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Evaluation of Physicochemical and Microbiological Characteristics of Borehole Water in Mgboushimini Community of Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author SSE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EDU and VNO managed the analyses of the study. Author OEU managed the literature searches and performed clinical analysis. All authors read and approved the final manuscript.

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ABSTRACT

This research was carried out to determine the physicochemical and microbiological characteristics of groundwater in boreholes used as drinking water in Mgboushimini community in Obio Akpor Local Government Area of Rivers State in Nigeria. Eight water samples (n=8) from different boreholes were collected randomly within the community. The total bacterial count and Coliform was determined by using the standard microbiological method and Most Probable Number (MPN) method. A total of four (4) genera of organisms were isolated from the water samples which included *Proteus spp, Citrobacter spp, Klebsiella* spp, *Candida* spp. The mean value of Total Heterotrophic Bacterial count ranged from 1.1±0.14 to 7.9±0.07. The mean concentration of

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chloride, calcium, magnesium, and salinity were 10.79, 2.11, 0.47 and 0.21, respectively. The recorded pH, total alkalinity, temperature, and turbidity were 4.31 to 4.66, 4.00, 29.6 to 29.9, and 0.00 NTU, respectively. The electrical conductivity, total hardness, total dissolved solids, phosphate and sulphate, showed the mean value of 438±67.14, 7.18±1.99, 284.88±49.48 mg/l, 0.02±0.01 mg/l, 4.15±0.76 mg/l, respectively. These values were compared with the World Health Organization (WHO) standard values for drinking water quality. The microbiological and physicochemical result of the eight borehole water samples analysed did not meet the WHO standard, and therefore requires robust purification strategies to ensure a good potable drinking water in the community as to reduce the outbreak of water-borne infections.

Keywords: Borehole water; physicochemical characteristics; microbiological characteristics; total heterotrophic bacterial count.

1. INTRODUCTION

Water is one of the most important and most valuable natural resources throughout the world [1,2]. It is essential in the life of all living organisms to the most complex living system known as the human body [3]. It is the most vital requirement for a successful aqua-cultural venture [4]. To describe water as potable, it must satisfy specific criteria of the physical, chemical and microbiological standard which are designated to ensure that water is potable and safe for drinking purposes [5].

Drinking water is a major issue in many countries including Nigeria and other developing countries. Surface water (rivers, stream, lake, dams), and groundwater (borehole and well) can serve as sources for drinking water but with the increasing contamination of surface water there is an increasing resilience on groundwater for drinking and domestic purposes, since it is believed to be pure through natural purification processes as endorsed by Shyamala et al. [6]. In Nigeria, borehole and packaged sachet water serve as the easily accessed and cheap commercial source of drinking water for millions of people. The quality of drinking water is essential for public health. In 2006, waterborne diseases were estimated to have caused around 1.8 million deaths each year, and are attributable to inadequate public sanitation systems and in these cases, proper sewage system must be installed [7]. The microbiological quality of drinking water is of serious concerned to consumers, water suppliers, regulators and public health authorities. The needs for the assessment of microbiological quality of water have become imperative due to a direct impact on the health of individuals. Physicochemical analysesof water is critically important to get exact idea about the quality of water to compare results of different physicochemical parameter values with standard values. The occurrence of waterborne illnesses has both economic and social impacts.

Aftab et al. [8] reported various physicochemical parameters and analysis of untreated fertiliser effluent. Their result revealed that the parameters like electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and ammonia were high above the permissible limits, and fungal analyses showed the presence of 15 species isolated on Malt Extract Agar (MEA) medium and thereby indicated the pollution-load of the effluent [9]. It was revealed that dilution during rainy season decreases the metal concentration level to a considerable extent [10]. Generally, increased levels of faecal coliforms in drinking water provide a warning of failure in water treatment, a break in the integrity of the distribution system and possible potential contamination with pathogens [11,12]. When the level is high, there might be an elevated risk of waterborne gastroenteritis in the population that uses the water source [13].

This study, aims to ascertain the physicochemical and microbiological quality of drinking water sources in Mgboushimini community, Port Harcourt, Rivers State (Fig. 1).

1.1 Some Common Water-Related Diseases

List of some microorganisms that can be found in water and related diseases are presented in Table 1.

