Physicochemical and bacteriological assessment of groundwater quality in Etsako east local government area of Edo state, Nigeria

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ABSTRACT

One of the environmental determinants of health is the quality of drinking water. Good quality water is devoid of impurities and pathogenic microbes. Water samples from 12 boreholes at two locations in Etsako East Local Government Area (LGA) were analyzed to evaluate their quality. The physicochemical parameters were measured using standard methods and Total Heterotrophic Bacterial Count (THBC) was performed using nutrient agar. The Total Coliform Count (TCC) was performed using the multiple tube technique also called the most probable number (MPN). The physicochemical properties of all the borehole water samples analyzed were within the WHO permissible limits except pH, which was acidic in Agenebode region. The heavy metal concentrations did not conform to the WHO recommended standards, e.g., in Agenebode, Lead was 0.62±0.00 mg/L and Cadmium 0.01±0.00 mg/L and in Okpella it was 0.43±0.00 mg/L and 0.02±0.00 mg/L, respectively. The bacteriological parameters such as total coliform counts and total heterotrophic bacteria counts in Agenebode (277±406.57 MPN/100mL), (34.67×10^3±23.67 CFU/mL) and Okpella (786.67±583.19 MPN/100mL), (41.50×10^3±24.09 CFU/mL), respectively, also exceeded the WHO permissible limits. In one of the locations (Agenebode) a total of four bacterial groups were isolated from the water samples, i.e., *Staphylococcus* spp., *Neisseria* spp., *Streptococcus* spp., and *E. coli*, while in the other location (Okpella) a total of five bacteria were isolated from the water samples, i.e., *Staphylococcus* spp., *Klebsiella* spp., *Enterococcus* spp., *Enterobacter* spp., *Yersinia* spp. The heavy metals contamination and high bacteria load of the water samples render them unfit for human consumption.

Keywords: Water; Bacteriological; Physicochemical; Contaminations; Heavy metal; Nigeria
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INTRODUCTION

Water is indispensable for man's existence. Its importance is often underestimated by humans. Water is used in the human body for numerous functions, such as body lubricant, body temperature regulation, elimination of harmful toxins and xenobiotics in the body, and transportation of nutrients throughout the body (APEC Water, 2016). Appelo and Posma (2005), classified water based on location into two main groups and these include ground and surface water. Groundwater otherwise called underground water refers to any subterranean water that is found underneath the water table in soil

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and other hydrological forms (Rail, 2000). Water obtained from a borehole is a classic example of groundwater. The quality of groundwater can decline due to improper resource management and inadequate source protection (Li *et al*., 2021). Worldwide, there is a growing demand for freshwater that is safe for drinking. About one-quarter of the earth's population depends on groundwater for drinking and to meet other fundamental needs (Hill, 2004). Just like surface water, groundwater is also prone to different contaminants as a result of the close proximity of the soil surface to the water table and several sources of surface pollution (Singh *et al.*, 2013). Indiscriminate disposal of untreated wastes has rendered natural water sources harmful by different contaminants like pathogenic microbes such as bacteria, viruses, heavy metals, anions such Nitrates, Sulphates, and xenobiotic organic substances have polluted such water supplies in many cities and towns (Singh and Mosley, 2003). According to Agboola *et al.* (2016), over 40% of Nigerians in both industrialized and rural areas depend on polluted water for their domestic consumption. Certain water quality indicators can adversely affect the drinking water quality when their concentrations or values are above the permissible standards set by the World Health Organization (WHO) and other water Regulatory Authorities (WHO, 2011). In Nigeria, the quality and safety of drinking water is monitored by National Industrial Standard (NIS).

Consumption of water with overabundant physicochemical properties may result in various detrimental effects on human health and haleness. Microbial contamination of drinking water results in different water-borne disease conditions. Non-metallic inorganic compounds such as nitrates and heavy metals such as arsenic are also harmful to humans in excess concentrations. In Nigeria, the demand for borehole water which is a principal source of drinking water among the occupants across the country is increasing, and hence, it is important to conduct a regular evaluation of the quality of these borehole water sources to determine the levels of contaminations and their resultant adverse effects on human that consume the water.

MATERIALS AND METHODS

Study area

The study was conducted in Etsako East LGA, Edo State, Nigeria. Etsako East LGA is geographically located at latitude 7.2627° N and longitude 6.4503° E. The headquarters of Etsako East LGA is Agenebode. A systematic random sampling technique was used in this study, where samples were collected from areas whose inhabitants rely mainly on groundwater sources (boreholes) for drinking and meeting other household needs.

