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Physicochemical, Spectroscopic, and Bacteriological Analyses of Borehole Waters in Selected Areas of Makurdi-Nigeria

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Abstract

Physicochemical, spectroscopic, and bacteriological analyses were carried out to determine the quality of borehole waters in selected areas of the Makurdi metropolis. UV/Visible spectrophotometric methods of analysis were used for most determination. The results revealed that the physicochemical parameters are within the recommended national and international standards except for values of total hardness for the Brewery Area, Judge's Quarters, and Old GRA. The total coliform values range from 1-12cfu/10ml with borehole location C4 in the Benue State University area having the highest cfu/10ml. The bacterial isolates *E. coli* and *S. typhi*. The borehole waters are thus suitable for human and other consumption purposes.

Keywords: Water, heavy metals, nutrients, physicochemical, bacteriological, Spectroscopic

1 Introduction

Water's existence preceded the evolution of life. The reactions that make up life such as proteins and nucleotide synthesis occurred in the aqueous medium. It is for this reason that water forms a part of biological structures. An adult human has a water content of 65 – 70%, A normal adult person consumes two and a half liters of water a day and loses an equal amount [1]. The high dielectric constant of water makes it an excellent solvent, it is often referred to as the universal solvent, as a result,, natural water is never pure but a solution of substances that come into contact with it. When the number and or concentration of the chemicals entering a water source becomes so large that the natural qualities of water are altered, we say that the water has become polluted. When water is so polluted it is mandatory to purify it, however before water can be purified the nature of the pollutant must be identified [1][2]. Water pollutants are classified into four broad categories, chemical, physical, physiological, and biological. Chemical contaminants are sub-divided into organic and inorganic pollutants. Organic pollution which is the most common is caused by naturally occurring compounds like proteins, fats, carbohydrates, etc. as well as by synthetic compounds like dyes, pesticides, herbicides, etc. inorganic pollutants largely originate from industrial sources. Some common examples include are showed in Table 1.

Water is a chemical substance with the chemical formula H_2O. A water molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at ambient conditions but it often co-exists on Earth with its solid state, ice, and gaseous state. Water also exists in a liquid crystal state near hydrophilic surfaces, water covers 71% of the earth's surface and is vital for all known forms of life. On Earth, 96.5% of the planet's water is found in oceans, 1.7% in glaciers and the ice caps of Antarctica and green land, a small fraction in other large water bodies, and 0.001% in the air as vapor clouds and precipitates. Only 2.5% of the earth's water is fresh water and 98.8% of that water is in ice and groundwater. Less than 0.3% of all freshwater is in rivers, lakes and the atmosphere, and an even smaller amount of the earth's freshwater (0.003%) is confined within biological bodies and manufactured products. Water on Earth moves continually through the hydrological cycle of evaporation and transpiration, condensation, precipitation, and run-off [4]. Safe drinking water is essential to humans and other life forms. Access to safe drinking water has improved over the last decades in almost every part of the world but approximately one billion people still lack access to safe water and over 2.5 billion lack access to adequate sanitation [5]. Water appears in nature in all three forms of matter and may take many different forms on Earth. The major chemical and physical properties of water may include:

- Water is a liquid at Standard Temperature and Pressure (STP), it is tasteless and odorless. The intrinsic color of water and ice is a very slight blue hue, although both appear colorless in small quantities. Water vapor is essentially invisible as a gas.
- Water is transparent in the visible electromagnetic spectrum. Thus aquatic plants can live in water because sunlight can reach them, infra-red light is strongly absorbed by the Hydrogen Oxygen (H – O) bond and Hydroxyl (OH) bonds.
- Since the water molecule is not linear and the oxygen atom has a higher electronegativity than the hydrogen atom, it carries a slight negative charge, whereas the hydrogen atoms are slightly electropositive, as a result, water is a polar molecule with an electrical dipole moment. Water also can form an unusually large number of inter-molecular hydrogen bonds (four) for a molecule at it size. These

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factors lead to strong attractive forces between molecules of water giving rise to water-high surface tension and capillary forces [2, 3].

- Water is a good solvent and is often referred to as the universal solvent. Substances that dissolve in water example salt, sugars, acid, alkalis, and some gases, especially oxygen, and carbon dioxide are known as hydrophilic substances while those that are immiscible with water e.g. fats and oil are known as hydrophobic substances.
- Most of the major components in cells (protein, DNA, and polysaccharides) are also dissolved in water.
- Pure water has a low electrical conductivity but this increases significantly with the dissolution of a small amount of ionic material such as sodium chloride.
- The boiling point of water is dependent on the barometric pressure example on the top of Mount Everest water boils at 68^0C compared to 100^0C at sea level. Conversely, water deep in the oceans near geothermal vents can reach temperatures of hundreds of degrees and remain liquids.
- Elements which are more electropositive than hydrogen such as lithium, sodium, calcium, potassium, and cesium displace hydrogen from water forming hydroxide. Being a flammable gas the hydrogen given off is dangerous and the reaction of water with more electropositive of these elements may be violently explosive.
- An oxide of hydrogen water is formed when hydrogen or hydrogen-containing compounds react with oxygen or oxygen-containing compounds.
- Water can be split by electrolysis into hydrogen and oxygen.
- Water forms an azeotrope with many other solvents
- Water is miscible with many liquids such as ethanol in all proportions, forming a single homogenous liquid.
- Its density is 1000kg/m^3.
- The maximum density of water occurs at 3.98^0C it has the anomalous property of becoming less dense not more when it is cooled down to its solid form [5,6,7].

Groundwater is water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from and eventually flows to the surface naturally: natural discharge often occurs at springs and seeps, and can form oases or wetlands [7,8]. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is called hydrogeology [8]. A borehole is a generalized term for any narrow shaft bored in the ground, either vertically or horizontally. A borehole may be constructed for different purposes, including extraction of water or other liquids or gases [6]. Typically a borehole used as a water well is completed by installing a vertical pipe (casing) and well screen to keep the borehole from caving, this also helps to prevent surface contaminants from entering the borehole and protect any installed pump from drawing in sand and sediment. Drillers may sink a borehole using a drilling rig or a hand-operated rig. The machinery and techniques to advance a borehole vary considerably according to the manufacturer, geological conditions, and the intended purpose [7,8].

Water, our most precious natural resource is being threatened by a multitude of contaminants, resulting in an unprecedented crisis with local and national implications. The news is full of stories about communities that have been told that their water is unsafe to drink, and that is now struggling to clean up that water supply. Water contamination and pollution occur when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds. Water pollution affect plant and organism. Water pollution/contamination is a major global problem that requires ongoing evaluation and revision of water resource policy at all levels [4,7]. Groundwater and surface water interact complexly consequently leading to contamination. A spill or ongoing release of chemical or radionuclide contaminants into the soil may contaminate borehole water [7]. Drinking water contaminants include Microorganisms, Disinfectants, Disinfection Byproducts, Inorganic chemicals, Organic chemicals, and Radionuclides . The microorganism may include *Cryptosporidium, Giardia lamblia, Legionella,* total Coliform including fecal Coliform and *E. coli*, and Viruses. *Salmonella*, parasitic worms, *Burkholderia pseudomallei* [8]. Disinfection by-products may include Bromate, chlorite, Haloacetic acid, and total trihalomethanes [7]. Disinfectants may include Chloramines, chlorine, and chlorine dioxide [7,8]. Inorganic Chemicals may include Antimony, Arsenic, Asbestos, Barium, Beryllium, Cadmium, Copper, Cyanide, fluoride, Lead, Mercury, Nitrate, Nitrite, Selenium, Thallium, etc [7]. Organic Chemicals may include Acrylamine, Alachlor, Atrazine, Benzene, Benzo [a] pyrene, carbofuran, carbon tetrachloride, chlordane, chlorobenzens, Dalapon, 1,2–Dibromo-3-chloropropane, O-Dichlorobenzene, P-Dichlorobenzene, etc.[7]. Radionuclides may include Alpha particles, Beta particles, and photon emitters Radium 226 and Radium 228, and Uranium [7]. The Aim and Objectives of the study are:

