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Risk Based Assessment of Groundwater Contamination from Domestic Water Sources: A Case for Sustainable Water Safety

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Abstract

Groundwater quality in Ute Community, Ikpoba Okha L.G.A. (Edo State, Nigeria), was evaluated through a comprehensive hydrogeochemical analysis of twelve borehole samples to assess suitability for domestic use. Physicochemical and bacteriological parameters—including pH, electrical conductivity (EC), total dissolved solids (TDS), heavy metals (Cd, Pb), nitrate (NO_3^-), sulfate (SO_4^{2-}), and microbial contaminants (E. coli, total coliforms)—were analyzed using standardized protocols and compared against WHO (2021) and NSDWQ (2007) guidelines. Results revealed that 75% of samples exhibited acidic pH (5.98–6.41), exceeding permissible limits, while cadmium concentrations (0.06–0.61 mg/L) consistently surpassed WHO thresholds (0.003 mg/L). Nitrate levels (30.55–65.85 mg/L) in 75% of samples indicated anthropogenic pollution, likely from agricultural runoff. Although TDS (55.49–206.04 mg/L) and turbidity (0.68–3.19 NTU) complied with standards, persistent fecal coliform contamination (1.60–5.10 cfu/mL) highlighted risks of groundwater vulnerability due to shallow aquifer depths (2.75–6.0 m). This study underscores the imperative for targeted water treatment interventions, community education on pollution mitigation, and policy reforms to safeguard groundwater resources in rapidly urbanizing regions.

Keywords: Groundwater contamination, Hydro geochemistry, Borehole water quality, Heavy metals, Microbial pathogens, Water safety index, Anthropogenic pollution, Edo State aquifer, Nigeria, Drinking water standards, public health risk

INTRODUCTION

Water serves as the fundamental element for sustaining life, and access to clean drinking water is a basic human right that is crucial for the well-being of all individuals (Versari, et al., 2002). It plays a vital role in the health and sustainable development of humanity. Unfortunately, many people are deprived of adequate supplies of safe drinking water and sufficient water for basic hygiene. The consumption of contaminated water has severe consequences, leading to numerous daily deaths, primarily affecting children under the age of five in developing nations (WHO, 2004a). Therefore, the availability of clean and safe water, along with proper sanitation facilities, is not only a fundamental right but also a prerequisite for maintaining basic health (Palamuleni, 2002). In many low-income communities in developing countries, the utilization of shallow groundwater sources for drinking and domestic purposes is a common practice.

Groundwater refers to water that is located beneath the Earth's surface, either in the pore spaces of sedimentary rocks or in fractures within basement rocks. It accumulates through the infiltration of rainwater into the soil and bedrock

(Oladunjoye et al., 2011). During the infiltration process, water undergoes chemical changes as it interacts with rocks and soil, becoming contaminated with dissolved ions primarily derived from rocks, as well as other substances contributed by plants and animals living in and on the soil (Olaye, 2004). Shallow wells are typically situated in valleys where the groundwater table is relatively close to the surface, usually ranging from 1 to 4 meters below ground level. In these areas, rainfall and river water infiltration play significant roles in recharging the groundwater (Pritchard et al., 2008). Groundwater contamination occurs when polluted water infiltrates through the soil and rocks, eventually reaching the groundwater. This process can take several years and can occur at varying distances from different wells where such contamination is detected. Once the groundwater is contaminated, it becomes extremely challenging to remediate. However, advancements in technology can help reduce pollution levels (Geetha, et al., 2008). Failure to effectively manage water and land systems puts human health, agricultural development, and ecosystems at risk (Kehinde et al., 2009).

Groundwater pollution refers to the deterioration of water quality resulting from human activities (FEPA, 2005). This definition encompasses natural processes as well, such as the intrusion of saltwater into freshwater-bearing aquifers in coastal areas due to artificially lowered groundwater levels. Most groundwater pollution stems from the improper disposal of domestic, municipal, and industrial wastes on land surfaces, in shallow excavations including septic tanks, through deep wells and mines, the use of fertilizers and other agricultural chemicals, leaks in sewers, storage tanks, and pipelines, and animal feedlots (Hem, 1985). The extent of a pollution problem depends on various factors, including the size of the affected area, the quantity and properties of the pollutants involved, the solubility, toxicity, and density of the pollutants, the mineral composition and hydraulic characteristics of the soils and rocks through which the pollutants travel, and the actual or potential impact on groundwater usage (Akaninwor et al., 2007).

The growing global population, improved living standards, and escalating demand for clean water necessitate increased water resources for environmental needs, such as aquatic life, wildlife refuges, scenic values, and riparian habitats (Li, et al., 2007). Additionally, the proliferation of population and the establishment of industries involved in the production of various agrochemicals, petrochemicals, and household products have led to an increase in the production of hazardous substances, including heavy metals, in developing countries (Oguzie and Okhagbuzo, 2010). The application of agrochemicals and fertilizers in order to enhance agricultural yields can release contaminants like nitrates, bacteria, viruses, and hazardous household chemicals into the subsurface, posing potential risks to nearby wells and surface water. Human activities in and around agricultural farmlands have a significant impact on the physical and chemical properties of water, which are essential for the sustenance of various life forms. Historical and ongoing land pollution caused by heavy metals, resulting from atmospheric deposition and fertilizer application, has elevated the levels of heavy metals in both cultivated and uncultivated soil. These human-derived heavy metals, in conjunction with naturally occurring amounts in the soil, can seep into groundwater and surface water (Bonten and Groenenberg, 2008). The quality of underground water in basins can vary qualitatively and quantitatively due to factors such as industrial effluent influx, water influx through rainfall, soil composition, and agricultural practices.

For most communities, the most reliable source of safe drinking water is piped water from municipal treatment plants. However, these water treatment facilities often fail to meet the demands of the served community due to corruption, lack of maintenance, or population growth. Consequently, the scarcity of piped water has driven communities to seek alternative sources, such as groundwater sources. Wells are commonly used as a readily available groundwater source to meet the water needs of communities (Adekunle, 2009). Therefore, this study aims to examine the levels of potential pollutants and necessary substances in selected borehole water samples to determine their suitability for their intended purpose. It also implies a comparative analysis of these samples based on their location.

