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Physicochemical and bacteriological assessment of borehole water from Etsako west local government.

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Abstract

One of the environmental determinants of health is the quality of drinking water, and water of good quality is void of impurities and pathogenic microbes. Poor quality water has deleterious effects on man's health and wholeness. Conducting a periodic evaluation to ascertain the likely water pollution in the environment is imperative. The study evaluated the physical-chemical parameters (pH, temperature, total dissolved solids, electrical conductivity, total Hardness, Calcium Hardness, Magnesium Hardness, salinity, appearance, odour, Sulphate, Nitrate, Carbonate and Bicarbonate, Sodium, Calcium, and Magnesium contents), heavy metals (Cadmium, Arsenic, and Lead) concentrations and bacterial qualities (total heterotrophic bacteria count and total coliform count) of groundwater from twelve (12) boreholes in four different locations in Etsako West Local Government Area. All the physicochemical indicators analyzed in this study were within the recommended standards except for pH, which is acidic. The heavy metal concentrations and the total heterotrophic bacterial count mean values surpassed the WHO permissible limits. The research identified six genera of bacteria: Klebsiella spp, Staphylococcus spp, Streptococcus spp, Neisseria spp, Enterococcus spp, and E. coli. This study shows that groundwater quality from different boreholes across the LGA is unsuitable for consumption due to toxic metal contamination and high bacteria load. Therefore, there is a need for proper treatment of the water from different borehole sources by boiling or chlorination before consumption.

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1.0 Introduction

Water is a fundamental nutrient component of the human body and is vital for man's existence. It benefits living things, agricultural production, industrial processes, and human consumption (Hvitved and Yousef, 1991). According to Idiata (2006), water is an intracellular fluid found in the body and comprises about 75% of the total weight of an average man. Despite its proven relevance, we often overlook water in dietary recommendations and the essence of proper hydration. It thus serves as a multi-functional constituent of the human body. Water is a universal solvent, usually made up of a molecule of hydrogen and one atom of oxygen. The molecular formula representation of water is H2O. Water emerged via the unmediated reaction of oxygen and hydrogen (Bhat, 2014). Water makes up more than 70% of the earth's surface, indispensable for the survival of all biologically recognized organisms (Longe and Enekwechi, 2007).

Before water becomes portable and fit for drinking, it must meet the World Health Organization's specific physical, chemical, and microbiological guidelines. Portable water is void of disease-causing organisms and chemical substances harmful to man (Nikoladze and Akastal, 1989). Nigeria's core source of potable water originated from borehole water (Getso et al., 2018). Over 120 million Nigerians use boreholes as a primary source of drinking water (Obioma et al., 2020). Water scarcity is a significant problem that affects millions of people worldwide. Globally, the stress and strain associated with freshwater resources emanating from surface and groundwater are increasingly becoming unbearable due to a spike in population and rapid urbanization. Groundwater quality can decline due to improper resource management and inadequate source protection.

Accessibility to and obtainability of fresh, pure water still play a vital role in economic expansion and public welfare. However, key elements are health, agricultural production, and poverty ablation (Ashbolt et al., 2001). Microbial contamination of drinking water results in different water-borne disease conditions. Industrial and agricultural wastes act as contaminants in water and render them unsafe for consumption. These are challenges in Third-world countries with water-borne diseases. Worldwide, there is a growing need for freshwater that is safe for drinking. Several contaminants such as; bacteria, fungi, protozoans, viruses, algae, Sulphates, Nitrates, and salts and, heavy metals have rendered water supplies unsafe and unhealthy due to poor treatment and improper disposal of humans and livestock wastes and commercial discharges (Onyango et al., 2018). The global population requires adequate access to unpolluted and safe water for maximum sustainability (Braunstein, 2007). There are vital steps that facilitate the management of water resources. It is crucial to identify the various factors affecting water quality meant for domestic purposes (Keshavarzi et al., 2006). In Etsako West Local Government Area, boreholes serve as the core water source for meeting the residents' daily water requirements. In Nigeria, there is a rise in the demand for borehole water which is a principal source of drinking water among the occupants across the country. Hence, it is imperative to regularly examine the quality of these borehole water sources to ascertain the levels of contaminations and their resultant deleterious effects on man's health. This study evaluated the borehole water quality obtained from four locations (Iyamho, Auchi, South Ibie, and Aviele) in Etsako West Local Government, Edo State. The physicochemical properties, heavy metals contents, and bacterial parameters of the borehole water samples establish the safety index and possible contaminations that pose potential hazards to residents of this Local Government Area.