- To determine the physicochemical and bacteriological parameters in bore-hole water in certain areas in the Makurdi metropolis.
- To know if commercial and industrial activities within areas under investigation have a severe negative effects on human life.
- To know whether or not the bore-hole water parameters conform to national and international drinking water quality standards.
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Table 1: Examples of inorganic water pollutants and their sources [2]

Pollutant	Representative example	Sources
Acids	Sulphuric acid, phosphoric acid	Mines run off, wool scouring waste, iron pickle liquor
Alkalis	Caustic soda, lime	Tannery waste, cotton processing waste
Cations	Mercury (II), lead (II)	Metallurgical operations
Anions	Sulphide, cyanide	Plating waste, gas liquor mine runoff

2 Materials and Methods

2.1 Materials

i. Sterile 75cl water bottles – used for collection of water samples from the various bore-hole locations
ii. HACH direct reading UV/vis spectrophotometer, model DR2000 for determination of turbidity, color, suspend solid, etc, and most cationic and anionic parameters.
iii. Thermometer – for measuring temperature
iv. Hanna digital pH meter – for pH determination
v. Buffer solution, maneuver hardness indicator, ethylenediaminetetraacetic acid (EDTA), and 8M potassium hydroxide – for total hardness, calcium, and magnesium hardness.
vi. Sample bottles, autoclave, incubator beakers, conical flask, syringes, measuring cylinders, CLED (cystin-lactose Electrolyte Deficient) medium, Petri-dishes – for determination of total coliform bacteria.
vii. Cellotape – for labeling samples
viii. HACH C0150 conductivity meter model 50150 for determination of electrical conductivity.

2.2 Methods

2.2.1 Sample Collection

Five samples each were collected in four different areas in Makurdi – Brewery area (A), Judges Quarter area (B), Benue State University, BSU Area (C), and old GRA area (D). The samples were collected in the last week of August using sterile 75cl water bottles. Another set was collected in the last week of November.

2.2.2 Sample Analysis

Samples were analyzed in the Benue State Water Board Central Laboratory immediately after collection.

2.2.3 Temperature

The HANNA digital thermometer was immersed into the water sample and the reading was read and recorded. This was done for all the other samples.

2.2.4 Determination of Turbidity

The program number (750) for turbidity was entered and the wavelength was adjusted to 450nm and the FTU unit was displayed. A blank of 25mL of deionized water was measured into the sample cell and placed into the cell holder. The light shield was closed. The zero key was pressed, and the reading displayed 0.00FTU units. The blank was then removed, 25mL of the bore-hole water sample was measured using the sample cell bottle and placed into the cell holder and the light shield was closed. The read/enter key was pressed and the reading displayed in FTU unit was read and recorded. This procedure was repeated for all the other samples [15].

2.2.5 Determination of Colour

Direct reading spectrophotometer (DR/2000) from (HACH) company was used. The program number (120) for colour was entered and the wavelength was adjusted to 455nm and the unit pt.co colour was displayed. A blank of 25mL of deionized water was measured into the sample cell and placed into the cell holder. The light shield was closed, the zero key was pressed and the reading displayed 0.00 pt.Co colour unit. The blank was then removed, 25mL of the bore-hole water sample was measured using the sample cell bottle and placed into the cell holder. The light shield was closed. The read/enter key was pressed and the reading displayed in pt.Co colour unit was read and recorded. The procedure was repeated for all the other samples [15].

2.2.6 Determination of Suspended Solids

The HACH DR2000spectrophotometer was used. The program number (630) for suspended solids was entered and the wavelength was adjusted to 810nm and the mgL^{-1} unit was displayed. A blank of 25mL of deionised water was measured into the sample cell and placed into the cell holder. The light shield was closed, the zero key was pressed and the reading displayed $0.00mgL^{-1}$. The blank was then removed, 25ml of the bore-hold water sample was measured using the sample cell bottle and placed into the cell holder, the light shield was closed. The read/enter key was pressed and the reading displayed in mgL^{-1} was read and recorded. This procedure was repeated for all the other samples [15].

2.2.7 Determination of Total Dissolved Solid (TDS)

The TDS meter (model 50150 from HACH company) was switched on and the probe immerged into distilled water and agitated. `The reading displayed $0.00mgL^{-1}$. The probe was removed and then immerged into the water sample; the result displayed was read and recorded. This procedure was repeated for all the other samples [15].

2.2.8 Determination of Total Solids

Total solid was calculated from the addition of suspended solid and total dissolved solids.

2.2.9 Determination of Conductivity (µS/cm)

The conductivity meter (model 50150 from HACH Company) was switched on and the probe immerged into distilled water and agitated. The reading displayed 0.00µs/cm. the probe was removed and then immerged into the water sample, the result displayed was read and recorded. This procedure was repeated for all the water samples [15].

2.2.10 Determination of pH

The pH meter from HANNA company was switched on and the probe immersed into the water samples. The reading displayed was read as it stabilized and then recorded. This procedure was repeated for all the bore-hold water samples.

2.2.11 Determination of Total Hardness

Hardness test kit model HA-4P-MG-L was used. 5mL of the sample was measured using a plastic tube and poured into the mixing bottles. Three drops of butter hardness one solution was added and swirled to mix. One drop of ManVer hardness indicator solution was added. EDTA titrant was added drop by drop into the mixing bottle and the mixture swirled to allow for uniform mixing as each drop of the EDTA solution was added until the mixture colour changes from pink to blue. The hardness in mgL^{-1} was calculated by multiplying the number of drops added by a factor of 20. The procedure was repeated for other samples [16].

2.2.12 Determination of Calcium Hardness

The plastic tube was level filled with water to be tasted and the content poured into the mixing bottle. Two drops of 8M potassium hydroxide solution was added. One calver 2 calcium indicator powder pillow was added and titrated against EDTA by adding drop wisely until the pink colour of the mixture was changed to blue. The calcium hardness in mgL^{-1} was calculated to be equal to the number of drops of EDTA added multiplied by a factor of 20. This procedure was repeated for other samples [16].

2.2.13 Determination of Magnesium Hardness

This was calculated by subtracting the calcium hardness value from the total hardness value. This was done for all the samples.

2.2.14 Determination of Total Iron

The Ferrover powder pillow method was adopted. The program number (265) for iron was entered and the wavelength was adjusted to 510nm and the mgL^{-1} Fe was displayed. A blank of 25mL of deionised water was measured into the sample cell and placed into the cell holder, the light shield was closed and the zero key was pressed, the reading displayed $0.00mgL^{-1}$ Fe. The blank was then removed, 25mL of the sample was measured using the sample cell and one ferrover iron reagent powder pillow was added and allowed to stand for one minute reaction time after which it was placed into the cell holder. The read/enter key was pressed and the reading displayed in mg/L^{-1}Fe was read and recorded. The procedure was repeated for all the other samples [15].

