International Journal of Photochemistry and Photobiology
2018; 2(2): 39-48
http://www.sciencepublishinggroup.com/j/ijpp
doi: 10.11648/j.ijpp.20180202.11

Bacteriological Assessment of the Public Hand-Pump Borehole Water in Onueke, Ezza South Local Government Area, Ebonyi State, Nigeria

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To cite this article:
Onuorah Samuel, Nwoke John, Odibo Frederick. Bacteriological Assessment of the Public Hand-Pump Borehole Water in Onueke, Ezza South Local Government Area, Ebonyi State, Nigeria. *International Journal of Photochemistry and Photobiology*. Vol. 2, No. 2, 2018, pp. 39-48. doi: 10.11648/j.ijpp.20180202.11

Received: July 30, 2018; **Accepted**: August 23, 2018; **Published**: October 6, 2018

Abstract: Bacteriological assessment of public hand-pump borehole water in Onueke, Ezza South Local Government Area of Ebonyi State, Nigeria was carried out during the dry and wet seasons to determine their potability. Total bacterial, total coliform, faecal coliform, *Vibrio cholerae, Enterococcus faecalis* and *Clostridium perfringens* counts were carried out using the membrane filtration technique. The total bacterial counts during the dry season were 107 – 261 cfu/100ml; total coliforms, 0-11 cfu/100ml and *Vibrio* cholerae, 0-5 cfu/100ml. However, the total bacterial counts during the wet season were 119 – 275cfu/100ml; total coliforms, 0-23 cfu/100ml and *Vibrio cholerae*, 0-6 cfu/100ml while faecal coliforms, *Enterococcus faecalis* and *Clostridium perfringens* were not detected in any of the samples during both seasons. The bacterial isolates were identified as *Aeromonas hydrophila,* Serratia liquefaciens*, Micrococcus* luteus, *Klebsiella oxytoca, Serratia marcescens, Proteus vulgaris,* Vibrio cholerae, Citrobacter *freundii, Pseudomonas aeruginosa* and *Pseudomonas fluorescens. Pseudomonas aeruginosa* and *Vibrio cholerae* had the highest and lowest frequency of isolation respectively than the other isolates during both seasons. All the isolates during both seasons were sensitive to Ciprofloxacin and Augmentin. There was significant correlation between the total coliforms during both seasons indicating that they were affected by seasonal variations. Generally, the water from the boreholes studied did not comply with the World Health Organization bacteriological standard for potable water and must be treated adequately before drinking in order not to endanger the health of the users.

Keywords: Bacteriological, Assessment, Hand-Pump, Borehole, Water, Onueke

1. Introduction

Microorganisms play a major role in determining water quality. The most dangerous forms of water pollution are caused when faecal contaminants such as *Escherichia coli, Salmonella spp, Shigella spp*, and *Vibrio cholerae* are shed into water bodies and cause many diseases [1, 2]. The major risk to human health is faecal contamination of water supplies. Serious ill health can be caused by water contaminated from faeces being passed or washed into rivers, streams, pools or allowed to seep into wells or boreholes [3].

High prevalence of diarrhoea among children and infants can be due to the use of unsafe water and unhygienic practices [4]. Acute effects include nausea, lung irritation, skin rash, vomiting, dizziness and sometimes death. Chronic effects like cancer, birth defect, organs damage, disorder of the nervous system and damage to the immune system are usually more common [5]. Coliform bacteria are bacteria which are always present in the digestive system of humans and animals including their wastes. They are also present in the soil and plant materials [6] and are usually gram negative.

The most widely used source of water in Nigeria is borehole water which often meets the criteria of water quality. Water is consumed universally in large quantities and when polluted brings about broad spread of infections [7]. Borehole water varies in purity depending on the geologic conditions of the soil through which the ground water flows and some anthropogenic activities. Ground water has been thought of as being a standard of water purity until recently [8].

Borehole water contamination through many domestic waste water and livestock manure has been reported [9]. These wastes and sewage deposited near the boreholes may travel with percolating rain water directly into the borehole or may travel along the well wall or surrounding material of the drill-holes [9].

Onueke in Ezza South Local Government Area of Ebonyi State, Nigeria is a rapidly developing area with bore hole as the major source of water supply for drinking and domestic use. Incidence of water-borne diseases such as cholera, typhoid fever, dysentery etc. had been reported in the area in the past. It therefore becomes imperative that the bacteriological quality of the water from the boreholes in the area should be examined, hence the aim of this study.

