Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol 2, No.6, 2012

Quality Assessment of Some Groundwater Samples in *Ogbomoso* Metropolis, Southwest Nigeria

Agbaje Lateef[1*] Lanre Lateef Kolawole[2] Semawon Olusola Agosu[1]

1. Department of Pure and Applied Biology, Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, Nigeria
2. Department of Earth Sciences, Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, Nigeria

* E-mail of the corresponding author: agbaje72@yahoo.com

Abstract

This study examines the physico-chemical and microbiological attributes of water samples obtained from ten boreholes that were sampled twice a month for a period of five months. The physico-chemical attributes revealed that the ammonia, manganese, nitrate, nitrite, fluoride, chloride contents, conductivity and total dissolved solids were below the permissible levels. However, total alkalinity and total hardness values of some water samples were higher than the permissible levels, while all the water samples had BOD and COD values that were higher than the permissible levels. The pH of water samples ranged from 5.8-6.9, showing that only two samples fell within the permissible levels. Similarly, the temperature ranged from 31.5-35.4 ^{o}C, with only two samples having values that fell within the permissible levels. The microbial quality of the water samples indicates extensive microbial contamination involving heterotrophic bacteria, coliforms, yeasts/molds, staphylococci, and *Shigella*. However, *Salmonella* was not isolated in this study. Bacterial isolates such as *Proteus, Escherichia, Shigella, Streptococcus, Staphylococcus, Bacillus, Pseudomonas, Enterobacter,* and *Klebsiella* with multiple-drug resistance ranging from 2-8 were encountered. The safety of the borehole water can be enhanced through regular cleaning, disinfection of storage tanks and further treatment by end-users to ensure the potability of water. This study provides baseline data with regard to the quality of underground water within *Ogbomoso* metropolis, Nigeria.

Keywords: ground water, boreholes, microbiology, physico-chemical attributes, antibiotic resistance

1. Introduction

Water is a vital resource in the ecosystem since it supports life of all living organisms. Though, it occupies about 70% of the earth's surface, yet a greater percentage of the world's population, most especially in developing countries live without access to safe water (Adriano and Joana, 2007). This is due to lack of infrastructure for the treatment of water and its eventual distribution for the populace. In Nigeria, lack of efficient water supply facilities has led to the prospecting of underground water by individuals for the provision of drinking water. Because of the problems associated with shallow wells, which include drying-out of water during the dry season, seepage and easy contamination, there seems to be increased drilling of boreholes for the search of underground water by individuals, educational institutions, industries/commercial outlets and even governmental and non-governmental agencies. Since most of the water obtained from these sources is seldomly treated because of the perception that they are generally safe to drink, there is need to carry out investigations on the physico-chemical and microbiological attributes of water samples of these boreholes.

In the present study, attempts were made to analyze water samples from boreholes that were drilled for different purposes within *Ogbomoso* metropolis, Southwest Nigeria for an extended period of five months. The public health implications of the bacterial isolates encountered during the study were evaluated through antibiotic resistance phenomenon. To the best of our knowledge, the study represents the most comprehensive analysis of borehole water samples in *Ogbomoso* in particular and any part of the country in general.

2. Materials and Methods

2.1 Sampling

Water samples were obtained from ground water sources, otherwise known as boreholes located within *Ogbomoso* metropolis, Southwest Nigeria. During this investigation, water samples were obtained from ten boreholes at an interval of two weeks for a period of five months. In some cases, water samples were obtained from the storage tanks of end users in their various homes. Water samples were collected in 250 ml capacity sterile bottles. The bottles were sterilized in the autoclave at 121 ^{o}C for 15 min. After allowing several liters of water to run as waste, water samples were obtained by allowing water to flow aseptically from the dispensing tap into the glass bottles. The bottles were corked and kept at temperature below 5^{o}C during transportation to the laboratory. Samples were analyzed within 4hr of collection.

