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Assessment of quality of drinking water sources in the Federal University of Technology, Owerri, Imo state, Nigeria

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ABSTRACT
Objective: Concern over exposure to drinking water contaminants and the resultant adverse effect on human health has prompted several studies evaluating the quality of drinking water sources. The present study is aimed at assessing the quality of ground water and packaged water supply in the Federal University of Technology Owerri, South Eastern Nigeria.
Methodology and results: The study was carried out between May and July, 2009. The standard plate count method was used for the analysis, which involved serial doubling dilutions of the respective water samples. All the water sources sampled were within WHO physico-chemical standard for drinking water except for the slightly elevated levels of phosphate ions. The findings revealed that three of the samples were contaminated with bacterial pathogens including *Staphylococcus aureus* (in 50% of samples), *Streptococcus faecalis, Bacillus sp., and E. coli* (in 50%) of samples. The total heterotrophic plate count ranged from 1.5×10^5-5.4×10^6CFUml^{-1} with a mean of 1.9×10^6CFUml^{-1}, while the total coliform plate count gave a range of 1.5×10^5-3×10^5 cfu/ml with a mean of 2.3×10^5CFUml^{-1}. Faecal coliforms were found in (50% of the samples) with a mean of 6×10^4 CFU/100ml. *Conclusion and application of results*: A thorough treatment of the boreholes is recommended and this should focus on the elimination of coliform bacteria so as to prevent an epidemic of water related diseases.
Key words: Water sources, quality, contaminants, surveillance, treatment.

INTRODUCTION
Water is an essential element in the maintenance of all forms of life, and most living organisms can survive only for short periods without it (Pat, 1992; Kegley & Andrews, 1998). Water plays a key role in prevention of diseases; drinking eight glasses of water daily can decrease the risk of colon cancer by 45% and bladder cancer by 50% as well as reducing the risk of other cancers (APEC, 1999). In addition to being in abundant supply, the available water must have specific characteristics, signifying its quality (Deborah, 1996).

Traditionally, the most important of the quality characteristics has been the concentration of dissolved salts because of the relationship between salt and land productivity. Later, health related characteristics such as presence of disease-causing microorganisms became important. More, recently, the introduction of anthropogenic chemicals, that have impact on health when present in trace amounts, has become a problem (Kegley & Andrews, 1998).
Of all the water sources on earth, only 3% are good (in terms of quality or freshness). These

include: surface water (rivers, lakes, streams and reservoirs) and groundwater (Kegley & Andrews, 1998). With the decline in the use of surface water for drinking water supply due to contamination, there is an increase in the reliance on ground water as drinking water source. Unfortunately, little attention is being paid to drinking water quality issues and quantity remains the priority focus during water supply projects.

The need to define the quality of water has developed with the increasing demand for water which is suitable for specific uses and conforms to desired quality (Deborah, 1996). Although water quality and water quantity are inextricably linked, water quality deserves special attention because of its implications on public health and quality of life (Warren & Mark, 1998).

Truly, the danger that unsafe drinking water poses to health is enormous (Njoku and Osinlu, 2007). Unsatisfactory water supplies and un-wholesome sanitary conditions can result in poor human health (Chukwu, 2008). A recent study in Lagos, South western Nigeria, on wells and tap waters used as drinking water sources revealed that all the well waters from the locations under study were contaminated with one or more bacterial pathogens, e.g. : *E. coli, Klebsiella pneumonia, Shigella dysenteriae, Proteus vulgaris* and *Salmonella typhi* (Akinyemi *et al*., 2006). Every year, thousands of cholera cases causing many human fatalities are said to occur in Nigeria. In addition, it has been confirmed in the country that water-related diarrhea is the most prevalent disease among the population after malaria, prompting the need for safe drinking (Njoku & Osinlu, 2007).

Worldwide, roughly 1.1 billion people lack access to safe water and 1.7 million people are said to die every year from water-diarrheal diseases (Cutter & Miller, 2005). Consequently the most fundamental need is for water that is suitable for drinking, food preparation and personal hygiene, and that poses no risk in any way, to human health. Obviously, more stringent control of water contaminants and higher quality standard apply to water intended for human consumption than for other uses. These standards are expressed in terms of the microbiological, chemical and physical characteristics of water (Njoku & Osinlu, 2007).

This study is intended to assess the overall physical, chemical and biological qualities of water supplied to Federal University of Technology, Owerri (FUTO), based on World Health Organization (WHO) guideline for drinking water standards and to recommend feasible strategies for remediation and treatment of general and specific cases.

