



EVALUATION OF PHYSICOCHEMICAL AND MICROBIAL CHARACTERISTICS OF SOME BOREHOLE WATER IN EDO STATE, NIGERIA



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Abstract

Borehole water was collected from some communities in Edo state to assess the water quality by examining the physicochemical properties of the water. A total of twenty-five (25) such parameters were analysed in order to confirm whether groundwater is safe, pleasant, and usable or not, it is necessary to evaluate its bio physicochemical concentration (mg/l) in relation to the water suitability standard of the World Health Organization (WHO, 2006) and the Federal Environment Protection Agency (FEPA). The methods employed in the study are in accordance to standard procedure and already established procedures. The observed values of different physicochemical parameters were compared with standard values recommended by World Health Organization (W.H.O.) The outcome of the study, shows that the electrical conductivity (EC), pH and the Total dissolved solid (TDS) were all within the acceptable limits by the W.H.O. with a range of 34.0 - 61.0 uS/cm, (6.15 - 7.94) mg/L, (30.5 - 50.0) mg/L respectively. Likewise, the Alkalinity, salinity and chemical oxygen demand (COD) with averages (3.28, 24.64 & 20.40) mg/L accordingly are all within the acceptable limit by W.H.O for quality drinking water. Also the range for the chloride (10.88 - 19.52) mg/L falls within the permissible limit by W.H.O. for quality drinking water in the terms of its chloride content. The cations (K^+ , Na^+ , Ca^{2+} & Mg^{2+}) and anions (SO_4^{2-} , PO_4^{3-} , & NO_3^-) present in the water were all within acceptable limits going by the established standard. Furthermore, the heavy metals in the water (Cd^{+2} , Zn^{+2} , Pb^{+2} , V^{+3} , Mn^{+2} , Cr^{+6} , Cu^{2+} , Ni^{+2} & As) are all within W.H.O permissible limits with the exception of Zinc which is above the acceptable standard for quality water, thus would require some sort of treatment. The bacteria test reveals the presence of coliform bacteria, although within permissible limits with the exception of borehole samples GW3 & GW5 which have amount coliform, hence the need of a routine treatment. The result of this research portends a groundwater that is relatively potable for drinking with minimal treatment required.

Keywords:

Physico-chemical, TDS, EC, COD, W.H.O., Heavy metals

Introduction

One of the two sources of water supply that are available to humans is ground water; the other is surface water. In the zone of saturation, groundwater is a useful resource that fills the pore spaces between ground in sedimentary rock bodies and clastic sedimentary rock as well as fractures and crevices in all kinds of rock (Plummer *et al.*, 2008). One of the most significant and prevalent resources on the surface of the globe, water is necessary for life to exist. More than any other environmental aspect, the availability of water determines the types and amounts of plants that grow in different regions of the earth's surface. Early civilization understood the value of water, and it played a significant role in ancient cosmologies and mythologies.

Compared to the oceans and seas, which contain more than 97% of the world's water, groundwater makes only about 0.6% of the total, (Ilevbare and Omorogieva, 2020). There are 35 times as many rivers and lakes as there are underground. However, according to Plummer *et al.*, 2008 the overall volume of fresh water preserved in glaciers is 3.5 times more than the entire volume of ground water. At the moment, attention is focused not just on how abundant water is, but also on whether or not its quality is sufficient to support its varied applications (Udom *et al.*, 1999).

The appropriateness of groundwater for domestic, commercial, and agricultural uses depends on its quality. The types of local geology and minerals present in an area where groundwater recharges and flows, anthropogenic activities like mining and water disposal, as well as climate

and geography, strongly influence the chemical composition of groundwater and the types of water found there (Akujieze, 2004). One of the key prerequisites for a healthy life, human sustainability, and environmental sustainability is the adequate and portable extraction of groundwater resources for man's consumption (domestic, agricultural, and industrial). Many surface water features, including rivers and wetlands, as well as more general environmental issues and, in some cases, potential environmental solutions, are strongly influenced by groundwater. Groundwater is susceptible to contamination (from sewages from septic, industrial effluents and leaching of heavy metals and trace elements from dumpsites from anthropogenic activities) from despite the fact that it is fundamentally important to both man and the biota, along with surface water.

As meteoric water moves through the atmospheric medium, it dissolves airborne particles and water-soluble gases, as well as incorporates airborne microbes, giving it some of its physical properties, chemical composition, and bacteriological traits, (Essumang, *et al.*, 2011). By catalyzing the leaching and weathering of the geological medium, which snowball the dissolution or precipitation of some soluble mineral (cations and anions) constituent in the soil, water quality may be negatively impacted as it seeps into the soil. This would enrich groundwater with minerals and increase its salinity, which is beneficial to human nutrition and the minimum acceptable limit of Chloride according to WHO, 2006 is 200 mg/L). The quality status

