Assessment of Physicochemical and Bacteriological Qualities of Borehole Water Sources in Gokana Local Government Area, Rivers State, Nigeria

C. P. Aleru[1*], O. A. Ollor[1], V. N. Agi[1] and C. A. Azike[1]

[1]Department of Medical Laboratory Science, Rivers State University, Nkpolu-Oroworukwo, P.M.B.5080, Port Harcourt, Rivers State, Nigeria.

Original Research Article

ABSTRACT

This study was carried out to assess the Physicochemical and Bacteriological qualities of borehole water sources in Gokana Local Government Area, Rivers State, Nigeria. Twenty (20) boreholes were used for the study and a total of sixty (60) water samples were collected for bacteriological analyses. All the Physicochemical parameters were measured in situ using Horiba Water Checker (Model-10). Heterotrophic Plate Count, Most Probable Number technique and Eijkman test were used for the enumeration, isolation and identification of bacteria. All analyses for Physicochemical parameters were within the acceptable limits (pH: 6.3 to 7.7; Temperature: 27 to 30; Turbidity: 0.61 to 2.01). Bacteriological quality was higher than the World Health Organisation standard recommended limits. The detection of bacteria such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Staphylococcus aureus*, *Proteus* and *Klebsiella species* in the borehole water sources that are intended for human consumption could cause one to think that water from those sources may lead to severe health risks to consumers. Hence, it is not suitable

---

*Corresponding author: Email: constancy.aleru1@ust.edu.ng;

for direct human consumption without treatment. Therefore, it is recommended that onsite treatment intervention be mobilised in order to protect residents of Gokana LGA of Rivers State, Nigeria from further possible consequences of using the borehole water sources.

1. INTRODUCTION

What make up water quality are the biological, chemical and physical characteristics of water. Water is extremely important and necessary to sustain life and an adequate and accessible, as well as safe supply must be available to every living thing. Making better the access to safe drinking water could result in reasonable benefits to human health. As a result, effort should be made as to attain a drinking water quality that would be as safe as practicable. According to World Health Organisation (WHO), those who are at greatest risk of waterborne disease are infants and young children, those who are weak (debilitated) or living under unsanitary conditions and the elderly [1,2].

African continent has been noted to have the highest number of people who do not have access to water that is safe and drinkable [3]. According to WHO, majority of Africans (more than 3.4 million) die each year from water sanitation and hygiene-related causes [1]. Back in the day, many African societies depended on surface water, but because challenges of contaminated surface water associated with diseases like, sleeping sickness, river blindness, guinea worm and others, people began to dig boreholes [4]. Locally, nationally and internationally, the digging of boreholes has been adopted as an alternative to polluted surface drinking water sources [3,4,5]. In 1997, it was noted that borehole water quality is dependent on hydrology, local geology and geochemical characteristics of the aquifers [6]. In addition, Fournier and Truesdell (1973) stated that the activities of microorganisms, pressure and temperature are responsible for the chemical characteristic of groundwater [7]. Water that is intended for drinking should be free of contaminants, such as chemical, physical and bacteriological. For this reason, it is needful to make sure that drinking water is safe and reliable.

Among the countries in Africa, Nigeria faces the problems of accessibility to pure water. However, the United Nations Children's Fund (2007) reported that 27 million new Nigerians have gained access to clean drinking water since 1990 [8]. Even if in Nigeria, most people depend on water from borehole, the purity of the drinking water from borehole remains doubtful [3]. In 2015, some researchers who carried out their researches in Nigeria reported higher values of turbidity, iron, pH and chlorine [3]. Further, pollution of boreholes with pathogenic bacteria has also been revealed in studies carried out in some parts of Nigeria and as result, there is need for adequate treatment of borehole water sources [3]. Lack of good water supply in Nigeria is being blamed for causing diseases, such as Cholera, Bilharzias and Typhoid [9].

In an attempt to ascertain the health risk of consumers of borehole water sources, this study assessed the physicochemical parameters and bacteriological contents of borehole water in Gokana Local Government Area of Rivers State, Nigeria.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The area of this study was Gokana Local Government Area (LGA) of Rivers State, Nigeria. Gokana LGA is in Ogoniland and it is located in the Southern part of Rivers State. Ogoniland covers some 1,000 km^2 in the South-East of the Niger Delta basin. According to the 2006 National Census, the region has a population of close to 832,000 [10]. The geological profile of Ogoniland shows that there is only one Aquifer that is being tapped by deeper boreholes and shallow wells. The entire population of Ogoni depends aquifers for drinking water. According to reports, the aquifers are very shallow with the highest groundwater levels occurring between close to the surface and a depth of 10 m. In order for the people of Ogoni to tap the aquifers, they construct open and hand-dug wells of about 60 cm in diameter. Then, withdraw the water manually or with pumps. Wells can be up to 50 m deep in some areas affected by localized pollution [11].