MATERIALS AND METHODS

Study site: The study was carried out in Federal University of Technology, Owerri (FUTO), which is in South Eastern Nigeria between $5^0$24'N and $7^0$1' E. Geologically, the topsoil of the site consists of coastal plain sands. Beneath the tertiary deposits are sedimentary rocks from the cretaceous period. These rocks are mainly made up of shales, sandstones and limestoneThe area has an average rainfall of 130cm annually and is about 100m above sea level (FUTO Masterplan, 1983).

On-site observation: This involved the assessment of the immediate surroundings of the water source (boreholes), and the identification of the level of protection or ease of contamination of the water source from man and animal activities within the vicinity of the boreholes. Observations included: examination of the plinths to ascertain if they are cracked, eroded or watertight, observation for signs of water accumulation close to the borehole tap-stand, identification of activities such as washing of cloths, urination and brushing of teeth, with potential to affect water quality, within 5 meter radius of the borehole. Others were assessment of the activities of animals e.g. cows goats and dogs around the borehole facility, assessment of the closeness of the borehole to septic tanks, sewers or waste dumps (Cheesbrough, 2000).

Sample collection: All the boreholes studied were accessed by both students and non-students resident on campus. The water samples from the boreholes were collected using sterile 750 ml containers. Before collection, the mouth and the outer parts of the borehole taps were sterilized with the flame of a cigarette lighter, and allowed to cool by running the water for about 1 minute. Thereafter, the sample bottles were rinsed with the sample water before filling them. The bottles were held at the bottom while filling, to avoid contamination of water from the hands

or fingers. After recording the time of collection, the samples were labeled with code names before going to the laboratory for analysis, as recommended by Cheesbrough (2000).

Packaged water samples (bottled and sachet) were bought from selected shops within the campus in conditions in which the students and non-students purchase and use them. Preliminary survey was conducted before selection of the packaged water samples in order to identify popular brands commonly patronized within the environment as recommended by Dada (2009).

Physico-chemical assessment: This involved visual assessment of the external features of the water samples, which includes specific odour, temperature and appearance (colour, turbidity and presence of floating particles, or extraneous materials). Parameters such as total hardness, acidity, conductivity, presence of minerals (such as magnesium, chlorine, calcium, iron and phosphates) were determined by methods described by Kegley and Andrews (1998); Foster and Leslie (1978).

*pH determination***:** The pH of the water sample was determined using a pH meter.

Turbidity determination: A two part calibrated turbidity tube was used, with calibrations from 5-25 turbidity units. The joined tubes were held over a while 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.

Chlorine determination: To a 50ml of the sample was added 5 drops of a phenolphthalein indicator solution and neutralized with 0.1N sulphuric acid to the colourless side of phenolphthalein. 1ml 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 quality was calculated as follows:

$$\text{Chloride, mg/l} = \frac{[(A-B)\ (N)\ (35.45)}{V} \times \frac{100}{}$$

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

V = Sample volume (in ml)

Phosphate determination: The mild acid hydrolysis was used to convert the phosphate content to the soluble orthophosophate before colorimetric determination was carried out. One drop of phenolphthalein indicator solution was added to 100ml of the sample and the colour adjusted to red by the addition of 7N sodium hydroxide solution. A strong sulphuric acid was added to the solution which was thereafter boiled gently for 90mins, while adding water to keep the volume between 25 and 50ml. The solution was then cooled, neutralized to a faint pink colour, and diluted to the original 100ml volume. The transmittance of the sample was measured against a reagent blank at 400-490 nm, and the result compared with a calibration curve of a standard phosphate solution.

$$\text{Phosphate, phosphorus, mg/l} = \frac{\text{Phosphorus content (mg)} \times 1000}{\text{Sample volume (ml)}}$$

Conductivity determination: A self-contained conductivity bridge was used with a suitable conductance cell of constant of 1 to 2. A standard 0.01M potassium chloride solution and the water sample were placed in two separate pairs of cylinders immersed in a water bath for 30mins to attain a constant temperature of 25^{o}C. Thereafter, the resistances of the standard solution and water sample were measured with the conductivity cell and the specific conductance of the sample calculated.

Determination of cations in the water samples: The standard solution of each element under investigation was aspirated into a nebulizer burner assembly and the corresponding absorbance readings obtained from the digital readout of the Atomic Absorption Spectrophotometer (AAS) at the wavelength of the element under investigation. This was followed by the aspiration of the water sample and the absorbance reading obtained from the digital readout. The concentration of each element in the water sample was obtained by extrapolation from the standard curve. The elements determined included magnesium, calcium, and iron. The instrument used was Solar Unicam 969 AAS.

