

Investigation of the water Quality of Selected Boreholes in Ekpoma

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ABSTRACT: Groundwater serves as the primary source of drinking water for many residents of Ekpoma, Edo State, Nigeria. This study assessed the quality of water from selected boreholes by comparing physicochemical parameters with the standards of the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). Water samples were collected and analyzed for pH, temperature, turbidity, electrical conductivity, total dissolved solids (TDS), and total hardness. Descriptive statistics, graphical analysis, and Pearson correlation analysis were used to evaluate the results. Findings revealed variations in water quality among the sampled boreholes. Most parameters were within the permissible limits of WHO and NSDWQ standards; however,

elevated turbidity was observed in Borehole C, indicating possible contamination. Correlation analysis showed significant relationships among some parameters, suggesting common sources of influence on groundwater quality. The study recommends regular monitoring, improved borehole protection, and appropriate water treatment measures to ensure safe and sustainable groundwater use in Ekpoma.

Keywords: *Borehole water quality, groundwater, physicochemical parameters, WHO standards, NSDWQ, Ekpoma.*

1. INTRODUCTION

Access to safe and clean water is fundamental to human health, economic development, and environmental sustainability. Groundwater obtained from boreholes constitutes a major source of potable water in many developing countries, including Nigeria, because it is generally considered less susceptible to contamination than surface water sources (WHO, 2017). However, groundwater quality can be significantly influenced by geological formations, agricultural activities, industrial discharges, urbanization, and improper waste disposal practices, which may introduce physical, chemical, and microbiological contaminants into aquifer systems (Akinbile & Omoniyi, 2018).

Ekpoma, the administrative headquarters of Esan West Local Government Area in Edo State, Nigeria, has experienced rapid population growth due to urban expansion and the presence of Ambrose Alli University. The increasing demand for potable water, coupled with the inadequacy of public water supply systems, has resulted in heavy reliance on boreholes, water vendors, and reservoir storage systems. Despite the widespread use of groundwater resources, concerns regarding borehole water quality have increased because of potential contamination from anthropogenic and natural sources.

The hydrogeological conditions of Ekpoma present additional challenges for groundwater development. Studies have shown that groundwater aquifers in the area occur at considerable depths ranging from approximately 144 m to 529 m due to the underlying geological formations and the presence of solid mineral deposits, making borehole construction difficult and expensive (Otoijaghale et al., 2023). Furthermore, increasing urbanization, inadequate waste management practices, and agricultural activities may contribute to groundwater quality deterioration.

Previous studies conducted in various parts of Nigeria have reported elevated concentrations of nitrates, heavy metals, and microbial contaminants in groundwater sources, posing significant risks to public health (Olalekan et al., 2020). However, limited information exists regarding the current quality status of borehole water in Ekpoma. Consequently, a systematic assessment of borehole water quality is necessary to determine its suitability for drinking and domestic purposes.

This study therefore evaluates the physicochemical characteristics of selected borehole water sources in Ekpoma and compares the results with the standards established by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). The study further seeks to identify possible contamination sources and provide recommendations for improving groundwater quality management in the area. The findings contribute to existing knowledge on groundwater quality in Nigeria and support efforts toward achieving Sustainable Development Goal 6, which aims to ensure the availability and sustainable management of water and sanitation for all (United Nations, 2015).

2.0 Literature Review

2.1 Groundwater and Borehole Water Quality

Groundwater is one of the most important sources of freshwater globally and serves as a major source of potable water in many developing countries. In Nigeria, borehole water is widely utilized for domestic, agricultural, and industrial purposes due to inadequate public water supply systems. Groundwater quality is determined by its physical, chemical, and biological characteristics and is influenced by natural geological processes as well as human activities (WHO, 2022).

Studies conducted across Nigeria have shown considerable variation in groundwater quality parameters, including pH, turbidity, electrical conductivity, total dissolved solids (TDS), hardness, and nitrate concentration (Agbontaen & Agada, 2018). Although groundwater is generally considered safer than surface water, contamination from anthropogenic activities such as waste disposal, agricultural runoff, and industrial effluents has become a growing concern. Consequently, periodic assessment of borehole water quality is essential to ensure compliance with drinking water standards and protect public health.