MATERIALS AND METHOD

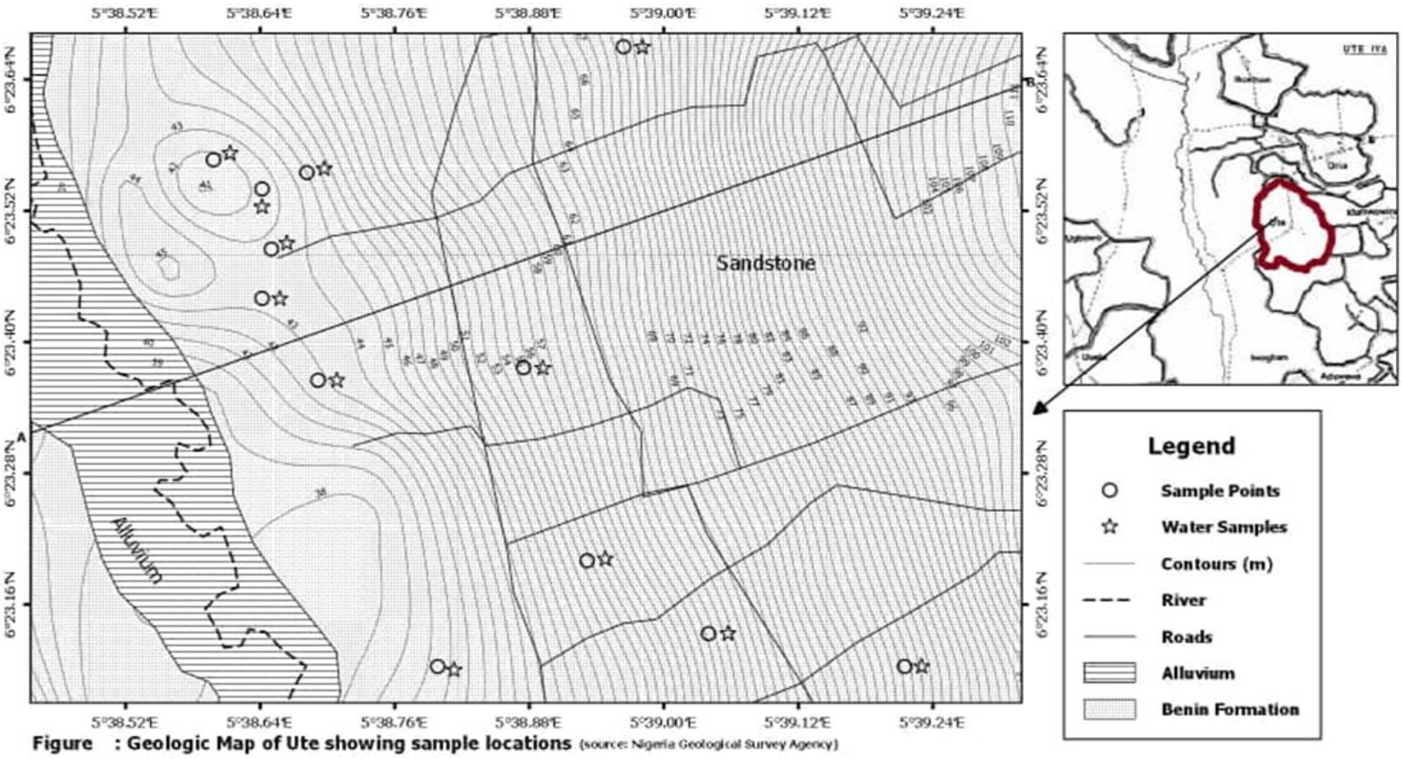

Figure : Geologic Map of Ute showing sample locations (source: Nigeria Geological Survey Agency)

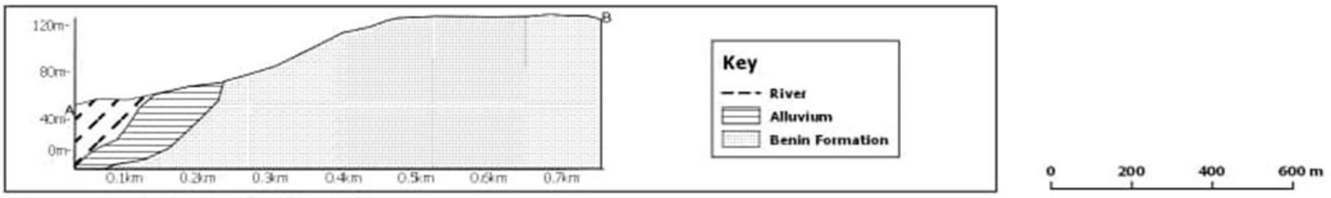

Figure : Geologic Cross Section of Ute

Figure 1: Map of Study Area

A. MATERIALS

Some of the materials used include: test tubes, Petri-dish, inoculating lamp, syringe pipette, aluminum foil, test tube track, cotton-wool, slides, matches, Microscope, Incubator, Refrigerator, Autoclave, Mettle balance.

B. SAMPLE COLLECTION AND PRESERVATION

Twelve (12) samples in all were taken from twelve (12) distinct boreholes in Ute. The samples were gathered in pristine plastic cans for examination, and there were enough of them to look into all the relevant criteria. The method used to gather water samples for analysis was appropriate given the intended use of the analysis's findings. Because water usually undergoes frequent changes, samples were preserved by adding preservatives or by keeping them in a refrigerator.

All of the water samples that were used were gathered and sent straight to the lab due to the nature of the project. Because the sampling wells were selected at random, there was a fair distribution of them over the whole research region.

C. DEPTH TO GROUNDWATER

The depth to groundwater varies from 2.75 m to 6.0 m which is relatively shallow. The groundwater system's shallowness is detrimental since it makes it more vulnerable to anthropogenic sources of contamination.