2.2.15 Determination of Zinc

The program number (780) for zinc in water was entered and the wavelength was adjusted to 620nm, the unit mg/L^{-} Zn was display. The zincon method was adopted. A 50mL mixing graduated cylinder was filled to the 50mL mark with the sample. One ZinCover 5 reagent powder pillow was added, the solution was stopperd and inverted several times to completely dissolve the powder. 25mL of the solution was measured into a sample cell (the blank) and 1.0mL of cyclo hexanone was added to the remaining solution in the cylinder. The cylinder was stopppered and shook for thirty seconds and then allowed to stand for about three minutes. The solution was then proved from the cylinder into the sample cell. The blank was placed into the cell holder and the light shield closed. The zero key was pressed and the display showed 0.00mg/L Zn. The prepared sample was then placed into the cell holder and the light shield closed, the read/enter key was pressed and the result in mg/L Zn was displayed, read and recorded. This procedure was repeated for the rest samples [15].

2.2.16 Determination of Chromium

The 1,5 – diphenylcarbohydrazine method was adopted. The program number (90) for Cr^{+6} was entered and the wavelength adjusted to 540nm and the mgL^{-1} Cr^{+6} was displayed. A blank of 25mL of deionised water was measured into the sample cell and placed into the cell holder and the light shield closed. The zero key was pressed and the reading displayed $0.00mgL^{-}Cr^{+6}$. The blank was then removed, 25mL of the sample was measured into the sample cell and one chromaver 3 reagent powder pillow was added and allowed to stand for one minute reaction time. After which it was placed into the cell holder. The read/enter key was pressed and the reading displayed in mgL^{-1} Cr^{+6} was read and recorded. This procedure was repeated for all the other samples [15].

2.2.17 Determination of Copper

The Bicinchoninate method was adopted. The stored program number (135) for copper (Cu) bicinchoninate powder pillow was entered and the wavelength adjusted to 560nm, the read/enter key was pressed and the display showed mg/L Cu Bicn. A sample cell was filled with 25mL of the sample and the content of one CuVer 1 copper reagent powder pillow was added to the sample cell and then swirled to mixed. The solution was allowed to stand for about two minutes. The second sample cell (the blank) was filled with 25mL of the sample and placed in the cell holder and the light shield closed, the zero key was pressed and the display showed 0.00mg/L Cu Bicn. The prepared sample was then placed into the cell holder and the light shield closed, the read/enter key was pressed and the displayed showed the result in mg/L copper which was read and recorded. This procedure was repeated for the other samples [15].

2.2.18 Determination of Manganese

The periodate oxidation method was adopted. The stored program number (295) for manganese periodate oxidation was entered and the wavelength adjusted to 525nm, the read/enter key was pressed and the displayed showed mg/L Mn H. 25mL of the sample was filled in a cell and the contents of one Buffer powder pillow citrate type was poured into the sample and swirled to mix. The contents of one sodium periodate powder pillow was added to the sample cell (the prepared sample) and swirled to mix. The solution was allowed for two minutes. Another sample cell (blank) was filled with 25mL of the sample and placed into the cell holder, the light shield was closed and the zero key pressed, the display showed 0.00mg/L Mn H. The prepared sample was then placed into the cell holder and the light shield closed, the read/enter key was pressed and the displayed result in mg/L was read and recorded. This procedure was repeated for the other samples [15].

2.2.19 Determination of Nitrate

The Nitriver 5 (powder pillow) method was adopted. The program number (355) for nitrate was entered and the wavelength was adjusted to 500nm and the mgL^{-1} NO_3^{-} was displayed. A blank of 25ml of deionized water was measured into the sample cell and placed into the cell holder. The light shield was closed. The zero key was pressed and the reading displayed $0.00mgL^{-1}$ NO_3^{-}. The blank was the removed, 25mL of the water sample was measured using the sample cell bottle and one Nitriver 5 nitrate powder pillow was added and allowed to stand for one minute reaction time, after which it was placed into the cell holder. The read/enter key was pressed and the reading displayed in mgL^{-1} NO_3^{-} was read and recorded. This procedure was repeated for all the other samples [15].

2.2.20 Determination of Sulphate

The sulfaver 4 method (powder pillow) was adopted. The program number (580) for sulphate was entered and the wavelength was adjusted to 450nm and the mgL^{-1} SO_4^{2-} was displayed. A blank of 25mL of deionised water was measured into the sample cell and placed into the cell holder. The light shield was closed. The zero key was pressed and the reading displayed $0.00mgL^{-1}$ SO_4^{2-}. The blank was removed, 25mL of the sample was measured using the sample cell bottle and one sulfaver 4 sulphate reagent was added to the sample and allowed to stand for five minute reaction period, after which it was placed into the cell holder. The read/enter key was pressed and the reading displayed in mgL^{-1} SO_4^{2-} was read and recorded. The procedure was repeated for all the other water samples [15].

2.2.21 Determination of Phosphate

The phosver 3 method was adopted. The program number (490) for phosphate was entered and the wavelength was adjusted to 890nm and the mgL^{-1} PO_4^{3-} was displayed. A blank of 25mL of deionised water was measured into the sample cell and in the cell holder, the light shield was closed and the zero key was pressed, the reading displayed $0.00mgL^{-1}$ PO_4^{3-}. The blank was then removed, 25mL of the sample was measured using the sample cell bottle and one phosVer 3 phosphate powder pillow was added and allowed to stand for two minute reaction period, after which it was placed into the cell holder.

The read/enter key was pressed and the reading displayed in mgL^{-1} PO_4^{3-} was read and recorded. This procedure was repeated for all the water samples [15].

2.2.22 Determination of Chloride

The program number (70) for chloride was entered and the wavelength was adjusted to 455nm and the mgL^{-1} Cl^- was displayed. A blank of 25ml of deionized water was measured into the sample cell and placed into the cell holder. The light shield was closed. The zero key was pressed and the reading displayed 0.00mg/L^{-1} Cl^-. The blank was then removed. 25ml of water sample was measured using the sample cell bottle and 2.0mL of mercuric thiocyanate solution was mixed and 1.0mL of ferric ion solution was also added and allowed for two minutes reaction period after which it was placed into the cell holder. The read/enter key was pressed and the reading displayed in mgL^{-1} Cl^- was read and recorded. This procedure was repeated for all the other samples [15].

2.2.23 Determination of Fluoride

The SPADNS method was adopted. The program number (190) for fluoride was entered and the wavelength adjusted to 580nm, the read/enter key was pressed and the display showed mg/L F^-. 25mL of the sample was measured into a dry sample cell (the prepared sample). 25mL of deionised water was then measured into a second cell (the blank). 5.00mL of SPADNS reagent was pipetted into each cell, swirled to mixed. The solution allowed to stand for a one minute reaction period. The blank was placed into the cell holder and the light shield closed, the zero key was pressed and the display showed 0.00mg/L F^-. The prepared sample was placed into the cell holder and the light shield closed, the read/enter key was pressed and the displayed showed result in mg/L F^- which was read and recorded. This procedure was repeated for all the water samples [15].