1.2 Standard of Quality Drinking Water

According to WHO [16], all water intended for drinking must satisfy the certain bacteriological

Fig. 1. Map of Obio/Akpor local government area showing study area

standard. Specific disease-causing organisms in water are not identified easily, due to the complex nature of the technique involved in complete bacteriological examination. However, tests that indicate the relative degree of contamination can be easily performed test and are generally used, since they provide the primary results required for a necessary assessment. Furthermore, water contents have different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Therefore, it is pertinent to perform some physical test on the water to ascertain the temperature, colour, odour, pH, turbidity, TDS of water samples. In the same vein, the chemical tests should also be performed for the values of the dissolved oxygen, alkalinity, hardness and other parameters. Furthermore, to obtain better and pure quality water, an investigation for the presence of trace metal, heavy metal contents and organic matter (pesticide residue) can also be carried out. It is important that drinking water should pass these entire (parameters listed above) tests and it should also contain the required amount of minerals [17,18]. Regrettably, these criteria are only stringently monitored only in the developed countries.

1.3 Possible Sources of Pollutants to Borehole Water

The primary sources of pollution to borehole water are mainly from domestic, industrial, environmental and agricultural wastes. Domestic pollution can also be resulted from leakage of broken septic tanks, pit latrines. Industrial pollution can originated from the discharge of used water containing chemicals such as metals and radioactive elements, or it could be as a result of contaminated water from damaged pipelines infiltrating into the borehole. Sewage connections are connected to storm drain pipes can also allow human sewage into surface waters. Some older industrial cities, uses a combined sewer system to handle waste, for example, combined sewer carries both domestic sewage and storm water. During high rainfall periods, a combined sewer can become overloaded and overflow to a nearby stream or river, bypassing treatment and causing pollution [19].

Table 1. Common diseases associated with polluted water and their pathogens

Names of microorganism	Diseases caused
Vibrio cholera	Cholera [14].
Shigella species	Shigellosis [15].
Salmonella typhi	Typhoid fever [16].
Other salmonella	Salmonellosi [14].
Campylobacter jejuni	Gastroenteritis [12]

Agricultural pollution mostly stems from irrigation water channel and runoff water after rains, pesticides, herbicides and faecal matter. Agricultural practices such as allowing livestock to graze near water bodies, spreading manure as fertiliser on fields during wet periods, using sewage sludge bio-solids and allowing livestock watering in streams can all contribute to faecal coliform contamination [20]. Finally, environmental pollutions may come from seawater into coastal aquifer [21]. Failing home septic can allow coliforms in the effluent to flow into the table, aquifers, drainage ditches and nearby surface waters. To limit the effects of the above listed sources of pollution to boreholes water, WHO [16] recommended that boreholes should be located at least 30 m away from latrines and about 17 m from septic tanks.

2. MATERIALS AND METHODS

2.1 Sample Collection

All the water samples were collected from eight (8) different borehole water sources viz., Agip by Ada George Road (AGR), Mgboshimini by Agip gate (AG), Mgboshemini II by Market (MM), First Avenue by Agip estate, Road 27 (AE), No 3. Oroakwor, Agip (OR), New Life Baptist Church, Road 24 (BC), Second Avenue by Agip estate, Road 1(AS) and No 14 Oroakwor (ORO). Cotton wool soaked in 70% acetone alcohol was used to sterilise the nozzle of the tap before collection, water was allowed to run from the tap for about two minutes after which the sterile bottle was uncapped aseptically to collect the water and carefully capped back to avoid aerosol contamination, the samples were labelled and transported to the laboratory in a cooler packed with ice blocks for analysis.

2.2 Method of Sterilization

All media used were sterilised by autoclaving at 121°C for 15 minutes at the pressure of 15 pounds. Glasswares were sterilised in a hot air oven at 160°C for 2 hours. Glass spreader (Hockey Stick) was sterilised by dipping in alcohol and flamed, to prevent contamination. Inoculating loops were sterilised by flaming to red hot using Bunsen burner flame.