2. Materials and Methods

2.1. Samples Collection

Water samples for bacteriological analysis were collected from fifteen Public hand-pump boreholes during the dry (January- March 2018) and wet (April- June 2018) seasons. The boreholes were sited at the following locations within Onueke, the area under study.

(a) Community Secondary School Amuzu
(b) Ntezi Amuzu
(c) UBA Onueke
(d) Orinte play ground Amuzu
(e) Ndufu Amana
(f) Ochudo Estate Onueke
(g) Motor Park Onueke
(h) Umuanyingor Ndufu Ezzama
(i) Sacred Heart Parish I Onueke
(j) Sacred Heart Parish II Onueke
(k) Ezza High School Amuzu
(l) Oferekpe Play ground I Ezzama
(m) Oferekpe Play ground II Ezzama
(n) Central School Onueke
(o) Pie- Junction Ndufu Ezzama

The samples were aseptically collected in sterilized one – litre plastic containers with screw caps. Sterile cotton wool soaked in 70% ethanol was used to sanitize the nozzles of each of the boreholes taps after which the taps were opened and the water allowed to run for five minutes before the samples were collected. Each of the sterile plastic containers was aseptically uncapped, rinsed with 70% ethanol, distilled water and the water sample to be collected before collection and recapped immediately. The samples were transported to the laboratory in an ice-packed container and analyzed within twenty four hours of collection.

2.2. Sample Processing

The samples were processed using the membrane filtration method as described by Cheesbrough [3]. A sterile filtration apparatus was put in position and connected to a vacuum pump. The apparatus was rinsed by passing some amount of the water sample to be analysed through the funnel using the vacuum pump. The membrane filter funnel was unscrewed and a sterile smooth – tipped forceps was used to collect the membrane filter paper which was thereafter placed aseptically into the porous disc of the filter base. The sterile funnel was carefully replaced on the filter base and then screwed. The water sample was thoroughly mixed by inverting the container twenty five times after which one hundred milliliters of it were poured into the funnel and slowly filtered through the membrane filter with the aid of the vacuum pump.

2.3. Total Bacterial Count

The membrane filter paper was aseptically placed with the grid-side upper most on the surface of a sterile molten Nutrient agar contained in a Petri dish. Duplicate plates were prepared for each of the water samples. The Petri dishes were incubated in an inverted position at 37°C for twenty four hours after which the bacterial colonies that developed on the membrane filter papers were counted and the number recorded. Each colony was subcultured and stored on sterile Nutrient agar slant for characterization and identification.

2.4. Total Coliform Count

The membrane filter paper was aseptically transferred to the surface of a sterilized and cooled MacConkey agar in a Petri dish with the aid of a sterile forceps. The Petri dish was incubated at 37°C for 48 hours in an inverted position after which the pink colonies of the coliform bacteria that developed on the filter paper were counted and recorded. Each of the colonies was subcultured and stored on sterile nutrient agar slant for further use.

2.5. Faecal Coliform Count

Eosin methylene blue agar was sterilized, introduced into a Petri dish and allowed to solidify. The membrane filter paper was thereafter placed aseptically on the surface of the medium using a sterile forceps. Incubation was carried out in an inverted position at 37°C for 48 hours after which the coliform bacteria that developed were counted and the result recorded. Each colony of the bacteria was later subcultured and stored on sterile nutrient agar slant for further studies.

2.6. Vibrio Cholerae Count

Thiosulphate citrate bile salt sucrose agar was used as the growth medium. It was prepared, sterilized and introduced into a Petri dish and allowed to solidify. The membrane filter paper was thereafter transferred to the surface of the medium using a sterile forceps. Incubation of the Petri dish was carried out at 37°C for 48 hours in an inverted position after which the colonies that developed on the filter paper were counted and the number recorded. Each of the colonies was later subcultured and stored on nutrient agar slant for characterization and identification.

2.7. Enterococcus Faecalis Count

The membrane filter paper was aseptically placed on the surface of sterile Glucose azide agar contained in a Petri dish using a sterile forceps. The Petri dish was thereafter incubated in an inverted position at 37°C for 48 hours for the development of colonies.

2.8. Clostridium Perfringens Count

The membrane filter paper was aseptically placed on the surface of sterile Differential Reinforced Clostridial agar contained in a Petri dish using a sterile forceps. The Petri dish was thereafter incubated in an inverted position at 37°C for 48 hours and observed for the development of colonies.