2.0 Materials and Methods

2.1 Study Area

The study covered the area of Etsako West Local Government Area, Edo State, Nigeria. Etsako West Local Government Area covered latitude 7.0080° N and longitude 6.2801° E. The headquarters of Etsako West Local Government is Auchi. The researcher adopted a systematic random sampling technique and obtained samples from heavily populated areas whose residents depend majorly on groundwater sources (boreholes) for drinking and meeting other household needs. S

2.2 Sample Collection

This study involved the collection of twelve (12) water samples from four locations across the Local Government Area. The samples were obtained by pumping water fresh from the deep wells (boreholes) through the tap, which was precisely collected in universal sterile labelled containers for bacterial analysis and also in 1.5 L labelled bottles for physicochemical analysis. The samples for biological analysis were collected in sterile universal containers stored in an insulated icebox at the temperature of 1 – 4 oC and conveyed to the microbiology laboratory of Edo State University, Uzairue, Edo State, and analyzed within 48 hours of collection.

2.3 Sterilization of Materials

To prevent contamination and recontamination, all glassware and other materials used to conduct the microbial facet of this experimental research, namely, beakers, distilled water, measuring cylinders, and test tubes, were sterilized in an autoclave for 15 minutes at 121oC.

2.4 Physiochemical Analysis

The researchers centred analysis on the borehole water samples 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.

2.4.1 pH, Temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Salinity

The physicochemical indicators pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), and salinity were determined using a multi-parameter meter with model PH111BL 23A after calibration with three standard solutions at pH 4.00, 6.86, and 9.18 on-site. The multi-parameter 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 samples collected from local government areas.

2.4.2 Determination of Total Hardness, Calcium Hardness, Magnesium Hardness, Calcium Ion, and Magnesium Ion

The analysis centred on the borehole water samples for total hardness, Calcium hardness, Magnesium hardness, Magnesium content, and Calcium concentrations utilizing the methods described by APHA (1995).

2.4.3 Determination of Nitrate and Sulphate

The concentrations of Nitrate and Sulphate were determined using the turbidity method and Phenoldisulphonic acid method as described by APHA (1995).

2.4.4 Carbonate and Bicarbonate Determination

The study determined the Bicarbonate and Carbonate contents by the titrimetric method described by APHA (1995).

2.4.5 Heavy Metal Analysis

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

2.5 Total Counts of Heterotrophic Bacteria

The pour plate method determined the total heterotrophic bacterial counts of the water samples. An aliquot of 1 ml of the 10-5 dilutions of the samples obtained from Etsako West Local Government incubates the Petri Dishes in triplicates. The researcher incubates the plates at 37oC for 24hrs. After 24 hours, the mean counts of the bacteria colonies were taken and recorded. The estimation of the Coliform Forming Unit number of the samples from the colony count obtained with the aid of a colony counter and multiplied by the dilution factor, which accounts for the cfu/ml in the experimental sample using the standard method described by Pant et al., (2016). The bacteria isolates obtained from the initial culture were further subcultured for another 24 hours to obtain pure cultures. The pure bacteria isolates were subjected to morphological characterization and different biochemical tests to determine the probable bacteria species using the standard microbial method.

2.5.1 Total Coliform Count and Faecal Coliform

The researcher collected the total coliform count and the faecal coliforms in water samples from the locations within the Etsako West Local Government Area by the Most Probable Number (MPN). The study applied the 3-3-3 index. The methodology also applied the most probable number of bacteria present in a sample APHA (1995). The most probable number technique is done in three phases: the presumptive test, confirmatory test, and completed test.

2.5.2 Identification of Bacterial Isolates and Biochemical Characterization

This study further examined the pure isolates from the sub-culture to verify their discrete morphological characteristics and various biochemical tests (oxidase test, mixture change test, indole test, urease, and Simon citrate test). It identified the probable organisms using standard methods described by Cheesbrough (2006).