Five major communities in the LGA were chosen at random for this study; the communities included: Bodo City, Bomu, Kpor, K-Dere and Mogho. The sample analyses were carried out in Medical Microbiology Laboratory of the Department of Medical Laboratory Science, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt.

2.2 Sample Collection

The samples were collected using sterile water bottles from different borehole taps. The taps were opened and allowed to flow for 5 minutes; then, a sterile bottle was opened and placed under the flowing water and the desired volume was collected and the container capped. This was repeated for all the borehole water samples collected. A total of 60 water samples were collected in triplicate from the boreholes in each community. The water samples were transported to the laboratory for analyses within 2 hours.

2.3 Sample Analysis (Physicochemical Parameters and Bacteria)

Levels of Physicochemical parameters were analysed in this study. Before samples were analysed, all media and reagents were prepared in the laboratory according to the manufacturers' instructions and directions.

2.4 Analysis of Water Samples for Physicochemical Parameters

All the physicochemical parameters (pH, Temperature and Turbidity) were analysed in situ using Horiba Water Checker (Model U-10).

2.5 Cultivation of Microorganisms

Media such as Nutrient agar, MacConkey agar, MacConkey broth, Brilliant green lactose (bile) broth and CHROMagar for *Escherichia coli* and other Coliform (CHROMagar ECC) were prepared and used following the manufacturers' instructions and directions. After the preparation of the media, the media plates were labelled clearly and stored appropriately in the refrigerator at 4-6°C.

For the enumeration of bacteria, data were acquired from Heterotrophic Plate Count (HPC), Total Coliform Count (TCC) and Total *Escherichia coli* Count (TEC); the TCC and TEC were carried out using the Most Probable Number (MPN) technique, which was statistically determined by the use of MacCrady table.

2.6 Heterotrophic Plate Count (HPC)

In carrying out the physicochemical parameters, a row of tubes was arranged in a test-tube rack and the tubes held 9 ml of diluent (sterile normal saline) each. Using a sterile pipette, 1 ml of the original water sample was transferred to tube 1 (9 ml of diluent and 1 ml of sample). Then, using another sterile pipette, 1 ml of the diluted solution in tube 1 was transferred to tube 2 and so on, until 1ml of the content of tube 3 was transferred to tube 4 (10^4). Further, 0.1 ml was transferred from diluted solution in the tubes to the appropriate media plate (nutrient agar) and spread (spread plate technique) using a sterile glass spreader. Finally, the plates were incubated at 37°C for 18 to 24 hours in incubator and afterwards, the visible colonies on the culture plates were counted and reported in colony forming unit per millilitre (cfu/ml). The above procedure was carried out on all water samples from all the Twenty (20) boreholes [12].

2.7 The Most Probable Number (MPN) Technique

The MPN of bacteria present was estimated from the number of tubes inoculated and the number of positive tubes obtained in the test, using a specially devised statistical table (MacCrady table) [13,14,15]. Moreover, for confirmation of the thermotolerant coliform bacteria (*E. coli)*, positive tubes obtained in the test were further incubated in water bath at 45°C for 24 hours (Eijkman test); the positive tubes showed gas formation and yellow colour.

In addition, in order to further confirm, CHROMagar ECC (CHROMagar for *E. coli* and other coliforms) was inoculated with materials taken from the positive tubes (positive tubes incubated at 45°C). Following an appropriate incubation time, the culture plates were examined for the presence of *E. coli* (showed a blue colour) [16].

3. RESULTS

3.1 Physicochemical Parameters of the Borehole Water

Table 1 shows the results of the physicochemical parameters and according to the results, the pH

ranged from 6.3 to 7.7, Temperature ranged from 27 to 30 and Turbidity ranged from 0.61 to 2.01.

3.2 Different Bacteria Isolated from the Various Boreholes

According to the Table 2, the bacteria isolated were: *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Staphylococcus aureus*, *Proteus* and *Klebsiella species*.