2.2.24 Determination of Silicate

The silicomolybdate method was adopted. The program number (656) for silica high range was entered and wavelength adjusted to 452nm. The read/enter key was pressed and the display showed mg/L S_iO_2 H. 25mL of the sample was filled into a sample cell and the contents of one molybdate reagent powder pillow was added, the solution was swirled to mix. The contents of one acid reagent powder pillow for high range silica was added swirled to mix. The solution was then left to stand for a ten minute reaction period. Shift ABS key was pressed and the display sowed Abs, the zero key was then pressed and the display showed 0.000ABS. the capped square mixing bottle with holmium trichloride solution was placed into the cell holder and the light shield closed. Starting at 460nm the wavelength dial was slowly turned down to decrease the wavelength. The display was watched for the peak absorbance which occurred between 450 – 454nm. Without moving the wavelength dial, the holmium trichloride solution was removed from the cell holder. The contents of one citric acid powder pillow was added to the sample cell (the prepared sample) and swirled to mix. The shift Conc. and shift timer keys were pressed and a two minute reaction period began. The timer beeps and the display showed 0.0mg/L S_iO_2 H. A second sample cell was filled with 25mL of the sample (the blank) and placed in the cell holder, the light shield closed and the zero key pressed. The display showed 0.0mg/L S_iO_2 H. within three minutes after the second timer beeps, the prepared sample was placed into the cell holder, the light shield closed and the result in mg/L silica was displayed, read and recorded. This procedure was repeated for all the other samples [15].

2.2.25 Determination of Total Alkalinity

This was determine using sulphuric acid method described by Saxena (1990). Two indictors were used – phenolphthalein and methyl orange. The phenolphthalein alkalinity was kept as zero. 50mL of the sample was collected in a conical flask and 2 drops of phenolphthalein indicator was added to the sample followed by 2 drops of methyl orange indicator. The solution was then titrated against 0.02N solution of sulphuric acid until a pink coloration was observed. The value for the total alkalinity was calculated using the relationship [16].

$$\text{Total Alkalinity as } CaCO_3 \left(\frac{\text{mg}}{\text{L}}\right) = \frac{a \times 100}{V}$$

where a is volume of sulphuric acid used and V is volume of sample. This procedure was repeated for all the other samples.

2.2.26 Determination of Free Carbonate

This was determined titrimetrically using the sodium hydroxide method described by Sexena (1990) 50mL of the sample was poured into a round bottom flask and 2 drops of phenolphthalein indicator was added. The sample was then titrated against 0.02272M sodium hydroxide solution till a pink colour was observed. The free carbonate was calculated using the relationship [28].

$$\text{Free carbonate } CO2 \left(\frac{\text{mg}}{\text{L}}\right) = \frac{x \times 100}{V}$$

where x is volume of sodium hydroxide used and V is volume of sample. This procedure was repeated for all the other samples.

2.2.27 Determination of Coliform

This was done using the plate count method.

Culture media preparation and sterilization: 15g of CLED (cystin – lactose – Electrolyte Deficient) medium was dissolved in 1 litre of distilled water and autoclaved at 121^0C for fifteen minutes and left to cool. The top of the conical flask was wrapped with foil to prevent contamination. The area (bench) where the work was to be done was properly cleaned with dettol and water.

Sample Dillution: The sample was diluted using the serial dilution method. Dillution was done to the second power ie. 10^{-2}. lmL of the sample was mixed with 9mL of distilled water making up 10mL of solution. From the 10mL of solution another lmL was thus collected and mixed with 9mL of distilled water, another 10mL of solution was again gotten. From the later 10mL solution, lmL was collected into the agar.

Culturing, Incubating, Colony Count and Identification: The sterilized Petri-dish was poured the CLED agar medium and shaken in an anticlockwise direction to enable even spreading of the agar and possibly setting. Upon setting, lmL of the diluted sample was poured into the Petri-dish and shaken randomly for even spreading on the agar surface. The plates of bacterial count were kept in an incubator at 37^0C for 24 hours. Colonies appeared as cluster and each plate was counted and recorded [16].

3 Results and Discussion

3.1 Results

The physico-chemical and bacteriological analyses are summarized in Table 2a, 2b, 2c, 2d, and $2a^1$, $2b^1$, $2c^1$, $2d^1$.

Table 2a: Summary of the Physico-Chemical and Bacteriological Analysis in Brewery Area, Makurdi (August)

Parameters	A_1	A_2	A_3	A_4	A_5	Mean
	PHYSICAL PARAMETERS					
Appearance	Clear	Clear	Not clear	Not clear	Not clear	Not clear
Colour (pt/Co)	0.00	0.00	4.00	8.00	4.00	3.20
Temperature (^{O}C)	27.80	29.20	28.10	27.50	27.30	27.98
Turbidity (FTU)	0.00	0.00	1.00	3.00	1.00	1.00
Conductivity (µS/cm)	137.00	171.00	104.00	138.10	104.30	130.88
Suspended solid (mg/L)	0.00	0.00	0.00	2.00	0.00	0.40
TDS (mg/L)	36.40	27.00	30.40	36.80	29.00	31.92
Total solid (mg/L)	36.40	27.00	30.40	38.80	29.00	32.32
	CHEMICAL PARAMETERS mg/L					
pH	7.40	7.30	6.90	7.30	6.80	7.14
Total alkalinity	100	9.60	8.00	12.40	8.00	9.60
Total hardness	120	120	120	140	160	132
Calcium hardness	80	100	100	100	100	96
Magnesium hardness	40	20	20	40	60	36
Chloride Cl^-	30.80	27.40	34.00	19.90	21.00	26.62
Fluoride F^-	0.00	0.00	0.10	0.10	0.00	0.03
Nitrate NO_3^-	26.80	20.00	22.00	28.00	24.800	24.32
Sulphate SO^{2-}_4	20.00	16.00	31.00	26.00	22.00	23.00
Phosphate PO_4^{2-}	1.42	1.22	1.16	1.36	1.18	1.21
Silicate S_iO_2	0.00	0.00	0.00	0.00	0.00	0.00
Free CO_2	0.20	0.40	0.20	0.20	0.20	0.24
Potassium K^+	1.42	1.36	0.86	0.92	0.74	1.06
Manganese Mn^{2+}	0.08	0.06	0.06	0.12	0.09	0.08
Iron Fe^{2+}	0.77	0.16	2.69	0.84	1.42	1.18
Zinc Zn^{2+}	2.64	1.42	2.96	2.22	1.84	2.22
Copper Cu^{2+}	0.98	0.64	0.74	0.58	0.44	0.68
Lead Pb^{2+}	0.004	0.000	0.002	0.003	0.000	0.002
Chromium Cr^{6+}	0.02	0.00	0.00	0.01	0.02	0.01
Arsenic As^{3+}	0.00	0.00	0.001	0.000	0.000	0.0002
	MICROBIAL PARAMETER cfu/10mL					
E.coli	2	4	2	1	2	2.20
S.Typhi	0	0	0	0	0	0.00
Total coliform	2	4	2	1	2	2.20

Table 2a[1]: Summary of the Physico-Chemical and Bacteriological Analysis in Brewery Area, Makurdi (November)

