Bacteriological and Physicochemical Qualities of Some Borehole Waters in Aba South Metropolis, Abia State Nigeria

Hope C. Okereke[1], Eze S. Ogbonnaya[2], Sunday O. Eze[3]

[1, 2] Department of Microbiology, [3] Department of Chemistry,
Abia State University, Uturu, NIGERIA.

[3] sundayoeze@yahoo.com

ABSTRACT

Microbial qualities of some borehole water in Aba South Metropolis, Abia State were investigated. Thirty borehole water samples were collected in three different zones within the Local Government Area and examined. The physicochemical parameters of the water examined were all within the permissible limit of WHO for drinking water standards. Quantitative examination of microorganisms revealed a total heterotrophic bacterial counts range of 1.0 – 9.0 x 10^2 cfu/ml of water in all the boreholes examined. Total coliform counts ranged from 0.8 – 9.0 x 10^2 cfu/ml of water. Statistical analysis ($P < 0.05$) shows that there was no significant difference in the total heterotrophic bacteria counts, and total coliform counts of water in the three zones. The predominant bacteria isolated from the water and biofilms were Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Enterobacter aerogenes, Bacillus species, Klebsiella pnuemonae, Shigella species and Streptococcus species. The physicochemical and microbial qualities of some of the borehole water show that there are frequent pollution of groundwater by household waste and sewage. The high levels of bacterial counts of water observed in this work show that most of the borehole water is not safe for human consumption. Regular washing of tanks with disinfectants, adequate plumbing systems within public and private buildings and maintenance of public and private environmental sanitation will help to reduce the rate of contamination of ground water and present better portable water for public use.

Keywords: Bacteriological, physicochemical, borehole water, qualities

INTRODUCTION

The access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection. In December 2003 the United Nations General Assembly declared the period from 2005 to 2015 as the International Decade for Action, "Water for Life" (WHO, 2008). Drinking water is not only a liquid for hydration; it interacts with industrial, agricultural, economical, social and cultural components characterizing the human society (Ancuţa, 2012). Drinking water is an important vehicle for spreading microorganisms that interact with human body. Water pollution results in transmission of infectious diseases such as dysentery, cholera, diarrhea, typhoid, shigellosis, salmonellosis, and varieties of other bacteria as well as fungi, viral, and parasitic infection (Nwachukwu and Ume, 2013). The water quality of borehole is generally neglected based on the general belief that it is pure through the natural purification process. Due to the absence of municipal water supply, many of the inhabitants of Aba, in Abia State of Nigeria depend on boreholes for their need.

However, the quality is under intense stress from increasing demand and withdrawal, significant changes in land use pattern, climate change and pollution arising from geology and geochemistry of the environment (Onwughara *et al*., 2013). Consequently, monitoring

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the levels of contamination and the prevention of disease outbreaks is important from both economic and public health perspectives.

The need to assess the microbiological quality of water has become imperative because it has a direct effect on the health of individuals. The recognition of the connection between pollution and the need to protect human health, recreation and fisheries production led to the early development of water quality regulations and monitoring methods (Anyanwu and Okoli, 2012). Pollution of groundwater stems from different sources that include insanitary condition during borehole construction, splashing of runoff into wells left uncovered, flooding at borehole site, leachate from old buried waste pit or latrine into the hole through cracks in aquifer and annular of the hole, closeness of boreholes to septic tanks especially where space is a constraint and as such boreholes are drilled at times at old garbage landfill site formations through which the wastewater is retrieved from the holes (Onwughara *et al*., 2013).

MATERIALS AND METHODS

Water Sampling

Thirty (30) water samples were collected aseptically from different boreholes in Aba South metropolis after agitation of the tanks into sterile duplicate 500ml dark-brown plastic bottles following the guidelines of APHA (1998) and World Health Organization (1998) for sampling from various sources.

Physicochemical Studies of Water Samples

The temperature of the water samples were determined on-site using digital thermometer (Model: sp 701). The pH of the water was determined on-site using pH meter with a censor (probe) (Model: WTW 9802085). Total dissolved solids were determined using Dissolved solid (DO) meter (HACH). The conductivity of the water samples were analyzed on-site using conductivity meter (WTW 885840). Turbidity, total suspended solids, nitrate, nitrite, calcium, sulphate, phosphate, chloride, copper, iron, zinc, and aluminium were determined using spectrophotometer HACH DR/2010.