2.9. Characterization and Identification of the Bacterial Isolates

The characterization of the bacterial isolates was based on their morphological and biochemical characteristics. Gram staining, catalase, oxidase, coagulase, indole, motility, citrate utilization, carbohydrate (glucose, lactose, sucrose, mannitol) fermentation, methyl red and voges proskaeur tests were carried out as done by Onuorah et al [10]. The isolates were identified according to the scheme of Krieg and Holt [11].

2.10. Statistical Analysis of Data

The data obtained were subjected to Pearson's correlation analysis using IBM SPSS package version 20.

3. Results

The bacteriological characteristics investigated in the public hand-pump borehole water samples during the dry season are shown in Table 1. The total bacterial counts were 107-261 cfu/100ml; total coliform, 0-11 cfu/100ml; faecal coliforms, 0cfu/100ml, *Vibrio cholerae,* 0-5cfu/100ml; *Enterococcus faecalis*, 0cfu/100ml and *Clostridium perfringens,* 0cfu/100ml.

Table 1. *Bacteriological characteristics investigated in the public hand-pump borehole water samples during the dry season.*

Sample location	Total bacterial count (cfu/100ml)	Total coliform count (cfu/100ml)	Faecal coliform count (cfu/100ml)
Community Secondary School Amuzu	115	7	0
Ntezi Amuzu	220	0	0
UBA Onueke	257	0	0
Orinte Playground Amuzu	162	5	0
Ndufu Amana	232	10	0
Ochudo Estate Onueke	143	0	0
Motor Park Onueke	107	8	0
Umuanyingor Ndufu Ezzama	190	10	0
Sacred Heart Parish I Onueke	137	9	0
Sacred Heart Parish II Onueke	154	3	0
Ezza High School Amuzu	224	0	0
Oferekpe playground I Ezzama	206	0	0
Oferekpe playground II Ezzama	216	0	0
Central School Onueke	261	0	0
Pie-Junction Ndufu Ezzama	165	11	0
WHO Standard	100	10	0

Table 1. *Continued.*

Sample location	Vibrio cholerae count (cfu/100ml)	Enterococcus faecalis count (cfu/100ml)	*Clostridium perfringens* count (cfu/100ml)
Community Secondary School Amuzu	0	0	0
Ntezi Amuzu	0	0	0
UBA Onueke	0	0	0
Orinte Playground Amuzu	5	0	0
Ndufu Amana	0	0	0
Ochudo Estate Onueke	0	0	0
Motor Park Onueke	0	0	0
Umuanyingor Ndufu Ezzama	0	0	0
Sacred Heart Parish I Onueke	0	0	0
Sacred Heart Parish II Onueke	0	0	0
Ezza High School Amuzu	0	0	0
Oferekpe playground I Ezzama	4	0	0
Oferekpe playground II Ezzama	0	0	0
Central School Onueke	0	0	0
Pie-Junction Ndufu Ezzama	0	0	0
WHO Standard	0	0	0

WHO = World Health Organization
Cfu/100ml = colony forming unit per one hundred millilitres of the samples

Table 2 showed the bacteriological characteristics investigated in the public hand-pump borehole water samples during the

wet season. The total bacterial counts ranged from 119 to 275 cfu/100ml, total coliforms from 0 to 23 cfu/100ml; faecal coliforms, 0cfu/100ml; *Vibrio cholerae*, 0 to 6cfu/100ml; *Enterococcus faecalis,* 0cfu/100ml and *Clostridium perfringens*, 0cfu/100ml.

Table 2. *Bacteriological characteristics investigated in the public hand-pump borehole water samples during the wet season.*

Sample location	Total bacterial count (cfu/100ml)	Total coliform count (cfu/100ml)	Faecal coliform count (cfu/100ml)
Community Secondary School Amuzu	130	14	0
Ntezi Amuzu	240	0	0
UBA Onueke	275	0	0
Orinte Playground Amuzu	183	7	0
Ndufu Amana	245	23	0
Ochudo Estate Onueke	168	0	0
Motor Park Onueke	119	13	0
Umuanyingor Ndufu Ezzama	202	20	0
Sacred Heart parish I Onueke	159	17	0
Sacred Heart Parish II Onueke	174	9	0
Ezza High School Amuzu	240	0	0
Oferekpe playground I Ezzama	222	16	0
Oferekpe playground II Ezzama	228	20	0
Central School Onueke	270	0	0
Pie-Junction Ndufu Ezzama	186	16	0
WHO Standard	100	10	0