Parameters	**A^1_1**	**A^1_2**	**A^1_3**	**A^1_4**	**A^1_5**	**Mean[1]**
	PHYSICAL PARAMETERS					
Appearance	Clear	Clear	Clear	Clear	Clear	Clear
Colour (pt/Co)	0.00	0.00	1.00	2.00	1.00	0.80
Temperature (^OC)	27.60	28.00	28.00	29.00	27.00	27.94
Turbidity (FTU)	0.00	0.00	1.00	2.00	1.00	0.80
Conductivity (µS/cm)	126.20	160.00	111.00	120.00	136.00	130.64
Suspended solid (mg/L)	0.00	0.00	0.00	1.00	0.00	0.20
TDS (mg/L)	34.40	30.10	29.80	32.10	28.00	30.88
Total solid (mg/L)	34.40	30.10	29.80	33.10	28.00	31.08
	CHEMICAL PARAMETERS mg/L					
pH	7.20	7.10	7.00	7.10	7.10	7.10
Total alkalinity	9.6	8.4	8.1	11.6	7.1	8.96
Total hardness	140	100	120	140	160	132
Calcium hardness	80	40	60	60	100	68
Magnesium hardness	60	60	60	80	60	64
Chloride Cl^-	32.80	26.40	36.20	20.00	22.20	27.52
Fluoride F^-	0.01	0.00	0.00	0.01	0.00	0.004
Nitrate NO_3^-	26.60	20.30	21.90	26.10	25.30	24.04
Sulphate SO^{2-}_4	24.20	20.20	31.00	26.40	23.30	25.02
Phosphate PO^{2-}_4	1.40	1.30	1.20	1.26	1.10	1.25
Silicate S_iO_2	0.00	0.00	0.00	0.00	0.00	0.00
Free CO_2	0.22	0.40	0.20	0.40	0.20	0.24
Potassium K^+	1.46	1.40	1.00	1.20	0.80	1.17
Manganese Mn^{2+}	0.06	0.08	0.08	0.10	0.07	0.08
Iron Fe^{2+}	0.80	0.20	3.20	1.20	1.62	1.40
Zinc Zn^{2+}	1.98	1.53	2.98	2.32	1.82	2.13
Copper Cu^{2+}	0.82	0.68	0.81	0.60	0.44	0.67
Lead Pb^{2+}	0.000	0.001	0.000	0.002	0.000	0.00
Chromium Cr^{6+}	0.01	0.000	0.00	0.02	0.01	0.02
Arsenic As^{3+}	0.00	0.00	0.00	0.00	0.00	0.00
	MICROBIAL PARAMETER cfu/10mL					
E.coli	1	1	1	2	1	1.20
S.typhi	0	0	0	0	0	0
Total coliform	1	1	1	2	1	1.20

Table 2b: Summary of the Physico-Chemical and Bacteriological Analysis in Judges Quarters, Makurdi (August)

Parameters	B_1	B_2	B_3	B_4	B_5	Mean
	PHYSICAL PARAMETERS					
Appearance	Not Clear	Clear	Clear	Clear	Clear	Clear
Colour (pt/Co)	8.00	4.00	2.00	12.00	16.00	8.40
Temperature (^{O}C)	28.70	29.10	28.30	28.30	29.10	28.62
Turbidity (FTU)	3.00	2.00	1.00	7.00	11.00	4.8
Conductivity (µS/cm)	103.30	113.90	116.80	112.70	197.10	128.76
Suspended solid (mg/L)	0.00	1.00	0.00	2.00	4.00	1.40
TDS (mg/L)	34.00	28.40	20.00	24.80	37.40	28.92
Total solid (mg/L)	34.00	29.40	20.00	26.80	41.40	30.32
	CHEMICAL PARAMETERS mg/L					
pH	7.10	7.30	7.20	6.80	6.70	7.02
Total alkalinity	8.0	11.4	10.6	7.8	7.4	9.04
Total hardness	160	140	180	160	140	156
Calcium hardness	100	100	120	100	100	104
Magnesium hardness	60	40	60	60	40	52
Chloride Cl^-	38.60	17.60	31.60	27.20	21.00	27.20
Fluoride F^-	0.00	0.00	0.00	0.10	0.10	0.03
Nitrate NO_3^-	28.40	26.00	30.00	24.60	20.80	25.96
Sulphate SO^{2-}_4	26.40	24.00	22.80	28.40	28.40	24.44
Phosphate PO^{2-}_4	1.36	1.26	1.18	1.12	1.62	1.31
Silicate S_iO_2	0.00	0.00	0.00	0.00	0.00	0.00
Free CO_2	0.20	0.40	0.40	0.20	0.20	0.28
Potassium K^+	0.94	1.00	0.96	1.54	1.66	1.22
Manganese Mn^{2+}	0.64	0.07	0.05	0.12	0.10	0.08
Iron Fe^{2+}	0.28	0.09	0.07	1.22	0.07	0.35
Zinc Zn^{2+}	2.24	2.68	2.14	2.34	1.66	2.21
Copper Cu^{2+}	0.84	0.68	0.76	0.54	0.68	0.70
Lead Pb^{2+}	0.003	0.000	0.002	0.002	0.003	0.002
Chromium Cr^{6+}	0.03	0.01	0.02	0.01	0.00	0.01
Arsenic As^{3+}	0.001	0.000	0.000	0.000	0.000	0.0002
	MICROBIAL PARAMETER cfu/10mL					
E.coli	3	2	0	4	6	3
S.typhi	1	0	0	0	0	0.2
Total coliform	4	2	0	4	6	3.2

Table 2b[1]: Summary of the Physico-Chemical and Bacteriological Analysis in judges Quarters, Makurdi (November)

Parameters	**B^1_1**	**B^1_2**	**B^1_3**	**B^1_4**	**B^1_5**	**Mean[1]**
	PHYSICAL PARAMETERS					
Appearance	Clear	Clear	Clear	Clear	Clear	Clear
Colour (pt/Co)	4.00	4.00	0.00	6.00	8.00	4.40
Temperature (^OC)	28.80	28.20	28.20	27.80	28.20	28.24
Turbidity (FTU)	1.00	1.00	1.00	2.00	2.00	1.40
Conductivity (µS/cm)	108.40	110.40	112.80	130.40	120.60	116.52
Suspended solid (mg/L)	0.00	0.00	0.00	1.00	1.00	0.40
TDS (mg/L)	30.00	32.00	32.40	38.40	38.80	34.32
Total solid (mg/L)	30.00	32.00	32.40	39.40	39.80	34.72
	CHEMICAL PARAMETERS mg/L					
pH	7.10	7.00	7.10	7.20	7.10	7.10
Total alkalinity	7.8	9.6	9.8	7.1	7.4	8.34
Total hardness	180	160	140	120	120	144
Calcium hardness	100	60	120	100	80	92
Magnesium hardness	80	100	20	20	40	52
Chloride Cl^-	39.60	20.60	30.00	26.10	20.00	27.26
Fluoride F^-	0.00	0.01	0.00	0.10	0.00	0.02
Nitrate NO_3^-	25.60	26.00	28.00	20.60	22.30	24.50
Sulphate SO^{2-}_4	26.00	26.20	24.80	26.40	20.80	24.84
Phosphate PO^{2-}_4	1.43	1.24	1.00	1.20	1.30	1.23
Silicate S_iO_2	0.00	0.00	0.00	0.00	0.00	0.00
Free CO_2	0.10	0.30	0.40	0.20	0.20	0.24
Potassium K^+	1.24	1.21	1.00	1.30	1.40	1.23
Manganese Mn^{2+}	0.03	0.06	0.04	0.20	0.30	0.13
Iron Fe^{2+}	0.30	0.10	0.10	1.30	1.10	0.58
Zinc Zn^{2+}	3.00	2.68	2.14	2.32	1.80	2.39
Copper Cu^{2+}	0.64	0.62	0.80	0.40	0.68	0.63
Lead Pb^{2+}	0.000	0.000	0.001	0.001	0.003	0.001
Chromium Cr^{6+}	0.01	0.01	0.02	0.01	0.00	0.01
Arsenic As^{3+}	0.000	0.000	0.000	0.000	0.000	0.000
	MICROBIAL PARAMETER cfu/10mL					
E. coli	1	1	1	0	3	1.2
S. Typhi	1	0	0	0	0	0.2
Total coliform	2	1	1	0	3	1.4