2.6 Statistical Analysis

The application of the Statistical Package for Social Sciences (SPSS) version 26 for Windows® to analyze the field data. The research applied a One-way Analysis of variance to evaluate the data with the turkey-Krammer multiple comparison post hoc test and Pearson r relationship analysis between the physicochemical parameters, heavy metals, and microbial growth. It indicated a high level of significance when $p < 0.05$. For reference purposes, comparing average water quality results with the World Health Organization and NIS drinking water standards.

3.0 Results

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 samples in the tables below;

Table 1

Table 1: Results of the Physical chemical Parameters of Water Samples Obtained in Etsako West Local Government.

S/N	parameters	Unit	Iyamho	Auchi	South Ibie	Aviele	WHO (2017)	NIS (2015)
1	Ph		5.52±0.22^{a}	4.66±0.70^{a}	5.22±0.42^{a}	5.70±0.47^{a}	7-8.5	6.5-8.5
2	Conductivity	µs/cm	36.33±9.87^{ac}	179.67±37.85^{b}	117.67±37.85^{bc}	68.67±42.12^{ac}	1000	1000
3	TDS	ppm	17.67±4.93^{ac}	90±19.05^{b}	59±18.25^{bc}	32.67±21.20^{ac}	500	1000
4	Total hardness	mg/L	17.33±2.31^{a}	104±14.42^{c}	73.33±14.05^{ab}	38.67±22.74^{ab}	500	150
5	Mg^{2+} Hardness	mg/L	6±2^{a}	67.33±14.19^{bc}	47.63±7.02^{b}	20.67±17.01^{ac}	-	-
6	Ca^{2+} Hardness	mg/L	11.33±3.06^{a}	36.67±5.77^{b}	26.67±13.32^{ab}	18±6^{ab}	-	-
7	Salinity	ppm	16.67±5.13^{a}	90±19.05^{b}	59±18.25^{ab}	33±20.60^{a}	200-250	200
8	Temperature	°C	25.10±0.96^{a}	29.60±0.85^{b}	29.97±0.25^{b}	30±1.40^{b}	20-30	Ambient
9	Appearance		Clear	Clear	Clear	Clear	-	-

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

Table 2

Table 2: Results of Ions Present in Borehole Water Samples Obtained from Etsako West Local Government Area

S/N	**Ions (mg/L)**	**Iyamho**	**Auchi**	**South Ibie**	**Aviele**	**WHO (2017;2011;2006)**
1	SO_4^{2-}	0.01±0.00^{a}	0.02±0.02^{a}	0.21±0.00^{b}	0.21±0.01^{b}	250- 500
2	NO_3^{-}	0.03±0.00^{a}	0.02±0.00^{a}	0.01±0.00^{b}	0.05±0.00^{c}	50

3	**CO_3^{2-}**	$3±1.41^a$	$4±0.00^a$	$3±1.41^a$	$4.5±0.71^a$	75
4	**HCO_3^-**	$62±2.83^a$	$89±1.41^b$	$92±2.83^b$	$62.5± 0.71^a$	120
5	**Na^+**	$0.13±0.04^a$	$1.08± 0.25^a$	$1.79±0.37^a$	$1.39±1.01^a$	200
6	**Ca^{2+}**	$6.95±0.93^{ab}$	$14.69±2.34^a$	$10.69±5.34^{ab}$	$4.54±1.22^b$	75
7	**Mg^{2+}**	$1.46±0.49^a$	$16.36±13.45^b$	$11.34±1.71^{bc}$	$5.02±4.14^{ac}$	50
8	**Pb**	$0.42±0.01^a$	$0.34±0.00^b$	$0.4±0.00^b$	$0.340±0.00^a$	0.01
9	**Cd**	$0.02±0.00^a$	$0.06±0.00^b$	$0.01±0.00^c$	$0.02±0.00^{ac}$	0.003
10	**Arsenic**	$0.020±0.00^a$	$0.01±0.00^b$	$0.01±0.00^b$	$0.02±0.00^c$	0.01

Pb= Lead, As= Arsenic, Cd= Cadmium, So42- =Sulphate, NO3- =Nitrate, CO32- = Carbonate, HCO3- =Bicarbonate, Na+ =Sodium, Mg2+ =Magnesium and Ca2+ =Calcium.