3.3 Bacterial Count of Borehole Water Sources

Results of the Heterotrophic Plate Count (HPC) ranged from 8.7×10^3 to 8.0×10^4, while the results of the Total Coliform Count (TCC) ranged from 7 to 15. However, the Total *Escherichia coli* Count (TEC) ranged from 3 to 4 (Table 3).

4. DISCUSSION

In this study, the values of the physicochemical parameters were within the standard recommended limits for drinking water. The pH ranged from 6.3 to 7; Temperature ranged from 27 to 30; Turbidity ranged from 0.61 to 2.01 (Table 1). The pH values of the boreholes were in line with the reports by other researchers [3, 17]. Also, the levels of the Temperature were similar to the levels reported by other researchers who carried out their analysis in Nigeria [3]. However, the turbidity were not in line with their reports [3]. In order for water to be fit for drinking, it must meet internationally acceptable standard and must be in agreement with the guidelines clearly stated by the World Health Organisation [18].

The bacteria recovered from this study were *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Staphylococcus aureus*, *Proteus* and *Klebsiella species* (Table 2). The Heterotrophic Plate Count (HPC), Total Coliform Count (TCC) and Total *Escherichia coli* Count (TEC) ranged from 8.7×10^3 to 8.0×10^4, 7 to 15 and 3 to 4, respectively (Table 3). These counts were higher than the standard recommended limits for drinking water [19]. This is indicative of high level of pollution of borehole water sources in Gokana Local Government Area of Rivers State, Nigeria. The most serious form of contamination obtained from different sources seems to be faecal contamination. There are various methods of faecal waste management that are possible sources of contamination. For example, shallow depth of well, the use of organic fertilizer, the use of human and animal excreta as manure and refuse disposal. There are also some human activities that could contaminate borehole water sources, one of them is the siting of sources of water supply close to loos or latrines [20].

Table 1. Physicochemical parameters of Borehole water

S/N	ph	Temperature (°C)	Turbidity (NTU)
1.	6.3	29	1.64
2.	7.6	29	1.44
3.	7.4	29	1.45
4.	6.9	28	1.38
5.	7.2	30	2.01
6.	6.7	29	2.01
7.	6.3	29	1.02
8.	6.5	30	1.91
9.	6.5	28	0.64
10.	6.8	27	0.61
11.	7.5	29	1.40
12.	6.3	30	1.44
13.	7.6	28	0.65
14.	7.1	28	0.71
15.	6.8	30	1.67
16.	7.0	30	1.98
17.	7.3	29	1.41
18.	7.7	29	0.65
19.	6.3	30	1.35
20.	6.6	29	0.66

Table 2. Different Bacteria Isolated from the Various Boreholes

S/N of Borehole	Bacterial Isolate
1	*Salmonella typhi, Pseudomonas aeruginosa, Proteus species, Klebsiella species, Escherichia coli, Staphylococcus aureus*
2	*Pseudomonas aeruginosa, Proteus species, Klebsiella species, Escherichia coli*
3	*Klebsiella species, Escherichia coli, Staphylococcus aureus*
4	*Salmonella typhi, Pseudomonas aeruginosa, Proteus species, Klebsiella species, Escherichia coli*
5	*Salmonella typhi, Pseudomonas aeruginosa, Proteus species, Klebsiella species, Escherichia coli, Staphylococcus aureus*
6	*Escherichia coli, Klebsiella species, Staphylococcus aureus*
7	*Escherichia coli, Staphylococcus aureus*
8	*Escherichia coli, Staphylococcus aureus*
9	*Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa*
10	*Salmonella typhi, Pseudomonas aeruginosa, Proteus species, Klebsiella species, Escherichia coli*
11	*Klebsiella species, Escherichia coli, Staphylococcus aureus*
12	*Salmonella typhi, Pseudomonas aeruginosa, Proteus species, Klebsiella species, Escherichia coli*
13	*Escherichia coli, Staphylococcus aureus*
14	*Salmonella typhi, Pseudomonas aeruginosa, Proteus species, Klebsiella species, Escherichia coli, Staphylococcus aureus*
15	*Klebsiella species, Escherichia coli, Staphylococcus aureus*
16	*Salmonella typhi, Klebsiella species, Escherichia coli, Staphylococcus aureus*
17	*Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa*
18	*Escherichia coli, Staphylococcus aureus, Salmonella typhi*
19	*Proteus species, Klebsiella species, Escherichia coli*
20	*Escherichia coli, Pseudomonas aeruginosa*