2.2 Physico-chemical analysis

Samples for physico-chemical analysis were collected in 2-L plastic containers. Prior to collection, these containers were thoroughly washed and rinsed with 5% HCl and left to dry overnight. Thereafter, each container was rinsed with the water to be collected before it was filled and then corked. Water samples were collected during the first and the fifth month of sampling for the physico-chemical analysis. Chemical oxygen demand (COD), biochemical oxygen demand (BOD), total dissolved solids, turbidity, chlorides, fluoride, nitrate, manganese, ammonia, Mg hardness, Ca hardness, total alkalinity and total hardness were determined according to American Public Health Association (APHA) methods (Greenberg *et al*., 1995). Other parameters of the water samples such as pH, electrical conductivity (EC), and temperature were determined on site using water analyzer meter (Systronics, India).

2.3Microbiological analysis

Appropriate dilutions of 10, 100 and 1000th fold of the water samples were done, and 0.2ml of diluent was used to inoculate the agar using the pour plate method. Agars that were used for enumeration and isolation of microorganisms are: yeast extract agar for aerobic bacteria, *Salmonella-Shigella* agar for *Salmonella* and *Shigella*, mannitol salt agar for *Staphylococcus*, potato dextrose agar (PDA) for yeasts and molds, and MacConkey agar for coliforms. All the plates were incubated at 37 ^{o}C for 24-48 h, except the PDA plates that were incubated at room temperature (30 ± 2 ^{o}C). At the end of incubation, the number of distinct colonies were counted and used to calculate the microbial load in each case. Thereafter, colonies were purified to obtain pure cultures and then stored on agar slants at 4 ^{o}C. Distinct bacterial colonies were screened and identified by means of taxonomic schemes and descriptions (Buchanan and Gibbons, 1974), which was complemented with the API identification kit (API System, bioMérieux, France).

2.4 Antibiotic sensitivity test

Selected strains of bacterial isolates were tested for their sensitivity to antibiotics by means of M2-A6 disc diffusion method recommended by the National Committee for Clinical Laboratory Standards, NCCLS (NCCLS, 1997) using Mueller Hinton agar. Antibiotics discs (Maxicare Medical Lab., Nigeria) containing: Augmentin (Aug), 30µg; Amoxycillin (Amx), 30µg; Septrin (Sep), 30µg; Sparfloxacin (Spx), 10µg; Ciprofloxacin (Cip), 10µg; Gentamycin, (Gen), 10µg; Pefloxacin (Pfx), 10µg; Trivid (Tvd), 10µg; and Streptomycin (Str), 30µg were used for Gram negative isolates. Pefloxacin (Pfx), 10µg; Gentamicin (Gen), 30µg; Ampiclox (Amp), 30µg; Zinnacef (Znf), 30µg; Amoxycillin (Amx), 30µg; Rocephin (Rcp), 30µg; Ciprofloxacin (Cpx), 10µg; Streptomycin (Str), 30µg; Septrin (Sep), 30µg; and Erythromycin (Ery), 19µg were used for Gram positive isolates. The plates were incubated at 37°C for 24h. After the incubation, zones of inhibition were examined and interpreted accordingly (Chortyk *et al.*, 1993) considering the appropriate breakpoints (Andrews, 2005). Earlier, the potencies of all the antibiotics used in the study were confirmed using susceptible *E. coli* strains.

3. Results

3.1 Descriptive analysis of the boreholes

The results of the descriptive analysis of the boreholes are as shown in Table 1. The boreholes were drilled for different purposes, ranging from private domestic use, industrial (production of sachet water), commercial (selling of untreated water) to agricultural use. They are equipped with motorized pumps, which pump water from the boreholes into overhead tanks; from which water is made available to the end users via taps. The age of the boreholes ranged from 2-18 years and all of them have been productive since they were drilled. In most cases, treatment of the water in storage tanks is non-existent, while most of the storage tanks are rarely washed or disinfected. The level of water consumption varied from about 600-5000 litres per day. The tanks are either made of PVC or galvanized metal, so also are the piping materials. At least 50% of the boreholes were located very close to open drainage channels and sewage tanks, while only two of the boreholes were close to refuse dump sites. Previous historical use of the borehole areas showed that most of the areas were used as farmlands, while two areas previously served as refuse dump sites.

