 ml of all water samples ranged from 1.8 x 10^1 to 1.7 x 10^2 while feacal coliform represented by *Escherichia coli* were 0.0 for all samples of borehole, branded sachet and one hand-dug well (HD3) water, and 1.0 in two hand-dug wells (HD1 and HD2).

Table 1: The pH, Conductivity, Total Alkalinity, Total Hardness and Total Dissolved Solids values of water samples from Osun State University, private student hostels, Osogbo

Water Sample	pH	Conductivity µS/cm	Total Alkalinity mg/l	Total Hardness mg/l	Total Dissolved Solids mg/l
BH1	6.8	113	34	124	168
BH2	6.3	220	28	103	328
BH3	7.8	305	20	186	455
HD1	6.4	112	25	118	165
HD2	6.1	110	36	95	173
HD3	7.0	176	45	446	253
SW1	6.9	97	35	124	145
SW2	6.7	117	45	146	174
SW3	7.5	119	24	98	178
SW4	6.9	172	35	96	257
SW5	6.5	145	24	75	223
SW6	7.1	127	40	84	194
SW7	7.8	126	37	206	188
SW8	8.4	218	25	178	325
SW9	7.7	167	42	287	249
WHO	**6.5 – 9.2**	**-**	**120**	**500**	**1500**

SON	**6.5 - 8.5**	**1000**	**-**	**500**	**500**

Table 2: Metal ion (Arsenic, Iron and Zinc), Chloride and Nitrate values of water samples from Osun State University, private student hostels, Osogbo

Water Sample	Arsenic mg/l	Iron mg/l	Zinc mg/l	Chloride mg/l	Nitrate mg/l
BH1	0.0	0.0	0.06	18	48
BH2	0.0	0.1	0.01	26	15
BH3	0.0	0.1	0.37	10	30
HD1	0.0	0.0	0.01	24	60
HD2	0.0	0.0	0.02	22	15
HD3	0.0	0.0	0.08	27	67
SW1	0.0	0.0	0.02	22	46
SW2	0.0	0.0	0.02	29	48
SW3	0.0	0.0	0.01	19	11
SW4	0.0	0.0	0.02	26	20
SW5	0.0	0.0	0.01	24	15
SW6	0.0	0.0	0.02	32	10
SW7	0.0	0.0	0.01	13	12
SW8	0.0	0.0	0.14	5	29
SW9	0.0	0.0	0.05	9	17

WHO	**0.01**	**0.3**	**4.0**	**250**	**50**
SON	**0.01**	**0.3**	**3.0**	**250**	**50**

Table 3: Mean population of bacteria in water samples from Osun State University, private student hostels, Osogbo

Water Sample	**Total bacterial count (cfu/ml)**	**Total coliform count (cfu/100ml)**	***Escherichia coli (cfu/100ml)***
BH1	2.5×10^1	4.5×10^1	0.0
BH2	6.0×10^1	1.1×10^2	0.0
BH3	7.0×10^1	1.3×10^2	0.0
HD1	2.3×10^3	1.7×10^2	1.0
HD2	1.9×10^3	1.6×10^2	1.0
HD3	1.5×10^3	1.4×10^2	0.0
SW1	2.5×10^1	2.4×10^1	0.0
SW2	2.0×10^1	3.2×10^1	0.0
SW3	2.7×10^1	1.8×10^1	0.0
SW4	3.5×10^1	5.4×10^1	0.0
SW5	5.3×10^1	6.5×10^1	0.0
SW6	7.0×10^1	6.1×10^1	0.0
SW7	4.8×10^1	7.3×10^1	0.0
SW8	6.5×10^1	8.0×10^1	0.0

