Bacteriological Quality Assessment of Borehole Water in Ogbaru Communities, Anambra State, Nigeria

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Abstract Ogbaru Communities are usually submerged by intense flood during the rainy season, but such flood recedes during the dry season. This natural occurrence makes the quality of the borehole water in the area questionable. The total bacterial, total coliform, faecal coliform and *Vibrio cholerae* counts of samples from fifteen boreholes in the communities were determined during both seasons using standard analytical methods. The values were 100-270 cfu/100ml; 10-42cfu/100ml; 0-28 cfu/100ml and 0-13cfu/100ml for total bacterial, total coliform, faecal coliform and *Vibrio cholerae* counts respectively during the dry season and 130-450 cfu/100ml; 25-86 cfu/100ml; 0-75 cfu/100ml and 0-18 cfu/100ml for the total bacterial, total coliform, faecal coliform and *Vibrio cholerae* counts respectively during the rainy season. *Salmonella typhi* (53.3%), *Enterobacter aerogenes* (53.3%), *Pseudomonas aeruginosa* (46.7%), *Proteus vulgaris* (46.7%), *klebsiella variicola* (26.7%), *Escherichia coli* (26.7%), *Staphylococcus aureus* (13.3%) and *Vibrio cholerae* (33.3%) were isolated during the dry season while *S. typhi* (60.0%), *E. aerogenes* (60.0%), *P. aeruginosa* (53.3%), *P. vulgaris* (46.7%), *K. variicola* (33.3%), *E. coli* (26.7%), *S. aureus* (13.3%), *V. cholerae* (46.7%) and *Providencia sneebia* (6.7%) were recovered during the rainy season. *S. typhi* occurred most frequently during both seasons. Total bacterial, total coliform and *Vibrio cholerae* counts were significant at 5% significance level using t-distribution. The boreholes analysed were polluted by bacteria and need adequate treatment such as sand filtration, chlorination and boiling before drinking to avert a public health hazard.

Keywords Bacteriological, Quality Assessment, Boreholes, Water, Ogbaru Communities, Nigeria

1. Introduction

Ground water is an increasingly important resource all over the world. It is the subsurface water that occurs

beneath the water table in soils and geological formation that are usually saturated. It supports drinking water supplies, livestock needs, irrigation, industrial and many commercial activities. Ground water is generally less susceptible to contamination and pollution when compared to surface water bodies [1]. Ground water pollution occurs widely from diverse sources such as water disposal facilities, industrial pollution, agricultural practices, atmosphere fallout, clearing of vegetation, over abstraction of ground water and excavation below the water table [2]. It not only affects water quality but also threatens human health, economic development and social prosperity [3]. Microbiological health risks are associated with many aspects of water use, including drinking water in developing countries, irrigation, reuse of treated wastewater and recreational water use [4]. It has been reported that drinking water supplies have a long history of association with a wide spectrum of microbial infections. Some microorganisms are native or adapted to saturated sediment and rock and are present in significant numbers in most water supply aquifers and even deep geoclinical formations. Biofilm formation sometimes encourages the growth of bacteria in wells and groundwater. Events which occur between and within bacteria and plankton populations also affect water quality [5].

A lot of bacterial, viral and protozoan pathogens are causing waterborne infections. Some are primarily the enteric bacterial pathogens such as *Vibrio cholerae*, *Salmonella spp*, *Shigella spp* and recognized pathogens from faecal sources such as *E. coli* [6]. Several new bacterial pathogens such as *legionella spp*, *Pseudomonas aeruginosa* and *Mycobacterium spp* are found in drinking water usually in low numbers and grow within the distribution system biofilms [7]. The evaluation of potable water supplies for coliform bacteria is important in determining the sanitary quality of drinking water. High coliform counts indicate a contaminated source, inadequate treatment or post treatment deficiencies. Many developing countries suffer from either chronic shortages of fresh water or the readily accessible water resources are heavily

polluted [8]. Ogbaru communities are located along the coast of River Niger in Anambra State of Nigeria. Agriculture including fish farming is the major occupation of the inhabitants of the area. The communities are usually submerged by flood during the rainy season. The flood recedes during the dry season leaving behind organic and inorganic materials including bacteria. It is therefore important that the bacteriological quality of water from the boreholes sited in the communities should be assessed to determine their potability during the dry and rainy seasons, which was the aim of this work.