Sample collection

Twelve water samples were collected from two different locations across the LGA. The samples were obtained by pumping water afresh from the boreholes through the tap, which was precisely collected in universal sterile labeled containers for bacteriological analysis and also in 1.5 L labeled bottles for physicochemical analysis. The samples for microbiological analysis were collected in sterile universal containers stored in an insulated icebox at the temperature of 4 ^{o}C and transported to the microbiology laboratory of Edo State University, Uzairue, Edo State, and analyzed within 48 hours of collection.

Physiochemical analysis

The borehole water samples collected from the various locations were analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness, Calcium hardness, Magnesium hardness, salinity, temperature, appearance, anion (nitrate, sulphate, bicarbonate, and carbonate) contents, cation (sodium, calcium, and magnesium) concentrations.

The physicochemical indicators; pH, temperature, EC, total dissolved solids (TDS), and salinity were determined using a multi-parameter meter (Fubara *et al*., 2022) with model PH111BL 23A after calibration with three standard buffer solutions of pH 4.00, 6.86, and 9.18 on-site. The multi-parameter meter probe was immersed in the water sample and held for a few minutes to attain an equilibrated reading state for pH, electrical conductivity, total dissolved solids, temperature, and salinity. After estimating each sample, the probe was adequately cleansed with deionized water to prevent cross-contamination among various samples collected from different locations within the LGA.

Determination of total hardness, calcium hardness, magnesium hardness, calcium ion, and magnesium ion

The borehole water samples were analyzed for total hardness, calcium hardness, magnesium hardness, magnesium content, and calcium concentrations utilizing the methods described by APHA (1995).

Determination of nitrate and sulphate

The concentrations of nitrate and sulphate were evaluated using the turbidity method and Phenoldisulphonic acid method described by APHA (1995).

Carbonate and bicarbonate determination

Bicarbonate and carbonate contents were estimated by the titrimetric method described by APHA (1995).

Heavy metal analysis

The heavy metals of interest, Lead (Pb), Cadmium (Cd), and Arsenic (As) were determined using a flame atomic absorption spectrometer (FAAS) with the model, PerkinElmer Analyst 400 AA Spectrometer and according to the standard method of APHA (1995)

Bacteriological analysis

The total heterotrophic bacterial count (THBC) was performed using nutrient agar (Pant *et al.,* 2016). The total coliform count (TCC) was performed using the multiple tube technique also called the most probable number (MPN). The media used for the MPN test were MacConkey broth, Brilliant Green Lactose Bile (BGLB) broth and Eosine Methylene Blue (EMB) agar. All media were prepared according to the manufacturers' instructions and all samples were serially diluted before analysis. The bacterial isolates were identified and characterized on the basis of morphology, gram stain reaction and key biochemical test (catalase, indole, urease, oxidase, and citrate utilization test) as described by Cheesbrough (2006).

Statistical analysis

Statistical Package for Social Sciences (SPSS) version 26 for Windows® was used to analyze the data. The data were tested using a one-way analysis of variance with the turkey-Krammer multiple comparison post hoc test. The data was considered significant when $p \leq 0.05$. The mean results of the water quality were compared with that of the WHO and NIS drinking water standards for reference.

RESULTS AND DISCUSSION

The mean and standard deviation values of some of the selected physicochemical properties, heavy metal concentrations, and bacteriological quality of the twelve (12) borehole water assayed are depicted in the Tables 1, 2, 3, 4, and 5, respectively. Man's impact on the environment is the primary cause of water pollution (Palit *et al.,* 2012). Water samples from Agenebode area within this LGA were acidic while Okpella water samples were within WHO permissible pH values. This is similar to the study conducted by Adeyemi (2020) who reported a pH value of 7.20 in the Itaogbolu area of Ondo-State, Nigeria. This finding is also in tandem with that of Osarenmwinda and Idaehor (2019) who recorded a pH range between 6.8 and 7.4 in water samples utilized for drinking purposes in Ekpoma. The electrical conductivity of samples across this LGA was within the WHO and NIS recommended standards. This result is consistent with the study conducted by Morka *et al.* (2021) on water used in different households in some localities in Edo State.