Table 3. Bacterial Count of Borehole Water Sources

S/N of Borehole	HPC (cfu/mL)	TCC (MPN/100 mL)	TEC (MPN/100 mL)
1	1.0×10^4	7	3
2	2.4×10^4	7	3
3	7.4×10^4	14	3
4	6.1×10^4	7	3
5	3.0×10^4	11	3
6	3.2×10^4	11	4
7	7.0×10^4	15	3
8	6.9×10^4	11	4
9	2.0×10^4	7	3
10	1.9×10^4	7	4
11	3.5×10^4	7	3
12	8.7×10^3	14	3
13	4.0×10^4	7	4
14	5.3×10^4	14	3
15	7.8×10^4	15	3
16	8.0×10^4	15	3
17	7.0×10^4	11	4
18	7.2×10^4	11	4
19	6.6×10^4	7	3
20	6.0×10^4	7	3

HPC: Heterotrophic Plate Count; MPN: Most Probable Number; TC: Total Coliforms Count; Total Escherichia coliCount

Several researches carried out in Nigeria revealed the presence of the bacteria recovered from this study [21,22,23]. *Escherichia coli* is known as an indicative bacterium, which means that their presence in water supply provides indication that other pathogenic bacteria may also be present in the water supply. The presence of *E. coli* also indicates that the water sources were contaminated with faecal materials. *Salmonella typhi*, which was one of the bacteria detected in this study, is the cause of Typhoid fever in humans. In fact, previous researchers in different parts of Nigeria have blamed water supply for causing Typhoid fever and Cholera [24 25]. *Escherichia coli*, also recovered in this study has been reported as the main cause of diarrhoea, Cystisis and other diseases in humans [26]. The presence of bacteria, such as *Salmonella typhi*, *Esherichia coli* and others possesses a public health risk.

Possible sources of contamination of boreholes/wells are septic tanks, livestock yards, silos, septic leach fields, petroleum tanks, liquid-tight manure storage, fertilizer storage and manure stacks. However, one of the most common sources of borehole/well as noted by Centre for Disease Control and Prevention (CDC) are failed tanks or septic systems [20]. The safety and effectiveness of a well or borehole depend greatly on its location. For this reason, it is necessary to maintain safe distances between wells or boreholes and possible contamination sources [20].

5. CONCLUSION

This study has revealed that the various borehole water supplies were of poor quality in terms of bacteriological assessment. Also, the presence of indicator bacteria, such as *E. coli*, shows that other pathogenic bacteria might be found in the water. The high microbial load observed makes the boreholes unsuitable for drinking, except they are treated appropriately or they are used for washing purposes only. Access to good quality water is very important. For this reason, every borehole or well providing drinking water should be checked at least a year for bacteria and other contaminants.

The things that pose a great pressure on safe drinking water provision are increased in human population and rise in their activities. Hence, effective water quality monitoring could help in checking how daily human activities affect the quality of borehole water. Further, in order to protect drinking water quality, all septic systems and every source of potential contamination should be located as far as possible from wells

and boreholes. Moreover, it is required that new septic tanks or human-waste lagoons be installed at least 50 feet from a well or borehole. Also, septic tank drain field must be at least 100 feet from a well.