2. Materials and Methods

2.1. Samples Collection

Samples for analysis were collected from fifteen boreholes located in Ogbaru communities during the dry (January – March 2018) and rainy (May – July 2018) seasons. The samples were collected from each of the boreholes in triplicates. The boreholes were sited at the following locations within Ogbaru communities.

- a) Odunze Street Atani
- b) Abiribose Atani
- c) Ujadimegwu Atani
- d) Ochuiche
- e) Akili-Ozizor
- f) Cathedral Road Atani
- g) Umundu Ohita
- h) Odekpe
- i) Iyiowa Odekpe
- j) Okoti Odekpe
- k) Okpotuno Odekpe
- l) Atani Road Okoti
- m) Okpoko
- n) Imeogbe
- o) Anibueze Odekpe

The samples were collected in sterile one -litre plastic containers with screw caps and legibly labeled. The containers were transported to the laboratory in an ice box and the samples were analysed within 24 hours of collection. All the plastic containers were sterilized with 70% ethanol and initially rinsed with sterile distilled water and thereafter with the water samples from the boreholes.

2.2. Samples Preparation

The membrane filtration apparatus was used. It was placed in position and the vacuum pump connected. The funnel was removed and a sterile smooth-tipped forceps was used to collect the membrane filter paper which was thereafter placed on the porous disc of the filter base. The sterile funnel was after that carefully and securely replaced on the filter base. The water sample was mixed thoroughly by inverting the container for twenty five times. One hundred milliliters of the water sample were poured into

the funnel and slowly filtered through the membrane filter paper which was then carefully removed with a sterile smooth-tipped forceps and placed with the grid side uppermost, on a selective culture medium contained in a Petri dish, ensuring that there were no air bubbles trapped under the membrane filter paper.

2.3. Bacteriological Analysis

The total bacterial, coliform, faecal coliform and *Vibrio cholerae* counts were determined as done by Onuorah *et al.* [9].

2.3.1. Total Bacterial Count

The membrane filter paper was carefully placed with the grid side uppermost on a sterile nutrient agar plate. Duplicate plates were prepared and incubated in an inverted position at 35°C for 24 hours after which the bacterial colonies that developed were counted. Each colony was subcultured and stored on a nutrient agar slant for characterization and identification.

2.3.2. Total Coliform Count

The membrane filter paper was aseptically placed with the grid side uppermost on MacConkey's agar plate. Duplicate plates were prepared and incubated at 28°C for 48 hours after which the coliform bacteria that developed were counted and each colony subcultured and stored on a sterile nutrient agar slant for further studies.

2.3.3. Faecal Coliform Count

The membrane filter paper was carefully placed with the grid side uppermost on Eosin methylene blue plate. Duplicate plates were prepared and incubation was carried out in an inverted position at 28°C for 48 hours after which the faecal coliform bacteria that grew were counted, subcultured and stored on nutrient agar slants for characterization and identification.

2.3.4. *Vibrio Cholerae* Count

The method described by Onuorah *et al.* [9] was used. The membrane filter paper was aseptically placed with the grid side uppermost on Thiosulphate Citrate Bile Sucrose agar plate. Incubation was in an inverted position at 28°C for 48 hours after which the colonies that developed were counted, subcultured and later stored on sterile nutrient agar slants for further studies.

2.4. Characterization and Identification of the Bacterial Isolates

The isolates were characterized on the basis of their morphological, biochemical and molecular characteristics. Gram staining, catalase, coagulase, motility, oxidase, citrate utilization, indole, vogesproskauer, methyl red, urease and sugar (glucose, lactose and sucrose) fermentation tests were carried out as done by Onuorah *et al.* [9]. Molecular characterization was done using the 16S rDNA sequencing. The isolates were identified as done by

Cheesbrough [10].