2.3 Experimental Analysis

The Bacteriological analysis was carried out using the spread plate method (Total Heterotrophic counts) while the physicochemical parameters were determined by using the standard protocol. The analysis of total heterotrophic bacteria count was performed by using spread plate method, serial dilution for each water sample was prepared using 1ml pipette, and 9 ml sterilised distilled water as diluents. 0.1 ml aliquot of each dilution was placed on Muller Hinton agar plate in replicates manner. The inoculated plates were incubated at 37°C for 24 hours before enumeration. Plates containing 30 to 300 colonies were selected and counted; the number was used for the calculation of colony forming units per ml (CFU/ml). Mathematically: CFU/ml = no. of colonies x dilution factor ÷ volume of culture plate.

2.4 Determination of Total Coliform and Faecal Coliform

The Most Probable Number (MPN) was used to determine the presence of faecal coliforms in water samples. Five double strength MacConkey broth tubes containing inverted Durham tubes were inoculated with 10 ml of water samples, five single strength broth tubes were inoculated with 1 ml of water sample, while the last five single strength broth tubes were inoculated with 0.1ml of the same sample. After incubation for 48 hours, no tubes produce acid and gas. Therefore, they were no further sub-culturing into fresh medium for confirmation.

2.5 Physicochemical Analysis

The water samples from each source (borehole) were examined for physicochemical parameter (i.e., physical and chemical properties) for example, temperature, pH, salinity, total dissolved solids were determined by using extech meter. Turbidity meter was used to examine turbidity. Calcium, total hardness, Nitrate, magnesium and chloride, colour, phosphate, sulphate, total alkalinity, electrical conductivity were measured using standard methods.

2.6 Statistical Analysis

The data were subjected to SPSS version 21 and Graph Pad Prism version 31. The statistical tool was explored to determine the mean, standard deviation and standard error of the mean. The results are presented in tables and graphs below.

3. RESULTS AND DISCUSSION

3.1 Results

The results of the physicochemical parameters analysed from borehole water in Mgboushimini revealed that temperature, pH, total alkalinity ranges from 29.0 to 29.8°C, 4.31 to 4.73 and 4.00 mg/l, respectively (Table 2). Also, the mean concentration of calcium, magnesium, chloride, nitrate, sulphate and phosphate were 2.11, 0.47, 10.79, 0.43, 4.15 and 0.02 mg/l, respectively.

Table 2. Physicochemical properties of various borehole water sampled from different points

Parameters	AGR	AG	MM	AE	OR	BC	AS	ORO	WHO standard (mg/l)	Mean±SD
pH	4.66	4.32	4.60	4.31	4.73	4.61	4.58	4.65	8.2	4.56±0.16
Electrical conductivity	383	482	421	533	331	392	478	484	1400.00	438±67.14
Turbidity (NTU)	0	0	0	0	0	0	0	0	5.00	0.00±0.00
Salinity %	0.18	0.23	0.20	0.26	0.16	0.24	0.23	0.19	0.00	0.2±0.04
Total dissolved solid mg/l	266	331	295	373	229	230	294	261	500.00	284.88±49.48
Phosphate mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	200	0.02±0.01
Sulphate mg/l	4.46	3.87	4.01	5.70	3.35	3.32	4.40	4.05	250.00	4.15±0.76
Nitrate mg/l	0.32	0.68	0.51	0.42	0.16	0.60	0.40	0.35	10.00	0.43±0.165
Chloride mg/l	10.87	12.35	10.36	13.33	5.93	10.85	10.30	12.33	250.00	10.79±2.25
Total Alkalinity	4	4	4	4	4	4	4	4	ND	4.00±0.00
Total Hardness	5.76	5.76	7.68	11.52	5.76	7.62	7.65	5.70	500.00	7.18±1.99
Calcium content	1.54	1.52	2.31	3.07	1.54	2.30	1.54	3.10	75.00	2.11±0.69
Magnesium	0.47	0.47	0.47	0.94	0.47	0.47	0.47	0.47	50.00	0.47±0.00
Temperature	29.6	29.7	29.8	29.8	29.8	29.9	29.8	29.0	25.00	29.76±0.29

Keys: AGR = Agip by Ada George Road; AG = Mgboushimini by Agip Gate; MM = No. 40 Mgboushimin by Market; AE = First Avenue by Agip Estate, Road 27; OR = No. 3 Oroakwor; BC = New Life Bible Church, Road 24; AS = Second Avenue by Agip Estate, Road 1; ORO = No. 14 Oroakwor, SD = Standard deviation, ND = not detected

Table 3. Descriptive statistics of heterotrophic count pathogen isolated from borehole water based on locations