3.2 Physico-chemical properties of the water samples

The physico-chemical attributes of the water samples from the boreholes are as presented in Table 2. The pH of water samples ranged from 5.8-6.9, while the temperature ranged from 31.5-35.4 ^{o}C. The total solid (TDS) ranged from 80-288.5 mg/l, and the total hardness ranged from 64-152.5 mg/l. The values of 30-117 mg/l and 26-139.5 mg/l were obtained for the BOD and COD respectively. Generally, the turbidity of the water samples was below 7 NTU, while the conductivity was below 0.5 mS/cm. A number of parameters such as ammonia, manganese, nitrate, nitrite, fluoride, chloride, conductivity and total dissolved solids had values that were generally below the permissible levels of standard for drinking water in Nigeria (NSDQW, 2007). The total alkalinity values were generally higher than the permissible level except in two samples, while only one sample had higher value for total hardness than the permissible level. All the values obtained for BOD and COD were higher than the permissible levels for the parameters. Only two samples had pH values falling within the permissible level, while the remaining samples had slightly acidic values. The temperature of the water samples showed that only two samples fell within the permissible levels, the remaining samples had higher values.

3.3 Microbiological attributes of the water samples obtained from the boreholes

The microbial loads of the water samples are as shown in Table 3. The aerobic plate count varied from 1.21-5.26 × 10^3 cfu/ml, coliform count from 1.12-2.66 × 10^3 cfu/ml, *Salmonella-Shigella* count from 0.02-0.8 × 10^3 cfu/ml, staphylococcal count from 0.14-0.7 × 10^3 cfu/ml, and mold/yeast count of 0.12-1.37 × 10^3 cfu/ml. All the one hundred water samples obtained from the ten boreholes were positive for heterotrophic bacteria and the coliforms, whereas only seven water samples from three boreholes showed growth on *Salmonella-Shigella* agar. While twenty two water samples obtained from four boreholes were positive for the growth of staphylococci, sixty one water samples obtained from the ten boreholes showed mold/yeast growth. The cumulative microbial loads of the water samples ranged from 3.14-8.6 × 10^3 cfu/ml. The level of microbial contamination of the water samples obtained in this study is B > A > C > D > G > F > I > J > H > E. The number of water samples indicating microbial contamination according to the microbial indicators used in this study varied from twenty seven samples for boreholes E and H, to thirty five for borehole B.

Table 1: Descriptive analysis of the boreholes

Parameters/Boreholes	A	B	C	D	E	F	G	H	I	J
Description	Public	Institution	Commercial	Industrial	Industrial	Agricultural	Industrial	Industrial	Agricultural	Private
Age (years)	8	14	12	7	4	10	5	7	18	2
Storage facility (tank)	Plastic	Metal	Metal	Plastic	Plastic	Plastic	Plastic	Plastic	Plastic	Plastic
Piping material	Plastic	Metal	Metal	Plastic	Metal	Metal	Plastic	Plastic	Plastic	Plastic
Treatment of stored water	No	No	No	No	No	No	Chlorination/ filtration	Chlorination/ filtration	None	None
Primary purpose	Domestic	Multipurpose	Domestic	Sachet water production	Sachet water	Agricultural	Sachet water production	Sachet water production	Agricultural	Domestic
Hydrological survey	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Level of consumption (litres/day)	1200	600	2500	2500	5000	2500	1500	1200	5000	2500
Cleaning of storage tank	Rare	Rare	Rare	Often	Rare	Rare	Often	Often	Rare	Often
Nearness to open drainage	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No
Nearness to dump site	No	No	No	No	No	Yes	No	No	Yes	No
Nearness to sewage tank	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No
Human activities around borehole	Workshop, & traffic	Workshop	Workshops & traffic	Workshops & traffic	Shops	Farming	Shops	Shops	Farming	Domestic
Previous history of the borehole's area	Road side	Farmland	Disposal of domestic waste	Disposal of domestic waste	Farm land	Farm land	Farm land	Farm land	Farm land	Farm land