2.5. Statistical Analysis

Pearson correlation coefficient was used to determine the relationship between the data obtained for both seasons while the critical value was determined using the t-distribution table.

3. Results

The bacterial counts of the borehole water investigated

in Ogbaru communities during the dry season are presented in Table 1. The total bacterial counts were 100-270 cfu/100ml; total coliforms, 10-42 cfu/100ml; faecal coliforms, 0-28 cfu/100ml and *Vibrio cholerae*, 0-13 cfu/100ml.

The bacterial counts of the borehole water investigated in Ogbaru communities during the rainy season are shown in Table 2. The total bacterial counts ranged from 130 to 450 cfu/100ml; total coliforms, 25 to 86 cfu/100ml; faecal coliforms, 0 to 75 cfu/100ml and *Vibrio cholerae*, 0-18 cfu/100ml.

Table 1. Bacterial counts of the borehole water investigated in Ogbaru communities during the dry season

Borehole location	Total bacterial counts (cfu/100ml)	Total coliform counts(cfu/100ml)	Faecal coliform counts(cfu/100ml)	<i>Vibrio cholerae</i> counts(cfu/100ml)
Odunze Street Atani	150	30	0	4
Abiribose Atani	120	20	0	0
Ujadimegwu Atani	220	42	0	6
Ochuche	140	18	18	0
Akili-Ozizor	100	21	0	0
Cathedral Road Atani	110	19	0	0
Umundu Ohita	100	18	0	0
Odekpe	140	13	0	10
Iyiowa Odekpe	120	17	17	0
Okoti Odekpe	140	39	0	0
Okpotuno Odekpe	150	10	0	0
Atani Road Okoti	120	12	12	9
Okpoko	270	28	28	0
Imeogbe	160	25	0	0
Anibueze Odekpe	146	15	0	13
WHO Standard	100	10	0	0

Table 2. Bacterial counts of the borehole water investigated in Ogbaru communities during the rainy season.

Borehole location	Total bacterial counts (cfu/100ml)	Total coliform counts (cfu/100ml)	Faecal coliform counts (cfu/100ml)	<i>Vibrio cholerae</i> counts(cfu/100ml)
Odunze Street Atani	170	48	0	12
Abiribose Atani	140	25	0	5
Ujadimegwu Atani	280	85	0	10
Ochuche	190	45	45	0
Akili-Ozizor	146	48	0	0
Cathedral Road Atani	150	56	0	0
Umundu Ohita	130	36	0	8
Odekpe	161	48	0	18
Iyiowa Odekpe	150	58	58	0
Okoti Odekpe	180	71	0	6
Okpotuno Odekpe	170	40	0	0
Atani Road Okoti	130	58	58	15
Okpoko	450	75	75	0
Imeogbe	183	86	0	0
Anibueze Odekpe	181	60	0	0
WHO Standard	100	10	0	0

The morphological and biochemical characteristics of the bacterial isolates in the borehole water investigated in Ogbaru communities during the dry and rainy seasons are presented in Table 3. The isolates were *Salmonella typhi*, *Enterobacter aerogenes*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, *Klebsiella variicola*, *Escherichia coli*, *Staphylococcus aureus*, *Vibrio cholerae* and *Providencia sneebia*.

Table 3. Morphological and biochemical characteristics of the bacterial isolates in the borehole water investigated in Ogbaru communities during the day and rainy seasons.