SW9	4.2×10^1	6.3×10^1	0.0
WHO			0.0
SON		1.0×10^3	0.0

Discussion

This study determined the quality of water from borehole, hand-dug wells and sachet water brands patronized by the students of Osun State University, main campus, residing in private hostels in Osogbo metropolis. Virtually all of the samples of sachet water examined in the study exhibited values of physical / organoleptic parameters, inorganic constituents, and mean coliform and *E. coli* counts per 100 ml below the WHO/SON (WHO, 2007; SON, 2007) maximum permissible levels; and are therefore, considered safe for drinking. The results of the physicochemical and bacteriological assessment of the collected sachet water samples confirmed with the work done earlier in Osogbo (Olowe *et al*., 2005), Ilorin (Adewoye *et al*., 2011), Ota (Chinedu *et al*., 2011), and Accra, Ghana (Addo *et al*., 2009) and this could be attributed to the total adherence to strict quality assurance procedures in the laboratory and production premises of the companies concerned. It is noteworthy, however, that some assessment of sachet water brands vended in Ondo (Onifade and Ilori, 2008), Kebbi (Kalpana *et al*., 2011) Ogbomoso (Oladipo *et al*., 2009) and Ibadan (Adekunle *et al*., 2004; Ajayi *et al*., 2008) have physicochemical values of concern and/or evidence of feacal coliforms. These contradictory reports highlight the need for ongoing implementation of the several legislations put in place by National Agency for Drug Administration and Control (NAFDAC) in Nigeria, and continuous monitoring to increase reduction in the sales of contaminated brands of sachet water; and this may be the reflection of what we have observed in this work.

The presence of iron in groundwater supplies is a common problem (Merrill et al., 2009) The slightly elevated levels of iron in water samples from the borehole category, BH2 and BH3 may have arisen naturally in the aquifer, and its levels could also be increased by dissolution of ferrous borehole or by the action of iron related bacteria. Interestingly, no health-based value for iron in drinking water has been proposed in the WHO guidelines (WHO, 2003). Although, iron stains laundry at levels above 0.3 mg/l, there is usually no noticeable taste in iron concentration below 0.3 mg/l (WHO, 2003). The acceptability of water samples from the boreholes examined in this study was not questionable for drinking purposes, given the mean coliform counts per 100 ml below the WHO/SON maximum permissible levels and lack of feacal *E. coli* in the samples. This work confirms the work done by Yusuf *et al*., (2012) which reported that all the borehole water sampled in Offa and Erin-Ile in Kwara State and in Ilesa and Osogbo in Osun State, Nigeria were free of *E. coli*. In a study conducted by Akpoveta *et al*., 2011, physicochemical parameters determined for borehole water used in the vicinities of Benin, Edo State and Agbor, Delta State of Nigeria were found to fall within the WHO/SON maximum permitted limit for potable water except for calcium and manganese.

The slightly elevated nitrate levels in samples from hand-dug wells, HD1 and HD3, and evidence of feacal coliform in samples from hand-dug wells HD1 and HD2 suggest that these water sources may have been contaminated as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks that were located in the close vicinity of the wells. According to WHO (2007), nitrate may have a role in protecting the gastrointestinal tract against a variety of gastrointestinal pathogens since nitrous oxide and acidified nitrite have antibacterial properties, however, nitrate in drinking water is an important risk factor for bottle-fed infants (under three months) given increases in methaemaglobinaemia and possible cyanosis (Greer and Shannon, 2005). Older children are relatively insensitive to the effects of nitrate (Craun, Greathouse & Gunderson, 1981). A number of studies (Gatseva & Argirova, 2008; Radikova *et al*., 2008; Ward *et al*., 2010) have reported a correlation between various measures of nitrate intake and effects on thyroid function, but all suffer from methodological and data problems that preclude definitive conclusions being drawn about the effect of nitrates in adults. Practical considerations to control nitrate concentration in well water include appropriate management of agricultural practices, well thought-out siting of pit latrines and septic tanks, sewer leakage control, as well as management of fertilizer and manure applications (WHO, 2007).

E. coli may have entered the private wells through contamination with feacal matter from infested or infected humans or animals, through sewage overflows, polluted storm water runoff, and agricultural runoff. In addition, the wells may have been more vulnerable to such contamination after flooding, since most hand-dug wells are usually shallow (Ayantobo *et al*., 2013). The evidence for *E. coli* in two of three hand-dug wells examined in this study raises concern given the rise of infection rate of E. coli O157:H7, a potentially life-threatening pathogen, in Southwest Nigeria where 4.3% out of one thousand and eight hundred diarrhoeic patients sampled in a recent study were positive for the organism, the highest occurrence (4.5%) was found among those using well water, and 5.8% among those people using dunghill as toilet (Ademokoya *et al*., 2013). Boil water orders, water avoidance advisories, proper excreta disposal and improvement in general hygiene would enhance the quality of *E. coli* infested well water sources and reduce possible infection by the indicator bacteria.