D. METHODS

The water samples were analyzed using specific instruments. The HANNA conductivity and temperature meter EC/TDS were used to measure the conductivity and temperature values of the water. Turbidity was determined using the wag-WT 3020 turbidity meter, which is waterproof and has the serial number 197619. To analyze parameters such as NO3, Fe2+, Na+, Mg2+, and Ca2+, a spectrophotometer was employed. Specifically, a Wagtech photometer with a wavelength range of 410-640 and the serial number 3400-008 was used for this purpose. Additionally, during the fieldwork at the collection site, observations were made regarding physical parameters such as odour, taste, and color of the water.

E. DETERMINATION OF HARDNESS

Water hardness is caused by the presence of calcium (Ca) and magnesium (Mg). To determine the total hardness of the water sample, a titration method was employed. The water sample was titrated with ethylenediaminetetraacetic acid (EDTA) using Erichrome Black as the indicator. A buffer solution consisting of borax, sodium hydroxide, and sodium sulfide was utilized during the titration process.

Procedure:

A volume of 50ml from the water sample was carefully measured and transferred into a 150ml conical flask. Then, 10ml of buffer solution was added to the flask, followed by the addition of 10 drops of 5% hydroxylamine-hydrochloric solution. Next, 10 drops of a 2% analytical grade sodium solution were added, and 2 drops of Erichrome black T indicator were introduced. The water sample was titrated against EDTA until the endpoint was reached, which was indicated by a color change from purple to blue. The concentration of the water sample was expressed in parts per million (ppm) of calcium carbonate (CaCO3). To obtain the calcium hardness, the magnesium hardness value was subtracted from the total hardness.

F. DETERMINATION OF pH

pH is a measure of the acidity or alkalinity of an aqueous solution, and it is calculated as the negative logarithm of the hydrogen ion concentration. It provides a way to quantify the level of acidity or alkalinity in a solution. The pH value of water greatly affects the solubility of ions within it.

G. ODOUR AND TASTE

Manual sensing of the water samples was adopted.

H. DETERMINATION OF CONDUCTIVITY

The conductivity of the different samples was measured directly using a conductivity meter. Conductivity is a significant factor in assessing the electrical resistance of a solution, providing insights into the overall concentration of ions present in the solution. Water's conductance is linked to the combined concentration and mobility of dissolved ions, as well as temperature. Conductivity meters are commonly used to evaluate the purity of water.

Procedure:

The apparatus utilizes a cell as part of its functioning. To ensure accurate measurements, the measuring cell is detached from the instrument and then thoroughly cleaned using a bottle brush. It is rinsed with distilled water to remove any stubborn residue. Before filling the cell for measurement, a small amount of the solution being tested is used to rinse the cell. To obtain the readings, the button is pressed and the measuring dial pointer is slowly rotated until the balance indicator is centered. The measurements are expressed in microsiemens per centimeter (µS/cm).

I. TOTAL DISSOLVED SOLIDS (TDS)

Apparatus:

Evaporating dish or beaker, oven, desiccators, steam bath, 100ml-measuring cylinder.

Procedure:

The samples were measured to 100 milliliters, and then they were made up to 100 milliliters with distilled water and filtered into a 100-milliliter measuring cylinder using preweighed filter paper. Following that, it was put into a crucible that had been previously weighed, evaporated in a steam water bath to become dry, dried in an oven for 11/2 hours at

1800 degrees Celsius, cooled in desiccators, and then weighed. The crucible's weight, W1, was recorded, and the dissolved solid, W2, was recorded.

Total Suspended Solids (TSS):

This is the amount of solid that a filter retains. Half an hour was spent drying the pre-weighed filter paper for total dissolved solids at 1050C. After cooling in desiccators, it was weighed. The weight of the filter paper that had been pre-weighed was W1, and the weight of the paper and residue upon drying was W2.

J. DETERMINATION OF CHLORIDE

The chloride ion present in the water precipitated as white silver chloride when the Mohr's method was applied, with potassium chromate serving as the end point indicator and silver nitrate as the titrate.

Procedure:

Ten drops of potassium chromate were added to 50 milliliters of the sample, which was measured into a conical flask. This caused the water samples to turn yellow. Once the water samples were titrated against 0.05 milliliters of silver nitrate, the color of the samples changed from yellow to reddish brown, which is the titration endpoint.

K. DETERMINATION OF NITRATE

The chlorimetric method was used to determine the nitrate content. This required the employment of copper sulphate ($CuSO4.5H2O$) and hydrazine sulphate ($N2H2.H2SO4$) as a catalyst to produce a red color, whose intensity was thereafter compared to the standard Aqua Merck nitrate color scale. The scale displayed the corresponding concentration in parts per million. The kit's unique benefit is that it makes it possible to quickly determine the ionic concentration at or near the spot. Using the Aqua Merk water analysis reagent kit, nitrite, silicate, and phosphate were measured using a methodology similar to the one described previously (Merck, 1982).

L. DETERMINATION OF COLIFORM CONTENT/LOAD.

To ensure sterility, all equipment to be used was subjected to autoclave sterilization. A series of dilutions were prepared for the water sample, reaching up to a dilution of 10-2. The diluted sample was poured into a Petri dish and covered. Some nutrient broth was added to the dish. The mixture was gently and evenly swirled to ensure proper distribution, and then allowed to solidify by gelation. Afterward, it was incubated for a period of 3 days, following which it was transferred to a refrigerator.

The water sample was cultured using both single and double strength methods. This was determined by observing a yellow or pale-yellow color change in the medium and the presence of gas formation in the Durham tubes. Samples showing these characteristics were further cultured using Eosin methylene blue. The presence of colonies exhibiting a green metallic sheen or colonies showing the Eosin methylene blue characteristics confirmed the presence of E. coli in the sample.