Table 1. Physicochemical indices of the sampled water in Etsako east local government area (N=12)

S/N	Parameters	Unit	Agenebode	Okpella	WHO (2017)	NIS (2015)
1	pH		5.01 ± 0.52^a	7.13 ± 0.34^b	7- 8.50	6.50 – 8.50
2	Conductivity	µs/cm	218 ± 143.78^a	427.83 ± 81.55^b	1000	1000
3	TDS (ppm)	ppm	113.50 ± 78.70^a	212.67 ± 65.02^b	500	1000
4	Total hardness	mg/L	54.67 ± 24.61^a	168 ± 35.69^b	500	150
5	Ca^{2+} hardness	mg/L	37.33 ± 19.29^a	142 ± 42.97^b	-	-
6	Mg^{2+} hardness	mg/L	17.33 ± 10.33^a	262 ± 10.43^b	-	-
7	Salinity	ppm	113.83 ± 78.73^a	212 ± 40.20^b	200-250	200
8	Temperature	°C	25.98 ± 0.46^a	26.37 ± 2.12^a	20-30	Ambient
9	Appearance		Clear	Clear		
10	Odor		Odorless	Odorless	Odorless	Odorless

Data are expressed as Mean±SD. Values in the same row with different alphabetic superscripts are considered significantly different (P< 0.05).

Table 2. Determination of selected anions, cations, and heavy metals present in borehole water samples obtained from Etsako east local government

S/N	Ions Unit (mg/L)	Agenebode	Okpella	WHO (2017, 2011, 2006)
1	SO_4^{2-}	0.06 ± 0.05^a	0.13 ± 0.09^a	250- 500
2	NO_3	0.02 ± 0.01^a	0.03 ± 0.00^a	50
3	CO_3^{2-}	3.50 ± 1.0^a	4.25 ± 1.26^a	75
4	HCO_3^-	83.50 ± 13.03^a	69 ± 17.57^a	120
5	Na^+	0.85 ± 0.26^a	1.36±0.68a	200
6	Ca^{2+}	14.96 ± 7.73^a	56.91 ± 17.22^b	75
7	Mg^{2+}	4.21 ± 2.51^a	6.32 ± 2.54^a	50
8	Pb	0.62 ± 0.00^a	0.43 ± 0.00^b	0.01
9	Cd	0.01 ± 0.00^a	0.02 ± 0.00^b	0.003
10	As	0.01 ± 0.00^a	0.01 ± 0.00^b	0.01

Pb= Lead, As= Arsenic, Cd= Cadmium, So_4^{2-} =Sulphate, NO_3^- =Nitrate, CO_3^{2-} = Carbonate, HCO_3^- =Bicarbonate, Na^+ =Sodium, Mg^{2+} =Magnesium and Ca^{2+} =Calcium. Data are expressed as Mean±SD. Values in the same row with different alphabetic superscripts are considered significantly different (P< 0.05).

These authors further recorded values that were within the allowable limit of WHO standards. The taste of water is greatly affected by the presence of total dissolved solids. The total dissolved solids of water samples analyzed across the LGA were within the permissible limit of WHO. The result of this study is similar to that of Morka *et al.* (2021) who recorded a total dissolved solids range of 56.44 mg/L to 138.42 mg/L from water utilized in different regions in Edo State. The total hardness of the various water across the two locations in this LGA was within the WHO recommended limit of 500 mg/L.

Table 3. Total heterotrophic bacteria count and total coliform count in Etsako east local government

Parameters	**Sampling Point**		**WHO (2017)**
	Agenebode	**Okpella**	
THBC × 10^3 (CFU/mL)	$34.67 \times 10^3 \pm 23.67^a$	$41.50 \times 10^3 \pm 24.09^a$	1×10^2
TCC × 10^3 (MPN/100mL)	277 ± 406.57^a	786.67 ± 583.19^a	0

TCC = Total Coliform Count, THBC= Total Heterotrophic Bacteria Count.
Data are expressed as Mean±SD. Values in the same row with different alphabetic superscripts are considered significantly different (P<0.05)