2.2 Hydrogeological Characteristics of Ekpoma

The quality and availability of groundwater are strongly influenced by the geological and hydrogeological characteristics of the area. Ekpoma is located within the sedimentary basin of southern Nigeria and is predominantly underlain by the Bende-Ameki Formation, consisting mainly of sandstone, siltstone, and clay deposits (Salufu & Ujuanbi, 2015). Other formations found within the area include the Imo Shale and Ogwashi-Asaba Formations.

According to Aizebeokhai and Oyeyemi (2021), groundwater in Ekpoma occurs within confined and semi-confined aquifers at varying depths. Aquifers within the Imo Shale Formation are generally encountered at shallower depths and often provide moderate-quality groundwater, while deeper aquifers within the Bende-Ameki Formation tend to exhibit higher mineral concentrations due to prolonged water-rock interaction. The hydrogeological conditions therefore play a critical role in determining groundwater quality, accessibility, and vulnerability to contamination.

2.3 Factors Affecting Borehole Water Quality

Several factors influence groundwater quality in boreholes. These factors can be broadly classified into geological, hydrological, anthropogenic, and seasonal influences.

The mineral composition of aquifer materials significantly affects groundwater chemistry. Dissolution of minerals from surrounding rocks contributes to concentrations of calcium, magnesium, iron, manganese, and other dissolved constituents. Elevated levels of iron and manganese have been reported in groundwater obtained from the Bende-Ameki Formation (Salufu & Ujuanbi, 2015).

The depth of groundwater occurrence influences its quality. Shallow aquifers are more susceptible to contamination from surface activities, while deeper aquifers generally offer greater protection from microbial pollution. However, deeper groundwater may contain higher concentrations of dissolved minerals due to longer residence times within geological formations (Aigbedion et al., 2019).

Anthropogenic activities are major contributors to groundwater contamination. Agricultural practices involving fertilizers and pesticides may introduce nitrates and other

chemicals into aquifers. Similarly, poor waste disposal practices, septic tank leakage, and industrial discharges can result in chemical and microbial contamination of groundwater resources (Aizebeokhai & Oyeyemi, 2021).

Seasonal changes also influence groundwater quality. During the rainy season, increased infiltration and surface runoff facilitate the transport of pollutants into aquifers. Aremu et al. (2019) reported higher contamination levels during wet seasons due to increased leaching of contaminants from surrounding land surfaces.

2.4 Groundwater Contamination and Public Health Concerns

Groundwater contamination remains a major environmental and public health challenge worldwide. In Nigeria, contamination arises from both natural and anthropogenic sources, including geogenic contaminants, agricultural runoff, industrial activities, and improper waste management practices.

Agricultural runoff contributes significantly to groundwater pollution through the introduction of nitrates, phosphates, and pesticide residues. High nitrate concentrations in drinking water have been linked to adverse health effects such as methemoglobinemia in infants (WHO, 2022). Industrial discharges may introduce toxic heavy metals such as lead, cadmium, chromium, and mercury into groundwater systems. Long-term exposure to these contaminants can result in neurological disorders, kidney damage, cardiovascular diseases, and other chronic health conditions (Uzoekwe et al., 2021).

Microbial contamination is another major concern. The presence of coliform bacteria and *Escherichia coli* in groundwater indicates fecal contamination and the potential presence of disease-causing microorganisms. Consumption of microbiologically contaminated water can lead to diseases such as cholera, typhoid fever, dysentery, hepatitis, and gastroenteritis (Ogbeibu et al., 2020).

2.5 Water Quality Assessment Techniques

Water quality assessment involves the evaluation of physical, chemical, and biological parameters to determine the suitability of water for specific uses. Physicochemical analysis commonly includes measurement of pH, temperature, turbidity, electrical conductivity, total dissolved solids, hardness, and concentrations of major ions and trace metals.

Microbiological analysis is conducted to detect the presence of pathogenic microorganisms and indicator organisms such as total coliforms and *E. coli*. These analyses provide valuable information regarding the sanitary condition of water sources and associated health risks (UNICEF & WHO, 2017).