of water is a crucial factor in what the water is to be used for (Udom and Acra, 2006). For instance, water meant for drinking and domestic use must meet established local and international standards; otherwise, consumers run the risk of contracting water-borne illnesses like typhoid fever, dysentery, and diarrhea. Additionally, the chemical constituents of groundwater are known to pose some health risks, so the supply cannot be said to be safe (Nwankoala and Udom, 2011). The fundamental reason why the microbiological load of ground water, especially from deep bore holes, is relatively low and rarely exceeds the tolerable threshold is that the water undergoes natural filtering as it travels from the surface to the aquifer. The majority of the parameters chosen for analysis are required by the Directive and include dissolved organic carbon (DOC), heavy metals (Cd, Pb, Cu, Cr, and Ni), ions (F^- , NO_2^- , NO_3^- , Br^- , PO_4^{3-} , SO_4^{2-} , and pH), as well as physicochemical (such as pH, conductivity, and TDS) and chemical properties related to the treatment of the water itself (DOC). These characteristics are either non-toxic or are toxic enough to have major negative effects on human health. According to Jordao *et al.*, (2002) nitrate (NO_3^-) and nitrites (NO_2^-) are naturally occurring in water, with nitrate being more harmful to humans than nitrite. Nitrite's participation in the oxidation of healthy hemoglobin to methaemoglobin, which is unable to carry oxygen to the tissues, is its main biological function. Methaemoglobinemia caused by nitrate-derived nitrite is thought to be the main human health concern linked to nitrate ingestion (Van Busse *et al.*, 2012). Both geogenic and human-made sources can be blamed for the presence of heavy metals in water. All of these heavy metals, including Cd, Cr, Co, Hg, Ni, Pb, and Zn, have cancer-causing effects on human health when consumed in excess (Gilani *et al.*, 2013; Shah *et al.*, 2012).

Regardless of any potential geological differences in this vein, adequate provision of portable water is essential for public health and safety. Therefore, in order to confirm whether groundwater is safe, pleasant, and usable or not, it is necessary to evaluate its bio physicochemical concentration (mg/l) in relation to the water suitability standard of the World Health Organization (WHO, 2006) and the Federal Environment Protection Agency (FEPA).

Study Location

The extent of this work encompasses desk and reconnaissance study (appraisal) of samples collected from selected villages within Ovia North East Local Government area of Edo state. The study area is located between latitude $006^{\circ} 45'N$ and $006^{\circ} 38'N$ of the equator and longitude $005^{\circ}30'E$ and $005^{\circ}45'E$ of the Greenwich meridian. This is located in Ovia North East Local Government area of Edo State South-South geopolitical zone of the country. The area of study and sampling points are indicated in figure (1) below. The area is a flat low lying terrain belonging to the coastal plain sands.

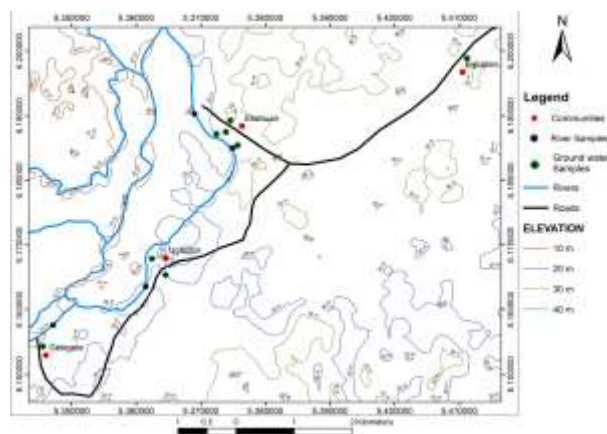


Fig.1: The Study Area indicating sampling points
Topography, Climate, Vegetation, Accessibility and Drainage

High lands can be found at Ekehuan and its surroundings, which slope downward in the south. The lowest location measured was around 1 m above sea level, and the highest point was 280 m. The land gently slopes in the direction of the ocean. Except for precipitation, there are no obvious seasonal differences in Ekehuan and its surroundings. The dry season lasts from November to March, and the wet season from April to October. The typical yearly rainfall is 250 mm. The normal mean annual temperature is below 28 C, and the relative humidity is 70%.

Equatorial (Tropical / Evergreen) forest vegetation is present. During the dry season, trees are deciduous in nature. Where original trees have been cut down or cleared to make room for new farms and settlements, secondary woods are abundant. Ekehuan and its surroundings, a crucial microcosm of Edo state, can be reached by a convoluted network of paved, unpaved, and footpaths that lead to and from many locations in the region. Due to the existence of rivers, canoes and speed boats can also be used to visit the area. The rivers in Ekehuan and Gelegele communities both drain the area. Rivers run into the Atlantic Ocean and have a dendritic pattern (figure 1).

Local Geology

Reconnaissance field mapping has revealed that the Benin and Ogwashi-Asaba formations are present in the study region that crosses the Ovia north-east local government area of Edo state, which is located at the southern end of the Anambra basin. It is located in the Niger Delta basin's northern Benin deltaic plain sands, which are located above the coastal plain sands. Medium to coarse grained sand, silt, and clay are its defining features. Age-wise, it is quaternary (Short and Stauble 1967). The soil's texture makes it easy for water and other things to seep through it. According to the lithologies of the boreholes in Ekehuan, Ughotan, and Gelegele, the Benin formation is mostly made up of sandstones with interspersed shales, whereas the Ogwashi-Asaba formation is made up of Shale, ferruginized sandstone, loose sand, clay, and lignite make up the formation. Texturally, the sand is mainly sub-angular to highly rounded, with occasional poorly sorted lignite streaks and thin, dispersed, greyish-brown shale deposits.