Table 2c: Summary of the Physico-Chemical and Bacteriological Analysis in BSU Area, Makurdi (August)

Parameters	C_1	C_2	C_3	C_4	C_5	Mean
	PHYSICAL PARAMETERS					
Appearance	Clear	Not Clear	Not Clear	Clear	Clear	Clear
Colour (pt/Co)	2.00	14.00	12.00	0.00	0.00	5.60
Temperature (^{O}C)	28.20	27.40	25.30	26.70	24.90	26.50
Turbidity (FTU)	1.00	7.00	5.00	0.00	0.00	2.60
Conductivity (µS/cm)	161.10	135.00	173.60	131.30	111.10	142.42
Suspended solid (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00
TDS (mg/L)	28.20	30.80	30.60	32.00	27.00	29.72
Total solid (mg/L)	28.20	30.80	30.60	32.00	27.00	29.72
	CHEMICAL PARAMETERS mg/L					
pH	7.30	6.90	6.80	7.40	7.30	7.14
Total alkalinity	16.0	3.6	8.4	7.2	8.0	8.64
Total hardness	80	80	80	80	100	84
Calcium hardness	60	60	60	60	60	60
Magnesium hardness	20	20	20	20	40	24
Chloride Cl^-	19.60	28.40	17.40	36.40	19.00	24.16
Fluoride F^-	0.00	0.20	0.10	0.00	0.10	0.08
Nitrate NO_3^-	22.00	22.40	16.80	21.60	28.60	22.28
Sulphate SO^{2-}_4	28.40	28.00	24.00	26.00	18.00	24.16
Phosphate PO^{2-}_4	1.46	1.28	1.72	1.34	1.22	1.40
Silicate S_iO_2	0.00	0.00	0.00	0.00	0.00	0.00
Free CO_2	0.20	0.40	0.20	0.40	0.40	0.32
Potassium K^+	1.04	1.36	1.22	1.28	0.86	1.15
Manganese Mn^{2+}	0.07	0.05	0.07	0.04	0.08	0.06
Iron Fe^{2+}	0.12	0.10	0.21	0.14	0.12	0.14
Zinc Zn^{2+}	2.42	2.68	1.42	1.68	1.66	1.97
Copper Cu^{2+}	1.18	1.22	0.54	1.20	0.92	1.01
Lead Pb^{2+}	0.002	0.004	0.003	0.004	0.005	0.004
Chromium Cr^{6+}	0.00	0.02	0.00	0.01	0.03	0.01
Arsenic As^{3+}	0.000	0.002	0.000	0.000	0.000	0.00
	MICROBIAL PARAMETER cfu/10mL					
E. coli	1	2	5	12	4	4.80
S. Typhi	0	0	0	0	0	0.00
Total coliform	1	2	5	12	4	4.80

Table 2c[1]: Summary of the Physico-Chemical and Bacteriological Analysis in BSU Area, Makurdi (November)

Parameters	**C^1_1**	**C^1_2**	**C^1_3**	**C^1_4**	**C^1_5**	**Mean[1]**
	PHYSICAL PARAMETERS					
Appearance	Clear	Clear	Clear	Clear	Clear	Clear
Colour (pt/Co)	2.00	4.00	4.00	0.00	0.00	2.00
Temperature (^OC)	29.00	28.10	28.20	28.00	26.00	27.86
Turbidity (FTU)	1.00	2.00	3.00	1.00	0.00	1.40
Conductivity (µS/cm)	131.00	136.00	138.10	176.10	110.30	138.30
Suspended solid (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00
TDS (mg/L)	29.20	31.30	33.40	28.20	26.80	29.78
Total solid (mg/L)	29.20	31.30	33.40	28.20	26.80	29.78
	CHEMICAL PARAMETERS mg/L					
pH	7.1	7.00	6.90	7.30	7.10	7.08
Total alkalinity	10.6	6.1	8.6	7.3	7.8	8.08
Total hardness	100	100	100	100	100	100
Calcium hardness	60	80	60	80	60	68
Magnesium hardness	40	20	40	20	40	32
Chloride Cl^-	20.00	26.60	18.00	33.60	20.00	23.64
Fluoride F^-	0.00	0.10	0.10	0.00	0.10	0.06
Nitrate NO_3^-	23.00	20.40	16.00	20.60	26.80	21.36
Sulphate SO^{2-}_4	28.60	26.40	23.60	23.40	19.90	24.38
Phosphate PO^{2-}_4	1.43	1.30	1.62	1.30	1.20	1.37
Silicate S_iO_2	0.00	0.00	0.00	0.00	0.00	0.00
Free CO_2	0.20	0.20	0.40	0.40	0.40	0.32
Potassium K^+	1.10	1.40	1.30	1.18	1.01	1.20
Manganese Mn^{2+}	0.06	0.07	0.05	0.06	0.05	0.06
Iron Fe^{2+}	0.96	1.30	1.41	0.98	1.12	1.15
Zinc Zn^{2+}	2.89	2.68	2.10	1.80	1.80	2.25
Copper Cu^{2+}	1.00	1.30	1.00	1.20	1.10	1.12
Lead Pb^{2+}	0.000	0.000	0.001	0.000	0.000	0.00
Chromium Cr^{6+}	0.00	0.00	0.00	0.02	0.01	0.01
Arsenic As^{3+}	0.000	0.000	0.000	0.000	0.000	0.00
	MICROBIAL PARAMETER cfu/10mL					
E. coli	0	0	1	1	1	0.6
S. Typhi	0	1	0	0	0	0.2
Total coliform	0	1	1	1	1	0.8

Table 2d: Summary of the Physico-Chemical and Bacteriological Analysis in Old GRA, Makurdi (August)

Parameters	D_1	D_2	D_3	D_4	D_5	Mean
	PHYSICAL PARAMETERS					
Appearance	Clear	Clear	Clear	Clear	Not Clear	Clear
Colour (pt/Co)	0.00	7.00	10.00	9.00	18.00	8.80
Temperature (^{O}C)	27.80	29.30	29.40	26.90	27.30	28.14
Turbidity (FTU)	0.00	3.00	4.00	6.00	12.00	5.00
Conductivity (µS/cm)	112.70	147.30	162.20	149.30	181.10	150.58
Suspended solid (mg/L)	0.00	1.00	2.00	2.00	3.00	1.60
TDS (Mg/L)	25.80	36.00	37.40	34.20	39.00	34.48
Total solid (mg/L)	25.80	37.00	39.40	36.20	42.00	36.08
	CHEMICAL PARAMETERS mg/L					
pH	7.40	6.90	6.80	7.10	7.20	7.08
Total hardness	80	100	180	160	180	140
Calcium hardness	60	60	100	100	100	84
Magnesium hardness	20	40	80	60	80	56
Chloride Cl^-	17.90	20.10	37.00	30.80	35.40	28.25
Fluoride F^-	0.10	0.10	0.10	0.12	0.14	0.11
Nitrate NO_3^-	18.40	24.00	26.40	27.00	29.60	25.08
Sulphate SO^{2-}_4	22.00	36.00	38.00	32.00	40.00	33.60
Phosphate PO^{2-}_4	1.28	1.36	1.28	1.24	2.22	1.48
Silicate S_iO_2	0.00	0.00	0.00	0.00	1.00	0.20
Free CO_2	0.20	0.40	0.20	0.20	0.60	0.32
Potassium K^+	0.97	1.16	1.28	1.12	1.42	1.19
Manganese Mn^{2+}	0.12	0.10	0.08	0.07	0.12	0.10
Iron Fe^{2+}	0.15	0.11	0.14	0.09	2.84	0.67
Zinc Zn^{2+}	1.28	1.42	1.16	1.22	2.42	1.50
Copper Cu^{2+}	0.86	0.64	1.14	1.18	1.26	1.02
Lead Pb^{2+}	0.002	0.007	0.004	0.005	0.14	0.03
Chromium Cr^{6+}	0.01	0.02	0.01	0.01	0.06	0.02
Arsenic As^{3+}	0.000	0.000	0.000	0.000	0.004	0.00
	MICROBIAL PARAMETER cfu/10mL					
E. coli	2	4	6	4	7	4.60
S. Typhi	0	0	0	0	0	0.00
Total coliform	2	4	6	4	7	4.60