Microbiological analysis: All media, chemicals and reagents used were prepared according to manufacturer's specifications. The culture media used were sterilized using an autoclave at 121^{o}C for 15 minutes, while Petri-dishes, pipettes and other glass wares were sterilized in a hot air oven at 160^{o}C for 1 hour. The standard plate count method was used for the analysis. In this method, serial doubling dilutions of the respective water samples were made as follows: A row of sterile bottles containing 90ml of peptone water, labeled 1-5, was set up for each water sample. Ten (10ml) volume of each test sample was added to the first bottles on each row containing 90ml of diluents, to give 1:10 dilution. This

was thoroughly mixed, and 10ml volume was transferred from the first bottle on the same row to the second bottle (1:100). This process was carried out up to the fifth bottle and for the respective samples using different sterile pipettes for each sample (1:10; 1:100; 1:1000; 1:10000 and 1:100,000).

Thereafter, 0.1ml of each diluted sample was inoculated in duplicates unto already sterile solidified nutrient and MacConkey agar using a fresh sterile 1ml pipette for each dilution. Using a sterile glass spreader, the inoculum was spread on the surface of the solid agar medium. The inoculated plates were incubated, some at 37°C for 24 hours for the growth of faecal coliforms while some plates were incubated at 22°C for 24 hours for saprophytic coliforms. The viable organisms were counted using the electronic colony counter after incubation. Cultural and morphological characteristics of the isolates were recorded. The colonies were further purified by inoculating them onto fresh sterile nutrient and MacConkey for use in biochemical identification of the species. The Colony Forming Unit (CFU/ml) was calculated for each sample from the lowest concentration that showed viable growth.

Finally microscopy and various biochemical tests including catalase, oxidase, coagulase, indole and fermentation tests using various carbohydrate sugars were carried out for the identification of each isolate.

Data analyses: The data obtained from the analysis of the water samples were compared with WHO standards using ANOVA. The parameters where also correlated against each other to determine their relationship with each other. This was done using (Ms Excel and SPSS software).

RESULTS AND DISCUSSION

Physical conditions of immediate environment of water supplies: Observations revealed the presence of conditions and activities that could affect the quality of the water supplies particularly from the boreholes (table 1). The surroundings of the boreholes were generally dirty with stagnant water at the site. The physical appearance of the immediate environments of the packaged water vendors were generally clean and far from any potential source of water contamination.

Table 1: Physical survey of the environment of water supply studied.

Sample water sources	Cracked plinth	Physical appearance	Standing water at site	Washing activity (within site)	Animal activity (within site)	Proximity to septic tank	Proximity to refuse dump	Proximity to drainage
BHHB	No	Dirty	Yes	Yes	Yes	<40 m	<26 m	<15 m
BHHC	No	Bushy and dirty	Yes	Yes	Yes	>50 m	<16 m	Far
SW	NA	Clean	NA	NA	NA	Far	Far	Far
BW	NA	Clean	NA	NA	NA	Far	Far	Far

Key: NA = Not Applicable; BHH_B - Hall B from Borehole; BHH_C - Hall C borehole; SW - Sachet water from vendors; BW - Bottled water

Physico-chemical characteristics of sampled water: A total of fourteen parameters were assessed in the physico-chemical analysis of the water samples, two of these are qualitative and the rest are quantitative. The pH value ranged from 6.0 to 6.9 (mean: 6.47 ± 0.374) while conductivity was (mean: 47.80 ± 55.65) (table 2) which was within the WHO standard except for the sachet water whose value short up 30μs/cm above the recommended 90μs/cm. The Total Dissolved Solid (TDS) ranged from 13.80-119.0 mg/l with a mean of 45.45 mg/l ± 50.50 and falls within the recommended limits. Though below one–third of the guideline limit, yet the sachet water presented the highest value (119.0mg/l) for TDS, while the lowest was from the borehole at Hall B.

The chloride content ranged from 2.50 to 21.30 mg/l (table 2) which falls within the WHO limits for drinking water. The concentrations of calcium and magnesium ions in the water samples ranged from 0.72 to 2.80mg/l and 0.24mg/l to 1.50mg/l, respectively, while chloride ion content ranged from 2.50 to 21.30mg/l with a mean of 10.86 ± 8.10 mg/l. Generally, the physico-chemical characteristics of the water supplies are within WHO guideline standard except for the slightly acidic pH values of the boreholes and high phosphate ion concentrations (range: 0.34 – 1.46mg/l; mean: 1.05 ± 0.49 mg/l).