Table 1: Sequence Stratigraphy of Niger Delta (Reyment, 1965)

| Age | Formation | Lithology | Thickness (m) |
|-------------------|---------------------------|--|---------------|
| Miocene-Recent | Benin formation | Unconsolidated sandstone with lenses of clay | 200 |
| Oligocene-Miocene | Ogwasbi-Asaba formation | Unconsolidated sandstone and clay with lignite seams | 300 |
| Eocene | Ameki formation | Sandstone, clay and shales | 84 |
| Paleocene | Imo formation (Imo shale) | Blue to grey dark shales, sandstones and shales | 314 |
| Maastrichtian | Nsukka formation | With coal seams | 233 |

Niger Delta Stratigraphy

The Niger Delta is made up of early terrestrial deposits in a saltwater environment with strong energy. Currently, deposition takes place simultaneously under entirely terrestrial (fluvial) settings, fully marine conditions, and situations where there is interaction between terrestrial and marine effects (Adebayo, 2022). Three significant stratigraphic units were suggested and identified in the Niger Delta's subsoil. They belong to the Akata formation and the Benin formation, respectively (Oldest).

Benin Formation (FM)

The Benin Formation is the tertiary Niger Delta's youngest formation. It is composed of huge, very porous, fresh water-bearing sandstone and regionally thin inter-beds of shale, which are believed to have originated in braided streams. When present, the shale inter-beds typically have scattered lignite and some plant debris. The delta margins are where it gets thinner and is thicker in the center of the onshore portion, where it is roughly 1970m (1.97km) long. As the Benin Formation is non-marine in origin, Doust & Omatsola (1989) conducted studies on it at the Elele1 well, 39 km northwest of Port Harcourt. They designated the base of the formation as the first marine foraminifera within shale's. The formation dates from the Miocene to the Recent.

Agbada Formation (FM)

The delta-front, distributary channel, and deltaic plain origin deposits are represented by the paralic sequence of sandstone and shale known as the Agbada Formation. The majority of the vast, very porous, fresh water-bearing sandstone that makes up the continental Benin formation is assumed to be of braided-strain origin. The material is made up of deposits from the upper deltaic plain. Shale may be a back swamp deposit, while sand and sandstone may be point-bar deposits, channel fills, or crevasse splays (Ekweozor & Daukoru, (1984); Adebayo (2022). These strata, which range in age from the Eocene to the Holocene, are stratigraphically stacked in both space and time (Evamy *et al.*, 1978; Tuttle *et al.*, 1999; Reijers, 2011).

Akata Formation (FM)

The Akata formation is thought to be the earliest and lowest-lying unit in the tertiary Niger Delta series. The medium- to dark-gray shale that makes up the maritime Akata formation is a continuous unit. The shales are not sufficiently compacted and could have lenses of unusually high-pressure siltstone or fine-grained sandstone. The formation is between 600 and 6000 meters thick. A diverse foraminifera fauna can be found in the Akata formation. Over 50% of the micro fauna may be made up of planktonic foraminifera. Due to the homogeneity of the shale at its deep burial, the Akata formation may serve as the primary source rock for the oil found in the Niger Delta. The formation is between Eocene and Recent in age (Ilevbare & Omorogieva, 2020).

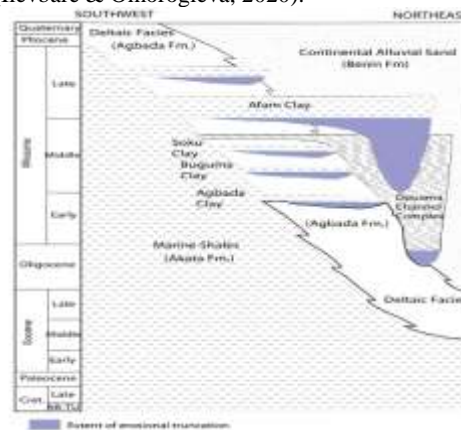


Figure 2. Stratigraphy of Niger Delta Basin (after Adebayo, 2022)

Regional Geology of Niger Delta

The Niger Delta has a depobelt area of 300,000 km² and an average elevation of 92 m above sea level. It is roughly found between longitudes 5000' to 8000'E and latitudes 4°00' to 8°00'N, (Akujieze and Oteze, 2007). It originated with the separation of the South American and African plates in the late Jurassic, according to Reijers (2011). As a result, the Benue Trough and the vast continental edges of West Africa were formed. Early Tertiary periods saw the beginning of marine sedimentation (Doust and Omatsola, 1990; Obaje, 2009), which has progressed over time over a distance of more than 250 km from the Benin and Calabar flanks to the current delta front (Evamy *et al.*, 1978; Oladele & Ojo, 2013). The progradation of the Niger Delta series, according to Merki (1972), has been influenced by synsedimentary faults, folding, and interactions between subsidence and sediment supply. The Niger, Benue, and Cross Rivers provided the majority of the sediment supply.

Materials and Methods

Sample Collection and Preservation

In the communities of Ekehuan, Gelegele, and Ughoton, all in Edo State's Ovia North East Local Government Area, six (6) water samples were taken from already-existing boreholes. The container needs to be thoroughly washed with the solution it will hold before any samples are collected. To reduce oxygen contamination and the escape of dissolved gases, the samples were taken using the

discrete sampling technique at several locations and placed into sterile bottles that were tightly capped. The samples were then brought to the lab for analysis after being properly labeled.

A Celsius thermometer is used to measure the temperature of water samples, 120 ml plastic bottles are used for sample collection, marking tape is used to identify samples, and a Global Positioning System (GPS) is used to determine elevation and coordinates before transporting the samples to the lab for examination, the samples were preserved using trioxonitrate V acid and tetraoxosulphate VI acid, along with reagents for samples preservation and a thick black polythene bag for protection from ultraviolet light.