Table 2: The physico-chemical properties of the water samples

Parameters/boreholes	A	B	C	D	E	F	G	H	I	J	NSDWQ (2007)
pH	6.4	5.8	6.4	6.9	5.9	6.1	6.3	6.9	6.3	6.2	6.5-8.5
Temp (^oC)	35.3	35.1	35.3	35	31.5	35.2	35.4	32.3	35	35.1	30-32.5
Turbidity (NTU)	4	4	6	5	4	4	4	4	4	4	5
TDS (mg/l)	207	151	288.5	212	151	119	141.5	120	207	80	500
Conductivity (mS/cm)	0.22	0.19	0.33	0.29	0.16	0.11	0.18	0.13	0.23	0.07	1
Redox potential (mV)	154	161	133.5	122	159	153	147.5	145.5	152	90	-
Total hardness (mg/l)	98	78	152.5	105	75	71	68	64	100	112	150
Total alkalinity (mg/l)	114	106	144	112	104.5	87	106	43	111	114	100
Chloride (mg/l)	40	12	21.5	24	26	41	28.5	22	40	18	250
Fluoride (mg/l)	0.83	1.01	0.57	0.92	1.17	0.47	1.16	0.57	0.77	0.49	1.5
Nitrate (mg/l)	0.62	27	13.04	10.96	2.58	0.64	2.74	2.33	0.60	2.13	50
Nitrite (mg/l)	0.00	0.00	0.08	0.09	0.00	0.00	0.02	0.03	0.10	0.00	0.2
Mn^{2+} (mg/l)	0.04	0.00	0.15	0.29	0.09	0.11	0.04	0.10	0.05	0.03	0.20
Ammonia (mg/l)	0.19	1.21	0.16	0.31	0.21	0.96	0.47	0.80	1.20	0.93	1
BOD (mg/l)	44	30	117	96	76	55	70.5	100.5	50	42	10
COD (mg/l)	34	37	139.5	120	57	41	96	119	33	26	10

Each value is an average of four readings of parameters.

Table 3: The microbial loads (cfu/ml × 10^3) of the water samples from the boreholes*

Boreholes	APC	CC	SSC	STC	MYC	Cumulative microbial load
A	5.26 (10)	2.62 (10)	0	0.2 (4)	0.12 (4)	8.2 (28)
B	4.94 (10)	2.66 (10)	0.02 (1)	0.7 (10)	0.28 (4)	8.6 (35)
C	2.0 (10)	1.8 (10)	0.8 (3)	0	1.0 (7)	5.6 (30)
D	1.8 (10)	1.6 (10)	0.6 (3)	0	0.8 (8)	4.8 (31)
E	1.21 (10)	1.21 (10)	0	0	0.72 (7)	3.14 (27)
F	1.49 (10)	1.62 (10)	0	0	1.37 (8)	4.48 (28)
G	2.2 (10)	1.9 (10)	0	0	0.5 (8)	4.6 (28)
H	1.5 (10)	1.7 (10)	0	0	0.4 (7)	3.6 (27)
I	2.42 (10)	1.24 (10)	0	0.14 (4)	0.14 (4)	3.94 (28)
J	2.48 (10)	1.12 (10)	0	0.18 (4)	0.12 (4)	3.9 (28)

APC, aerobic plate count; CC, coliform count; SSC, *salmonella-shigella* count; STC, staphylococcal count; MYC, mould-yeast count; * microbial load is an average ten readings and has uniform index of 10^3; number in parenthesis indicate the number of positive samples.

3. 4 Microbiological attributes of water samples from the end users

Table 4 shows the microbiological attributes of water samples obtained from the household of ten end users of the boreholes. Microbial growth was found associated with all the water samples, except for water samples obtained from two end users (A3 and A5) of borehole A. Aside, staphylococci were not encountered in the water samples of end users of borehole C. However, the heterotrophic bacteria count varied from 1.6-5.32 × 10^3 cfu/ml, coliform count from 1.4-3.1 × 10^3 cfu/ml, *Salmonella-Shigella* count from 0.06-0.6 × 10^3 cfu/ml, while the mold/yeast count in the range of 0.18-0.8 × 10^3 cfu/ml was obtained. In all, 80, 79, 50, 24, and 14 out of 100 water samples from the end users were contaminated with heterotrophic bacteria, coliforms, mold/yeast, *Salmonella-Shigella* and staphylococci respectively. The cumulative microbial load varied from 0 to 9.03 × 10^3 cfu/ml, and the level of contamination is A3 = A5 < C2 = C3 = C5 < C1 < A1 < C4 < A2 < A4. In each case, the number of water samples that were contaminated varied from 0 (A3 and A5), to 28 (C3, C4, and C5), 29 (A1), 31 (C1), 32(C2), 34 (A2) and 37 (A4) out of 50 water samples.