This corroborates the result of a previous study conducted by Raji *et al.* (2019) on borehole water used in Okada, Edo State and they recorded values that were within the permissible limits of WHO. Water hardness that surpassed the WHO recommended standard makes the water unsuitable for consumption, jeopardizes usage for baking, cooking and hinders laundry activities as well as increases corrosion in metallic pipes (Stocchi, 1990). The mean salinity values in Agenebode (113.83±78.73) and Okpella (212±40.20) obtained from the water samples analyzed within this LGA were within the permissible limit set by WHO. Ibietela *et al.* (2021) conducted a study on borehole water sources in Abonnema Rivers State and reported a similar outcome where they had mean values that conformed to the WHO recommended limit. Man's impact on the environment is the primary cause of water pollution (Palit *et al.*, 2012). Water samples from Agenebode area within this LGA were acidic while Okpella water samples were within WHO permissible pH values. The growth of microorganisms is influenced by an increased temperature of water (WHO, 2011). The temperature of water samples analyzed from the two different locations within this LGA was within the recommended standard of the WHO. This outcome corroborates the report of Oka and Upula, (2021), who got a range of 23.5 °C to 25.5 °C in their study area. Low sulphate concentrations within the permissible limit of WHO were recorded in this study. The values of nitrate ion concentrations in our study area are in line with the WHO recommended standard of 50 mg/L. This result is in tandem with Raji *et al.* (2019) who reported mean values that were within the allowable limits of WHO. The mean values for carbonate and bicarbonate ion concentrations were 4.25±11.26 mg/L and 83.5±13.03 mg/L respectively and these results are in line with the WHO recommended standard. Again, these results are consistent with the findings of Garba *et al.* (2021) who had carbonate and bicarbonate concentrations from different water sources in Bauchi State that were within the permissible limit set by the WHO. The concentration of calcium in all the water samples analyzed in Okpella was 56.91±17.22 mg/L while Agenebode area had a mean concentration of 14.96±7.73 mg/L.

Table 4. Morphology of the bacterial isolates and biochemical characterization tests done for identification in Agenebode location

Location (Agenebode)	**Gram staining**	**Shape**	**Catalase**	**Urease**	**Simon citrate**	**Oxidase**	**Indole**	**Possible bacteria**
A	+	Cocci	+	+	+	-	-	*Staphylococcus* spp.
B	-	Cocci	+	-	-	+	-	*Neisseria* spp.
B	+	Cocci	-	+	+	-	-	*Streptococcus* spp.
C	-	Rod	+	-	-	-	+	*E . coli*
D	-	Cocci	+	-	-	+	-	*Neisseria* spp.
E	+	Cocci	-	+	+	-	-	*Streptococcus* spp.
F	-	Cocci	+	-	-	+	-	*Neisseria* spp.

+ = Positive, - = Negative, A= Location 1, B= Location 2, C=Location 3, D=Location 4, E=Location 5, F=Location 6

Table 5. Morphology of the bacterial isolates and biochemical characterization tests done for identification in Okpella location

Location (Okpella**)**	**Gram staining**	**Shape**	**Catalase**	**Urease**	**Simon citrate**	**Oxidase**	**Indole**	**Possible bacteria**
A	+	Cocci	+	+	+	-	-	*Staphylococcus* spp.
B	-	Rod	+	+	+	-	+	*Klebsiella* spp.
C	+	Cocci	-	-	-	-	-	*Enterococcus* spp.
D	-	Rod	-	-	-	-	-	*Enterobacter* spp.
D	+	Cocci	+	+	+	-	-	*Staphylococcus* spp.
E	+	Cocci	+	+	+	-	-	*Staphyloccocus* spp.
E	-	Rod	+	-	+	-	-	*Yersinia* spp.

+ = Positive, - = Negative, A= Location 1, B= Location 2, C=Location 3, D=Location 4, E=Location 5

These values are within the guideline value of 75 mg/L set by WHO. This result is similar to that of Morka *et al.* (2021) who recorded values that were within the permissible limit by WHO. The mean concentrations of magnesium ions recorded were within the WHO recommended limit of 50 mg/L. This is in tandem with the work of Chegbeleh *et al.* (2020), who recorded magnesium concentrations that were within the guideline value. Low values of sodium ion concentrations that were within the WHO permissible limit of 200 mg/L were recorded. The Pb concentrations recorded in the water samples within our study area surpassed the WHO and NIS standard limits of 0.01 mg/L. These results align with the study conducted by Fakeye *et al.* (2018) on borehole water assayed in some rural areas in Edo State and they obtained values that surpassed the WHO recommended standard.