Laboratory Procedure

The samples were examined for physical, chemical, and bacteriological parameters. According to the American Public Health Association's (1985) recommended standard operating procedure, physical and chemical parameters were determined. pH, electrical conductivity, turbidity, chlorides, calcium, sodium, sulphate, phosphate, magnesium, and nitrate are just a few of the chemical tests that were done on the samples in the laboratory. In addition to analyzing heavy metals like iron, manganese, zinc, chromium, cadmium, nickel, lead, and vanadium. Bacteriological testing on the water samples included counting the total number of coliform bacteria.

Determination of Parameter

Determination of pH

One of the most crucial and commonly performed tests in water chemistry is the measurement of pH. Hydrogen ions at a specific temperature can be used to determine how acidic a solution is. A pH meter with a glass electrode is used to electrically measure pH in both the field and the laboratory. The material required is a standard buffer solution with a pH between 4 and 9. This was measured using a pH meter.

Electrical Conductivity

Using a Hanna conductivity meter, the samples' electrical conductivity was determined. Readings from the meter are shown digitally and are expressed in ohms. Another crucial factor in determining a solution's electrical resistance is conductivity, which may be used to determine the overall ionic concentration in the solution. The overall concentration of dissolved ions, their valences, mobility, and temperature all affect the conductivity of water. Conductivity meters are frequently used to determine the cleanliness of water.

Procedure

The equipment was initially calibrated using buffer solutions with pH values of 4.01 and 10.01. After being properly inserted into the sample, the electrode was left to stand until the reading became steady, at which point it was eventually recorded.

Total Hardness

The water was pipetted into a conical flask in an amount of about 50ml. Two drops of the Eriochrome Black T indicator were added to two milliliters of buffer solution. After that, the solution was titrated against EDTA until the red wine turned completely blue. To determine the average value, the process was then repeated twice more.

Calcium

To obtain the Calcium, the process was then done twice more. Two milliliters of NaOH solution were tilted into a 100 milliliter conical flask after measuring out around 50 milliliters of the samples. With a clean spatula, 0.1 to 0.2g of murexide indicator was applied. Following a titration with EDTA, the solution was repeatedly mixed until the color changed from pink to purple. His calcium average value was then computed using this formula.

$$Ca^{2+} = \frac{mg/l \text{ of } 0.01M \text{ EDTA} \times 1000 \times 0.4008}{ml \text{ of sample}}$$

Nitrates

Pipette 10ml of the material into a 50ml flask, then add 2ml of 2M HCl that has been diluted to around 30ml.

Sulphanilic acid (2 ml) is added, mixed, and then let to stand for approximately 5 minutes. Then, mix in 10ml of alpha-naphthelamine before recording the volume. After a few minutes, the color develops. After 20 minutes, read the absorbent off the instrument after letting the solution stand.

Sulphate

Pipette 10 ml of the filtrate into a 50 ml flask, and then add water to make 20 ml more. Add 1 ml of the gelatinous BaCl₂ solution. Allow to stand for 30 minutes, add water to the required volume, and then read the spectrophotometer at 420 nm.

Phosphate

Concentrated HNO₃, HClO₄, distilled water, 6M NaOH, and methyl orange indicator are among the reagents employed. The sample underwent wet oxidation, followed by hydrolysis, which produced orthophosphates from the inorganic and organic phosphates. Total phosphate is determined through measurement.

Chloride

This is ascertained by titrating 0.1M of AgNO₃ against water samples while using potassium dichromate as the reagent. At the termination point, the color of the precipitate changed from yellow to red.

Total Solid

A 25ml sample is pipetted into an evaporating dish that has already been dried and weighed. Samples were dried out using hot water and heated for three hours at 105°C in an oven. To determine the result, the sample is desisted and weighed.

Determination of Alkalinity

100cm³ of the sample was obtained, 2.3 drops of phenolphthalein indicator were added, and the color change was noted. After that, 0.1N HCl was added in titrations until the pink color turned colorless.

Determination of Metals and Heavy Metals

Metals and heavy metals were identified using the flame atomic absorption spectrophotometer (AAS) throughout the examination. The samples were inhaled into flames, where the metal-containing compounds were volatilized and broken down into ground-state atoms while the water was evaporated. A hollow cathode lamp serves as the radiation source and has a metal cathode inside for analysis. This emits the metal's wave length properties, and a distinct lamp is needed for every metal.

Atoms absorb the lamp's radiation and are stimulated to a higher energy level, which leads to a monochromatic, which chooses the desired analytical wavelength. The lamp's light is directed via the flame (the ground state). A

photomultiplier tube detects the monochromatic light and transforms it into an electrical signal.

added. They undergo 15 minutes of sterilization at 121°C. The first three tubes were then injected with test water samples following that.

Determination of Coli-form Bacteria

Procedure

Double the power Durham tubes were placed within three sets of three tubes each with Maconkey broth (37.5g/l)

Result and Discussion

The results of the physicochemical and bacteriological analysis of the groundwater within Ekehuan, Ughoton and Gele-gele communities are summarized in the table below.