RESULTS

Table 1: Result of Physio-Chemical and Bacteriological Analysis

Parameter	**Units**	**Loc1**	**Loc2**	**Loc3**	**Loc4**	**Loc5**	**Loc6**	**Loc7**	**Loc8**	**Loc9**	**Loc10**	**Loc11**	**Loc12**	**NSDWQ**	**WHO**
pH		5.98	5.89	5.96	5.93	6.19	6.23	6.32	6.25	6.22	6.62	6.56	6.41	6.5 – 8.5	6.5-8.5
EC	uS/cm	404	398	401	399	160	164	166.00	164.01	150	108	97	87	2500.0	1000
Chloride	mg/l	5.66	8.06	11.13	4.76	10.45	12.70	5.66	7.65	5.99	6.23	4.89	5.86	250.0	250.0
Alkalinity	mg/l	1.59	1.55	1.67	1.54	2.68	2.89	3.87	3.41	3.66	4.12	4.22	4.09	200.0	200.0
TDS	mg/l	206.04	199.21	205.01	179.23	87.45	58.11	84.66	79.35	82.54	65.57	90.74	55.49	500.0	500.0
Turbidity	NTU	1.76	1.34	2.11	1.65	2.44	2.21	2.67	3.19	1,88	1.45	0.68	1.21	4.0	5.0
COD	ppm	171.70	147.25	139.54	142.66	142.62	102.36	70.55	71.42	64.87	70.21	66.26	69.68	10.0	10.0
Dissolved O	mg/l	3.54	3.32	3.56	3.61	3.28	4.57	3.77	5.02	3.55	6.08	6.62	4.59	500.0	1000.0
BOD	mg/l	1.91	1.89	1.99	1.92	1.98	2.02	2.04	2.28	2.32	2.29	1.90	2.21	5.0	100.0
Sulphate	mg/l	20.20	18.23	30.22	16.65	39.12	22.68	8.30	10.021	8.66	16.48	10.20	11.44	250.0	400.0
Nitrate	mg/l	65.85	54.33	46.86	54.72	30.55	52.49	65.85	60.24	47.87	60.44	56.67	62.51	50.0	50.0
Phosphate	mg/l	0.98	0.11	0.43	0.39	0.60	0.22	0.60	0.42	0.36	0.24	0.33	0.88	0.10	0.50
Cadmium	mg/l	0.48	0.42	0.61	0.52	0.18	0.27	0.33	0.14	0.06	0.08	0.16	0.28	0.005	0.003
Calcium	mg/l	14.42	19.71	25.79	15.98	18.67	14.64	5.93	7.56	5.69	5.77	9.60	5.99	100.0	200.0
Magnesium	mg/l	33.53	35.76	31.55	34.09	33.44	32.02	13.78	10,67	10.77	12.23	15.76	20,25	0.20	50.0
Sodium	mg/l	25.45	18.44	23.12	20.60	16.88	14.39	10.46	12.42	8.66	8.48	10.44	9.46	200.0	200.0
Potassium	mg/l	85.65	72.66	80.49	60.75	59.43	40.70	35.19	20.69	11.18	15.77	13.60	12.54	100.0	3000.0
Coliform	Cfu/ml	4.11	5.10	3.89	3.48	4.66	4.81	3.24	3.41	2.20	3.10	1.60	1.90	10.0	10.0
E.coli	Cfu/ml	2.40	2.30	1.50	1.90	2.10	1.80	1.20	1.40	0.88	1.10	1.0	1.20	NA	NA