According to Edori and Edori (2012), increased levels of Pb in the blood lead to brain damage, irritation, and plumbism. Constant exposure to Cd over a long period can lead to tubular proteinuria. The borehole water samples analyzed in our study area had Cd concentrations that exceeded the WHO permissible limit of 0.003 mg/L. This result is a clear indication that the sampled water is not fit enough for human consumption. This finding is similar to that of Eseyin (2020) who reported Cd concentrations of borehole water in Port Harcourt that was beyond the WHO guideline value. As in water exists at oxidation states of +5 and +3, it is more stable at an oxidation state of +3 due to loss of oxygen (WHO, 2011). The mean concentrations of As analyzed in the various water samples collected in this study were within the recommended standard by WHO. The detection of a high count of fecal coliforms in the borehole water samples denotes fecal contamination and this increases the chances of waterborne disease outbreaks in the LGA (Zige *et al.*, 2018). Although a high count of total coliforms may not reflect the magnitude of pathogenic bacteria contamination, this at least denotes the absence or improper chlorination and this indicates pathogenic bacteria contamination of the various borehole water samples. The water samples collected from Agenebode had a mean total heterotrophic bacteria count (THBC) of $34.67 \times 10^3 \pm 23.67$ CFU/mL. However, the water samples collected from Okpella recorded a mean value of $41.50 \times 10^3 \pm 24.09$ CFU/mL. The most probable number of the borehole water samples varied from 277±406.57 MPN/100 mL to 786.67±583.19 MPN/100 mL. The results of the THBCs obtained from the LGA were high and beyond the WHO limit of 1.0×10^2 CFU/mL. In the same vein, the total coliform counts of the borehole water samples analyzed across the two locations within the LGA surpassed the WHO limit of zero MPN/100 mL and the NIS guideline value of 10 MPN/100 mL. This finding agrees with the investigation of Abubakar *et al.* (2020), who reported values that exceeded the WHO limits in water samples analyzed in Dutse, Jigawa State. This result also corroborates the outcome of a similar study conducted in Ekpoma, Edo State by Osarenmwinda and Idaehor (2019) who reported high heterotrophic bacteria count and faecal coliform count. The results denote a high level of faecal coliform contaminations and other viable bacteria in the assayed water. It is therefore unsafe to drink untreated water from the various borehole sources within this community. Eight bacterial isolates were isolated from the various borehole water samples assayed in this study. Using appropriate biochemical characterization tests, the bacterial isolates were identified as; *Staphylococcus* spp., *Neisseria* spp., *Streptococcus* spp., *E. coli*, *Enterococcus* spp., *Klebsiella* spp., *Enterobacter* spp., *and Yersinia* spp. The detection of these bacteria in the assayed water samples is in agreement with the study conducted by Oka and Upula (2021) who recorded a high bacteria count and total coliform count in the borehole water analyzed in Ugep, North West of Calabar thus rendering the water unfit. The presence of *E. coli* in the various water samples in this study can be attributed to the unhygienic practices of the populace residing in the area. Similar observation has been reported by Zige *et al.* (2013).

CONCLUSION

The findings from the study have shown that the physicochemical parameters were within the WHO allowable limits except for pH, which was acidic in Agenebode region. The concentrations of As detected in the various water samples also met the WHO permissible limit while Cd and Pb concentrations surpassed the WHO allowable limits. This implies that the long-term consumption of water from the various boreholes by the inhabitants of this LGA may lead to deleterious health effects such as renal disorders, cardiovascular disorders, and cancer. The bacteriological quality of the borehole water samples was poor as a high count of viable bacteria and total coliform were found. The presence of bacteria such as *Staphylococcus* spp., *Neisseria* spp., *Streptococcus* spp., *E. coli*, *Enterococcus* spp., *Klebsiella* spp., *Enterobacter* spp., *and Yersinia* spp. in the water samples has automatically rendered it unsuitable and unfit for human consumption without adequate and sanitary treatment.

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Competing interests

There is no competing interest.

Authors contribution

Conceptualization and methodology by Ugbenyen A.M. and Ajayi O.O.; formal analysis and investigation by Young G.I. and Onobun D.O.; writing - original draft preparation by Young G.I. and Onobun D.O.; writing -

review and editing by Ugbenyen A.M.and Ajayi O.O.; Resources by Ugbenyen A.M., Ajayi O.O., Young G.I. and Onobun D.O.; supervision by Ugbenyen A.M., Ajayi O.O.

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