Microbiological Studies

Water samples were analyzed in terms of total heterotrophic bacterial counts (THBC), total coliforms counts (TCC), faecal coliform counts (FCC), total Pseudomonas count (TPC) and total Salmonella-Shigella counts (TSSC) according to the method described by Dubey and Maheshwari, 2004. Total heterotrophic bacteria counts were detected by membrane filtration on nutrient agar. Total coliforms were detected by membrane filtration on MacConkey agar. Faecal coliforms were detected by membrane filtration on Eosin methylene blue agar according to standard methods (APHA 1998). 100 ml water samples were filtered through membrane filter (0.45 µm pore-size), and were then placed on the selective media and incubated at 37^{o}C for 18-24 h.

For isolation of *Pseudomonas* species, each water samples (100 ml) were filtered by cellulose membrane filter (0.45 µm) and these filters were placed on Pseudomonas base agar and plates were incubated at 27^{o}C for 48 hours (Ayten *et al.,* 2008). For isolation of Vibro species and Salmonella-Shigella species, each water samples (100 ml) were filtered by cellulose membrane filter (0.45 µm) and these filters were placed on Thiosulfate-Citrate-bile-salt (TCBS) agar and Sallmonella-Shigella agar and cultured at 29^{0}C and 37^{0}C respectively. All media used were Oxoid (England) manufactured.

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DETERMINATION OF TOTAL AND FAECAL COLIFOM COUNTS

The total coliform count (TCC cfu/ml) and faecal coliform count (FCC cfu/ml) of each water sample was determined by plating method 1ml of each serially diluted sample were dropped into different sterile MacConkey agar plates and Eosin methylene blue agar in duplicates and incubation at 37^{o}C for 18-24h according to the method described by Uwaezuoke (2006).

RESULTS AND DISCUSSION

All the borehole water samples were colourless, odourless and without objectionable taste, except in 3 tanks with slightly objectionable taste which could be due to the presence of decomposed vegetation and colloidal substances in the water, influenced by the drilling depth to water of the borehole. Generally these characteristics of the water met the WHO standards for drinking water as they recorded turbidity range of 1.3 – 3.0 NTU below 5 NTU standards for drinking water. This result is similar with that reported by Nwachukwu and Ume (2013) in a similar work in Eastern Nigeria.

The results obtained from the physicochemical analysis indicate that the drinking waters are weakly acidic to neutral with a pH range of 6.0 to 7.5 (Table 1). This hydrogen ion concentration level is safe for drinking water except for samples with pH less than 6.5 which is slightly acidic. This result is in agreement with that reported by Adindu *et al*., (2012) who obtained pH range of 6.0 to 6.6 in a similar work at osisioma LGA but at variance with that reported by Agwu *et al.,* (2013) who recorded more acidic pH of 5.26 to 5.80 in Aba Metropolis.

Table 1. The Physicochemical Properties of Borehole Water Samples from All the Sampling Points

Parameter	*SP1*	*SP2*	*SP3*	*WHO*
pH	6.7±0.56	6.8±0.52	6.9±0.32	6.5-8.5
Temperature	26.8±0.29	26.7±0.42	26.8±0.56	32
Conductivity	36.9±15.3	46.1±20.2	40.7±23.9	500
Turbidity	2.1±0.51	2.0±0.48	2.1±0.36	5
TSS	16.2±10.7	14.2±7.88	16.0±6.47	100
TDS	20.2±8.12	25.5±12.1	23.5±14.7	1000

TSS, Total suspended solid; TDS, Total dissolved solid;
SP1- SP3, Sampling points 1-3
(Sampling points 1-3 = East, Mosque, and Main park zones respectively)

The pH of water is very important in that changes in pH values may affect the toxicity of microbial poisons in the water (Okonko *et al.,* 2008). This near neutrality of most of the waters examined in this study poses no health risk to consumers who use the water for cooking, washing, drinking, bathing and for other domestic purposes. Acidic pH observed in most of the samples may be an indication of contamination of the borehole water by household waste and sewage.

The temperature of water in the storage tanks 26.0 to 27.6 ^{o}C observed in all the sampling points lie within the range of <32^{o}C for safe drinking water. The temperature range observed in this work will discourage rate of chemical and biochemical reactions, solubility of gases in the water which could impact negatively on the taste and odour of the water at higher temperatures (Ayoko *et al*., 2007).

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The electrical conductivity in all the water samples ranged from 17.0 to 96.5 µs/cm. It is a function of magnesium, calcium, sodium and sulphates in the water (Adindu *et al*., 2012). The salinity of the ground water observed in this work is in agreement with that reported by Adindu and colleagues (23.0 - 145 µs/cm) in Osisioma and Onwughara *et al.,* (2013) 42.5 to 124.0 µs/cm who conducted similar work in Umuahia North, Abia State; but differs from that reported by Agwu and colleagues (0.20 to 0.73 µs/cm) in a similar work at Aba Metropolis (Agwu *et al.,* 2013). The conductivity level of the samples reveal that there are moderate dissolved salts in the water, and that the water in the sample points are in contact with less inorganic constituents within the aquiferous materials and is within limits approved for safe drinking water.