Table 2: Physico-chemical characteristics of assessed water samples:

Parameter	SW	BW	BHH_B	BHH_C	WHO
pH	6.90	6.57	6.4	6.0	6.50-8.50
Temperature ^oC	29.0	29.0	27.0	27.0	-
Turbidity NTU	0.30	0.10	2.20	1.80	5.00
Conductivity $\mu s/cm$	130.90	17.60	15.20	27.0	90.00
Appearance	Clear	Clear	Clear	Clear	Clear
Odour	Odourless	Odourless	Odourless	Odourless	Odourless
Colour TCU	0.00	0.00	0.00	0.00	15 TCU
Calcium mg/l	2.00	0.72	2.50	2.80	75.00
Magnesium mg/l	1.20	0.43	1.50	0.24	30.00
Phosphate mg/l	1.46	1.09	1.30	0.34	0.03
Iron mg/l	0.00	0.00	0.03	0.02	0.1
Chloride mg/l	21.30	12.64	2.50	7.00	100.00
Total hardness *mg/l*	3.20	1.15	4.00	3.04	30.00
TDS *mg/l*	119.00	16.00	13.80	25.00	500

Key: TDS = Total Dissolved solids; BHH_C = Hall C Borehole; BHH_B = Hall B Borehole; SW = Sachet Water; BW =Bottled Water

Microbial characteristics: A total of six different colonies were identified: one in satchet water, two in borehole at hall B, and three in borehole at hall C. The total heterotrophic count and colonial characteristics of bacteria isolates from water samples on Nutrient and Mackonkey agar are presented in Table 3. The samples gave heterotrophic plate counts ranging from 1.5×10^5 to 5.4×10^6 CFU/ml. The total coliform count ranged from 3×10^5 to 1.5×10^5CFU/100ml, while the faecal coliform counts were 2×10^4 and 1.0×10^5 CFU/100ml for water from borehole in hall B and C respectively. There was no bacterial presence in the bottled water sample, and no faecal coliform was identified in the sachet water. The six colonies observed were subjected to specific biochemical tests for further differentiation and identification. A total of fourteen tests were carried out, which in consequence helped in identifying the organisms to include *Staphylococcus aureus* for the sachet water, *E. coli* and *Bacillus sp.* for Hall B borehole, *E. coli, Streptococcus faecalis and Staphylococcus aureus* for Hall C borehole (table 4).

The correlation analysis (Table 5) indicated pH being correlated positively with conductivity, temperature, phosphate, chloride, and Total Dissolved Solids (TDS) with r = 0.712, r = 0.825, r = 0.892, r = 0.776 and r = 0.712, respectively; negatively correlated with turbidity r = -0.717. Temperature correlated negatively with iron and turbidity with r = -0.962; $p < 0.05$ and r = -0.985; $p < 0.05$, respectively. There was a perfect positive correlation between conductivity and TDS (r = 1.00; $p> 0.01$). Calcium had a positively good relationship with total hardness (r = 0.873; $p < 0.05$ and turbidity (r = 0.822; $p < 0.05$), but negatively correlated with temperature (r = -0.811; $p < 0.05$). Magnesium related positively (r = 0.805, and r = 0.672) with phosphate and total hardness, respectively.

Figure 1: A section of the water pipe supplying water to Hall B positioned above a sewer.

Figure 2: A refuse dump close to a water borehole on campus.

Table 3: Total Heterotrophic Count and Colonial Characteristics of Bacterial Isolates from Water Samples on Nutrient and Mackonkey Agar

SAMPLE CODE	CFU/ml (NA)	Coliform count/100 ml (MAC)	Faecal coliform/ 100ml (MAC)	Colony type	Size (mm)	Shape	Colour	Edge	Elevation	Consistency/surface
BW	-ve	-ve	-ve	Nil	-ve	-ve	-ve	-ve	-ve	-ve
SW	1.5×10^5	-ve	-ve	SW	0.5mm	round	pinkish	entire	Slightly raised	Dry
BHH_B	1.3×10^5	3×10^5	2×10^4	BHH_B1 BHH_B2	1mm 2.5mm	round irregular	Pinkish creamy white	Smooth rough	Slightly raised flat	Moist Dry & Slimy
BHH_C	5.4×10^6	1.5×10^5	1.0×10^5	BHH_C1 BHH_C2 BHH_C3	1mm pin point 0.5mm	round round	Pinkish pinkish	entire entire	slightly raised raised	Moist Dry Dry
						round	pinkish	smooth	slightly raised	

NA = Nutrient Agar MAC = MacConkey Agar
CFU = Coliform Forming Unit

Table 4: Microscopic And Biochemical Characteristics of Bacteria Isolates in water sampled from various sources in Nigeria.