Table 2: Result of the Physicochemical analysis for water samples

| Parameters | GW1 | GW2 | GW3 | GW4 | GW5 | GW6 | WHO (2006) |
|-------------------------------------|--------|--------|--------|--------|--------|--------|------------|
| pH | 6.03 | 5.98 | 6.13 | 6.32 | 5.94 | 6.21 | 6.5 |
| EC (uS/cm) | 34 | 42.00 | 38.00 | 53.00 | 61.00 | 47.00 | 100 |
| TDS (mg/L) | 17.00 | 21.00 | 19.00 | 26.50 | 30.50 | 23.50 | 500 |
| Cl ⁻ (mg/L) | 10.88 | 13.44 | 12.16 | 16.96 | 19.52 | 15.04 | 200 |
| Salinity (mg/L) | 18.28 | 22.58 | 20.43 | 28.49 | 32.79 | 25.27 | 150 |
| Alkalinity(mg/L) | 3.32 | 3.34 | 3.26 | 3.16 | 3.37 | 3.22 | 100 |
| SO ₄ ²⁻ mg/L) | 0.48 | 0.59 | 0.53 | 0.74 | 0.85 | 0.66 | 250 |
| NO ₃ ⁻ (mg/L) | 0.75 | 0.92 | 0.84 | 1.17 | 1.34 | 1.03 | 10 |
| PO ₄ ³⁻ mg/L) | 0.10 | 0.13 | 0.11 | 0.16 | 0.18 | 0.14 | 500 |
| Na ⁺ (mg/L) | 0.55 | 0.68 | 0.61 | 0.85 | 0.98 | 0.76 | 200 |
| K ⁺ (mg/L) | 0.92 | 1.13 | 1.03 | 1.43 | 1.65 | 1.27 | N/S |
| Mg ²⁺ mg/L) | 0.41 | 0.50 | 0.46 | 0.64 | 0.73 | 0.56 | 20 |
| Ca ²⁺ (mg/L) | 0.27 | 0.34 | 0.30 | 0.42 | 0.49 | 0.38 | N/S |
| Fe ³⁺ (mg/L) | 0.14 | 0.17 | 0.15 | 0.21 | 0.24 | 0.19 | 0.3 |
| Zn ²⁺ (mg/L) | 0.17 | 0.21 | 0.19 | 0.21 | 0.31 | 0.24 | 0.01 |
| Mn ²⁺ (mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.1 |
| Cu ²⁺ (mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.5 |
| Ni ²⁺ (mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.02 |
| Cd ²⁺ (mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 |
| V ³⁺ (mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 |
| Cr ⁶⁺ (mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.05 |
| Pb ²⁺ (mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 |
| As(mg/L) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 |
| COD(mg/L) | 13.94 | 18.90 | 17.10 | 23.85 | 27.45 | 21.15 | 100 |
| Coli form(mg/L) | 0 | 0 | 23 | 0 | 11 | 0 | 0 |

GW= Groundwater from borehole GW1-3 from Ekehuan, GW4-5 from Ughoton and GW6 from Gele-gele communities respectively.

Electrical Conductivity (EC)

Electrical conductivity measurements ranged from 34 S/cm to 61 S/cm, with sample GW1 (Figure 5) having the lowest value and GW5 having the greatest value. The W.H.O. maximum permissible EC level for drinking water is between 100 S/cm, (WHO, 2006) hence the EC for the analyzed borehole water is entirely within acceptable bounds. An indication of the flavor or salt of the water is electrical conductivity. Values beyond the limits are a sign that saline water has mixed with groundwater and millions of tons of salt are present in the salt range (Jehan *et al.*, 2009; Reimann, 2003). Several factors, including variations in the mineral content of the area due to its geological settings, differences in the water body's mineral and chemical composition, which cause

excessive scaling in water pipelines, heaters, boilers, and home equipment Essumang *et al.*, 2011; Obiefuna & Sheriff (2011). Although this parameter poses minimal immediate danger to health, high EC values are associated with a bad taste and a high concentration of total dissolved solids (Beamonte, 2007; Howard *et al.*, 2003; Omorogieva *et al.*, 2022). For this type of interpretation, values given in graphs are simpler to understand. The W.H.O. has set the electrical conductivity for drinking water at 1200 uS/cm (2006). The levels found in this investigation were well below the allowable limit, demonstrating the safety of the groundwater for human consumption.

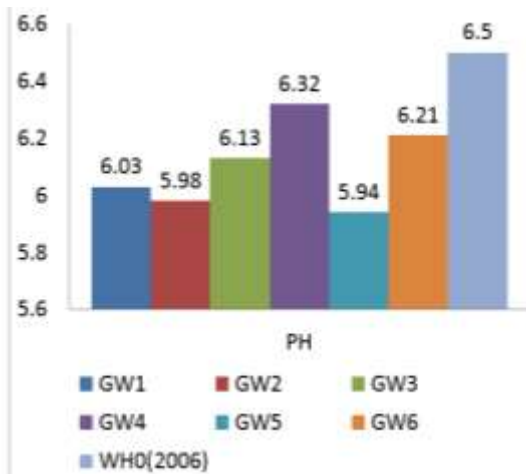


Figure 3: Graphical Representation of Samples pH against W.H.O. Standard

pH
The pH value reveals whether water is acidic or alkaline. The pH may drop below the safe level for acids. Acidic pH in drinking water can lead to corrosion in the distribution system's metal pipes. Acidic water is prone to corrode pipes and faucets if the pH is below 6, (Agwu *et al.*, 2013). Although pH doesn't directly affect human health, it can have an indirect impact by changing other factors like the solubility of metals and the survival of viruses (Howard & Smith, 2003). The pH values were discovered to be between 6.15 and 7.94. The greatest acceptable pH limit for drinking water is 6.5, as seen on the graph (Figure 3) above, according to World Health Organization (2006). Comparing the pH readings from the research, according to the pH value, it was found that all were within the limit, hence the groundwater is considered drinkable.