Isolates	Gram Staining	Form	Catalase test	Coagulase test	Motility test	Oxidase test	Citrate utilization test	Indole test	Voges proskauer test	Methyl red test	Urease test	Glucose Utilization test	Lactose Utilization test	Sucrose utilization test	Identity
1	-	Rod	+	-	+	-	-	-	-	+	-	+	-	-	<i>Salmonella typhi</i>
2	-	Rod	+	-	+	-	+	-	+	+	+	+	-	+	<i>Enterobacter aerogenes</i>
3	-	Rod	+	-	+	+	-	-	+	-	-	-	-	-	<i>Pseudomonas aeruginosa</i>
4	-	Rod	+	-	+	-	-	+	-	+	+	+	-	-	<i>Proteus vulgaris</i>
5	-	Rod	+	-	+	-	-	-	+	-	+	+	+	+	<i>Klebsiella variicola</i>
6	-	Rod	+	-	+	-	+	+	+	-	-	+	+	+	<i>Escherichia coli</i>
7	+	Coccus	+	+	+	-	-	-	-	-	-	+	+	+	<i>Staphylococcus aureus</i>
8	-	Curved Rod	+	-	+	+	-	+	+	-	-	-	-	+	<i>Vibrio cholerae</i>
9	-	Rod	+	-	+	-	+	+	-	+	+	-	-	-	<i>Providencia sneebia</i>

+ = Positive test

= Negative test

Table 4 showed the occurrence of the bacterial isolates in the borehole water investigated in Ogbaru communities during the dry season. *Salmonella typhi* and *Enterobacter aerogenes* were each detected in eight (53.3%); *Pseudomonas aeruginosa* and *Proteus vulgaris* each in

seven (46.7%); *Klebsiella variicola* and *Escherichia coli* in four (26.7%); *Staphylococcus aureus* in two (13.3%) and *Vibrio cholerae* in five (33.3%) of the boreholes investigated.

Table 4. Occurrence of the bacterial isolates in the borehole water investigated in Ogbaru communities during the dry season.

Borehole location	<i>Salmonella typhi</i>	<i>Enterobacter aerogenes</i>	<i>Pseudomonas aeruginosa</i>	<i>Proteus vulgaris</i>	<i>Klebsiella variicola</i>	<i>E.coli</i>	<i>Staph aureus</i>	<i>Vibrio cholerae</i>
Odunze Street Atani	-	+	+	+	+	-	-	+
Abiribose Atani	-	-	+	-	+	-	-	-
Ujadimegwu Atani	-	+	+	-	-	-	-	+
Ochuche	-	-	-	+	-	+	-	-
Akili-Ozior	+	+	-	-	-	-	+	-
Cathedral Road Atani	+	+	-	+	-	-	-	-
Umundu Ohita	+	+	-	-	-	-	-	-
Odekpe	-	-	+	+	+	-	-	+
Iyiowa Odekpe	-	-	+	-	-	+	+	-
Okoti Odekpe	+	+	-	-	-	-	-	-
Okpotuno Odekpe	+	+	+	+	-	-	-	-
Atani Road Okoti	+	-	-	-	-	+	-	+
Okpoko	+	-	-	+	-	+	-	-
Imeogbe	+	-	+	-	+	-	-	-
Anibueze Odekpe	-	+	-	+	-	-	-	+

Table 5 showed the occurrence of the bacterial isolates in the borehole water investigated in Ogbaru communities during the rainy season. *Salmonella typhi* and *Enterobacter aerogenes* were each isolated from nine (60.0%), *Pseudomonas aeruginosa* from eight (53.3%), *Proteus vulgaris* from seven (46.7%), *klebsiella variicola* from five (33.3%), *Escherichia coli* from four (26.7%), *Staphylococcus aureus* from two (13.3%), *Vibrio cholerae* from seven (46.7%) and *Providencia sneebia* from one (6.7%) of the boreholes studied.

Table 5. Occurrence of the bacterial isolates in the borehole water investigated in Ogbaru communities during the rainy season.