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

Table 3:

Table 3: Total Heterotrophic Bacteria Count and Total Coliform Count in Etsako West

Location	Total Heterotrophic Bacteria Count (cfu/ml)	THBC WHO (2017) permissible limit	Total Coliform Count (MPN/100ml)	TCC WHO (2017) Permissible limit
Iyamho	$87x10^5±13.23^a$	$1.0x10^2$ cfu/ml	$1400±0.00^a$	0MPN/100ml
Auchi	$90.67x10^5±17.79^a$	$1.0x10^2$ cfu/ml	$887±369.50^a$	0MPN/100ml
South Ibie	$97.67x10^5±12.66^a$	$1.0x10^2$ cfu/ml	$1300±173.21^a$	0MPN/100ml
Aviele	$30.33x10^5±16.69^b$	$1.0x10^2$ cfu/ml	$690±627.46^a$	0MPN/100ml

TCC = Total Coliform Count, THBC= Total Heterotrophic Bacteria Count.

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

Table 4

Table 4: Bacterial isolation and biochemical characterization in Etsako West Local Government Area

Location	Gram staining	Catalase	Urease	Simon citrate	Oxidase	Indole	Shape	Suspected organism
South Ibie	+	-	-	-	-	-	cocci	Enterococcus spp

Iyamho	-	+	-	-	-	+	Rod	E. coli
Auchi	+	-	+	+	-	-	cocci	Streptococcus spp
Auchi	-	+	-	-	+	-	cocci	Neisseria spp
Aviele	-	+	+	+	-	+	Rod	Klebsiella spp
Aviele	+	+	+	+	-	-	cocci	Staphylococcus spp