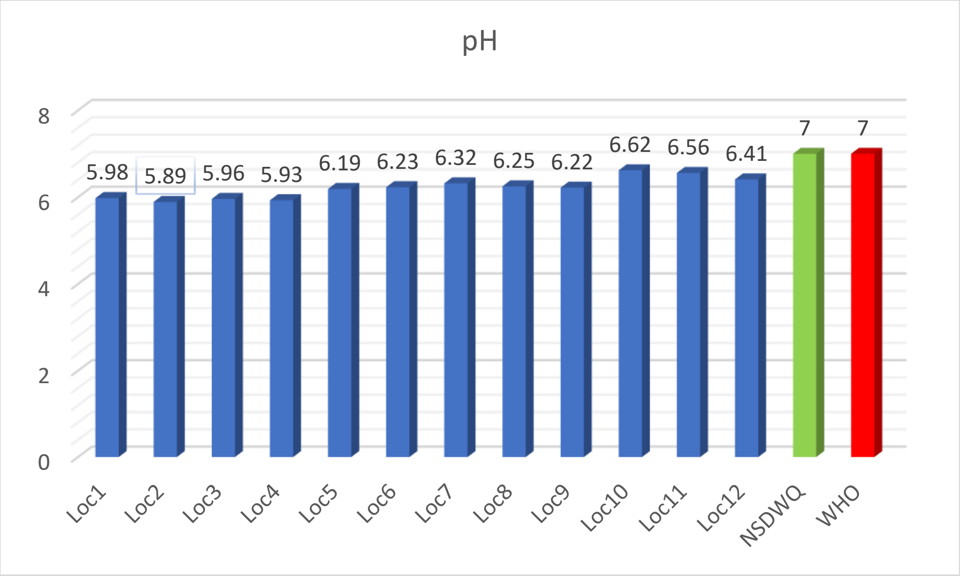

Figure 2: Showing pH concentration

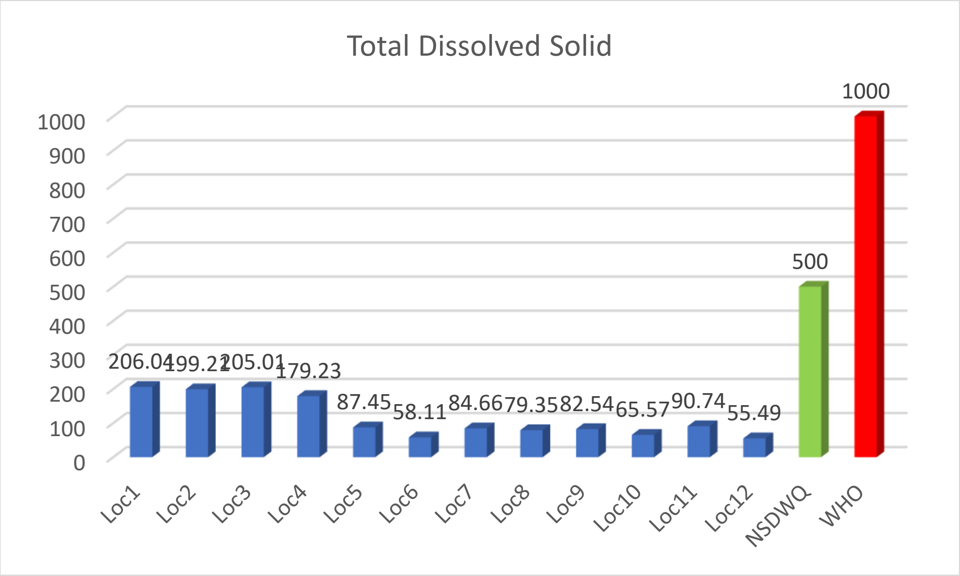

Figure 3: Showing TDS concentration

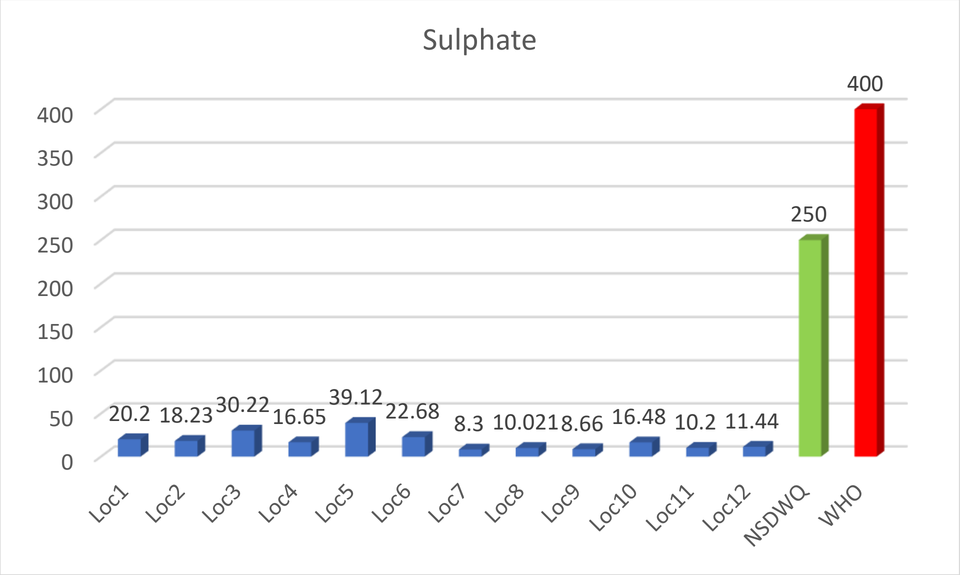

Figure 4: Showing Sulpate concentration

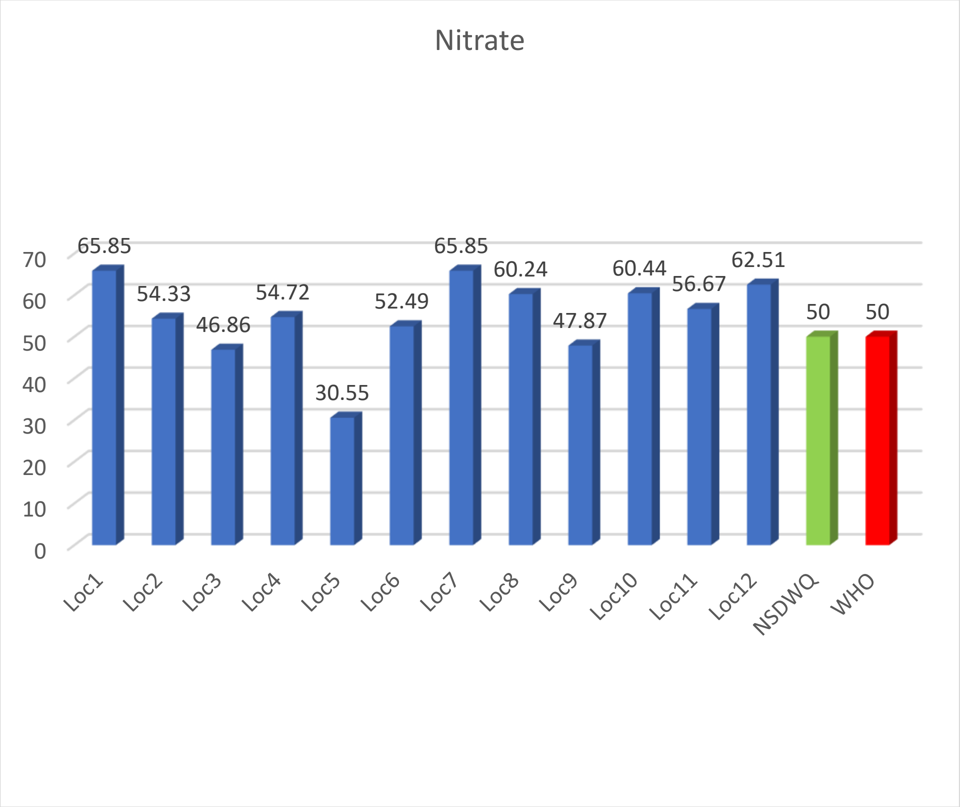

Figure 5: Showing Nitrate concentration

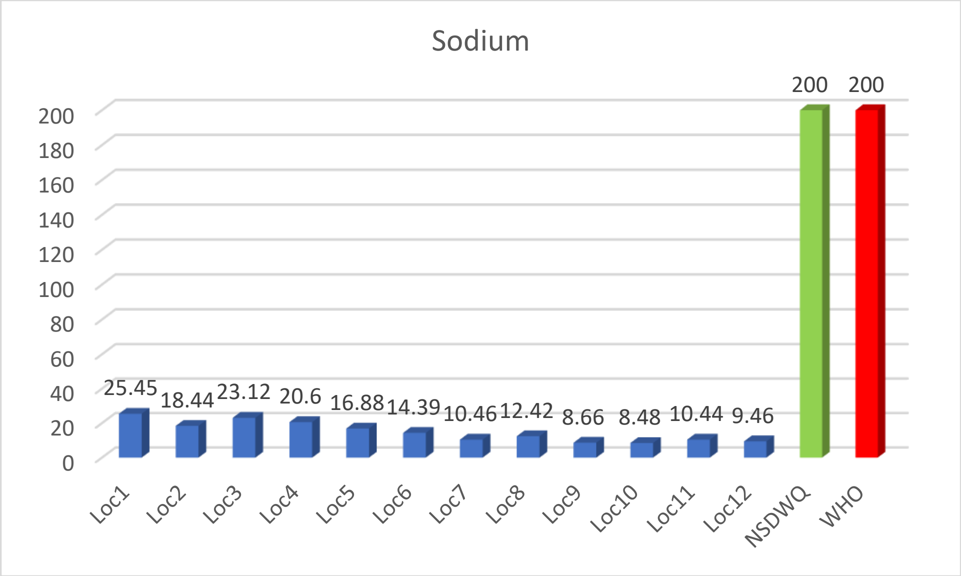

Figure 6: Showing Sodium concentration

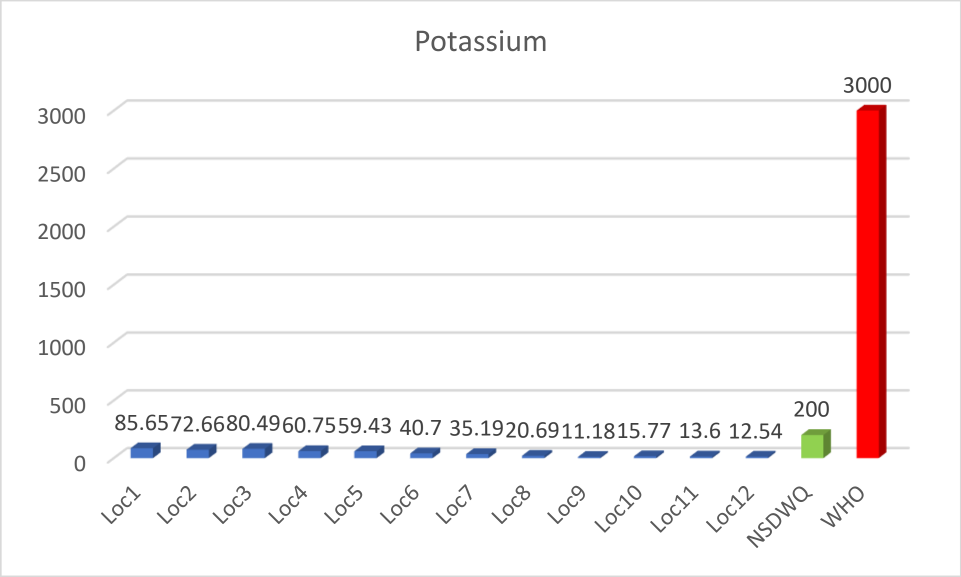

Figure 7: Showing Potassium concentration

A. PHYSICAL ANALYSIS

pH

The pH values of the borehole water samples ranged from 5.98 to 6.41, indicating a weakly acidic to slightly alkaline nature. According to the World Health Organization (WHO) standards for portable water, all the sampled boreholes fell within the recommended range of 6.5 to 8.5, which is considered acceptable for drinking water. However, none of the samples met the specified limits of 6.5 to 8.5 (NSDWQ, 2007) and 6.5 to 9.2 (EGASPIN, 2002). The increased acidity is likely attributed to the presence of organic matter in the soil (Udom et al., 2002). Acidic water promotes the growth of iron bacteria, which can lead to pipe encrustation. The objectionable color observed in the water samples resulted from the leaching of organic debris. However, it's important to note that the color number does not directly indicate the actual amount of organic material causing the color (Hem, 1985).

Conductivity

The conductivity values obtained from all the sampled wells ranged from 87 to 404 µS/m, which are all below the recommended drinking water standards set by the World Health Organization (WHO). This suggests that the water has relatively low electrical conductivity in terms of dissolved ions. Although the electrical conductivity (EC) for all locations fell below the NSDWQ limit of 2500 µS/cm and the WHO limit of 1000 µS/cm, the mean values showed statistical differences at a 95% confidence level. According to Moore (1989), EC serves as an estimation of the total dissolved solids (TDS) or the overall number of dissolved ions in the water. It is influenced by various factors, including the types of rocks and the presence of wastewater from sewage treatment plants and other sources of ions.

Total Dissolved Solid