Borehole location	<i>Salmonella typhi</i>	<i>Enterobacter aerogenes</i>	<i>Pseudomonas aeruginosa</i>	<i>Proteus vulgaris</i>	<i>Klebsiella variicola</i>	<i>E.coli</i>	<i>Staph aureus</i>	<i>Vibrio cholerae</i>	<i>Providencia sneebia</i>
Odunze Street Atani	-	+	-	+	-	-	-	+	-
Abiribose Atani	+	-	+	+	+	-	-	+	-
Ujadimegwu Atani	-	+	+	-	-	-	-	+	-
Ochuche	+	-	-	+	-	+	-	-	-
Akili-Ozizor	+	+	+	-	-	-	+	-	+
Cathedral Road Atani	+	+	-	-	-	-	-	-	-
Umundu Ohita	+	+	+	-	-	-	-	+	-
Odekpe	-	-	+	+	+	-	-	+	-
Iyiowa Odekpe	-	-	+	+	-	+	+	-	-
Okoti Odekpe	+	+	-	-	-	-	-	+	-
Okpotuno Odekpe	-	+	+	+	+	-	-	-	-
Atani Road Okoti	+	-	-	-	-	+	-	+	-
Okpoko	+	-	-	+	-	+	-	-	-
Imeogbe	-	+	+	-	+	-	-	-	-
Anibueze Odekpe	+	+	-	-	+	-	-	-	-

The frequency of occurrence of the bacterial isolates in the borehole water investigated in Ogbaru communities during the dry season is shown in Table 6. *Salmonella typhi* had the highest frequency of occurrence of 31.3% while *Staphylococcus aureus* had the lowest frequency of occurrence of 0.8%.

Table 6. Frequency of occurrence of the bacterial isolates in the borehole water investigated in Ogbaru communities during the dry season.

Bacterial isolates	Number of colonies isolated	Frequency of occurrence (%)
<i>Salmonella typhi</i>	685	31.3
<i>Enterobacter aerogenes</i>	174	12.5
<i>Pseudomonas aeruginosa</i>	624	24.0
<i>Proteus vulgaris</i>	446	20.4
<i>Klebsiella variicola</i>	78	4.7
<i>Escherichia coli</i>	75	4.3
<i>Staphylococcus aureus</i>	62	0.8
<i>Vibrio cholerae</i>	42	1.9
Total	2186	100

Table 7. Frequency of occurrence of the bacterial isolates the borehole water investigated in Ogbaru communities the rainy season.

Bacterial isolates	Number of colonies isolated	Frequency of occurrence (%)
<i>Salmonella typhi</i>	736	26.2
<i>Enterobacte raerogenes</i>	454	16.2
<i>Pseudomonas aeruginosa</i>	578	20.6
<i>Proteus vulgaris</i>	544	19.4
<i>Klebsiella variicola</i>	149	5.3
<i>Escherichia coli</i>	236	8.4
<i>Staphylococcus aureus</i>	25	0.9
<i>Vibrio cholerae</i>	74	2.6
<i>Providencia sneebia</i>	15	0.5
Total	2811	100

The frequency of occurrence of the bacterial isolates in the borehole water investigated in Ogbaru communities during the rainy season is presented in Table 7. *Salmonella typhi* also had the highest frequency of occurrence of 26.2% while *Providencia sneebia* had the least frequency of occurrence of 0.5%.

4. Discussion

The total bacterial counts of the borehole water were 100-270 cfu/100ml and 130-450 cfu/100ml during the dry and rainy seasons respectively (Tables 1 and 2). Two (13.3%) of the boreholes examined complied with the World Health Organization permissible limit of 100ml cfu/100ml during the dry season while none of them met the standard during the rainy season. This result agreed with the work of Onuorah *et al.* [9] that reported the total bacterial counts of 107-261 and 119-275 cfu/100ml for the public hand-pump borehole water they studied in Onueke, Ezza South Local Government Area of Ebonyi State, Nigeria during the dry and wet seasons respectively.

The total coliforms isolated from the samples ranged from 10 to 42 cfu/100ml during the dry season and 25 to 86 cfu/100ml during the rainy season (Tables 1 and 2). One (6.7%) of the boreholes analysed complied with the WHO

standard of total coliforms of 10 cfu/100ml for potable water during the dry season while all the boreholes did not meet the standard during the rainy season. Similar results were obtained by Mustafa *et al.* [11] and Ngele *et al.* [12] who reported total coliform counts of 6×10^3 – 145×10^3 MPN/100ml and 280-540 MPN/100ml respectively for the borehole water samples they analysed.