In recent years, statistical tools such as descriptive statistics, correlation analysis, and Water Quality Index (WQI) models have been widely applied to groundwater studies. These techniques simplify data interpretation, identify relationships among parameters, and facilitate comparison with regulatory standards (Tyagi et al., 2013).

2.6 Borehole Water Quality in Nigeria and Ekpoma

Several studies conducted across Nigeria have highlighted the growing challenges associated with groundwater contamination. Elevated levels of nitrates, heavy metals, and microbial contaminants have been reported in many urban and semi-urban communities due to increasing population growth, urbanization, and inadequate environmental management practices (Adekola & Eleta, 2007; Benson et al., 2008).

In Ekpoma, groundwater serves as the primary source of potable water because of the limited availability of municipal water supply. Research has identified concerns relating to microbial contamination, heavy metal occurrence, and seasonal variations in water quality. Ogbeibu et al. (2020) reported the presence of coliform bacteria in some borehole water samples, indicating potential fecal contamination. Similarly, studies have observed elevated turbidity and dissolved mineral concentrations in selected groundwater sources within the area.

The growing population of Ekpoma, coupled with rapid urbanization and inadequate waste management infrastructure, has increased pressure on groundwater resources. Consequently, regular monitoring and evaluation of borehole water quality are necessary to ensure compliance with WHO and NSDWQ standards and to safeguard public health.

Although previous studies have provided useful information on groundwater quality in Ekpoma, important knowledge gaps remain. Most existing studies are limited to short-term assessments and do not adequately capture seasonal variations in water quality. There is

also limited information on the effects of emerging contaminants such as pharmaceutical residues and endocrine-disrupting compounds.

Furthermore, few studies have integrated water quality data with comprehensive health risk assessments or examined the direct impacts of groundwater contamination on local communities. Addressing these gaps will improve understanding of groundwater quality dynamics and support the development of effective groundwater management policies.

The reviewed literature indicates that groundwater quality is influenced by geological formations, aquifer characteristics, human activities, and seasonal conditions. Studies conducted in Nigeria and Ekpoma have identified microbial contamination, heavy metal pollution, and elevated nutrient concentrations as major concerns affecting groundwater safety. While previous research has provided valuable insights into groundwater quality issues, further investigations are needed to address existing knowledge gaps and provide updated information for sustainable groundwater management. Therefore, assessing the quality of selected borehole water sources in Ekpoma remains essential for protecting public health and ensuring compliance with WHO and NSDWQ drinking water standards.

3. MATERIALS AND METHODS

3.1 Study Area

This study was conducted in Ekpoma, Edo State, Nigeria, located at approximately 6.75°N latitude and 6.13°E longitude. The town experiences a tropical climate characterized by distinct wet and dry seasons. Groundwater obtained from boreholes serves as a major source of potable water for residents due to the inadequacy of public water supply systems. Three boreholes located in different parts of the town were selected to provide representative information on groundwater quality across the study area.

3.2 Borehole Selection and Sample Collection

Three boreholes were selected based on their geographical distribution, age, and drilling method. The selected boreholes included both recently constructed and older installations as well as manually and mechanically drilled boreholes. This selection was intended to capture possible variations in groundwater quality resulting from location and borehole characteristics.

Water samples were collected in accordance with World Health Organization (WHO) guidelines for drinking water sampling. Sterile 1-L polyethylene bottles were used for sample collection. Prior to sampling, each bottle was rinsed with water from the respective borehole. Boreholes were allowed to run continuously for approximately 2–3 minutes before sample collection to eliminate the influence of stagnant water within the distribution system. Samples intended for laboratory analysis were appropriately labeled and transported under controlled conditions.

3.3 Laboratory Analysis

The collected water samples were analyzed for selected physicochemical parameters commonly used in evaluating drinking water quality. Temperature was measured in situ using a digital thermometer, while pH was determined using a calibrated pH meter. Turbidity was measured using a nephelometric turbidity meter and reported in Nephelometric Turbidity Units (NTU). Electrical conductivity (EC) and total dissolved solids (TDS) were determined using standard conductivity and TDS meters, respectively.