+ = Positive, - = Negative

4 Discussion

Public health concern associated with poor drinking water quality index is synonymous with developing countries such as Nigeria. These exempted inhabitants of Etsako West Local Government Areas from this burden. The pH of water samples from Etsako West Local Government Areas was acidic. pH denotes the degree of the acidity or alkalinity of a solution. pH is a vital water parameter because the survival of most microorganisms depends on it. The deviation from neutral pH to an acidic level (lower pH) of the water samples obtained from Etsako West Local Government Area may result in an irregular change in carbon dioxide, Carbonate, or Bicarbonate equilibrium, this could affect the microbial count. Adefemi and Awokunmi (2010) reported acidic water to be responsible for rusting of cooking utensils and corrosiveness in steel and metallic pipes, which ultimately results in blockage and unpleasant smell in food and drinks. Conversely, water consumption with increased pH values can irritate the eye, skin, and mucosa (Godwill et al., 2015). A similar result was obtained by Josiah et al. (2014), with a pH range of 4.35-5.39. Treating the water to increase the pH to a recommended limit will help reduce or prevent the potentially detrimental effects it poses. The electrical conductivity of samples obtained from Etasako West Local Government Areas ranged from 36.33±9.87 µs/cm to 179±37.85 µs/cm, and this is within the WHO, and NIS recommended standards. Total dissolved solids (TDS) is a term that denotes the availability of inorganic matter in water or other solutions. The availability of total dissolved solids in water may affect the taste. According to WHO (1996), drinking water with a low concentration of total dissolved solids may reduce its suitability for consumption due to its unappetizing taste. The dissolved solids of water samples analyzed across the four locations within Etsako West Local Government Area were within the permissible limit of WHO and NIS. The values varied from 17.6±4.93 ppm to 90±19.05 ppm. The hardness of the various water across the Etsako West Local Government Area was within the WHO recommended limit of 500 mg/L. The water samples from this Local Government Area are moderately hard. Hard water is crucial for the formation of strong bones and robust teeth. Hard water forms scale on metallic pipelines, which hinders likely disintegration and solubility of heavy metals like Cadmium, Arsenic, and Chromium. Hard water can lead to rheumatic pains and goitre; hence, it is unsuitable for drinking (Bahar and Reza, 2010). Salinity refers to the measure of the salt level present in water that makes water unfit for domestic, industrial, or agricultural utilization. Salinity occurs in the form of chloride ions, regarded as one of the core anions in water. It is essential for regulating acid-base balance; thus, concentrations surpassing the permissible limit set by WHO can result in edema (Ekpete, 2002). The Etsako West Local Government Area result was within the WHO and NIS permissible limit of 200- 250 mg/L. Generally, natural water with high and low salinities is composed of Chloride and Sodium ions. Continuous water consumption with high salinity content often leads to hypertension in humans. Also, increased salinity levels in water lower the oxygen content of water; hence, fresh, natural water contains more oxygen than salt water. Temperature is one of the most vital indicators of water quality and plays a crucial role in the growth of organisms in a water environment. The temperature of water samples analyzed in this Local Government fell within the permissible limit set by the WHO. Sulfate (SO42-), Chloride (Cl-), and Nitrate (NO3-) are the core mineral anion salts that are soluble in water. The research recorded a Sulphate range of 0.01±0.00 mg/L to 0.21±0.00 mg/L in this Local Government Area, within the permissible limit set by WHO. Nitrate is a vital indicator of water quality because of its role in pathogenic microorganisms. Nitrates originated from nitrogenous fertilizers, agricultural wastes, industrial wastes, and the nitrogen cycle. The Nitrate concentrations of borehole water samples collected from Etsako West Local Government ranged from 0.01±0.00-0.05±0.00 mg/L, which fell within the recommended standard. Carbonate and Bicarbonate are anions that contain atoms of oxygen and carbon. These anions form precipitates with Magnesium and Calcium in the form of Magnesium Carbonate and Calcium Carbonate. The WHO permissible limits for Carbonate and Bicarbonate are 75 mg/L and 120 mg/L, respectively. In this Local Government Area, Carbonate and Bicarbonate mean values are within the ranges of 3.0±1.41-4.5±0.71 mg/L and 62±2.82-92±2.83 mg/L, respectively. Carbonate and Bicarbonate particles in the water samples obtained across the several locations within this Local Government Area may be due to the dissolution of Carbonate rocks in the different locations. The result indicates that the borehole water sources from the study area are void of Carbonate and Bicarbonate contaminations. High concentrations of Calcium and Magnesium ions are responsible for hardness in underground water. Calcium concentration in all the water samples analyzed across the various locations within the study area varied from 4.54±1.22-14.69±2.34 mg/L, which falls within the permissible limit of WHO. Calcium is vital for maintaining the functioning of the cardiovascular and nervous systems and blood coagulation. Low concentrations of Calcium in portable water used mainly for drinking may lead to rickets and teeth dysfunction. Magnesium is an important nutrient required by humans for nerve and muscle functions and by plants for photosynthesis and growth. The WHO recommended limit for Magnesium in drinking water is 50 mg/L. The concentration of Magnesium in all the water samples investigated within this Local Government varied from 1.46±0.49-16.36±13.45 mg/L. Without Magnesium and Calcium ions, there will be no hardness of the water. Sodium is a vital nutrient that helps regulate electrolyte balance in humans. The concentration of Sodium in all the water samples tested within this Local Government varied from 0.13±0.04-1.79±0.37 mg/L. Low values of Sodium-ion concentrations within the WHO permissible limit of 200 mg/L. Although some heavy metals are essential for maintaining proper body functions, they become poisonous or toxic when their concentrations exceed the permissible limit. Because of the severity of their toxicity, Cadmium, Arsenic, Lead, Chromium, and Mercury is considered metals of public health importance. Lead is one of the essential heavy metals. The Lead concentrations recorded in Etsako West are within the range of 0.34±0.00-0.42±0.00 mg/L. The Lead concentrations recorded in the water samples within the locations surpassed the WHO and NIS standard limits of 0.01 mg/L. Increased concentrations of Lead in water beyond the recommended standard pose a serious threat to man's health. Lead in high concentrations is toxic and inhibits the synthesis of haemoglobin. Its carcinogenic properties can lead to liver dysfunction and hair loss in humans. Continuous exposure to Lead can impede mental and physical development in children and infants, while in adults, it leads to kidney complications and hypertension (Imam et al., 2018). Cadmium is a heavy metal that is required even at a low concentration. Man's activities, such as mining, metal production, and fossil fuel combustion, can increase the concentrations of Cadmium in the environment. From Table 2 above, the Cadmium concentrations recorded within Etsako West Local Government varied from 0.01±0.00 to 0.06±0.00 mg/L, exceeding the WHO permissible limit of 0.003 mg/L. According to Sanders and Buchner (2009), Cadmium has a detrimental effect on man's health, such as hypertension, cancer, cardiovascular diseases, and kidney dysfunctions. Arsenic is a broadly spread heavy metal found in soil, rocks, air, and water. Increased concentrations of Arsenic in water are toxic and may lead to cardiovascular and central nervous system complications, gastrointestinal disorders, and death. The Etsako West Local Government Area result showed Arsenic mean concentration variations of 0.01±0.00 to 0.02±0.00 mg/L. The mean concentrations of Arsenic obtained from water samples analyzed across Etsako West Local Government these areas are beyond the WHO recommended limit of 0.01 mg/L. Arsenic toxicity results in a condition known as Arsenicosis, which takes decades or years to manifest fully. Children and infants are more affected by Arsenic toxicity than adults. It impedes mental development in children and causes skin lesions.