The faecal coliforms ranged from 0 to 28 cfu/100ml and 0 to 75 cfu/100ml during the dry and rainy seasons respectively (Tables 1 and 2). Eleven (73.3%) of the boreholes sampled met the WHO standard of faecal coliforms of 0cfu/100ml for drinking water during both seasons. However, Onuorah *et al.* [9]; Abdullahi *et al.* [13]; Olajuba and Ogunika [14] and Nkamare *et al.* [15] reported the absence of faecal coliforms in the borehole water samples they examined in Onueke, Ebonyi State; the Science Department and Staff school of Nigeri State Polytechnic Zungeru Campus; AkungbaAkoko, Ondo State and Okutukutu, Bayelsa State respectively, all Nigeria.

The *Vibrio cholerae* counts of the boreholes were 0-13cfu/100ml and 0-18cfu/100ml during the dry and rainy seasons respectively (Tables 1 and 2). Ten (66.7%) of the boreholes studied complied with the WHO standard of *Vibriocholerae* of 0cfu/100ml for potable water during the dry season while eight (53.3%) met the standard during the

rainy season. However, Onuorah *et al.* [9] reported that 86.7% of the boreholes they analysed in Onueke, Ebonyi State, Nigeria during the dry season complied with the WHO standard while 66.7% met the standard during the wet season.

The isolates from the boreholes during both seasons were *Salmonella typhi*, *Enterobacter aerogenes*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, *Klebsiella variicola*, *Escherichia coli*, *Staphylococcus aureus*, *Vibrio cholerae* and *Providencia sneebia*. (Table 3) Onuorah *et al.* [9] isolated *Klebsiella oxytoca*, *Proteus vulgaris*, *Vibrio cholerae* and *Pseudomonas aeruginosa* from the borehole water they examined in Onueke, Ebonyi State, Nigeria while Abdullahiet *al.* [13] isolated *E.coli*, *Klebsiella* and *Salmonella* from the Staff school, Science Department and female hostel boreholes in Niger State Polytechnic, Zungeru campus.

Ngeleet *al.* [12] isolated *Escherichia coli*, *Proteus sp.*, *Pseudomonas aeruginosa* and *Enterobacter aerogenes* in selected borehole samples in Amike-Aba, Abakaliki while Olujuba and Ogunika [14] isolated *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Salmonella paratyphi* and *Proteus vulgaris* from borehole samples from Akungba-Akoko, Ondo State, Nigeria. In addition, Josiah *et al.* [16] isolated *Staphylococcus aureus*, *Salmonella sp.*, *Escherichia coli* and *Pseudomonas aeruginosa* from drinking water and water used for domestic purposes in Okada Town, Edo State, Nigeria.

Ibe and Okpalenye [17] detected *Escherichia coli*, *Klebsiella sp.*, *Enterobacter sp.*, *Pseudomonas sp.* and *Staphylococcus aureus* in the borehole water they analysed in Uli, Anambra State, Nigeria while Uhuet *al.* [18] isolated *Escherichia coli*, *Klebsiella aerogenes* and *Salmonella sp.* from the borehole water in Peri-Urban areas of Abakaliki, Ebonyi State, Nigeria. Ukpong and Okon [19] also analysed public and private borehole water supply sources in Uruan Local Government Area of Akwa Ibom State and isolated *Escherichia coli*, *Proteus vulgaris*, *Klebsiella aerogenes* and *Staphylococcus aureus* in the samples.

The isolates were detected in more of the boreholes studied during the rainy than the dry season. (Tables 4 and 5). This may be attributed to the prevailing environmental conditions during the rainy season which must have been more favourable to the isolates and flood water that must have introduced some organic and inorganic matters including bacteria into the boreholes. *Salmonella typhi* was the predominant bacterium isolated from the boreholes during both seasons (Tables 6 and 7) indicating that the environmental conditions were most favourable to the organism than the other isolates. However, *Pseudomonas aeruginosa* and *Escherichia coli* were the predominant bacteria isolated by Onuorah *et al.* [9] and Uhuet *al.* [18] respectively from the borehole water samples they analysed. The variation showed that any organism

favoured most by the available nutrients and environmental conditions will predominate over others.