Colony code	Gram reaction	Catalase	Oxidase	Indole at 44°C	Growth on EMB	Growth on Mackonkey	Coagulase	Citrate	Motility	H_2S	Lactose	Glucose	Sucrose	Mannitol	Probable orgaism
SW	+ve Cocci in clusters	+ve	ND	ND	ND	ND	+ ve	ND	-ve	ND	A	A	A	A	*Staphylococcus. aureus*
BHH_{B1}	-ve rods	-ve	-ve	+ve	+ve metallic sheen	+ve	ND	-ve	+ve	-ve	AG	AG	-ve	AG	*Escherichia coli*
BHH_{B2}	+ve rod chains	+ve	-ve	-ve	-ve	-ve	-ve	+ve	+ve	-ve	A	A	-ve	A	*Bacillus sp.*
BHH_{C1}	-ve rods	-ve	-ve	+ve	+ve metallic sheen	+ve	ND	-ve	+ve	-ve	AG	AG	-ve	AG	*Escherichia coli*
BHH_{C2}	+ve cocci in short chains	-ve	ND	ND	ND	+ve	-ve	ND	ND	ND	A	A	-ve	AG	*Streptococcus faecalis*
BHH_{C3}	+ve cocci in clusters	+ve	ND	ND	ND	ND	+ve	ND	-ve	ND	A	A	A	A	*Staphylococcus. aureus*

Key: +Ve = positive; Ve =Negative; EMB = Eosin Methylene Blue; AG = Acid & Gas production; A = Acid Production ; H_2S = Hydrogen Sulphate; -; ND = Not Done

Table 5: Correlations of measured parameters of water from various sources.

Parameter		PH	Temp	Cd	Ca	Mg	P	Fe	Cl	Total hard	Td	Tb
PH	Pearson Correlation	1	.825	.712	-.523	.516	.892	-.675	.776	-.140	.712	-.717
	Sig. (2-tailed)		.175	.288	.477	.484	.108	.325	.224	.860	.288	.283
	N	4	4	4	4	4	4	4	4	4	4	4
Temperature	Pearson Correlation	.825	1	.549	-.811	-.053	.530	-.962(*)	.871	-.643	.549	-.985(*)
	Sig. (2-tailed)	.175		.451	.189	.947	.470	.038	.129	.357	.451	.015
	N	4	4	4	4	4	4	4	4	4	4	4
Conductivity	Pearson Correlation	.712	.549	1	.040	.327	.473	-.553	.861	.194	1.000(**)	-.490
	Sig. (2-tailed)	.288	.451		.960	.673	.527	.447	.139	.806	.000	.510
	N	4	4	4	4	4	4	4	4	4	4	4
Calcium	Pearson Correlation	-.523	-.811	.040	1	.225	-.362	.744	-.428	.873	.040	.822
	Sig. (2-tailed)	.477	.189	.960		.775	.638	.256	.572	.127	.960	.178
	N	4	4	4	4	4	4	4	4	4	4	4
Magnesium	Pearson Correlation	.516	-.053	.327	.225	1	.805	.283	-.012	.672	.327	.224
	Sig. (2-tailed)	.484	.947	.673	.775		.195	.717	.988	.328	.673	.776
	N	4	4	4	4	4	4	4	4	4	4	4
Phosphate	Pearson Correlation	.892	.530	.473	-.362	.805	1	-.295	.415	.127	.473	-.376
	Sig. (2-tailed)	.108	.470	.527	.638	.195		.705	.585	.873	.527	.624
	N	4	4	4	4	4	4	4	4	4	4	4
Iron	Pearson Correlation	-.675	-.962(*)	-.553	.744	.283	-.295	1	-.900	.707	-.553	.990(*)
	Sig. (2-tailed)	.325	.038	.447	.256	.717	.705		.100	.293	.447	.010
	N	4	4	4	4	4	4	4	4	4	4	4
Chloride	Pearson Correlation	.776	.871	.861	-.428	-.012	.415	-.900	1	-.331	.861	-.859
	Sig. (2-tailed)	.224	.129	.139	.572	.988	.585	.100		.669	.139	.141
	N	4	4	4	4	4	4	4	4	4	4	4
Total hardness	Pearson Correlation	-.140	-.643	.194	.873	.672	.127	.707	-.331	1	.194	.738
	Sig. (2-tailed)	.860	.357	.806	.127	.328	.873	.293	.669		.806	.262
	N	4	4	4	4	4	4	4	4	4	4	4
TDS	Pearson Correlation	.712	.549	1.000(**)	.040	.327	.473	-.553	.861	.194	1	-.490
	Sig. (2-tailed)	.288	.451	.000	.960	.673	.527	.447	.139	.806		.510
	N	4	4	4	4	4	4	4	4	4	4	4
Turbidity	Pearson Correlation	-.717	-.985(*)	-.490	.822	.224	-.376	.990(*)	-.859	.738	-.490	1
	Sig. (2-tailed)	.283	.015	.510	.178	.776	.624	.010	.141	.262	.510	
	N	4	4	4	4	4	4	4	4	4	4	4

Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed)

DISCUSSION

The data obtained from the study shows that among all the samples analyzed, pH values of water in the two boreholes were below the WHO standard (WHO 1996), indicating slight acidic groundwater sources within FUTO. There were variations in temperature of the samples which is attributed to sampling locations; the bottled and sachet water samples were sourced above the ground, while the borehole samples were sourced from underground. The higher the temperature of water, the lower the dissolved oxygen as well as the survival rate of micro-organisms. However there is no guideline value recommended for temperature of drinking water (Howard, 2009).

Conductivity is a numeric measure of the capacity of an aqueous solution to pass electric current. Pure water has a conductivity of 1μs/cm and is not expected to conduct electricity. The low conductivity values of the samples, apart from sachet water obtained in this study, imply that the dissolved salts is minimal. The total dissolved solid for the sachet water is the highest among the samples, thus indicating a direct relationship between conductivity and total dissolved solid (TDS). The main constituents of the total dissolved solids were calcium, magnesium, sodium, bicarbonates, chlorides and sulphates. Total dissolved solids affect the taste of drinking water if present at levels above the WHO recommended 500 mg/l. The TDS in the water samples were within the recommended limits.

According to Freeze and Cherry (1979) classifications, the water samples were soft. The magnesium and calcium concentrations were below WHO recommended limits of 30mg/l and 75mg/l, respectively. Calcium, which is essential for nervous system and for the formation of bones, is commonly present in all water bodies where it usually comes from the leaching of rocks (Agunwamba, 2000). On the other hand Magnesium is usually less abundant in water than calcium, perhaps due to the fact that magnesium is found in the earth's crust in much lower amounts as compared to calcium (Frantisek, 2003). High concentration of magnesium in drinking water gives unpleasant taste to the water (WHO, 1996).

Calcium and magnesium concentrations in water have been linked to outcomes in heart diseases (Lucie, 2004). There is epidemiological evidence to suggest a lower incidence of heart disease in communities with hard water (high calcium and magnesium content). (Anderson & Le Riche, 1971; Anderson *et al.,* 1996; Frantisek, 2003).

All the water samples assessed in this study were observed to have high concentration of phosphate ions. There were, however, no agricultural farms within 300 meters of the borehole to explain the high phosphate levels observed, except that student laundry operations using phosphate-based detergents within 10 meter radius of the boreholes could be a contributory factor. Phosphate in water sources usually indicates contamination by run-off from agricultural farms that depend on inorganic fertilizers (Taha & Younis, 2009). It is one of the major nutrients that stimulate plant growth. Similarly the phosphate concentrations observed in the sachet and bottled water samples could not easily be explained, but one could infer that the sources of water used for their production may have been contaminated either by agricultural run-off, or detergent in waste water. These observations imply that the water from these sources cannot be stored for a long time in open containers as the presence of phosphate in them will encourage the growth of algae and consequently cause adverse changes in the colour, taste and safety conditions of the water (Agunwamba, 2000).

Chloride distribution in the samples used in this study indicated that chloride concentration of the samples lie within the desirable limits recommended for drinking water. A limit of 100 mg/l of chloride has been recommended as maximum permissible limit for drinking water (WHO, 1996). This limit has been laid down primarily based on taste considerations. However, no adverse health effects on humans have been reported from intake of water containing even higher concentrations of chloride (Jim, 1995). Odour and appearance of the water samples were equally found to be unobjectionable and clear. Odour in water is usually caused by volatile substances associated with organic and inorganic chemical materials such as algae and hydrogen, respectively (LaDou, 2004).

An important indicator of water quality is the number of bacteria present in the water. Though it would be difficult to determine the presence of all bacteria in a sample, certain types of microorganisms can serve as indicators of pollution (Kegley & Andrews, 1998). Chief among these are the coliform bacteria which survive better, longer and are easier to detect than other pathogens (Kegley & Andrews, 1998; Agunwamba, 2000).

Among the bacteria isolated in this study was *Escherichia coli. E.coli* is regarded as the most sensitive indicator of faecal pollution. Its presence in the borehole water samples is of a major health

concern and calls for remedial attention. The presence of this pathogen in the samples was an indication of the likely presence of other enteric pathogens (Petridis *et al*., 2002).