Table 4: The microbial loads (cfu/ml × 10^3) of the water samples obtained from the end users*

Boreholes	APC	CC	SSC	STC	MYC	Cumulative microbial load
A1	3.22 (10)	1.54 (10)	0.06 (2)	0.12 (2)	0.24 (5)	5.18 (29)
A2	5.32 (10)	2.76 (10)	0.16 (4)	0.44 (6)	0.18 (4)	8.86 (34)
A3	0	0	0	0	0	0
A4	5.28 (10)	3.1 (10)	0.04 (2)	0.16 (6)	0.45 (9)	9.03 (37)
A5	0	0	0	0	0	0
C1	2.0 (10)	2.0 (10)	0.4 (3)	0	0.6 (8)	5.0 (31)
C2	1.6 (10)	1.6 (9)	0.4 (5)	0	0.5 (8)	4.6 (32)
C3	1.6 (10)	1.4 (10)	0.4 (2)	0	1.2 (6)	4.6 (28)
C4	2.0 (10)	1.8 (10)	0.6 (3)	0	0.8 (5)	5.2 (28)
C5	1.8 (10)	1.6 (10)	0.6 (3)	0	0.6 (5)	4.6 (28)

APC, aerobic plate count; CC, coliform count; SSC, *salmonella-shigella* count; STC, staphylococcal count; MYC, mould-yeast count; * microbial load is an average ten readings and has uniform index of 10^3; number in parenthesis indicate the number of positive samples; 1-5, different end-users.

3.5 Antibiotic resistance pattern

The results of the sensitivity of the bacterial isolates to some antibiotics are as presented in Table 5. Three bacterial isolates of *Proteus mirabilis*, *E. coli* and *S. aureus* were not resistant to the antibiotics, while seven other isolates were resistant to only one type of antibiotics, namely Amoxycillin, Chloramphenicol, Ampiclox, Augmentin and Sparfloxacin. In all, thirty-nine bacterial isolates showed multiple drug resistance to antibiotics ranging from 2-8. In this study, bacterial species belonging to following genera were isolated: *Proteus, Escherichia, Shigella, Streptococcus, Staphylococcus, Bacillus, Pseudomonas, Enterobacter,* and *Klebsiella.* Strains of *Salmonella* were not isolated during the investigation.

Table 5: The antibiogram profile of bacteria isolated from the water samples

Number of antibiotics	*Resistance patterns	Isolates	Sources
0	Nil	*Proteus mirabilis*	A1
		E. coli	A1
		S. aureus	J
1	Amx	*Proteus mirabilis; E. coli*	A; J
	Chl	*Shigella* sp	C; D
	Amp	*Klebsiella* sp; *S. pyogenes*	E
	Aug	*S. pyogenes*	G
	Spx	*P. mirabilis*	I
2	Amx, Amp	*S. pyogenes*	C; D
	Amp, Aug	*E. coli*	F
	Amx, Tvd	*Klebsiella* sp	F
	Amx, Amp	*Proteus vulgaris*	H