The total suspended solids (TSS mg/l) in all the samples ranged from 3.5 to 39.8 mg/l. Similar TSS value 15 – 20 mg/l was obtained by Agwu *et al.,* (2013). These values are within limits for safe drinking water. The suspended solids are insoluble solids particles that either float on water or are in suspension causing turbidty (Sammori *et al.,* 2004). Although the value of total suspended solids obtained in this work is within limits, it is however relatively high and may support the growth of bacteria and favour biofilm formation since suspended solids acts as points of attachment for bacteria.

The total dissolved solids (TDS) ranged from 10.3 to 60.3 mg/l in all the water sampled. There were higher differences in TDS in few water samples. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water (WHO, 2011). It was observed in this work that the electrical conductivity of samples increased with increasing TDS results. The TDS values obtained in this work is within the WHO standard of 1000 mg/l for drinking water. The values obtained is in agreement with that (25- 67 mg/l) recorded by Adindu *et al*., (2012) and (28 – 60 mg/l) by Agwu *et al*., (2013). This result indicates low impurities in the drinking water.

Table 2. The Chemical Properties of Borehole Water Samples from All the Sampling Points

Parameter	*SP1*	*SP2*	*SP3*	*WHO*
Nitrate	0.9±0.43	0.9±0.44	1.0±0.44	50
Nitrite	1.5±0.79	1.4±0.84	1.2±0.78	3
Calcium	2.4±0.76	2.2±0.66	2.2±0.64	75
Sulphate	3.7±2.10	3.3±1.91	3.0±1.98	100
Phosphate	0.11±0.04	0.1±0.04	0.1±0.04	2.5
Chloride	9.8±5.31	8.2±6.40	10.2±6.14	250
Copper	0.02±0.01	0.01±0.01	0.01±0.01	2
Iron	0.02±0.01	0.02±0.01	0.02±0.01	0.3
Zinc	0.1±0.04	0.13±0.06	0.1±0.04	3
Aluminium	0.006±0.008	0.008±0.009	0.005±0.00	0.2

SP1- SP3, Sampling points 1-3
(Sampling points 1-3 = East, Mosque, and Main park zones respectively)

The presence of calcium in all the samples with a range value of 0.8 to 3.4 mg/l confirms the fact that the groundwater is soft (Table 2). Adindu and colleagues reported similar calcium

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level of 2.13 – 3.72 mg/l for borehole water in Osisioma local government area. This result disagrees with the report of Onwughara and colleagues, who recorded higher values of calcium ions in Umuahia north local government area (Onwughara *et al.,* 2013).

The Nitrate (NO_3^-) content of the water 0.2 – 1.6 mg/l is considerably low and poses no health risk to consumers. High Nitrate content in the presence of microbial contamination can lead to Methaemoglobinaemia, or blue baby syndrome, in bottle-fed infants (WHO 2011), thus nitrate levels above 100 mg/l is not recommended for use in infants. Nitrate is found naturally in the environment and it is an important plant nutrient. The nitrate level observed in this work show that there is less exposure of the water to inorganic constituents within the aquiferous materials, and this pose no health risk to consumers as the nitrate level is within the standard for drinking water.

The sulphate content of the water range from 1.3 to 7.4 mg/l. Sulphate was below detection levels in 6 samples. This result is in agreement with that (3.0 – 10.0) recorded by Agwu and colleagues (2013). Sulphate occur naturally in numerous minerals, and are used commercially principally in the chemical industry. They are discharged into water in industrial warts. However, their sources in drinking water are mainly by natural mineralization. It is however not surprising that it was below detection levels in few samples as there is a low content of inorganic salts and minerals in contact with the water. This value is within permissible limit of WHO drinking water standard.

The phosphate level of the water samples ranged from 0.03 to 0.13 mg/l. This value is within standard limit of phosphate in drinking water. The value is lower than phosphate content (0.04 – 0.7 mg/l) reported by Adindu *et al.,* (2012). This result may be due to low levels of agricultural activities, mechanization and constructions in the locality of this study.