Table 2. *Continued.*

Sample location	*Vibrio cholerae* count (cfu/100ml)	*Enterococcus faecalis* count (cfu/100ml)	*Clostridium perfringens* count (cfu/100ml)
Community Secondary School Amuzu	0	0	0
Ntezi Amuzu	0	0	0
UBA Onueke	0	0	0
Orinte Playground Amuzu	6	0	0
Ndufu Amana	0	0	0
Ochudo Estate Onueke	0	0	0
Motor Park Onueke	1	0	0
Umuanyingor Ndufu Ezzama	2	0	0
Sacred Heart parish I Onueke	0	0	0
Sacred Heart Parish II Onueke	0	0	0
Ezza High School Amuzu	0	0	0
Oferekpe playground I Ezzama	5	0	0
Oferekpe playground II Ezzama	3	0	0
Central School Onueke	0	0	0
Pie-Junction Ndufu Ezzama	0	0	0
WHO Standard	0	0	0

WHO = World Health Organization
Cfu/100ml = colony forming unit per one hundred millilitres of the samples

The morphological and biochemical characteristics of the bacterial isolates from the public hand – pump borehole water samples during the dry and wet seasons are presented in Table 3. The isolates were *Aeromonas hydrophila, Serratia liquefaciens, Micrococcus luteus, Klebsiella* oxytoca, Serratia marcescens, Proteus *vulgaris, Vibrio cholerae, Citrobacter freundii, Pseudomonas aeruginosa* and *Pseudomonas fluorescens.*

Table 3. *Morphological and biochemical characteristics of the bacterial isolates from the public hand-pump borehole water samples during the dry and wet seasons.*

Isolates	Gram reaction	Form	Catalase test	Oxidase test	Motility test	Coagulase test	Indole test	Citrate utilization test	Sucrose fermentation test	Identity
1	-	Rod	+	+	+	-	+	-	+	*Aeromonas hydrophila*
2	-	Rod	+	-	+	-	-	+	+	*Serratia liquefaciens*
3	+	coccus	+	+	-	-	-	+	-	*Micrococcus luteus*
4	-	Rod	+	-	-	-	+	+	+	*Klebsiella oxytoca*
5	-	Rod	+	-	+	-	-	+	+	*Serratia marcescens*
6	-	Rod	+	-	+	-	+	+	+	*Proteus vulgaris*
7	-	Rod	+	+	+	-	+	+	+	*Vibrio cholerae*
8	-	Rod	+	-	+	-	-	+	+	*Citrobacter freundii*
9	-	Rod	+	+	+	-	-	+	-	*Pseudomonas aeruginosa*
10	-	Rod	+	+	+	-	-	+	-	*Pseudomonas fluorescens*

Table 3. *Continued.*

Isolates	Gram reaction	Form	Methyl red test	Voges - Proskaeur test	Glucose fermentation test	Lactose fermentation test	Mannitol fermentation test	Sucrose fermentation test	Identity
1	-	Rod	+	+	+	+	+	+	*Aeromonas hydrophila*
2	-	Rod	+	+	+	-	+	+	*Serratia liquefaciens*
3	+	coccus	-	-	-	+	-	-	*Micrococcus luteus*
4	-	Rod	-	+	+	+	+	+	*Klebsiella oxytoca*
5	-	Rod	-	+	+	-	+	+	*Serratia marcescens*
6	-	Rod	+	-	+	-	-	+	*Proteus vulgaris*
7	-	Rod	-	-	+	-	+	+	*Vibrio cholerae*
8	-	Rod	+	-	+	+	+	+	*Citrobacter freundii*
9	-	Rod	-	-	-	-	-	-	*Pseudomonas aeruginosa*
10	-	Rod	-	-	-	-	-	-	*Pseudomonas fluorescens*

+ = positive result
- = Negative result

The occurrence of the bacterial isolates in the public hand-pump borehole water samples during the dry season is shown in Table 4. *Aeromonas hydrophila* was detected in 5 (33.3%), Serratia *liquefaciens in 3 (20.0%), Micrococcus luteus in 4 (26.7%), Klebsiella oxytoca in 5 (33.3%), Serratia marcescens in 4 (26.7*%), Proteus vulgaris in 2 (13.3%), *Vibrio cholerae* in 2 (13.3%), *Citiobacter freundii* in 4 (26.7%), *Pseudomonas aeruginosa* in 7 (46.7%) and *Pseudomonas fluorescens* in 6 (40.0%) of the borehole water samples examined.