Therefore, this study would recommend the following: that water quality monitoring be a continuous process, around the vicinity of the borehole, proper sanitation should be strictly observed and, regular and adequate treatment of the borehole should be encouraged. Preferably, the regular treatment should be done in the water tank, which is the source from where water is distributed. Finally, this study would recommend that further research be carried out on the seasonal analysis of borehole water quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. World Health Organisation (WHO). Guidelines for drinking-water quality, (3rd edition). World Health Organisation, Geneva. 2008;1.
2. Aleru CP, Wachukwu CK, Abbey SD, Amala SE, Mbata CA Ollor OA. Assessment of physicochemical qualities, heavy metals concentration and bacterial pathogens in Elechi Creek, Port Harcourt, Nigeria. International Journal of Science and Research. 2019;8(9):447-432.
3. Adekola O, Bashir A,Kasimu A. Physicochemical characteristics of borehole water quality in GassolTaraba State, Nigeria. African Journal of Environmental Science and Technology. 2015;9(2):143-154.
4. Chigor VN, Umor VJ, Okuofu CA, Ameh JB, Igbinosa EO, Okoh AJ Water quality assessment of surface water sources used for drinking and irrigation in Zaria, Nigeria are a public health hazard. Environmental Monitoring and Assessment. 2012; 184(5):3389-3400.
5. Carpenter BR, Carao NF, Correll DL, Howarth RW, Sharpley AN, Smith VH. Non point pollution of surface waters with phosphorus and nitrogen. Ecological Application. 1988;8(3):559-568.
6. Bhattacharya P, Chatterjee D, Jack G (1997). Occurrence of arsenic-contaminated groundwater in alluvial aquifers from Delta plains, Eastern India: Options for safe drinking water supply. International Journal of Water Resources Development. 1997;13(1):79-92.
7. Foumier R, Truesdell A. An empirical Na, K and C geothermometer for natural waters. Geochimica et Cosmochimica Acta. 1973;37(5):1255-1275.
8. The United Nations Children's Fund. Photo essay: Nigeria's water and sanitation challenge; 2007.
9. Uzomah VC, Scholz M. Water availability assessment and corresponding public health implications for a Rural Area in Nigeria. Water and Environment Journal. 2002;16(4):296-299.
10. National Population Commission (NPC). Nigeria Demographic and Health Survey 2008; 2009.
11. United Nations Environment Programme (UNEP). Geology of Ogoniland. UNEP Ogoniland fact sheet; 2011.
12. Cheesebrough M. District laboratory practice in tropical countries: Part 2. Madrid: Cambridge University Press; 2002.
13. Rand MC, Taras MJ, Greenberg RE standard methods for the examination of water and waste water (14th Ed.). Washington, American Public Health Association; 1976.
14. World Health Organization (WHO). Guidelines for drinking-water quality, volume 3: Drinking-water control in small community supplies. Geneva: World Health Organization; 1985.
15. International Organization for Standardization, Geneva (ISO). Water quality C detection and enumeration of coliform organisms, thermotolerant coliform organisms and presumptive Escherichia coli. Part 2: Multiple tube (most probable number) method. International Standard ISO 9308-2, International Organization for Standardiza-tion, Geneva; 1990.
16. National Institute of Industrial Technology (NIIT). Comparison and recovery of *Escherichia coli* thermotolerant coliforms in water with a chromogenic medium incubated at 41°C and 44.5°C. Applied Environmental Microbiology. 2001;65(8): 37-46.
17. Ikeme CH, Dioha IJ, Olasusi KA, Chukwu PU. Physicochemical analysis of selected borehole water in Umuihi Town, Imo State, Nigeria. International Journal of Scientific and Engineering Research. 2014;5(8):680-689.

18. World Health Organisation (WHO). Guidelines for drinking-water quality (2nd Ed.). World Health Organisation, Geneva; 1976.

19. World Health Organisation (WHO). Guidelines for drinking-water quality (2nd Ed.). World Health Organisation, Geneva; 1993.

20. Centre for Disease Control and Prevention (CDC). Drinking water: Siting and contaminants; 2009. Available:https://www.cdc.gov/healthywater/drinking/private/wells/location.html[Retrieved 07/03/2020].

21. Aina DA, Olawuyi OJ, Coker OA, Ojelabi DO, Alatise FA. Bacteriological analysis of borehole water from different towns in Ogun State, Nigeria. African Journal of Microbiology Research. 2012;6(10):2462-2468.

22. Ngele SO, Itumoh EJ, Onwa NC, Alobu F Quality assessment of selected ground water samples in Amike-Aba, Abakaliki, Ebonyi State, Nigeria. Canadian Journal of Pure and Applied Science. 2014;8(1): 2801-2805.

23. Olajubu, FA, Ogunika F. Assessment of the physicochemical and microbiologicl properties of borehole water samples from AKUNGBA-Akoko, Ondo State, Nigeria. International Journal of Pharma Science and Research. 2014;5(7):367-374.

24. Uzomah VC, Scholz M. Water availability assessment and corresponding public health implications for a Rural Area in Nigeria. Water and Environment Journal. 2002;16(4):296-299.

25. Alexander P. Evaluation of ground water quality of Mubic Town in Adamawa State, Nigeria. Afri. J. Biotechnol. 2010;7(11).

26. Kennedy KJ, Roberts JL, Collins PJ *Escherichia coli* bacteraemia in canberra: Incidence and clinical features. Medical Journals. 2008;88(5):209-213.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55400