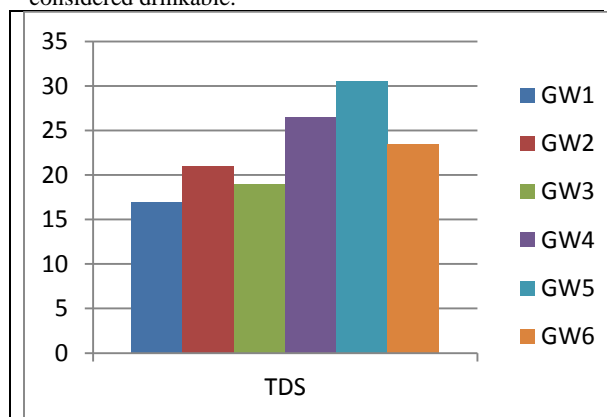


Figure 4: Total Dissolve Solid (TDS)

Total dissolved solids (TDS)

The behavior of groundwater's salinity is revealed by total dissolved solids. The water samples of drilling water had the highest TDS level. Samples with high TDS values also had high EC values and pH levels below 7. (Khan *et al.*, 2013, van Busse, 2012). Total Dissolved Solids (TDS) typically represent the volume of dissolved minerals in water. High TDS levels in practically all saltwater sources

may be the result of groundwater runoff from sedimentary rocks, primarily limestone and gypsum. The majority of total suspended solids were found in the host sedimentary rocks, primarily limestone and dolomite, may have leaked carbonates and bicarbonates into the water aquifer. The majority of these dissolved materials were found to be larger in size and to generate suspension rather than turbidity. Since the electrical conductivity and total dissolve solid are directly proportional, the total dissolve solid rises as the electrical conductivity does. (Emmanuel, 2009; van Busse, 2012; Ogieriakhi and Ilevbare, 2020). All of the sampled boreholes within the research areas had geochemical results below 50 mg/L, with GW5 recording the highest value of 30.50 mg/L (Figure 4). The highest value obtained in GW5, were lower than the W.H.O. (2006) threshold of 500 mg/l, supporting the quality of the groundwater in the research locations.

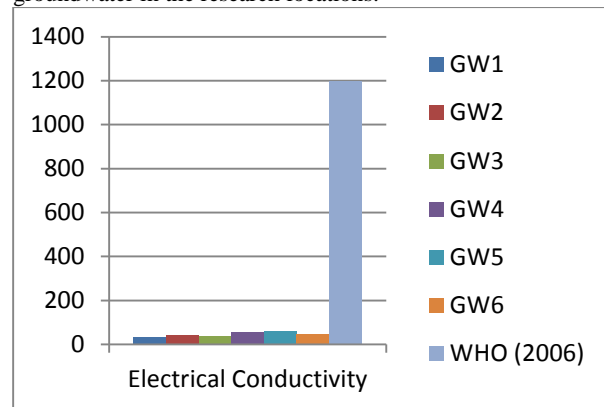


Figure 5: Graphical Representation of Electrical Conductivity against W.H.O. standard

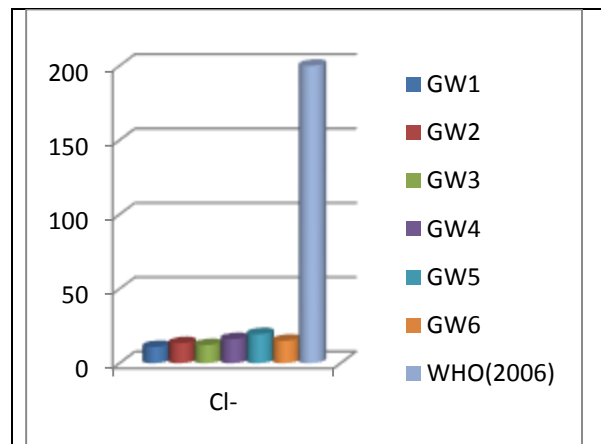


Figure 6: Graphical Representation of Chloride Chloride

Chloride is mostly created when hydrochloric acid salts, such as table salt (NaCl) and NaCO₃, dissolve and are then added to other substances, such as sewage, seawater, and industrial waste. Chloride concentrations in surface water bodies are frequently lower than those in subsurface water. Chloride concentrations should not exceed 200 mg/L, according to W.H.O. standards. Chloride levels in this study varied from 10.88 to 19.52 mg/L, with an average of 15.20 mg/L. As a result, the chloride

concentration in all of the samples is lower (Table 2). Chloride is primarily present in groundwater due to infiltration from septic tanks. World Health Organization (2006) states that water with 200 mg/L of chloride is unsafe to drink. 19.52 mg/L was the highest figure ever reported in the research locations in GW5 which in comparison was far below the set standard (Figure 6).

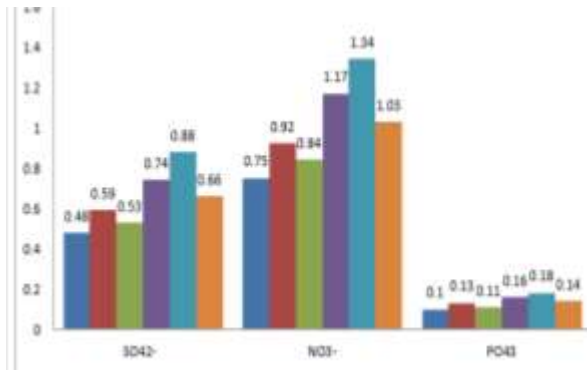


Figure 7: Anions in the analysed water sample
Anion radicals (SO₄²⁻, NO₃⁻ & PO₄³⁻)

Sulfate concentrations in natural water range from a few to several hundred mg/l, yet there have been no significant adverse effects on human health noted. The concentration of sulphate varied from 0.48 to 0.74 mg/L, with an average of 0.66 mg/L. The W.H.O. drinking water standards have set a respective limit of 250 mg/L. The human body has 95% of its calcium in the bones and teeth. Humans may develop rickets, poor blood clotting, bone fractures, and other conditions due to a high calcium deficit, and cardiovascular problems are caused by calcium levels that are too high.