Table 2d[1]: Summary of the Physico-Chemical and Bacteriological Analysis in Old GRA, Makurdi (November)

Parameters	**D^1_1**	**D^1_2**	**D^1_3**	**D^1_4**	**D^1_5**	**Mean[1]**
	PHYSICAL PARAMETERS					
Appearance	Clear	Clear	Clear	Clear	Clear	Clear
Colour (pt/Co)	0.00	1.00	2.00	2.00	3.00	1.60
Temperature (^OC)	28.90	28.30	29.80	27.80	27.90	28.54
Turbidity (FTU)	0.00	1.00	1.00	1.00	1.00	0.80
Conductivity (µS/cm)	116.80	150.30	161.31	150.10	173.10	150.32
Suspended solid (mg/L)	0.00	0.00	1.00	1.00	3.00	1.00
TDS (mg/L)	26.80	33.60	38.10	36.20	40.30	35.00
Total solid (mg/L)	26.80	33.60	39.10	37.20	43.30	36.00
	CHEMICAL PARAMETERS mg/L					
pH	7.10	7.00	6.90	7.20	7.00	7.04
Total hardness	120	160	160	100	180	144
Calcium hardness	100	100	120	80	140	108
Magnesium hardness	20	60	40	20	40	36
Chloride Cl^-	16.90	16.30	30.10	25.30	36.40	25.00
Fluoride F^-	0.10	0.20	0.00	0.10	0.10	0.10
Nitrate NO_3^-	20.40	24.60	22.40	25.30	28.60	24.26
Sulphate SO^{2-}_4	20.30	38.10	37.90	31.30	39.90	33.50
Phosphate PO^{2-}_4	1.10	1.26	1.28	1.28	3.10	1.60
Silicate S_iO_2	0.00	0.00	0.00	0.00	0.00	0.00
Free CO_2	0.10	0.20	0.10	0.10	0.40	0.18
Potassium K^+	1.21	1.13	1.30	1.10	1.43	1.23
Manganese Mn^{2+}	0.10	0.10	0.08	0.04	0.14	0.09
Iron Fe^{2+}	0.10	1.20	0.96	1.93	2.98	1.63
Zinc Zn^{2+}	2.36	1.96	1.86	1.30	2.60	2.02
Copper Cu^{2+}	0.76	0.46	0.92	1.30	1.12	0.91
Lead Pb^{2+}	0.001	0.000	0.002	0.001	0.010	0.00
Chromium Cr^{6+}	0.02	0.02	0.00	0.01	0.07	0.02
Arsenic As^{3+}	0.000	0.000	0.000	0.000	0.002	0.00
	MICROBIAL PARAMETER cfu/10mL					
E. coli	1	2	3	1	1	1.60
S. Typhi	0	0	1	0	1	0.40
Total coliform	1	2	4	1	2	2.00

Table3: Drinking Water Standards By NSDWQ (2007),
WHO (2004 & 2006), NAFDAC (2004)

Parameters	WHO Standard	NAFDAC Standard	NSDWQ Standard
Appearance			
Colour (pt/Co)	15		15
Temperature (^{O}C)	Ambient	Ambient	Ambient
Turbidity (FTU)	0 – 5		0 – 5
Conductivity (µS/cm)	1000		1000
Suspended solid (mg/L)	500		500
TDS (mg/L)	1000	500	500
Total solid (mg/L)	1000	500	500
CHEMICAL PARAMETERS mg/L			
pH	7.0 – 8.5	6.5 – 8.5	6.5 – 8.5
Total hardness	100		150
Calcium hardness			
Magnesium hardness			
Chloride Cl^-	250		250
Fluoride F^-	1.5		1.5
Nitrate NO^-_3	50		50
Sulphate SO^{2-}_4	200	200	100
Phosphate PO^{2-}_4			
Silicate S_iO_2	0.001		
Free CO_2	50		
Potassium K^+	1 – 2	1.0	
Manganese Mn^{2+}	0.05		0.2
Iron Fe^{2+}	0.05-0.3		0.3
Zinc Zn^{2+}	3.0		3.0
Copper Cu^{2+}	2.0		1.0
Lead Pb^{2+}	0.01		0.01
Chromium Cr^{6+}	0.05		0.05
Arsenic As^{3+}	0.01		0.01
MICROBIAL PARAMETER (cfu/10mL)			
E. coli			
S. Typhi			
Total coliform	10	10	10

3.2 Discussion

3.2.1 Physical Parameters

The physical parameters as represented in table 2a through 2d[1] shows that, the ambient temperatures ranges from 27.3^{0}C to 29.2^{0}C (A) 29.9^{0}C to 29.10^{0}C (B), 249^{0}C to 28.2^{0}C (C) and 26.9^{0}C to 29.4^{0}C to (D) with mean values of 27.98^{0}C, 28.62^{0}C, 26.50^{0}C and 28.14^{0}C respectively. Water for drinking purposes has a better fresh taste at lower temperature at about 15^{0}C, but higher temperature do not imply impurities [17]. Suspended solid is a term to express the muddiness or opaqueness of water. The value of the suspended solid varies from 0.00mg/L to 0.2mg/L (A), 0.00mg/L to 4.00mg/L (B), 0.00mg/L (C) and 0.00mg/L to 3.00mg/L (D) with mean values of 0.40mg/L, 1.40mg/L, 0.00mg/L and 1.60mg/L respectively. These values are far below the WHO and NSDWQ maximum recommended values of 500mg/L. The pH value for the borehole water ranges from 6.8 to 7.4 (A) 6.7 to 7.3 (B), 6.8 to 7.4 (C) and 6.8 to 7.4 (D) with mean values of 7.14, 7.02, 7.14 and 7.08 respectively when compared with the recommended range of 6.5 to 8.5 WHO and NSDWQ. The total dissolved solid (TDS) recommended by the WHO and NSDWQ for fresh water is between (0 – 500) mg/L. The bore hole water have TDS values ranging from 27mg/L to 36.8mg/L (A), 20mg/L to 37.4mg/L (B), 27mg/L to 32mg/L (C) and 25.8mg/L (D) with mean values of 31.92mg/L 28.92mg/L, 29.72mg/L and 34.48mg/L respectively. These values are within the acceptable limits of all of WHO, NSDWQ and NAFDAC. The value of total hardness ranges from 120mg/L to 160mg/L (A), 140mg/L to 180mg/L (B), 80mg/L to 100mg/L (C) and 80mg/L to 180mg/L (D) with mean values of 132mg/L, 156mg/L, 84mg/L and 140mg/L respectively. Areas A, B and D had hardness value above the WHO and NSDWQ permissible limit of 100mg/L and 150mg/L respectively. This implies that these areas have hard water. Hardness is beneficial in drinking water despite problem it creates for the piping system [14]. People who live in the hard water area suffer less from heart diseases than those who live in soft water [14]. The conductivity values ranges from 171.00µS/cm (A) 103.30µS/cm to 197.10µS/cm (B), 111.10µS/cm to 173.6µS/cm (C) and 112.7µS/cm, to 128.76µS/cm, 142.42µS/cm and 150.58µS/cm respectively. These values are below the permissible limit of 1000µS/cm of NSDWQ.