	Borehole water from different locations ($x10^3$ CFU/ml)							
	AGR	AG	MM	AE	OR	BC	AS	ORO
Mean	7.9	7.0	1.1	4.2	1.2	4.1	2.1	7.1
SEM	0.05	0.05	0.10	0.25	0.05	0.05	0.15	0.05
SD	0.07	0.07	0.14	0.35	0.07	0.07	0.21	0.07
p- value	P<0.05							

Table 4. Bacterial isolates obtained from water samples at different locations

Isolated Organisms	AGR	AG	MM	AE	OR	BC	AS	ORO
Klebsiella aerogenes	+	+	-	-	-	-	-	+
Proteus mirabilis	-	+	+	+	-	-	-	-
Candida albicans	-	-	-	-	+	-	-	+
Citrobacter freundii	-	-	-	+	+	+	+	-

(+) = Present; (-) = Absent

Turbidity, salinity, TDS, electrical conductivity of the water sample ranged from 0.00 to 0.00 NTU, 0.16 to 0.26%, 261 to 373 mg/l and 331 to 533 µs/cm, respectively. The determination of total coliform and faecal coliform carried out by using the most probable number technique in the analysed water samples were all negative.

Bacterial species were isolated, and prevalence rate of isolation ranges from 25-50%. The highest organism isolated was *Citrobacter freundii* with the prevalence rate of 50%. Indicator organism was not isolated from the sample that means, the water samples are not faecally contaminated but other enterobacteriaceae organisms such as *Proteus mirabilis, Klebsiella aerogenes, Citrobacter freundii*, and *Candida albicans* were isolated.

In Table 4 the bacterial isolates obtained from water samples are shown based on different location. The numbers of positive and negative organisms isolated were also shown. *Klebsiella aerogenes* and *Proteus mirabilis* were isolated in two different locations. *Citrabacter freundii* was also isolated which happens to be of the highest prevalence while *Candida albican* was the least in isolation.

3.2 Discussion

The present study investigated eight borehole water samples collected at different locations in Mgbonshimini/Agip area; an area with a high density of population of diverse works of life and different economic strata. The physicochemical parameters for some samples analysed were within the standards of WHO while some were beyond the limit.

The pH of all the eight samples analysed had the mean value of 4.5±0.16 [Table 1]. The pH values recorded in this study were slightly different from the results of Samuel et al. [23] which had an average pH of 6.14. The slight difference might be because of different study site. Comparatively, results from earlier studies suggested that the water sample in this study is acidic. The acidic nature of the water samples could be as a result of decomposition of organic matter in the overlying soil causing premature damage to metal piping and have associated aesthetic problems such as metallic or sour taste. Turbidity of the borehole water samples showed 0.00 NTU in all the samples analysed and this was within the minimum acceptable limits of World Health Organization (WHO) standard [16].

The conductivity values ranged from 331 to 533 NTU and the mean value was 438±67.14 [Table 1]. The electrical conductivity values may depend on the concentration and types of soluble ions. Chloride content of the water sample ranged from 10.30 mg/l to 12.33 mg/l with the mean value of 10.79±2.25 mg/l. The chloride concentration recorded in this study was similar to the previous study of Samuel et al. [22] which reported a mean value of 13.97±6.36 mg/l and both were lower than the WHO [16] standard. A high concentration of chloride above 250 mg/l sometimes gives a salty taste in drinking waters and might harm metallic pipe [23]. The mean value of TDS was 284.88±49.48, and this corresponds to the results obtained by Sebiawu et al. [24]. Total hardness recorded in this study ranged from 5.70 to 11.5 mg/l, with a mean value of 7.18±1.99. The total hardness obtained in this research indicates that the water samples were soft and suitable for domestic uses.

The nitrate concentration was 0.43±0.165 mg/l which is within the WHO permissible limits. This low concentration of nitrate in the water sample was in agreement with Mueller et al. [28]. Sulphate concentration of the water sample ranged from 3.32 to 5.70 mg/l with the mean value 4.15±0.76 mg/l. The mean calcium content for the water sample was 2.11±0.69 mg/l which found to be similar with the previous result of Samuel et al. [22]. The low concentration recorded in this study could be as a result of absence of rocks containing phosphate and sulphate in the study area. The average magnesium content in all water samples was 0.47±0.00 which is lower than the minimum limit of WHO [16] standard for potable water (Table 1). This study is in line with the previous study reported by Sebiawu et al. [23] and Cobbina et al. [24].