We conclude, on the bases of the physicochemical and bacteriological properties of the water samples examined in this study that water from boreholes and sachet water brands patronized by the students of Osun State University, main campus, residing in private hostels in Osogbo metropolis are safe for human consumption. While the water samples from hand-dug wells may be useful for other purposes such as cleaning, bathing, and toilet flushing, they are not safe for consumption by infants under three months old. Because of the presence of *E. coli* in some well water samples it is recommended that water from these sources should be boiled before consumption to ensure public health and safety.

Acknowledgements
The authors appreciate the laboratory access and support provided by the staff of Rural Water Environmental Sanitation Agency (RUWESA) under the Ministry of Agriculture, Osun State, Nigeria.

References

Addo, K. K., Mensah G. I., Bekoe M, Bonsu C. and Akyeh M. L. (2009). Bacteriological quality of sachet water produced and sold in Teshie-Nungua suburbs of Accra, Ghana. African Journal of Food Agriculture, Nutrition and Development **9**(4)**:** 1019-1030.

Adekunle, L.V., Sridhar M. K. C., Ajayi A. A., Oluwande P. A., Olawuyi J. F. (2004). An Assessment of health and social economic implications of sachet water in Ibadan: A public health challenge. Africa Journal of Biomedical Research **7:** 5-8.

Adekunle, I. M., Adetunji, M. T., Gbadebo A. M. and Banjoko O. B. (2007.) Assessment of groundwater quality in a tropical rural settlement in Southwest, Nigeria. Int. Journal of Environment and Public Health **4**(4)**:** 307-318.

Aderibigbe, S.A., Awoyemi, A. O. and Osagbemi, G. K. (2008). Availability, adequacy and quality of water supply in Ilorin metropolis, Nigeria. Eur.

Journal of Scientific Res. **23:** 528-536.

Adetunde L. A., Glover R. L. K. and Oguntola G. O. (2011). Assessment of the groundwater quality in Ogbomoso township of Oyo State, Nigeria. IJRRAS **8**(1)**:** 115-122.

Ademokoya A. A., Adebolu T. T. and Ogundare A. O. (2013). Infection rate of *E. coli* O157:H7 among diarrhoeic patients in Southwest Nigeria. International Journal of Current Microbiology and Applied Sciences **2** (10)**:** 524-533.

Adewoye S.O., Ogundiran M.A., and Adebayo E.A., (2011). Physicochemical and bacteriological quality of some vended sachet water samples in Ilorin, Nigeria. Journal of Research in Biology **2:** 122-128.

Ajayi, A.A, Sridhar, M.K.C, Adekunle , L.V, Oluwande , P.A. (2008). Quality of Packed Water Sold in Ibadan, Nigeria. *African Journal of Biomedical Research* **11:** 251-258.

Akpoveta O. V., Okoh B. E. and Osakwwe S. A. (2011). Quality assessment of borehole water used in the vicinities of Benin, Edo State and Agbor, Delta State of Nigeria. Current Research in Chemistry **3**(1): 62-69.

APHA (2005). Standard methods for the examination of water and wastewater. (21st ed). Washington, D.C. APHA. ISBN 0875530478

Ayantobo O. O., Oluwasanya G. O., Idowu O. A. and Eruola A. O. (2013). Water quality evaluation of hand-dug wells in Ibadan, Oyo State, Nigeria. Global Journal of Science Frontier Research Agriculture and Veterinary **13**(10): Version 1.0 Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Ayeni, A. O,Balogun,I. I and Soneye, A.S.O (2011). Seasonal assessment of physico chemical concentration of polluted urban river: case of Ala River in Southwestern Nigeria. Research Journal of Environmental Science **5**(1)**:** 22-33.

Barrow, G. I. and Feltham, R. K. A. (1993). Cowan and Steel's manual for the identification of medical bacteria. 3rd Edition, Cambridge University Press, Cambridge, 331.

Chinedu S. W. Nwinyi O. C. Oluwadamisi A.Y. and Eze V. N. (2011). Assessment of water quality in Cannaland, Ota, Southwest, Nigeria. Agriculture and Biology Journal of North America **2**(4)**:** 577 -583.

Craun G. F., Greathouse D. G., and Gunderson D. H. (1981). Methaemoglobin levels in young children consuming high nitrate well water in the United States. International Journal of Epidemiology **10:** 309–317.

Dada A. C. (2008). Sachet water phenomenon in Nigeria: Assessment of health impacts. Afr. J. Microbiol. Res. **3:** 15-21.