Water with a total dissolved solids (TDS) level below 600 mg/liter is generally regarded as having good palatability, while drinking water becomes noticeably less palatable as TDS levels exceed approximately 1000 mg/liter. The presence of elevated TDS levels can also be objectionable to consumers due to excessive scaling in water pipes, heaters, boilers, and household appliances. The electrical conductivity values obtained from the water samples taken from the hand-dug well ranged from 55.49 to 206.04, which is well below the permissible and acceptable limit for drinking water.

Turbidity

Turbidity in drinking water arises from the presence of suspended particles, which can originate from inadequate filtration of the source water or the re-suspension of sediment in the distribution system. It can also be caused by the presence of inorganic particulate matter in certain groundwater sources or the detachment of biofilm within the distribution system. Typically, water with a turbidity level below 5 NTU (Nephelometric Turbidity Units) is considered acceptable to consumers, although this may vary depending on local conditions. The values obtained from the water sample of the hand-dug well ranged from 0.68 to 3.19, which falls within the permissible limit for drinking water as set by the World Health Organization.

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B. CHEMICAL ANALYSIS (CATIONS)

Sodium (Na^+)

The primary source of sodium ions in natural water is the release of soluble sodium products during the weathering process of plagioclase feldspars. Sodium salts, such as sodium chloride, are present in almost all food (which is the main source of daily exposure) and drinking water. While concentrations of sodium in drinking water are typically below 20 mg/liter, they can exceed this level in certain countries (Akaninwor et al., 2007). The levels of sodium salts in the air are generally low compared to those in food or water. It is important to note that some water softeners can significantly increase the sodium content in drinking water. The concentration of sodium (Na+) in the samples obtained ranged from 8.48 to 25.45 mg/liter. These values fall within the acceptable levels for portable water according to the World Health Organization (WHO).