The salinity and phosphate concentration ranged from 0.16 to 0.23% and <0.05 in all the analysed samples with the mean values of 0.2±0.04 and 0.21±0.01 respectively. The temperature of borehole water samples ranged from 29.6°C to 29.8°C. Previous study reported by Samuel et al. [23] is in agreement with these results. These results were above the WHO [16] standard of 25°C for water temperature. High temperature in water can give undesirable taste and foul odour as well as increase the corrosive ability of water [16].

WHO [16] also reported that microorganisms can be present in drinking water, but it is often impossible to test all of these microorganisms. Therefore, to monitor microbial quality of drinking water, certain indicator microorganisms can be measured to test the faecal pollution. Here, MPN technique was employed to test the presence of common bacterial contaminant in the borehole water.

Microbiological analysis isolated four organisms from eight selected water samples in Mgbuoshimini; these included *Citrobacter freundii*, *Klebsiella aerogenes*, *Candida albicans*, and *Proteus mirabilis* (Table 4). *Klebsiella aerogenes* was found in three samples (AG, AGR, ORO). The presence of these bacterial organisms suggests faecal contamination. It could be stated that the pipes used for water distribution were rusty thus allowing seepages of microbial contaminants into the borehole. *Citobacter freundii* is a member of the family Enterobacteriaceae and is often the cause of significant opportunistic infections. *Citrobacter freundii* was found in four samples (AE, OR, BC, AS). It was the highest numbers of isolated organism from the analysed eight samples. *Candida albican* is a member of the human gut flora and does not seem to propitiate outside mammalian hosts [25]. *Candida albican* was found in two samples (ORO, OR) [Table 5]. The research carried out showed that the organisms isolated could pose an important health risk to individuals who drink these water [26]. Nevertheless, prominent enteric pathogens like *Salmonella species*, *Shigella species* and *Escherchia coli* etc. were absent from the analysed water. This study is in line with the guidelines of Prescott et al. [27].

The mean value for Total Heterotrophic Bacteria (THB) ranged from 1.1 to 7.9 CFU/ml, which corresponds to the report of Koul et al. [28]. The WHO standard for heterotrophic bacteria in potable water stated that the total heterotrophic bacteria count should not be more than 0.0 CFU/100ml. According to Premlata [29], total coliforms counts of 3 per 100 ml (3/100 ml) of unpiped water and zero per 100 ml (0/100 ml) sample of all piped water supplies could be acceptable but the WHO [16] guideline for drinking water stipulates that it should be zero faecal coliform count per 100 ml of water sample whether pipe-borne water or not. However, this study revealed a different heterotrophic bacteria with the least value of 1.1±0.14 from Mgboushimini by market (MM), and the highest count of 7.9±0.07 was recorded at Agip by Ada George (AGR) borehole water. Therefore, eight water samples analysed from different locations for Total Heterotrophic Bacteria were significant at $p < 0.05$ (Table 2).

Table 5. Percentage distribution of pathogens isolated from borehole water in mgboushimini

	Candida albicans	***Klebsiella aerogenes***	***Proteus mirabilis***	***Citrobacter freundii***
No. detected	2	3	3	4
Total number	8	8	8	8
Prevalence (%)	25%	38%	38%	50%

4. CONCLUSION

Microbiological quality of a few of the water samples analysed in this study did not meet the standard requirements set for drinking water by WHO. Moreover, the low pH recorded for all the water samples corresponds with WHO [23] standard. Finally, the presence of heterotrophic bacteria in all the water samples assessed implies that consumers of such water are vulnerable to infection. These findings raise a serious concern; therefore, to ensure a safe drinking water, it is imperative to design conventional water purification strategies by government agencies as well as individuals.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

DISCLAIMER

This paper is based on preliminary dataset. Readers are requested to consider this paper as preliminary research article, as authors wanted to publish the initial data as early as possible. Authors are aware that detailed statistical analysis is required to get a scientifically established conclusion. Readers are requested to use the conclusion of this paper judiciously as statistical analysis is absent. Authors also recommend detailed statistical analysis for similar future studies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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