3.2.2 Chemical Parameters

The chemical parameters as represented in table 2a through 2d[1] shows that, potassium values ranges from 0.74mg/L to 1.42mg/L (A) 0.94mg/L to 1.66mg/L (B), 0.86mg/L to 1.36mg/L (C) and 0.97mg/L to 1.42mg/L (D) with mean values of 1.06mg/L, 1.22mg/L, 1.15mg/L and 1.19mg/L respectively. The low concentration of potassium can be attributed to the shallowness of the borehole, because concentration of potassium increase with depth due to infiltration, it might also be attributed to the low rate of soil reaction, ion exchange, oxidation and reduction [4], the low concentration might also be caused by the paucity of soluble material in the bed rock of the formation and the overlying soil. The alkaline earth metal (calcium and magnesium) are also examined jointly. The calcium has value ranging from 80mg/L to 100mg/L (A), 100mg/L to 120mg/L (B), 60mg/L (C) and 60mg/L to 100mg/L (D) with mean value of 96mg/L, 104mg/, 60mg/L and 84mg/L respectively, while magnesium concentration varies from 20mg/L to 60mg/L (A) 40mg/L to 60mg/L (B) 20mg/L to 40mg/L (C) and 20mg/L to 80mg/L (D) with mean values of 36mg/L, 52mg/L, 24mg/L and 56mg/L respectively. Both magnesium and calcium ions are responsible for water hardness. Their high concentration implies that the bore-hole water is hard and such water does not foam easily/readily with soap. The concentration of iron varies from 0.16mg/L to 2.69mg/L (A), 0.07mg/L to 1.22mg/L (B), 0.10mg/L to 0.21mg/L (C) and 0.09mg/L to 2.84mg/L (D) with mean values of 1.18mg/L, 035mg/L, 0.14mg/L and 0.67mg/L respectively. The iron availability within the area covered is generally high compared WHO and NSDWQ. Iron is widely distributed in the earth's crust occurring in several ferromagnesian minerals. Pyrite is a common form of iron in sedimentary materials, whereas ferric oxides and hydroxides are important iron bearing minerals. The common form of iron in groundwater is the soluble ferrous ion Fe^{2+}. When exposed Fe^{2+} is oxidized to the ferric state Fe^{3+}, which is soluble and precipitates as ferric hydroxide, causing a brown discoloration of the water and the characteristic brown stains in sinks and laundered textiles, metal pipes for reticulation and scaling in pipes [4]. Corrosion of bore-hole casing and other pipes may also contribute iron to bore-hole water. Bacterial activity can decrease or increase iron concentration in ground water. Concentrations of manganese varies from 0.06mg/L to 0.12mg/L (A), 0.04mg/L to 0.12mg/L (B), 0.04mg/L to 0.08mg/L (C) and 0.07mg/L (D) with mean values of 0.08mg/L, 0.06mg/L (D) with mean values of 0.08mg/L, 0.08mg/L, and 0.10mg/L respectively. These values are below the permissible limit of 0.2mg/L of WHO and NSDWQ respectively. High concentration of manganese slightly above the WHO and NSDWQ maximum permissible limit causes neurological and gastrointestinal disorder (NSDWQ). The presence of iron, copper and manganese can give undesirable taste. The dissolution of carbonate rock in the ground by water molecule leads to the formation of bicarbonate. The value of sulphate ranges from 16mg/L to 31mg/L (A), 20.6mg/L to 28.4mg/L (B) 18mg/L to 28mg/L (C) and 22mg/L to 40mg/L (D) with mean values of 23mg/L, 22.44mg/L, 24.88mg/L and 33.60mg/L respectively. These values are below the maximum permissible limit of 200mg/L and 100mg/L [10,12,13]. The chloride concentration varies from 19.9mg/L to 34mg/L (A), 17.6mg/L to 38.6mg/L (B), 19.00mg/L to 36.4mg/L (C) 17.90mg/L to 37.00mg/L (D) with mean values of 26.62mg/L, 27.20mg/L, 24.16mg/L and 28.25mg/L respectively. These values are below the maximum permissible limit of 250mg/L (NSDWQ). The concentration of Nitrates ranges from 20.00mg/L to 26.80mg/L (A), 20.80mg/L to 30.00mg/L (B), 16.80mg/L to 28.60mg/L (C) 18.40mg/L to 29.60mg/L (D) with mean values of 24.32mg/L, 25.96mg/L, 22.28mg/L and 25.08mg/L respectively. These values are below the recommended value of 50mg/L [11,13]. Chromium concentrations ranges from 0.00mg/L to 0.02mg/L (A), 0.00mg/L to 0.03mg/L (B) 0.00mg/L to 0.03mg/L (C) and 0.01mg/L to 0.06mg/L (D) with mean value of 0.01mg/L, 0.01mg/L, 0.01mg/L and 0.02mg/L respectively. The values are below the permissible limit of 0.05mg/L [11,12].

3.2.3 Bacteriological Parameters

There are many different kinds of bacteria that may be present in water supply, some of these bacteria are disease causing (pathogens). The standard water test to determine the microbial quality of water is for total coliform bacteria. The total coliform value ranges from Icfu/10 mL to 4cfu/10mL (A), 0.0cfu/10mL to 6cfu/10mL (B) Icfu/10 mL (D) with mean values of 2.20 cfu/10mL, 3.2 cfu/10 mL, 4.8 cfu/10 mL and 4.6 cfu/10 mL respectively. These values are below the maximum permissible limit of 10 cfu/10 mL. This is an indication that faucal contamination by animals and human is at it lowest in the area covered. *E. coli* traces present may be attributed to the shallowness of the bore hole [18]. The *Salmonella typhi* traces may be due to poor storage conditions. The principal risk associated with water is that of infections disease and is related to faecal contamination, majority of the water-borne diseases are caused by pathogenic bacteria, virus, and protozoa contained in the human and animal faeces [1,7]. The water in the areas covered has low microbial contaminants, indicating good or adequate sanitary conditions in the areas.

3.3 Health Impact of Some Inorganic Parameters

- Arsenic (As) may cause potential Neuro-degenerative disorders
- Chromium (Cr^{6+}) may cause cancer
- Copper (Cu^{2+}) many cause gastrointestinal disorder
- Fluoride (F^-) may cause fluorosis, skeletal tissue (bones and teeth) morbidity.
- Lead (pb) may cause cancer, interference with vitamin D metabolism. Affect mental development in infants, toxic to the central and peripheral nervous system.
- Manganese (Mn^{2+}) may cause Neurological disorder
- Nitrate (NO_3^-) may cause cyanosis, asphyxia (blue-baby syndrome) in infants under 3 months [10-13]

4 Conclusion

The physico-chemical and bacteriological parameters in bore-hole water in the areas under study have been determined and found to conform with various national and international standards. Commercial activities do not have much negative effects on the quality of bore-hole water.

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Ethical issue

The Author is aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Author adhered to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The author declares that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

Bassey S. Okori perform the experimental design, prepared the manuscript text, compiled the data, performed the lterature review and manuscript edition.

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