	Amx, Amp	*S. pyogenes*	C
3	Amx, Sep, Cip Aug, Tvd, Cip Amp, Aug, Gen Amp, Znf, Pef Aug, Tvd, Spx	*E. coli; P. aeruginosa* *S. pyogenes* *E. coli* *B. subtilis* *P. aeruginosa*	C; D F E H I; J
4	Chl, Cip, Aug, Tvd Amx, Sep, Cip, Str Amx, Sep, Cip, Gen Amx, Amp, Znf, Rcp Amx, Sep, Amp, Znf Amx, Aug, Gen, Tvd Amx, Amp, Tvd, Str Amx, Aug, Pef, Spx,	*E. coli; S. pyogenes* *Enterobacter aerogenes* *P. aeruginosa* *S. aureus* *S. aureus* *E. coli* *P. aeruginosa* *E. coli*	B B A2 A A; A2 F E G
5	Chl, Tvd, Sep, Spx, Aug Amx, Amp, Rcp, Spx, Znf Amp, Tvd, Cip, Str, Znf Amx, Amp,Cip, Znf, Ery Aug, Tvd, Sep, Spx, Chl Amx, Amp, Sep, Str, Pfx	*E. coli* *B. subtilis* *P. aeruginosa; Klebsiella* sp *B. subtilis* *E. coli* *S. aureus*	A1; A4 C; D E G I; J I
6	Amp, Tvd, Cip, Pfx, Str, Znf Amp, Tvd, Cip, Pfx, Znf, Ery Amx, Amp, Tvd, Rcp, Sep, Chl Amx, Aug, Tvd, Sep, Pfx, Chl,	*S. pyogenes* *S. aureus* *S. aureus* *E. coli*	F F H J
7	Amx, Amp, Znf, Rcp, Sep, Str, Ery Amx, Chl, Tvd, Sep, Spx, Cip, Aug Amp, Pfx, Tvd, Str, Znf, Sep, Chl Amx, Aug, Tvd, Sep, Spx, Cip, Chl	*S. aureus* *E. coli* *Klebsiella* sp; *S. pyogenes* *E. coli*	A A4 E I
8	Amx, Amp, Str, Znf, Rcp, Sep, Pfx, Ery Amx, Chl, Tvd, Sep, Str, Spx, Cip, Aug Amx, Amp, Str, Pfx, Rcp, Cip, Znf, Ery	*S. aureus* *Shigella* sp *S. aureus*	A2 A1; A2 I; J

*, abbreviations of antibiotics are as defined under materials and methods; A-J, boreholes; 1, 2, 4, end users of water.

4. Discussion

The descriptive analysis of the boreholes showed that prospecting for underground water through drilling of boreholes can be traced to about two decades within the studied area. Interestingly, this was about the time, a non-residential University was established in *Ogbomoso*, which has tremendously increased its population. The drilling of boreholes has since become a frequent exercise among those who can afford it for various purposes. The uncontrolled manner in which these boreholes are drilled may have implications on the hydro-geology of the area and depletion of aquifers. It was observed through this work, that the water is rarely treated, while the storage tanks are not also washed or disinfected. These practices can contribute enormously to the contamination of water, since microbes that are associated with the water during piping can easily multiply in such tanks, and even form biofilm for the continuous contamination of the water. Since the aerial storage tanks are in vantage position to receive sunlight, ambient temperatures that can promote growth of microbes are provided.

The physico-chemical attributes of the water samples showed that most of them were slightly acidic and were not within permissible levels. This may be due to the elemental composition of the substratum of the studied area. Acidity increases the capacity of the water to attack geological materials and leach toxic trace metals into the water, making it potentially harmful for human consumption (Kolo *et al*., 2009). Thus, the moderate acidity of these waters suggests that the waters were susceptible to some degree of trace metal pollution, possibly present in the rock matrix through which the water percolated. Furthermore, acidity may give a sour taste to water. The pH for waters thus points that the consumers of these waters may suffer some taste problem.

Similarly, the temperatures of most of the water samples were higher than the permissible levels. The high temperature may be as a result of aerial tanks that are used for the storage of water before it is dispensed. The tanks are in vantage position to receive sunlight throughout the day time, which may contribute to the high temperature of the water samples. Most of the plastic containers used for the storage are black in colour which will serve the function of not only trapping the heat, but also retaining it for a long time. In the metal tanks however, high temperature has been found to be associated with corrosion problems, which may affect the quality of the stored water. Such temperatures as encountered in this study may favour the growth of microbes in the storage tanks, and even form biofilms that may ensure continuous contamination of the water.