Other important pathogens identified in the samples included *Streptococcus faecalis, Staphylococcus aureus* and *Bacillus sp.* These organisms have been variously implicated in gastro-intestinal disorders (Nwidu *et al*., 2008). The bottled water was found to be free from all pathogens indicating a very high microbial quality. Following biochemical tests, *Staphylococeus aureus* was identified in the water sample of Hall C borehole. This confirms the result of an earlier study by Okoli *et al*., (2005), indicating that the boreholes are heavily contaminated with faecal matter. The source of these contaminations could be attributed to the deliberate and indiscriminate littering of human and animal waste in adjoining bushes to the borehole sites. Similarly, Hall B borehole was not free from contamination since it is the oldest in use within the Campus and therefore subject to frequent repairs and maintenance operations which could play a significant part in introducing microbial contaminants into this water source. Furthermore, the presence of enterococcus in the water samples indicates recent faecal contamination. Bearing in mind that this study was conducted during the rainy season, it would be reasonable to assume that these contaminants may have infiltrated into the groundwater sources thereby constituting a serious health threat, since diseases such as diarrhea, meningitis, acute renal failure, urinary tract infections, and haemolytic anaemia have been known to result from consumption of such contaminated waters (NIS, 2007).

Aware that not all sachet water producers use boreholes as their water sources, the sources of water for the production of sachet water are really in question and should be investigated considering the high patronage from majority of Nigerians. The absence of *E. coli* in the sachet water samples analyzed in this study may be, as opined by Geldrich (1996), Adekunle *et al.,* (2004) and Dada (2008).

The location of the boreholes close to potential sources of drinking water pollution (especially refuse dumps) is against the NAFDAC's stipulated minimum distance of 30m (NAFDAC, 2004). A veritable refuse dump in Nigeria, is a collection of such potential contaminants as expired drugs, batteries, waste oils, synthetic detergents, disinfectants, human and animal wastes, among others, all of which could lead to ground water pollution, if found close to these sources of water (Lyle, 2008), as was the case in our study sites.

Activities such as washing of cloths, motorcycles, and cars within the borehole vicinity may have resulted in infiltration of detergents and other chemicals underground, thus polluting the groundwater with complex organic and inorganic chemicals. This may account for the high phosphate levels in the water from the two boreholes studied. Similarly actions such as preparing a landfill less than 48m from the bore hole sites to dispose human waste drawn from septic tanks, as was routinely done by the University management, could impact adversely on the water quality particularly in Hall B, considering the fact that such buried wastes could contaminate the soil and leach into groundwater.

Concerns by student and non student members of FUTO community over the quality of their drinking water sources led to this study. This apprehension stems from the observed closeness of these water supplies to potential sources of water pollution, coupled with the activities that take place around these water sources. Consequently, the University management should endeavour to provide reliable and safe drinking water to members of FUTO community, particularly students' resident within the campus. This will involve adequate treatment through chlorination or ozonization before the water is made available to students and other consumers. In addition, there should be consistent surveillance and monitoring of the borehole water supplies within the university campus for a possible detection of any adverse changes in quality. Finally a hydrological survey of the soil and aquifers to identify mineral characteristics as well as assess areas suitable for future sourcing of drinking water should be conducted.

REFERENCES

Adekunle LV, Sridhar MKC, Ajayi AA, Oluwale PA and Olawuyi JF 2004. An Assessment of Health and Socio-Economic Implications of Sachet in Ibadan, Nigeria: A Public Health Challenge. African Journal of Biomedical Research 7(1): 5-8.

Agunwamba JC 2000. Water Engineering Systems. 2nd edition Enugu: Immaculate Publications Limited, pp: 33-139.

Akinyemi KO, Oyefolu AOB, Salu OB, Adewale OA, Fasure AK 2006. Bacterial Pathogens Associated With Tap And Well Waters In

Lagos, Nigeria. East and Central African Journal of Surgery 11(1): 110-117.

Anderson TW and Le Riche WH 1971. Sudden death from ischemic heart disease in Ontario and its correlation with water wardness and other factors. Canadian Medical Association Journal 105:155-160.

Anderson TW. Le Riche WH, Hewiff D, Neri LC 1996. Magnesium, Water Hardness and Heart Disease. In: Itokawa Y and Durlach J (ed). Magnesium in Health and Disease. John Libbey Press, London. http://www.mgwater.com

APEC 1999. Health Information-Importance of Water and Human Health http://www.freedrinkingwater.xom/water_education/water_health.htm

Cheesbrough M 2000. District Laboratory Practice in Tropical Countries. Part 2. United Kingdom: Cambridge University Press, pp: 130-180.