The analytical procedures adopted in this study followed standard methods for water quality assessment and were compared with the permissible limits specified by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ).

3.4 Data Analysis

Data obtained from laboratory analyses were subjected to descriptive statistical analysis using mean, standard deviation, and range to summarize variations among the sampled boreholes. The measured values were compared with WHO and NSDWQ drinking water standards to evaluate water suitability for domestic consumption. Graphical techniques, including tables, bar charts, and trend plots, were employed to present the results. In addition, Pearson correlation analysis was used to examine relationships among the measured water quality parameters and identify possible sources of contamination.

3.5 Ethical Considerations

Permission was obtained from borehole owners prior to sample collection. To ensure confidentiality, the identities and exact locations of the sampled boreholes were anonymized and represented using coded identifiers throughout the study.

4. RESULTS AND DISCUSSION

4.1 Physicochemical Characteristics of Borehole Water

The physicochemical characteristics of the borehole water samples are presented in Tables 1 and 2. The analyzed parameters included pH, temperature, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total hardness, chloride, sodium, nitrate, and sulphate. The results were compared with the permissible limits specified by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ).

4.2 PHYSICAL PARAMETERS OF BOREHOLE WATER

The physical parameters analyzed include pH, temperature, turbidity, total dissolved solids (TDS), and electrical conductivity (EC). The results are presented in Table 4.1.

Table 4.1: Physical Characteristics of Borehole Water Samples

Parameters	Units	BH A	BH B	BH C	NSDWQ LIMITS	WHO LIMITS
Matrix		water	Water	water		
Physiochemical Parameters						
pH		5.6	5.3	7.8	6.5-8.5	6.5-8.5
Turbidity	NTU	15.64	0.29	1.16	5	≤5
Electrical conductivity	μs/cm	30	30	104	1000	≤1500
TDS	mg/l	15	15	52	500	≤1000
Temperature	°C	32.6	32.2	33.7	Ambient	Ambient

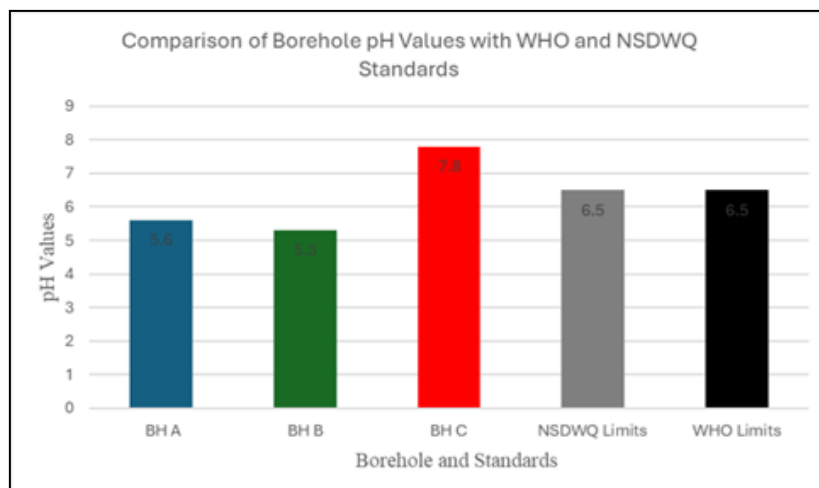


Figure 4.1 Borehole pH values with WHO and NSDWQ standards.