The total hardness of the water samples indicates their moderate hardness (Hem, 1970) having values in the range of 64-152.5 mg/l. Total hardness is an important criterion in determining the suitability of water for drinking, domestic and industrial purposes. Water with high level of hardness will not be suitable for washing as its usage will lead to the wastage of soap, with its attendant economical and medical implications.

Although the amount of nitrates found in the water samples fell below the permissible level, the high concentrations of nitrates encountered in the underground water may be a cause of concern. It has been observed that nitrate is relatively non-toxic to humans, but adverse effects can result when it is reduced to nitrite in the intestine of infants and death may result due to non-reversible reaction with haemoglobin (Blue-baby syndrome), if not timely and properly treated (Odo and Ijere, 1997). Most of the concentrations of manganese encountered were below permissible level, however, it should be pointed out that manganese contamination would result in neurological disorders in exposed persons (Tennant, 1981). Generally, the level of fluoride was less than the recommended standard of 1.5 ppm. While fluoride concentration of 1 ppm in drinking water has been found to be beneficial in ensuring reduction in dental caries, higher concentrations in excess of 2 ppm causes discoloration, the brown mottling of teeth in children below the age of 5 years (cosmetic effect) and could also be harmful (Lee, 1999) in causing fluorosis.

All the values obtained for BOD and COD were found to be higher than the permissible levels, indicating the abundant presence of organic materials in the water samples that can be oxidized by both microbes and chemicals present in the water samples. This has a lot of implication on the organic pollution levels of the water samples. In the case of total alkalinity, the values were higher than the permissible levels except in two samples, which may be an indication of the presence of carbonate rocks as underlying materials within the studied area. The turbidity of the water samples were within allowable limit except for a sample. Turbidity, which is a measure of cloudiness of water samples as may be caused by suspended solids that are generally invisible to the naked eyes can affect the quality of water. Higher levels of turbidity may increase the exposure to gastrointestinal infections, as pathogens such as bacteria and viruses may attach to the suspended solids. Such suspended solids may also reduce the efficiency of treatment techniques such as chlorination and UV sterilization.

The results of microbiological quality of the water samples showed that they were contaminated by bacteria and fungi/mold although to varying degrees and occurrences. The level of microbial contamination is such that the water samples did not meet required criteria for drinking water. Similar results have been reported by some authors on the quality of borehole water in some Nigerian cities (Ita and Akpan, 2005; Inyang, 2009). The presence of coliforms in all the water samples is appalling. However, among the ten-end users of some of the boreholes, water samples obtained from two users who chlorinated the water in the house after fetching from borehole tank were not contaminated at all with regard to the microbial indicators used in this study. This is an indication that the microbial safety of the water can be enhanced by post-fetching treatments such as chlorination. Several bacterial species belonging to the following genera were isolated: *Proteus, Escherichia, Shigella, Streptococcus, Staphylococcus, Bacillus, Pseudomonas, Enterobacter,* and *Klebsiella.* However, strains of *Salmonella* were not isolated in this study. A number of these bacterial isolates have the potential to cause various forms of infections in humans, thus may have grave consequences on public health. These organisms might have been introduced into the boreholes during the drilling process and fixing or piping of the boreholes to the storage tanks or through seepage from septic tanks.

The resistances of the bacterial isolates to commonly used antibiotics as obtained in this study indicate the potential dangers they may pose to the health of the public. It has been reported that major epidemics in the World had been linked with resistant pathogens (Levy, 2001; Canton *et al.,* 2003). Some authors have reported high level of antibiotic resistance among bacterial isolates obtained from water samples in Nigeria (Inyang *et al.,* 1995; Lateef *et al*., 2005, 2006). The high levels of resistance obtained may be due to a number of practices that encourage the use of drugs in agriculture and by patients without prescription. Since the antibiotics persist in the environment (Zuccato *et al*., 2000), bacteria are then exposed to sub-optimal doses of the drugs, thereby making them resistant. In nature, such resistant traits can be acquired by other non-resistant isolates thereby promoting and spreading drug-resistance problems.