Chukwu GU 2008. Water Quality Assessment of Boreholes in Umuahia South Local Government Area of Abia State, Nigeria. The Pacific Journal of Science and Technology 9 (2): 592-508. http://www.akanaiuniversity.us/PJST.htm

Cutter D and Miller G 2005. The Role of Public Health Improvements in Health Advances: The Twentieth Century United States. Demography, 42(1): 1-22. http://www.waterandhealth.org/newletter/chlorination.html .

Dada AC 2009. Sachet Water Phenomenon in Nigeria: Assessment of the Potential Health Impacts. African Journal of Microbiology Research 3(1): 015 – 021. http://www.academicjournals.or/ajmr

Deborah C 1996. Water quality assessments. A guide to use of biota, sediments and water in environmental monitoring (2nd ed.). UNESCO/WHO/UNEP, pp: 1-117

http://www.who.int/water_sanstationhealth/resourcesquality/wqachapter2.pdf.

Frantisek K 2003. Health Significance of Drinking Water Calcium and Magnesium. National Institute of Public Health. http://www.midasspring.com/typed%20documents/HealthSignificance.pdf

Freeze RA and Cherry J A 1979. Groundwater. Prentice-Hall Inc: Englewood Cliffs, NJ. http://www.akamauniversity.us/PJST9_2_592.pdf

FUTO Masterplan 1983. The Concarplan-Enplan Group.

Geldrich CE 1996. Microbial Quality of Water Supply In Distribution Systems. In: Aydin A. 2007 (ed). The Microbiological and Physico-chemical Quality of Ground water in West Thrace, Turkey. Polish Journal of Environmental Studies 16(3): 377-383.

Howard P 2009. Water Science for Schools: Water Properties, Water Measurements. http://www.ga.water.usgs.gov/edu/mwater.html

Jim S 1995. Can You Drink It? In: Randy J (2005) (ED). Drinking Water Resources. http://www.cyber-nook.com/water/index.html

Kegley ES and Andrew J 1998. The Chemistry of Water. 2nd edition, California: University Science books, pp: 13-162.

La Dou J 2004. Current Occupational and Environmental Medicine (3rded.). United States of America: Mc Graw-Hill, pp: 241-534.

Lucie L 2004. Clean Drinking Water Is A Powerful Healing Substance. http://www.healthrecipes.com/drinking-water.htm

Lyle SR 2008. Groundwater Contamination. New York State Water Resources Institute, Cornell University. http://www.mqtinfo.org/planningeduc0020.asp

National Agency for Food and Drug Administration (NAFDAC) 2004. NAFDAC story. In: NAFDAC Consumer Safety Bulletin. NAFDAC, Abuja.

Nigerian Industrial Standard (NIS), (2007). Nigerian Standard for Drinking Water Quality. ICS 13.060.20 http://www.unicef.org/nigeria/ng-publication_Nigeria_Standard_for_Drinking_Water_Quality.pdf

Njoku G and Osondu A 2007. New Standard for Drinking Water Quality in Nigeria to Ensure the Safety of Drinking Water and Protect Public Health. http://www.unicef.org/Nigeria/wash-2165.html

Nwidu LL, Oveh B, Okoriye T and Vaikosen NA 2008. Assessment of the Water Quality and Prevalence of Water Borne Diseases in Amassoma, Niger Delta, Nigeria. African Journal of Biotechnology 7 (17) 2993-2997. http://www.academicjournals.org/AJB..

Okoli G, Chidi IV, Njoku N, Chukwuocha AC, Njoku PC, and Njoku JD 2005. Quality Characteristics of Groundwater Utilized By Resident Students of a Nigerian University.

Journal of Applied Sciences 5(6): 1088-1091.

Pat K 1992. Drinking Water Quality and Health-Colorado State University http://www.cdc/gov/nnasd/does/d000001/d000100/d000009/d000009.html

Petridis H, Kidder G and Ogram A 2002. E. coli 0157:H7; A potential Health Concern. IFAS Extension. University of Florida. Gainesville. SL 146

Taha GM and Younis M 2009. Chemical and Bacteriological Evaluation Of Drinking Water: A Study Case In Wadi El Saaida Hamlets In Aswan Governorate, Upper Egypt. Environmental Issues Community-1 USA.

Warren V (Jr) and Mark JH 1998. Water Supply And Pollution Control (6th ed.). California: Addision Wesley Longman Inc, pp: 876.

World Health Organization (WHO) 1996. Guidelines for Drinking Water Quality, 2nd ed. 2: 31-305, Geneva.