Potassium (K^+)

Potassium, the most abundant cation found within cells, is an essential nutrient that naturally occurs in various foods and is also available as a dietary supplement. It is present in all bodily tissues and plays a crucial role in maintaining normal cell function by regulating intracellular fluid volume and trans-membrane electrochemical gradients (Institute of Medicine, 2005; Stone et al., 2016). Natural water contains a certain level of potassium (K+) concentration, which should ideally be below 10 parts per million (ppm). However, the analyzed samples showed potassium concentrations ranging from 11.18 to 85.65 mg/liter. Despite being slightly higher than the recommended limit, these values still fall within the permissible range according to the National Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) guidelines.

Calcium (Ca^{2+})

Calcium, the most abundant mineral in the body, is naturally found in certain foods, added to others, available as a dietary supplement, and can also be present in certain medications such as antacids. Calcium plays essential roles in vascular contraction, vasodilation, muscle function, nerve transmission, intracellular signaling, and hormonal secretion. However, less than 1% of the total body calcium is required to support these critical metabolic functions (Hersch and Peng, 1996). The table provided indicates that the concentration of calcium (Ca2+) in the samples ranged from 5.69 to 25.79 mg/liter. These findings demonstrate that all the samples had calcium values within the acceptable limits.

Magnesium (Mg^{2+})

The groundwater samples had varying concentrations of magnesium, ranging from 10.67 to 35.76 mg/L. Based on the results, it is evident that six out of the sampled boreholes exceeded the permissible limits for magnesium, while the remaining six wells had values that fell within the standards set by the World Health Organization (WHO).

Chemical Analysis of (anions)

Sulphate (so_4^{2-})

Sulfates are naturally present in various minerals and have commercial applications, primarily in the chemical industry. They can be released into water through industrial waste and atmospheric deposition. However, the highest levels of sulfates typically originate from natural sources and are found in groundwater. On average, a person's daily intake of sulfate from drinking water, air, and food amounts to approximately 500 mg, with food being the primary source. Nonetheless, in areas where drinking water supplies contain elevated sulfate levels, drinking water may become the main source of sulfate intake. Most sulfate compounds readily dissolve in water. The concentration of sulfates (SO42-) in the groundwater samples from the study area ranged from 8.30 to 39.12 mg/L. These sulfate values in the samples fall below the minimum limit of 250 mg/L set by the World Health Organization (WHO) for potable water.

Nitrate (NO_3^-)

Nitrates are naturally occurring ions that play a role in the nitrogen cycle. They are primarily utilized in inorganic fertilizers, and sodium nitrite is employed as a food preservative, particularly in cured meats. Normally, the concentration of nitrates in groundwater and surface water is low. However, it can become elevated due to leaching or runoff from agricultural land, or contamination from human or animal waste as a result of the oxidation of ammonia and similar sources. The water samples taken within the study area exhibited nitrate concentrations (NO3-) ranging from 30.55 to 65.85 mg/L. Among these samples, nine had values exceeding the maximum allowable limit of 50 mg/L, as recommended by the World Health Organization (WHO) for drinking water.

Phosphate (PO_4^{3-})

The groundwater samples in the study area displayed varying concentrations of phosphates, ranging from 12.36 to 40.11 mg/L. These values indicate that the phosphate levels exceed the maximum permissible limit of 10 mg/L, as set by the standards established by the World Health Organization (WHO).

Chloride (Cl^-)

High concentrations of chloride give a salty taste to water and beverages. Taste thresholds for the chloride anion depend on the associated cation and are in the range of 200–300 mg/litre for sodium, potassium and calcium chloride. From the result of the analysis carried out on the groundwater sample in the study area the concentration of chloride ranges from 4.76-12.70mg/l.

C. Bacteriological Analysis

Concentration of E-coli

Escherichia coli, commonly known as E. coli, is found in significant quantities within the normal intestinal flora of humans and animals, typically without causing harm. However, when present in other parts of the body, E. coli can lead to severe illnesses like urinary tract infections, bacteremia, and meningitis. The presence of E. coli (or thermotolerant coliforms) serves as an indication of recent fecal contamination, necessitating further action, such as additional sampling and investigation to identify potential sources like inadequate treatment or breaches in the integrity of the distribution system. The analysis of groundwater samples obtained from the study area revealed E. coli concentrations ranging from 1.60 to 5.10 mg/liter. These results indicate that all twelve boreholes sampled exhibited detectable levels of E. coli.

Concentration of coliform

Total coliforms encompass organisms capable of surviving and thriving in water. Consequently, they are not reliable indicators of fecal pathogens. However, they can serve as indicators of treatment efficacy and assist in assessing the cleanliness and integrity of distribution systems, as well as the potential presence of biofilms (Ashbolt et al., 2001). Nevertheless, there are more suitable indicators for these purposes. Total coliform bacteria can be found in both sewage and natural waters. While some of these bacteria are excreted in the feces of humans and animals, many coliforms are heterotrophic and capable of multiplying in water and soil environments (Ashbolt et al., 2001). Following disinfection, total coliforms should be absent, and their presence signifies inadequate treatment. The presence of total coliforms in distribution systems and stored water supplies can indicate potential regrowth, biofilm formation, or contamination due to the infiltration of foreign materials like soil or plants (Grabow, 1996).
The analysis of groundwater samples obtained from the study area revealed total coliform concentrations ranging from 1.6 to 5.10 mg/liter. These values fall within the permissible limits set by the National Standards for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO).