Table 4. *Occurrence of the bacterial isolates in the public hand-pump borehole water samples during the dry season.*

Sample Location	Aeromonas hydrophila	Serratia liquefaciens	Micrococcus luteus	Klebsiella oxytoca	Serratia marcescens
Community Secondary School Amuzu	+	-	+	+	-
Ntezi Amuzu	-	+	-	-	-
UBA Onueke	-	-	+	-	+
Orinte Playground Amuzu	+	-	-	-	-
Ndufu Amana	-	-	-	+	+
Ochudo Estate Onueke	-	-	-	-	-
Motor Park Onueke	+	-	-	-	-
Umuanyingor Ndufu Ezzama	-	-	-	+	+
Sacred Heart Parish I Onueke	+	-	-	+	-
Sacred Heart Parish II Onueke	-	-	-	-	-
Ezza High School Amuzu	-	-	+	-	-
Oferekpe Playground I Ezzama	-	-	-	-	-
Oferekpe Playground II Ezzama	+	-	+	-	+
Central School Onueke	-	+	-	-	-
Pie-Junction Ndufu Ezzama	-	+	-	+	-

Table 4. *Continued.*

Sample Location	Proteus vulgaris	Vibrio cholerae	Citrobacter freundii	Pseudomonas aeruginosa	Pseudomonas fluorescens
Community Secondary School Amuzu	-	-	-	+	-
Ntezi Amuzu	+	-	-	-	+
UBA Onueke	-	-	-	+	+
Orinte Playground Amuzu	-	+	+	+	-
Ndufu Amana	-	-	-	-	-
Ochudo Estate Onueke	-	-	-	+	+
Motor Park Onueke	+	-	+	-	-
Umuanyingor Ndufu Ezzama	-	-	-	-	+
Sacred Heart Parish I Onueke	-	-	-	+	-
Sacred Heart Parish II Onueke	-	-	+	-	-
Ezza High School Amuzu	-	-	-	-	+
Oferekpe Playground I Ezzama	-	+	-	+	-
Oferekpe Playground II Ezzama	-	-	-	-	+
Central School Onueke	-	-	-	+	-
Pie-Junction Ndufu Ezzama	-	-	+	-	-

+ = detected
- = not detected

Table 5 showed the occurrence of the bacterial isolates in the public hand-pump borehole water samples during the wet

season. Aeromonas hydrophila was present in 6 (40.0%), Serratia liquefaciens in 4 (26.7%), Micrococcus luteus in 6 (40.0%), Klebsiella oxytoca in 7 (46.7%), Serratia marcescens in 5 (33.3%), Proteus vulgaris in 3 (20.0%), Vibrio cholerae in 5 (33.3%), Citrobacter freundii in 5 (33.3%), Pseudomonas aeruginosa in 9 (60.0%) and Pseudomonas fluorescens in 7 (46.7%) of the water samples studied.

Table 5. *Occurrence of the bacterial isolates in the public hand-pump borehole water samples during the wet season.*

Sample Location	Aeromonas hydrophila	Serratia liquefaciens	Micro coccus luteus	Klebsiella oxytoca	Serratia marcescens
Community Secondary School Amuzu	+	-	+	+	-
Ntezi Amuzu	-	+	-	-	-
UBA Onueke	-	-	+	+	+
Orinte Playground Amuzu	+	+	-	+	-
Ndufu Amana	-	-	-	+	+
Ochudo Estate Onueke	-	-	-	-	-
Motor Park Onueke	+	-	+	-	-
Umuanyingor Ndufu Ezzama	+	-	+	+	+
Sacred Heart Parish I Onueke	+	-	-	+	+
Sacred Heart Parish II Onueke	-	-	-	-	-
Ezza High School Amuzu	-	-	+	-	-
Oferekpe Playground I Ezzama	-	-	-	-	-
Oferekpe Playground II Ezzama	+	-	+	-	+
Central School Onueke	-	+	-	-	-
Pie-Junction Ndufu Ezzama	-	+	-	+	-