Nitrate levels in ground water are typically low, although they can rise due to runoff or leaching from agricultural fields. The end result of ammonia's metabolic oxidation is represented by nitrates. Due to negative health impacts the effects of nitrates on people and animals, it is crucial to monitor nitrate levels in drinking water supplies (Sim, 2016). Since the concentration of nitrite ranged from 0.75 to 1.34 mg/L, which is far less than the permitted level, it was determined that all of the borehole samples' nitrite content was within the acceptable limit suggested by the W.H.O. (10 mg/L). Nitrites are known to have negative effects on human health, particularly in newborns who consume infant formula manufactured with the contaminated water source. The blood's hemoglobin is impacted by nitrate and nitrite, which results in blue baby syndrome. Additionally, there is a connection between nitrite exposure and cancer in people. Lifetime exposure to nitrite and nitrate at concentrations above the legal maximum could result in a variety of health issues, including an increase in starch deposits as well as splenic bleeding (Wiakowski, 2011). The three main anions under investigation (figure 7) are phosphate, nitrate, and sulphate. All of the study's results fell short of the W.H.O.'s established criterion (2006). This finding confirmed the hypothesis that the groundwater in the study locations is drinkable and thus safe for human consumption.

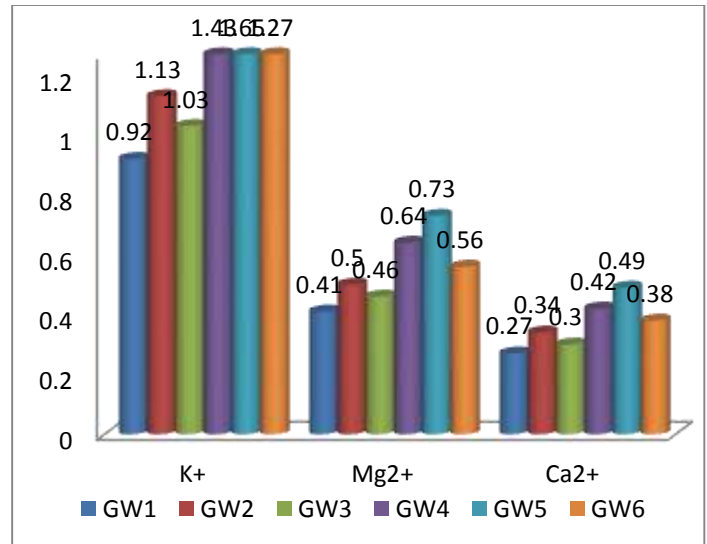


Figure 8: Major Cations in the analysed water sample
(mg/L)

Cation radicals (K⁺, Mg²⁺, Ca²⁺, Na⁺)

The main cat ions evaluated in the area under investigation were potassium, magnesium, and calcium (Figure 8). The geochemical data showed that 1.27 mg/L was the highest value. The Table provides a summary of the maximum permitted limit established by W.H.O. (2006). The values obtained fell short of the benchmarks established by the aforementioned organizations. With an average of 0.38 mg/L, calcium levels ranged from 0.27 to 0.49 mg/L. Magnesium makes up around 25% of the human body, 60% of which is found in bones and 40% in muscles and tissues. Magnesium ranges in concentration from 0.41 to 0.73 mg/L, with an average concentration of 0.36 mg/L. In smaller amounts, sodium is a silver-white metallic element that is present in water and when it is in excess in the human body numerous fatal disorders, such as kidney damage, hypertension, headaches, etc. are prevented. The sodium concentration in the borehole sample ranges between 0.55 and 0.98 mg/L, with an average of 0.77 mg/L. Potassium is a mineral that is essential for the health of all living things, including humans and animals, and is particularly abundant in plant cells. Between 110 and 140 g of potassium are found in the human body overall. It is essential for bodily processes including heart protection. The study's potassium concentration ranged from 0.92 to 1.65 mg/L, with an average value of 1.29 mg/L, according to the results. The samples' sodium concentrations ranged from 0.55 mg/L to 0.98 mg/L in the GW1 to GW6 communities (Table 2). The values were all within the 200 mg/L W.H.O. recommended limit. A higher availability of sodium ions in the blood stream as a result of too much sodium in drinking water causes higher-than-normal cardiac activity, heart hypertrophy, an increased risk of hypertension, and stroke. Stroke is the third biggest cause of death in the US today, behind heart disease (Feng *et al.*, 2016).