CONCLUSION

The findings of this groundwater quality assessment in Ute Community, Ikpoba Okha L.G.A., Edo State, present a concerning picture of the current state of borehole water resources relied upon by the local population. Through rigorous physicochemical and bacteriological analysis of twelve borehole samples, this study has identified multiple parameters that exceed established safety thresholds, posing significant risks to public health. The results demonstrate that while some indicators like total dissolved solids and turbidity fall within acceptable limits, critical contaminants reveal systemic challenges in water quality management. The persistent acidity of the groundwater, with pH levels ranging from 5.98 to 6.41 across most samples, creates an environment conducive to metal leaching and pipe corrosion, while simultaneously indicating inadequate natural buffering capacity of the local aquifer system of particular concern are the elevated cadmium concentrations found throughout the study area, ranging from 0.06 to 0.61 mg/L, which dramatically surpass the WHO permissible limit of 0.003 mg/L. This heavy metal contamination represents a severe long-term health hazard, as cadmium bioaccumulates in the human body and can lead to renal dysfunction, bone demineralization, and other chronic conditions even at low exposure levels. The widespread nitrate pollution, with concentrations between 30.55 and 65.85 mg/L in most samples, similarly points to substantial anthropogenic influence, likely stemming from agricultural runoff and inadequate waste disposal practices in the community. These chemical contaminants combine with microbiological threats, as evidenced by the consistent presence of fecal coliforms and E. coli, to create a multifaceted water quality crisis that demands immediate and coordinated intervention. The shallow depth of the aquifer system (2.75-6.0 meters) significantly contributes to its vulnerability, allowing surface pollutants relatively direct access to groundwater reserves. This hydrogeological characteristic, coupled with the community's reliance on on-site sanitation systems and intensive agricultural activities, creates ideal conditions for groundwater contamination. The study's findings align with broader regional patterns of groundwater quality degradation observed in Nigeria's sedimentary basins, but the specific contaminant profile in Ute Community reveals unique local challenges that require tailored solutions. The coexistence of geogenic factors (like natural aquifer acidity) and anthropogenic pressures (including poor waste management and agricultural intensification) creates a complex water quality scenario that standard treatment approaches may not adequately address. Addressing these challenges will require a multipronged strategy that combines immediate technical solutions with long-term institutional and community-based approaches. At the household level, point-of-use treatment technologies such as ceramic filters or solar disinfection systems could provide interim protection, while community-scale solutions might include the construction of centralized treatment facilities equipped to handle heavy metal removal. Regulatory enforcement must be strengthened to control pollution sources, particularly from agricultural activities and waste disposal sites. Simultaneously, community education programs are essential to build awareness about proper sanitation practices and the health risks associated with contaminated water. Looking forward, this study highlights several critical areas for further research. Detailed contaminant source tracking through isotopic analysis could help distinguish between various pollution origins, while hydrogeological modeling would improve understanding of contaminant transport mechanisms in the local aquifer system. Evaluation of nature-based treatment solutions, such as constructed wetlands tailored to local conditions, could offer sustainable alternatives to conventional treatment methods. The findings also underscore the need for expanded monitoring networks to track water quality trends over time and assess the effectiveness of intervention measures. Ultimately, the groundwater quality issues identified in Ute Community reflect broader challenges facing many rural and peri-urban areas in developing regions, where rapid environmental change outpaces the development of water management infrastructure. By addressing both the technical and social dimensions of water contamination, and by integrating local knowledge with scientific expertise, sustainable solutions can be developed to safeguard this vital resource. The data presented here provide a foundation for evidence-based decision making and underscore the urgent need for action to protect public health while preserving groundwater resources for future generations. This study contributes to the growing body of knowledge on groundwater quality in Nigeria and offers specific insights that can inform policy development and community action in similar hydrogeological settings across West Africa.

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REFERENCES

1. Adekunle, A. A. (2009). *Groundwater utilization and challenges in Nigeria*. Nigerian Journal of Hydrological Sciences, 12(3), 45-52.
2. Akaninwor, J. O., Wegwu, M. O., & Nwaichi, E. O. (2007). Levels of some heavy metals and physico-chemical properties of effluents from a beverage company in Rivers State, Nigeria. *Journal of Applied Sciences and Environmental Management, 11*(1), 27-30.
3. Bonten, L. T. C., & Groenenberg, J. E. (2008). *Effects of atmospheric deposition and fertilizer application on heavy metal accumulation in soil and groundwater*. Environmental Pollution Series, 15, 112-125.
4. Federal Environmental Protection Agency (FEPA). (2005). *Guidelines and standards for environmental pollution control in Nigeria*. FEPA Press.
5. Geetha, S., Goutham, R., & Karunakaran, K. (2008). *Advances in groundwater remediation technologies*. Journal of Environmental Technology, 22(4), 567-580.
6. Hem, J. D. (1985). *Study and interpretation of the chemical characteristics of natural water* (3rd ed.). U.S. Geological Survey Water-Supply Paper 2254.
7. Kehinde, M. O., Laniyan, T. A., & Ajayi, K. T. (2009). *Land use impacts on groundwater quality in southwestern Nigeria*. African Journal of Environmental Science, 3(2), 78-89.
8. Li, X., Zhang, Y., & Liu, J. (2007). *Global water demand and supply challenges in the 21st century*. International Journal of Water Resources Development, 23(2), 201-215.
9. Merck. (1982). *Aqua Merck water analysis manual* (5th ed.). Merck Publications.
10. Nigerian Standard for Drinking Water Quality (NSDWQ). (2007). *Standards Organization of Nigeria*. SON Press.
11. Oguzie, F. A., & Okhagbuzo, G. A. (2010). *Industrial pollution and heavy metal contamination in Nigerian water resources*. Journal of Applied Chemistry, 8(1), 34-42.
12. Oladunjoye, M. A., Olayinka, A. I., & Amidu, S. A. (2011). *Hydrogeochemical processes in shallow aquifers of southwestern Nigeria*. Environmental Geology, 60(1), 123-135.
13. Olaye, D. O. (2004). *Geochemical characterization of groundwater systems in sedimentary basins*. Nigerian Journal of Earth Sciences, 7(2), 45-53.

14. Palamuleni, L. G. (2002). *Access to clean water as a fundamental human right*. International Journal of Water Resources, 18(3), 345-356.
15. Pritchard, M., Mkandawire, T., & O'Neill, J. G. (2008). *Assessment of groundwater quality in shallow wells in developing countries*. Physics and Chemistry of the Earth, 33(8-13), 812-823.
16. Versari, A., Parpinello, G. P., & Galassi, S. (2002). *Water quality assessment for human consumption*. Journal of Environmental Monitoring, 4(1), 1-5.
17. World Health Organization (WHO). (2004a). *Guidelines for drinking-water quality* (3rd ed., Vol. 1). WHO Press.
18. World Health Organization (WHO). (2021). *Guidelines for drinking-water quality* (4th ed.). WHO Press.