Chloride concentration of the samples ranged from 2.5 to 24.0 mg/l. Excessive chloride concentrations increase rates of corrosion of metals in the distribution system, depending on the alkalinity of the water. This can lead to increased concentrations of metals in the supply. Chloride is one of the major anions in water. It is generally associated with sodium. High concentration of chloride ions may result in an objectionably salty taste (WHO, 2011). The level of chloride observed in this study is similar to that (11 – 22 mg/l) reported by Adindu *et al*., (2012) and (3.0 to 25 mg/l) by Agwu *et al.,* 2013. The presence of high amounts of chlorides may indicate the contamination of ground water by waste water. The relatively higher amount of chloride above 20 mg/l in some of the borehole samples may be an indication of pollution from domestic waste and sewage.

Heavy metals ranks as major polluting chemicals in both developed and developing countries. The copper (Cu) content of the water was below the WHO acceptable limit of 2.0 mg/l in all the sample zones. The Cu^{2+} ranged from 0.02 to 0.04 mg/l. It was below detection limits in 16 water samples examined. Copper value above 1 mg/l may cause gastrointestinal irritation. The presence of copper in the water may be from pipes or brass taps and chemicals leaching from coatings, taken up from contact with surface during water treatment or distribution.

Iron (Fe) was within the WHO acceptable limit. Iron content ranged from 0.01 to 0.04 mg/l. It was not detected in 4 samples. Iron is a natural constituent of the earth crust. It is present in drinking water as a result of the use of iron coagulants, or the corrosion of steel and cast iron pipes during water distribution (Who, 2011). It is of no health concern at the level found in this water.

The zinc content of the water range from 0.08 to 0.2 mg/l in all the zones. This was within the permissible limit of 3.0 mg/l of WHO.

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Aluminium was not detected in 17 samples. The aluminium content ranged from 0.01 to 0.02 in all the samples where it was detected. Its presence in the water could be from natural aluminium or aluminium salts used in the treatment of the water. The values obtained were within permissible limit of 0.2 mg/l. However these values were not statistically significant. Excess aluminium concentration above 0.2 mg/l leads to undesirable colour and turbidity, and poses potential neurotoxicity risk.

Bacteria are natural components of underground waters. Drinking water supply channels, like borehole water storage tanks, must provide the consumer with potable water of quality standards almost identical to that of the water leaving the treatment plant. However, drinking water generally reaches consumer with lower level of microbiological quality than that achieved at the outlet of the treatment plant (Sadik, 2009). A wide variety of bacteria were observed to survive and grow in the storage tanks. During the period of study, bacteria belonging to the genera *Staphylococcus, Escherichia, Pseudomonas, Enterobacter, Bacillus, Klebsiella, Shigella and Streptococcus* were isolated from water in the storage tanks (Table 4).

The isolation of *Escherichia coli, Streptococcus spp., Enterobacter spp.*, and *Klebsiella species* from most samples shows pollution of the water by human activities. These organisms are capable of surviving in the aquatic environment after introduction. High levels of coliform bacteria were isolated from the borehole storage tanks. The total coliform values 0.8 to 9.0 x 10^2 cfu/ml recorded are on high side considering the WHO standard limit of 0 for drinking water. Most of the samples had more than three coliform organisms present in them. In a similar work conducted in Aba Metropolis, *Bacillus subtilis, Escherichia coli, Streptococcus faecalis, Staphylococcus species, Streptococcus species* and *Shigella species* were isolated from borehole waters, and total coliform levels 1.5 to 3.9 x 10^2 cfu/ml was recorded (Agwu *et al.,* 2013). Anyanwu and Okoli (2012) isolated *Enterobacter* species, *Esherichia coli,* and *Klebsiella* species from borehole water, and recorded higher total coliform levels 0.92 – 1.41 x 10^4 in a similar work in Nsukka, Southern Nigeria. Nwachukwu and Ume (2013) isolated *Pseudomonas aeruginosa, Escherichia coli, Klebsiella* species, *Enterobacter aerogenes, Proteus* species, *Staphylococcus* species, *Aeromonas* species, *Vibrio cholera* and recorded a mean total coliform counts of 3.0×10^3. Faecal coliform count (FCC) ranged from 1.6 to 6.3 x 10^2 cfu/ml in all the zones examined (Table 3).