Salmonella typhi which is chiefly spread through contaminated water is a gram negative bacterium and a strong pathogen that causes systemic infections and typhoid fever in humans. It is usually found in both warm and cold-blooded animals and has caused many deaths in developing countries with poor sanitation. Symptoms of the disease caused by this bacterium include a sudden onset of high fever, headache, nausea, loss of appetite, diarrhea and enlargement of the spleen [20].

Enterobacter aerogenes is a gram negative, rod-shaped bacterium and an opportunistic pathogen that is ubiquitous in nature. They are numerous in faecal materials and that results in their wide distribution in soil, water, sewage, plants and humans. The bacterium has been reported to cause a range of health conditions including meningitis, bacteremia, pneumonia, urinary tract infections and eye and skin infections [21].

Pseudomonas aeruginosa is a gram negative, rod shaped asporogenous bacterium and an opportunistic nosocomial pathogen of immune compromised persons which is found in the soil, water, plants, the skin on moist parts of a healthy human body and most man-made environments. The bacterium is associated with urinary tract infections, wound infections, blood infections, dermatitis, osteomyelitis and community acquired pneumonias [22]. *Proteus vulgaris* is a gram negative, rod shaped bacterium that can infect the lungs or wounds and frequently causes urinary tract infections, severe abscesses and nosocomial infections [23]. It inhabits the intestinal tracts of humans and animals and can be found in soil, water and faecal matter.

Klebsiella variicola is a gram negative, non-motile, rod shaped bacterium and an opportunistic pathogen that has been isolated from cows suffering from bovine mastitis [24]. The bacterium has been associated with diseases in humans and cattle. *Escherichia coli* is a gram negative, rod-shaped bacterium that resides in the intestinal tract of humans and animals and is the best indicator of faecal pollution of water [25]. Its presence is an indication of faecal contamination of water which may be of human or animal origin as well as the presence of pathogenic bacteria, viruses and protozoans [26]. The bacterium has been reported to cause diarrheal diseases, urethrocystitis, prostatitis and pyelonephritis.

Staphylococcus aureus is a gram positive coccus that is frequently found in the nose, respiratory tract and on the skin of humans and has been reported to cause a variety of illness such as pimples, impetigo, boils, pneumonia, abscesses, meningitis, endocarditis, sepsis and osteomyelitis [27]. *Vibrio cholerae* is a comma shaped, gram negative bacterium and a facultative human pathogen that is usually isolated from the estuarine and aquatic environments and is the causative agent of cholera which is responsible for significant mortality and economic damage particularly in

the underdeveloped countries [28].

Providencia sneebia is a gram negative bacterium that is associated with humans, many other vertebrates and invertebrates including dogs and insects such as *Drosophila* flies. This organism has been reported to be pathogenic [29]. Higher bacterial counts were obtained during the rainy than the dry season which may be attributed to flood which must have emptied its contents including nutrients and bacteria into the boreholes assessed. This result conformed to the work of Obiri-Danso *et al.* [30] that reported higher bacterial counts during the wet than the dry season for the borehole water samples they assessed in some peri-urban communities in Kumasi, Ghana.

The total bacterial, total coliform and *Vibrio cholerae* counts were significant at 5% significance level using t-distribution indicating that seasonal variation had pronounced effects on their growth and proliferation in the boreholes water assessed.

5. Conclusions

The water from the boreholes assessed in Ogbaru communities were of poor quality in terms of the bacteriological parameters. The detection of total bacteria, coliforms and faecal coliforms in significant numbers indicated a breach of the sanitary integrity of the boreholes. The existence of indicator bacteria demonstrated that there may be pathogenic bacteria in the water assessed, therefore it is necessary that the boreholes must be treated before human use. Fumigation of the area after each seasonal flooding must be carried out. Household treatment such as filtration and boiling before use of such water must be encouraged. In addition, periodic bacteriological analysis of the borehole water is recommended to determine their potability.

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