Table 5. *Continued.*

Sample Location	Proteus vulgaris	Vibrio cholerae	Citrobacter freundii	Pseudomonas aeruginosa	Pseudomonas fluorescens
Community Secondary School Amuzu	_	-	-	+	-
Ntezi Amuzu	+	-	-	-	+
UBA Onueke	-	-	-	+	+
Orinte Playground Amuzu	-	+	-	+	-
Ndufu Amana	+	-	+	-	+
Ochudo Estate Onueke	-	-	-	+	+
Motor Park Onueke	+	+	-	+	-
Umuanyingor Ndufu Ezzama	-	+	-	-	+
Sacred Heart Parish I Onueke	-	-	+	+	-
Sacred Heart Parish II Onueke	-	-	+	+	-
Ezza High School Amuzu	-	-	-	-	+
Oferekpe Playground I Ezzama	-	+	-	+	-
Oferekpe Playground II Ezzama	-	+	-	-	+
Central School Onueke	-	-	+	+	-
Pie-Junction Ndufu Ezzama	-	-	+	-	-

+ = detected
- = not detected

The frequency of isolation of the bacterial isolates in the public hand-pump borehole water samples during the dry season is shown in Table 6.. The values were between 0.3 and 19.7% with *Pseudomonas aeruginosa* having the highest frequency of 19.7% while *Vibrio cholerae* had the lowest frequency of isolation of 0.3%.

Table 6. *Frequency of occurrence of the bacterial isolates in the public hand-pump bore hole water samples during the dry season.*

Bacterial isolates	Number of Colonies isolated	Frequency of Isolation (%)
Aeromonas hydrophila	410	14.7
Serratia liquefaciens	305	10.9
Micrococcus luteus	364	13.1
Klebsiella oxytoca	40	1.4
Serratia marcescens	340	12.2
Proteus vulgaris	275	9.9
Vibrio cholerae	9	0.3
Citrobacter freundii	23	0.8
Pseudomonas aeruginosa	548	19.7
Pseudomonas fluorescens	475	17.0
Total	2789	100.0

The frequency of isolation of the bacterial isolates in the public hand-pump borehole water samples during the wet season is

shown in Table 7. The values ranged from 0.6 to 18.7%. *Pseudomonas aeruginosa* was also isolated most frequently (18.7%) while Vibrio cholerae had the least frequency of isolation of 0.6%.

Table 7. *Frequency of occurrence of the bacterial isolates in the public hand-pump bore hole water samples during the wet season.*

Bacterial isolates	Number of Colonies isolated	Frequency of Isolation (%)
Aeromonas hydrophila	435	14.3
Serratia liquefaciens	324	10.7
Micrococcus luteus	386	12.7
Klebsiella oxytoca	92	3.0
Serratia marcescens	361	11.9
Proteus vulgaris	296	9.7
Vibrio cholerae	17	0.6
Citrobacter freundii	63	2.1
Pseudomonas aeruginosa	570	18.7
Pseudomonas fluorescens	497	16.3
Total	3041	100.0

The susceptibility test of the bacterial isolates to antibacterial agents is shown in Table 8. All the isolates were sensitive to Ciprofloxacin and Augmentin. In addition, 3 (30.0%), 5 (50.0%), 9 (90.0%), 2 (20.0%), 9 (90.0%), 9 (90.0%), 8 (80.0%) and 3 (30.0%) of the isolates were sensitive to Septrin, Chloramphenicol, Sparfloxacin, Amoxicillin, Gentamycin, Pefloxacin, Tarivid and Streptomycin respectively.

Table 8. *Susceptibility test of the bacterial isolates to antibacterial agents.*

Bacterial isolates	Septrin	Chloramphenicol	Sparfloxacin	Ciprofloxacin	Amoxicilin
Aeromonas hydrophila	R	S	S	S	R
Serratia liquefaciens	S	S	S	S	R
Micrococcus luteus	R	S	S	S	R
Klebsiella oxytoca	S	R	S	S	S
Serratia marcescens	R	R	S	S	R
Proteus vulgaris	S	R	S	S	S
Vibrio cholerae	R	R	R	S	R
Citrobacter freundii	R	R	S	S	R
Pseudomonas aeruginosa	R	S	S	S	R
Pseudomonas fluorescens	R	S	S	S	R

Table 8. *Continued.*

Bacterial isolates	Augmentin	Gentamycin	Pefloxacin	Tarivid	Streptomycin
Aeromonas hydrophila	S	S	S	S	R
Serratia liquefaciens	S	S	S	S	R
Micrococcus luteus	S	S	S	S	S
Klebsiella oxytoca	S	S	S	S	R
Serratia marcescens	S	S	S	S	R
Proteus vulgaris	S	S	S	R	S
Vibrio cholerae	S	R	R	R	R
Citrobacter freundii	S	S	S	S	R
Pseudomonas aeruginosa	S	S	S	S	S
Pseudomonas fluorescens	S	S	S	S	R

S = Sensitive
R =Resistant
= Resistant

4. Discussion

The bacteriological characteristics of the public hand-pump borehole water studied during both the dry and wet seasons showed that the total bacterial counts exceeded the World Health Organization (WHO) standard of 100cfu/ml for potable water (Table 1 and 2). Josiah et al. [12], Ibe and Okpalenye [13] and Ngele et al. [14] also studied some water samples in Okada town, Uli and Amike – Aba respectively both in Nigeria and reported that the water from all the boreholes did not meet the World Health Organization standard as the total viable counts exceeded the $1.0x10^2$cfu/ml for water.