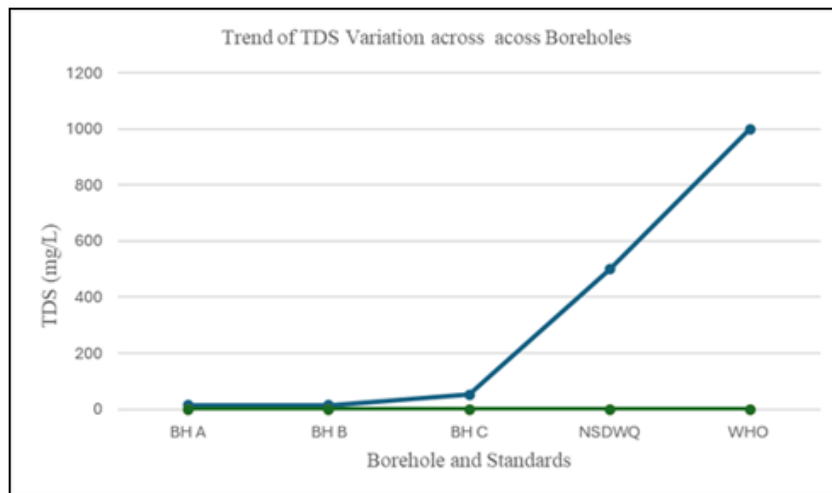


Figure 4.2 presents a trend graph of TDS variations.

Table 4.2 Mean concentrations of physical parameters in water samples

Parameters	BH A	BH B	BH C	Mean
pH	5.6	5.3	7.8	6.23
Turbidity	15.64	0.29	1.16	5.70
Electrical Conductivity	30	30	104	54.67
TDS	15	15	52	27.33
Temperature	32.6	32.2	33.7	32.83

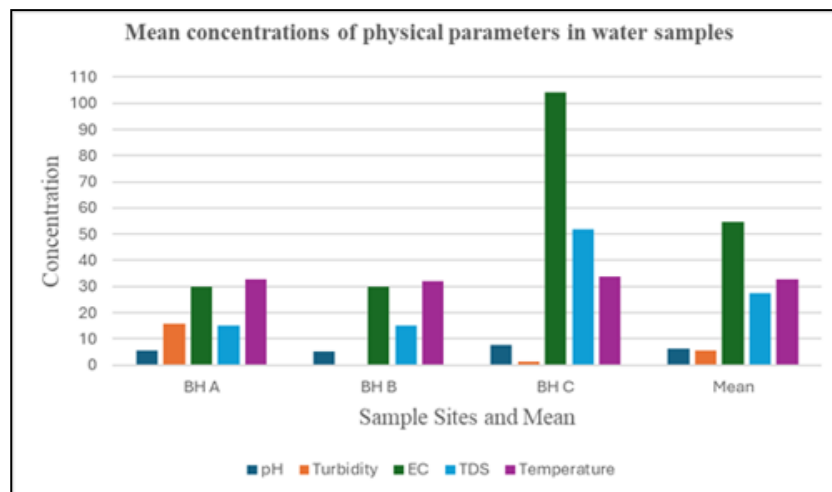


Figure 4.3 Mean Concentration of Physical Parameters in Water Samples

4.2.1 Analysis and Discussion of physical parameters Results

4.2.1.1 TEMPERATURE: The ambient temperatures of water the water samples range from 32.6°C to 33.7°C with mean value of 32.83°C (Table 4.2 and Figure 4.3). Water for drinking purposes has a better fresh taste at lower temperature of about 15°C, but higher temperatures do not imply impurities Onwuka and Ezeigbo (2004).

4.2.1.2 PH: pH is a measure of acidity or alkalinity of an environment or substance. The pH of water varies naturally within water bodies as a result of the geology and nature of the soil. pH values ranged from 5.6 to 7.8. The pH of BH A was below the WHO and NSDWQ permissible limit of (6.5–8.5), indicating acidity that could cause corrosion of pipes and leaching of heavy metals. The low pH may be due to soil formation and composition or the formation of tannic acids by decaying plants. High acidity may lead to acidosis and promote disease conditions.

4.2.1.3 TOTAL DISSOLVED SOLIDS: The total dissolved solids (TDS) recommended by the WHO and NSDWQ for freshwater is between (0 – 1000) mg/L. TDS are below the permissible limits of NSDWQ and WHO, suggesting moderate mineralization. The water samples have TDS values ranging from 15.0 mg/L to 52.0 mg/L with a mean of 27.33 mg/L (Table 4.2 and Figure 4.3).