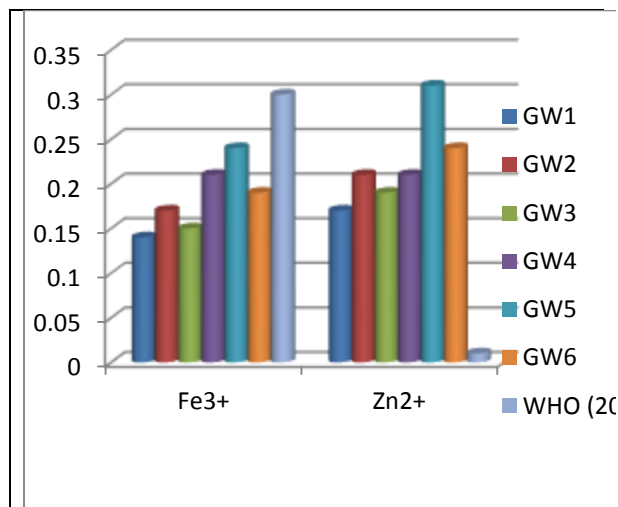


Figure 9: Heavy Metal (mg/L)

Heavy Metals

Kidney damage can result from long-term exposure to cadmium, which can also cause acute gastrointestinal issues like vomiting and diarrhea (Wei, *et al.*, 2009). The aesthetic and flavor value of iron in drinking water is more important than its effects on health. Ninety percent of the samples meet the W.H.O.-recommended iron level in drinking water (0.3 mg/L) (2006). Overexposure to iron is less prevalent than its shortage, but it can cause a number of major health issues, including diabetes, liver, and heart disease (Milman *et al.*, 2001; Rasmussen *et al.*, 2001). Low pH and turbidity have a high correlation with iron concentration. A high iron concentration imparts an unpleasant taste and brings turbidity up. The pH of water may decrease with increased mining activity, which also aids in the iron's dissolution in water (Banks *et al.*, 2004). Animals and plants require chromium as a micronutrient, yet it is also regarded as a severe pollutant. Salt scale Mineral resources like coal, gypsum, limestone, and chromate are abundant in the area. The main natural sources of chromium entrance into water in the area are leaching from rocks and coal mines. High chromium levels in drinking water are linked to ailments like asthma and skin allergy issues. Skin contact with chromium-contaminated water can cause skin conditions like dermatitis and scabies. Several chromium compounds, particularly those in its hexavalent form, are linked to skin conditions, cancer, and other illnesses respiratory, reproductive, and digestive systems (Zhang *et al.*, 2010; Feng *et al.*, 2016). Long-term chromium exposure frequently results in renal problems, dermatitis cases, and skin ulcerations (Hanaa *et al.*, 2000; Pandey, *et al.*, 2010). Most water sources had lead contents exceeding what many guidelines consider to be acceptable. Thus, given the current heavy reliance on alternative water sources other than tap water, it is necessary for the involved bodies to establish protections and frequent purifying procedures in addition to raising knowledge about how to handle wells and springs in a sanitary manner (Adebayo, 2022).

Heavy metals are metals that have a density larger (>) than 5 g/cm³ and can bio-accumulate in human tissues

and other organs. They build up when consumed and it becomes hazardous to the biological system when the concentration rises above usual. Only Iron and Zinc have record values for all the heavy metals examined, as shown in the graph in Figure (9) above. Others, such as lead, manganese, cadmium, vanadium, chromium, and arsenic, were less than 0.0001 (Table 2). While the zinc levels in the water samples analyzed were over the W.H.O.-permitted limit, the iron concentrations were below WHO standards (2006).

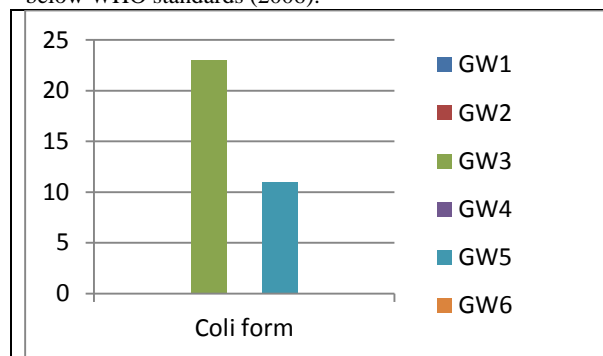


Figure 10: Total Coli form count

Bacteria Quality

The mean concentrations of *E. coli* and coliform bacteria in drinking water gathered from the sampled communities are also shown in table 2. When coliform bacteria from these three locations were detected in all drinking water samples, they ranged from 0 to 23 per 100 milliliters. Overall, it was discovered that the coliform bacteria exceeded the WHO guideline of 0 per 100 mL, necessitating treatment to eradicate the bacteria. The lack of sewage and solid waste disposal systems, leaks from septic tanks, and other factors that were the principal hazards to water resources in the towns studied in this study may have contributed to the coliform bacteria contamination of drinking water sources. Despite the fact that coliform bacteria are not known to be disease-causing signs of pathogenic contamination that can result in illnesses including cholera, typhoid fever, hepatitis, intestinal infections, and dysentery, among others (Emmanuel *et al.*, 2009). The World Health Organization suggests a coli form count in drinking water of zero. Two of the six examined boreholes had significantly elevated coli form counts (Figure 10). The boreholes have respective numbers GW3 and GW5. Alarm should be raised because of the high number of coliforms present.

Conclusion

Drinking water quality is equally as crucial as its availability. Because local geological conditions have an impact on the area's drinking water quality, quality differs from place to location. Lack of access to adequate quality water is the root cause of many health issues.

The geochemical analysis of the groundwater samples from the three communities under investigation revealed that the cations and anions were below World Health Organization permissible limits, the heavy metals were below permissible limits with the exception of zinc, which was discovered to be above World Health Organization

permissible limits in drinking water, and coli form count was present in GW3 and GW5 borehole samples.

In the groundwater under investigation, other parameters measured were below the allowed level. With the exception of samples GW3 and GW5, which have high levels of coliform bacteria and the heavy metal zinc, the geochemical information that is currently available and the results that have been discussed all indicate that the groundwater under investigation is generally potable across the well. Before drinking, the borehole water from samples GW3 and GW5 should undergo a standard treatment such as boiling and chlorination.

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