Higher bacterial counts were obtained during the wet than the dry season. The variation in the bacterial counts may be attributed to flood which may have emptied its contents into such boreholes. This result agreed with Obiri-Danso et al. [15] who reported higher bacterial counts during the wet season than in the dry season for the borehole water samples, they studied in some Petri-Urban communities in Kumasi, Ghana.

More total coliform bacteria were isolated from the

samples during the wet season than in the dry season (Tables 1 and 2). Fourteen (93.3%) of the boreholes sampled complied with the WHO standard of 10cfu/100ml for the total coliforms during the dry season while 46.7% met the standard during the wet season. However, Mustafa et al. [16] and Ngele et al. [14] reported total coliform counts of $6x10^3$ – 145 x 10^3 MPN/100ml and 280 – 540 MPN/100ml respectively for the borehole water samples they analysed.

Faecal coliforms, *Enterococcus faecalis* and *Clostridium perfringens* were however not detected in any of the samples analysed (Tables 1 and 2). This result conformed to the works of Abdullahi et al. [17], Olajuba and Ogunika [18] and Nkamare et al. [19] that reported the absence of faecal coliform bacteria in the borehole water samples they studied in the Science Department and Staff School of Niger State Polytechnic, ZungeruCampus, Akungba – Akoko, Ondo state and Okutukutu, Bayelsa State respectively, all in Nigeria.

The presence of faecal coliforms in any water sample is an evidence of faecal pollution of such water. The absence of faecal coliforms in the water analysed in this work may be attributed to the sanitary condition of such boreholes and their environments, as such boreholes were located a long distance away from possible sources of contamination such as pit latrines, septic tanks, animal rearing grounds and waste dumping sites.

However, since no faecal coliform bacteria, *Enterococcus faecalis* and *Clostridiumperfringens* were detected in any of the samples, the result indicated that the water samples were free from faecal pollution of recent and remote periods. This study showed that more *Vibrio cholera* were recovered from the water samples during the wet season than in the dry season (Tables 1 and 2). Thirteen (86.7%) of the boreholes studied during the dry season met the WHO standard of 0cfu/100ml for *Vibrio cholerae* while 66.7% complied with the standard during the wet season.

The bacterial isolates from the borehole water samples were *Aeromonas hydrophila, Serratia liquefaciens, Micrococcus luteus, Klebsiella oxytoca, Serratia marcescens,* Proteus vulgaris, *Vibrio cholerae, Citrobacter freundii*, Pseudomonas aeruginosa and *Pseudomonas fluorescens* [Table 3] Abdullahi et al. [17] isolated *E. coli, Klebsiella, Salmonella and Serratia* from the Staff School, Science Department and female hostel boreholes in Niger State Polytechnic Zungeru Campus.

Ngele et al. [14] detected *Escherichia coli, Proteus sp, Pseudomonas aeruginosa*, Enterobacter aerogenes, Streptococcus faecalis and Bacillus sp in selected borehole samples in Amike-Aba while Olujuba and Ogunika [18] isolated seven bacterial species which were identified as *Bacillus cereus, Bacillus subtilis, Pseudomonas aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus, Salmonella paratyphi* and *Proteus vulgaris* from borehole samples from Akungba – Akoko, Ondo State, Nigeria.

Josiah et al. [12] isolated *Staphylococcus aureus, Salmonella sp, Escherichia coli, Pseudomonas aeruginosa, Bacillus sp* and *Flavobacterium* from drinking water and water used for domestic purposes in Okada Town while Ibe and Okpalenye [13] detected *Escherichia coli, Klebsiella sp, Enterobacter sp, Pseudomonas sp and Staphylococcus aureus* in the borehole water in Uli, Anambra State.