We discovered faecal contaminants or pathogenic microorganisms in drinking water. Biological indicators of water quality, such as faecal coliform, total coliform counts, and total heterotrophic bacteria counts, to ascertain the suitability of the groundwater sources (borehole water) for consumption within this Local Government Area. The Enterobacteriaceae family of bacteria is one of the generally accepted biological (bacteria) indicators used in evaluating water quality. Some bacteria from the family, as mentioned earlier, are native to soil and water; hence, the same bacterium that is specific to water contamination, known as faecal coliform bacteria, is used to assess the degree of water pollution. Detecting faecal coliform in water is suggestive of faecal pollution of the water. It is because of the enteric disease-causing organisms found in the faeces of animals. The total heterotrophic bacteria count (THBC) in boreholes water samples in Etsako West LGA ranged from 30.33x105±16.69 to 97.67x105±12.66 cfu/ml. The most probable number varied from 690 ±627.46 to 1400±0.00 MPN/100ml. The results of the total heterotrophic bacteria counts obtained from this Local Government Area were high, and they surpassed the WHO limit of 1.0x102 CFU/ml.

Similarly, the total coliform counts of the borehole water samples analyzed across the Local Government Areas exceeded the WHO limit of zero MPN/100ml and the NIS guideline value of 10 MPN/100ml. This study's total heterotrophic bacteria count and total coliform count results are in tandem with that of Obioma et al. (2020), who recorded values that surpassed the WHO permissible limits. In this study, the microbial analysis of the different borehole water samples collected from the Local Government Area revealed massive contamination with faecal coliforms and other viable bacteria. The high bacteria contamination recorded in this study described the inappropriate disposal of sewage materials like domestic wastes. Therefore, drinking untreated borehole waters in this study area should be a public health concern as diseases such as dysentery, cholera, and food poisoning may likely occur. Six (6) genera of bacteria isolate identified, including; Klebsiella spp, Staphylococcus spp, Streptococcus spp, Neisseria spp, Enterococcus spp, and E. coli. The aforementioned disease-causing microbes indicate faecal contaminations of the borehole water sources. These agree with the findings of Zige et al. (2018), who recorded total coliform count and total multi-trophic count that surpassed the WHO limits and the presence of enteric pathogens like Enterobacter aerogenes, Klebsiella pneumonia, Salmonella spp, and E. coli. These pathogenic microbes can facilitate the spread of diarrhoea, enteric fever, pneumonia, rheumatic fever, and painful boils.

Conclusion

The results showed the water's physicochemical properties within the recommended limits of WHO standards except for pH. On the other hand, the microbial indicators were beyond the recommended standard limits set by WHO and NIS. The analysis revealed the presence of prominent bacteria genera such as Klebsiella spp, Staphylococcus spp, Streptococcus spp, Neisseria spp, Enterococcus spp, and E. coli. Borehole water sources from this local government area are unsafe for consumption without adequate treatment before utilization as they could harbour pathogenic organisms to man and animals. Hence, compared to the guideline value, the borehole water assessed could be chemically good but microbiologically unfit for consumption as raw water for drinking, animal breeding, agricultural use, and recreational purposes. As a matter of urgency, stringent measures to halt the further accumulation of pathogenic microorganisms and heavy metals to prevent a future outbreak of water-borne diseases and other related health risks resulting from increased toxic metal concentrations.

Implications of the study

The high concentrations of heavy metals observed in this research suggest that the inhabitants in this Local Government Area within the study area. Consequently, consuming water from these boreholes will expose consumers to detrimental health risks like; renal dysfunction, gastrointestinal disorders, plumbism, osteoporosis, cardiovascular diseases, neurodegenerative disorders, Arsenicosis, cancer, growth retardation, and death. Similarly, the high bacteria load and presence of faecal coliform imply that the residents in this study area may be prone to water-borne diseases.

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