It can be concluded from the results obtained in this study, that there is need to improve on the quality of borehole water through regular cleaning and disinfection of storage tanks. It is also important that further treatment should be carried out by end-users to ensure the potability of water.

Acknowledgement

We gratefully acknowledged a number of our students who participated in this study, and also the authority of LAUTECH., *Ogbomoso* for the provision of some of the facilities used.

References

Andrews, J.M. (2005), "BSAC standardized disc susceptibility testing method (version 4)", *Journal of Antimicrobial Chemotherapy* **56**, 60-76.

Buchanan, R.M. & Gibbons, N.E. (1974), "*Bergey's Manual of Determinative Bacteriology* (8th Ed.)", Baltimore, MD: The Williams and Wilkins Company.

Canton, R., Coque, T.M. & Baquero, F. (2003), "Multi-resistant gram-negative bacilli: from epidemics to endemics. Nosocomial and hospital-related infections", *Current Opinion in Infectious Diseases* **16**, 315-325.

Chortyk, T.O., Severson, R.F., Cutler, H.C. & Siesson, V.A. (1993), "Antibiotic activities of sugar Esters isolated from selected *Nicotiana* species", *Bioscience, Biotechnology, and Biochemistry* **57**, 1355-1356.

Greenberg, A.E., Connors, J.J., Jenkins, D., & Franson, M.A. (1995), "Standard Methods for the Examination of Water and Wastewater", 15th Ed. American Public Health Association, Washington, DC.

Hem, J.D. (1970), "Study and interpretation of the chemical characteristic of natural water, 2 (Edn)", *U.S. Geol. Survey Water Supply Paper* 1473: 363.

Inyang, C.U (2009), "Antibiogram of Bacteria Isolated from Borehole Water", *Nigerian Journal of Microbiology* **23**, 1810-1816.

Itah, A.Y & Akpan, C.E (2005), "Potability of Drinking Water in an Oil Impacted Community in Southern Nigeria", *Journal of Applied Sciences and Environmental Management* **9**, 135- 141

Kolo, B., Dibal, J.M., & Ndakawa, I.I. (2009), "Elemental Analysis of Tap and Borehole Waters in Maiduguri, Semi Arid Region, Nigeria", *European Journal of Applied Sciences* **1**(2), 26-29.

Lateef, A., Oloke, J.K. & Gueguim Kana, E.B. (2005), "The prevalence of bacterial resistance in clinical, food, water and some environmental samples in Southwest Nigeria", *Environmental Monitoring and Assessment* **100**, 59-69.

Lateef, A., Oloke, J.K., Gueguim Kana, E.B. & Pacheco, E. (2006), "The Microbiological Quality of Ice Used to Cool Drinks and Foods in *Ogbomoso* Metropolis, Southwest, Nigeria", *Internet Journal of Food Safety* **8**, 39-43

Lee, J.D. (1999), "Concise Inorganic Chemistry", Fifth edition. Blackwell Science Ltd. Oxford, UK. ISBN: 978-0-632-05293-6.

Levy, S.B. (2001), "Antibiotic resistance: consequences of inaction", *Clinical Infectious Diseases* **33**, S124–S129.

NCCLS. (1997), "*Performance Standards for Antimicrobial Disk Susceptibility Tests* (6th Ed.)", Approved Standards. Document M2-A6. Wayne, PA: NCCLS.

Nigerian Standard for Drinking Water Quality NIS 554 (2007), Standards Organization of Nigeria. Lagos, Nigeria

Odo, P.E., & Ijere, J.A. (1997), "Quality analysis of water from Alau dam area in the Northeastern Nigeria for irrigation suitability and some related agronomic and environmental implications", In Daura, M.M. (ed.). *Issues in Environmental Monitoring*. Nigerian Geographical Association. pp.63-67

Tennant, D.R. (1981), "Manganese", World Health Organization International Programme on Chemical Safety. *Environmental Health Criteria* **17**, 218-220.

Zuccato, E., Calamar, D., Natangelo, M. & Fanelli, R. (2000), "Presence of therapeutic drugs in the environment", *Lancet* **355**, 1789-1790.