Ukpong and Okon [20] conducted a comparative analysis of the public and private borehole water supply sources in Uruan Local Government Area of Akwa Ibom State and detected *Escherichia coli, Bacillus subtilis, Streptococcus faecalis, Proteus vulgaris, Klebsiella aerogenes, Micrococcus varians, Clostridium perfringens* and *Staphylococcus aureus* in the samples while Uhuo et al. [21] detected *Escherichia coli, Klebsiella aerogenes, Bacillus sp, Salmonella sp* and *Bacillus subtilis* from the borehole water in Peri-Urban areas of Abakaliki, Ebonyi State, Nigeria.

The bacterial isolates were isolated from more of the boreholes during the wet season than the dry season [Tables 4 and 5]. This could be attributed to rain water which must have introduced bacteria in it to the boreholes and the environmental conditions which must have been more favourable to the organisms.

Pseudomonas aeruginosa was the predominant bacterium isolated from the water samples during both the dry and wet seasons *while Vibrio cholerae* was less frequently isolated during both seasons (Tables 6 and 7). This result indicated that the environmental conditions were most favourable to *Pseudomonas aeruginosa* than the other bacterial isolates. However, Escherichia coli was the predominant bacterium isolated by Uhuo et al. [21] and Ukpong and Okon [20] from the borehole water samples they examined.

All the isolates from the water samples were sensitive to Ciprofloxacin and Augmentin (Table 8). There was high level of resistance to most of the commonly available antibiotics such as Chloramphenicol, Septrin and Streptomycin. Similar resistance pattern was reported by Olajubu and Ogunika [18]. The total coliform bacteria were significant at $P<0.05$ level showing that there was a great difference in their number in the water samples with respect to season.

Aeromonas hydrophila is an opportunistic pathogenic bacterium found in a variety of aquatic environments including bottled water, chlorinated water, well water and heavily polluted waters [22, 23] and is pathogenic to humans, causing gastroenteritis, cellulitis, myonecrosis and eczema in people with compromised immune systems [24].

Serratia liquefaciens is a widespread bacterium that is capable of colonizing soil, water, plants and the digestive tracts of rodents, insects, fishes and humans [25]. The pathogenic strains cause urinary tract infections, bloodstream infections, sepsis, pneumonia, meningocephalitis and other debilitating infections and sometimes death [25].

Micrococcus luteus is an opportunistic pathogen that is found in the soil, dust, water and human skin. It can be responsible for nosocomial infections and can cause skin infections as well as septic shock in immuno compromised individuals [26]. *Klebsiella oxytoca* is a ubiquitous and opportunistic bacterium that is found in a variety of environments such as surface water, sewage, soil and on plants. They can also be found in mammals, insects and

humans. They cause urinary tract infections, wound infections, septicemia and nosocomial infections in immuno compromised patients [27].

Serratia marcescens occurs naturally in soil and water and is associated with urinary and respiratory infections, endocarditis, osteomyelitis, septicemia, wound infections, eye infections and meningitis [28]. *Proteus vulgaris* inhabits the intestinal tracts of humans and animals and can be found in soil, water and faecal matter. It is an opportunistic pathogen that can infect the lung or wounds and frequently causes urinary tract infections, severe abcesses and nosocomial infections [29].

Vibrio cholerae is a facultative human pathogen that can be isolated from the estuarine and aquatic environments. It is the causative agent of the human intestinal disease cholera which is responsible for significant mortality and economic damage especially in underdeveloped countries [30]. *Citrobacter freundii* habitat includes the soil, water, sewage, food and the intestinal tracts of animals and humans [31]. As an opportunistic pathogen, it is known to be the cause of a variety of nosocomial infections of the respiratory tract, urinary tract, blood and several other normally sterile sites in patients [32]. One fatal disease that *Citrobacter freundii* has been associated with is neonatal meningitis [33].

Pseudomonas aeruginosa is an opportunistic nosocomial pathogen of immune compromised persons that is found in the soil, water, plants, the skin on moist parts of a healthy human body and most man-made environments. It is associated with urinary tract infections, wound infections, blood infections, dermatitis, osteomyelitis and community acquired pneumonias [34]. *Pseudomonas fluorescens* can be found in the soil, plants and water surfaces and rarely cause diseases in humans. However, it has been associated with bacteremia and can affect persons with immuno compromised systems especially patients on cancer treatment [35].

5. Conclusion

This study showed that the public hand-pump borehole water samples analysed in Onueke, Ezza South Local Government Area of Ebonyi State did not meet the bacteriological standards established by regulatory authorities and therefore need adequate treatment such as boiling and chlorination before drinking by the public. Periodic assessment of the bacteriological quality of the borehole water is also recommended.

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