Table 3. Mean Microbial Counts of Water Samples from Aba South Metropolis

Parameter (cfu x 10^2)	*Sample Zones*		
	East	*Mosque*	*Main Park*
THBC	3.90	3.93	3.91
TCC	1.47	3.28	1.53
FCC	1.32	0.92	1.38
TPC	0.70	0.47	0.50
TSSC	1.05	0.70	0.82
TVC	0.0	0.0	0.0

THBC: Total Heterotrophic Bacterial Count; TCC: Total Coliforms Count; FCC: Feacal Coliforms Count; TPC: Total Pseudomonas Count; TSSC: Total Salmonella Shigella Count; TVC: Total Vibrio Count; THFC: Total Heterotrophic Fungal Count; BS: Biofilm Sample

The presence of faecal coliform like *E. coli* and *Klebsiella* in some samples is an indication of recent pollution by sewage. The high coliforms level recorded in this work could be attributed to poor refuse and sewage disposal system, mainly open air disposal method practiced in this area. Groundwater may have been contaminated through leaching from surface dumps into the water during rainfall, as well as by household sewage and domestic waste. Coliforms should be absent immediately after disinfection. The presence of these organisms may indicate inadequate water treatment or fresh contamination. Coliforms in distribution systems and stored water supplies can reveal re-growth and possible biofilm formation or contamination through ingress of foreign material, including soil or plants.

These waterborne bacterial pathogens are causative agents of many human diseases and their presence poses a potential threat to the human health. *Klebsiella species* poses health risk to patients with impaired immune systems, such as the elderly or very young, patients with burns or excessive wounds, and those undergoing immunosuppressive therapy. Pathogenic *E. coli* O157:H7 and *E. coli* O111, cause diarrhea and haemorrhagic colitis which usually develop into potentially fatal haemolytic uraemic syndrome in children, and characterized by acute renal failure and haemolytic anaemia (WHO, 2011).

Although *Staphylococcus aureus* is a common member of the human micro flora, it can produce disease through two different mechanisms. One is based on the ability of the organisms to multiply and spread widely in tissues, and the other is based on the ability of the organisms to produce extracellular polysaccharides and toxins. Multiplication in tissues can result in manifestations such as boils, skin sepsis, post-operative wound infections, enteric infections, septicaemia, endocarditis, osteomyelitis and pneumonia (WHO, 2011).

Gastrointestinal disease (enterocolitis or food poisoning) is caused by a heat-stable staphylococcal enterotoxin and characterized by projectile vomiting, diarrhoea, fever, abdominal cramps, electrolyte imbalance and loss of fluids. *Pseudomonas aeruginosa* is a recognized cause of hospital-acquired infections with potentially serious complications and has been isolated from a range of moist environments such as sinks, water baths, hot water systems, showers and pools (De Victorica and Galván, 2001). *Pseudomonas* count (TPC) observed in this work ranged from 4.7 to 7.0 x 10^2 cfu/ml, and was isolated in only 5 samples with means of 0.2 – 1.6 in all the samples. Although this value is relatively low; however, the presence of *P. aeruginosa* in drinking water in high volumes may be associated with complaints about taste, odour and turbidity.

Table 4. Frequency of Isolation of Bacteria from the Borehole Water in Aba South Metropolis

Organism	*Water*	*% Occurrence*
Staphylococcus aureus	6	20.0
Escherichia coli	7	23.3
Pseudomonas aeruginosa	3	10.0
Enterobacter aerogenes	5	16.7
Bacillus species	6	20.0
Klebsiella pnuemonae	5	16.7
Shigella species	5	16.7
Streptococcus species	6	20.0

Number of samples N = 30

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The total *Shigella* count (TSC) ranged from 1.9 – 7.0 x 10^2 cfu/ml isolated in few samples. A number of large waterborne outbreaks of shigellosis have been recorded. As the organisms are not particularly stable in water environments, their presence in drinking water indicates recent human faecal pollution (Alamanos *et al*., 2000). *Shigella* species are enteric pathogens predominantly transmitted by the faecal-oral route through person-to-person contact, contaminated food and water. Flies have also been identified as a transmission vector from contaminated faecal waste. The presence of *Shigella* species in high values observed in most samples in this work predisposes consumers to serious intestinal diseases, including bacillary dysentery. *Vibrio* species was not isolated in all the water samples.

CONCLUSION

Regular washing of tanks with disinfectants, and maintenance of public and private environmental sanitation will help to reduce the rate of contamination of ground water and formation of biofilms in storage materials. Prevention of inadequate plumbing systems within public and private buildings arising from poor design, incorrect installation, alterations and inadequate maintenance will aid in reducing contamination of drinking water. Outbreaks of gastrointestinal disease can occur through faecal contamination of drinking-water within buildings arising from deficiencies in roof storage tanks and cross-connections with wastewater pipes, for example. Plumbing materials, pipes, fittings and coatings can result in elevated heavy metal (e.g. lead) concentrations in drinking-water, and inappropriate materials can be conducive to bacterial growth. Potential adverse health effects may not be confined to the individual building. Exposure of other consumers to contaminants is possible through contamination of the local public distribution system, beyond the particular building, through cross-contamination of drinking-water and backflow.

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