Eckner, K.F. (1998) Comparison of membrane filtration and multiple-tube fermentation by the Colilert and Enterolert methods for detection of waterborne coliform bacteria, *Escherichia coli*, and enterococci used in drinking and bathing water quality monitoring in Southern Sweden. Appl. Environ. Microbiol. 64: 3079–3083.

FGN (2007) Legal notice on publications of the 2006 census report. Federal Government of Nigeria official gazette. 4(94)**:** 1-8.

Gatseva P. and Argirova M. D. (2008). High nitrate levels in drinking water may be a risk factor for thyroid dysfunction in children and pregnant women living in rural Bulgarian areas. International Journal of Hygiene and Environmental Health **211**(5–6)**:** 555–559.

Gbadegesin A. S. and Olorunfem F. B. (2007). Assessment of rural water supply management in selected rural areas of Oyo State, Nigeria. African Technology Studies (ATPS) Network Working Papers No. 47.

Greer F. R. and Shannon M. (2005). Infant methemoglobinemia: The role of dietary nitrate in food and water. Pediatrics **116**(3): 784-786.

Ishaku J. M., Ahmed A. S. and Abubakar M. A. (2011). Assessment of groundwater quality using chemical indices and GIS mapping in Jada area, Northeastern Nigeria. Journal of Earth Sciences and Geochemical Engineering **1**(1)**:** 35-60.

Jagals, P., Grabow, W. O. K.,Griesel, M. and Jagals C. (2000) Evaluation of selected membrane filtration and most probable number methods for the enumeration of faecal coliforms, Escherichia coli and Enterococci in environmental waters , Quantitative Microbiology **2**(2)**:** 129-140.

Kalpana, S, Bagudo, A.I, and Aliero, A. A (2011). Microbiological analysis of sachet drinking water marketed at two sites in Aliero, Kebbi State, Nigeria. *Continental J. Microbiology* **5** (1)**:** 29 – 36.

Merrill R. D., Shamim A. A.,Labrique A. B, Ali H., Schulze K., Rashid M., Christian P., and West, K. P. (2009). Validation of two portable instruments to measure iron concentration in groundwater in rural Bangladesh. J Health Popul Nutr. **27**(3)**:** 414–418.

Oladipo I.C., Oyenike I.C. and Adebiyi A.O. (2009). Microbiological analysis of some vended sachet water in Ogbomoso, Nigeria. African Journal of Food Science **3**(12)**:** 406-412.

Olowe, O.A., Ojurongbe, O., Opaleye, O.O.,Adedosu, O.T., Olowe, R.A., and Eniola, K.I.T (2005). Bacteriological quality of water samples in Osogbo metropolis. *African Journal of Clinical and Experimental Microbiology* **6**(3)**:** 219 – 222.

Onifade A. K. and Ilori R. M. (2008). Microbiological analysis of sachet water vended in Ondo State, Nigeria. Environmental Research Journal **2**(3): 107-110.

OSWC (2008). Review of organisational, technical, financial and commercial structures including PSP assessment. Final draft report. Pp 1-87.

Nwidu L. L., Oveh B., Okorioye T. and Vaikosen N. A. (2008). Assessment of the water quality and prevalence of water-borne diseases in Amassaoma, Niger Delta, Nigeria. African Journal of Biotechnology **7**(17)**:** 2993 – 2997.

Radikova Z., Tajtakova M., Kocan A., Trnovec T., Sebokova E., Klimes I., Langer P. (2008). Possible effects of environmental nitrates and toxic organochlorines on human thyroid in highly polluted areas of Slovakia. Thyroid 18(3)**:** 353–362.

UNEP (2001). Annual Evaluation Report. Pg 1-88.

SON (2007). Nigerian standards for drinking water quality. Pg 1-30.

Ward M. H., Kilfoy B. A., Weyer P. J., Anderson K. E., Folsom A. R., Cerhan J. R. (2010). Nitrate intake and the risk of thyroid cancer and thyroid disease. Epidemiology **21**(3)**:** 389–395.

WHO (2003) Iron in drinking water. Background document for preparation of WHO Guidelines for drinking water quality. Geneva, World Health Organization.

WHO (2007) Nitrate and nitrite in drinking water. Background document for preparation of WHO Guidelines for drinking water quality. Geneva, World Health Organization.

Yusuf K. O., Ibrahim A. M. and Famakinwa J. O. (2012). Productivity and quality analysis of selected boreholes in Osun and Kwara States, Nigeria. Agric. Eng. Int: CIGR Journal 14(30**):** 8-13.