4.2.1.4 CONDUCTIVITY: Conductivity in water is due to dissolved solutes. The conductivity values range from 30 $\mu\text{S}/\text{cm}$ to 104 $\mu\text{S}/\text{cm}$ with a mean value of 54.67 $\mu\text{S}/\text{cm}$ (Table 4.2 and Figure 4.3). These values are below the permissible limit of NSDWQ and WHO which indicate acceptable EC conditions for the selected boreholes.

4.2.1.5 TURBIDITY: Turbidity is the degree of cloudiness in water caused by both dissolved and suspended solids. The turbidity values range from 0.29 NTU to 15.64 NTU with mean value of 5.70 NTU (Table 4.2 and Figure 4.3). Turbidity exceeded the WHO and NSDWQ limits (≤ 5 and 5) in borehole BH A (15.64 NTU), indicating suspended solids or microbial contamination, but was within the acceptable limits of WHO and NSDWQ standards for borehole BH B and BH C (0.29NTU and 1.16NTU).

Table 4.3 Chemical Parameters of Borehole Water

Parameters	Units	BH A	BH B	BH C	NSDWQ LIMITS	WHO LIMITS
Matrix		water	water	water		
Physiochemical Parameters						
T. Hardness	mg/l	9.61	8.01	27.22	150	100
Chloride	mg/l	7.09	10.64	14.18	100	250
Sodium	mg/l	1.35	1.38	3.58	100	
Nitrate	mg/l	9.25	6.33	22.40	10	50
Sulphate	mg/l	4.79	0.30	0.27	100	200

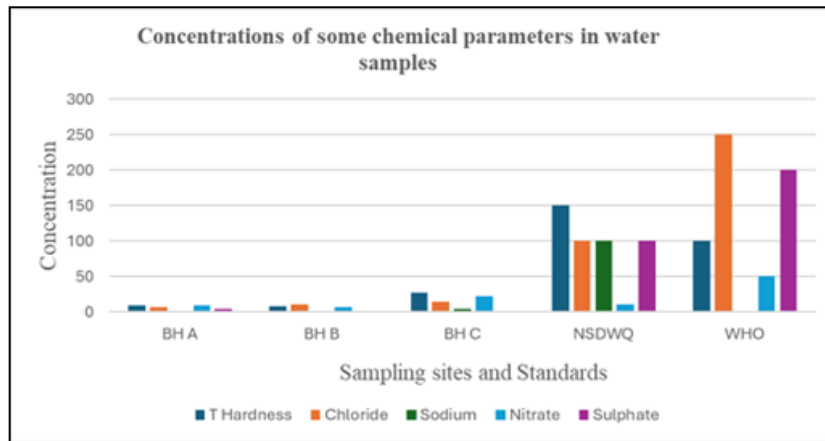


Figure 4.4 Concentration of some chemical parameters in waters Samples

Table 4.4: Mean concentrations of chemical parameters of water samples

Parameters	Units	BH A	BH B	BH C	Mean
Matrix		Water	water	water	Water
Physiochemical Parameters					
T. Hardness	mg/l	9.61	8.01	27.22	14.95
Chloride	mg/l	7.09	10.64	14.18	10.64
Sodium	mg/l	1.35	1.38	3.58	2.10
Nitrate	mg/l	9.25	6.33	22.40	12.66
Sulphate	mg/l	4.79	0.30	0.27	1.79

4.3.1 ANALYSIS AND DISCUSSION OF CHEMICAL AND MICROBIAL RESULTS: Chemical analysis included hardness, alkalinity, chloride, nitrate, sulphate, fluoride, and heavy metals. The chemical parameters are presented in Table 4.3.

4.3.1.1 TOTAL HARDNESS

The value of total hardness range from 9.61 mg/L to 27.22 mg/L with a mean value of 14.95 mg/L (Table 4.4 and Figure 4.5). All the underground water had hardness values below the WHO and NSDWQ permissible limits of 100 mg/L and 150 mg/L respectively, but hardness concentration are of considerable values across the boreholes. This implies that these areas have soft water. Though hardness is beneficial in drinking water despite the problem it creates for the piping system and laundry activities. People who live in the hard water area suffer less from heart diseases than those who live in soft water areas (Onwuka, Uma & Ezeigbo, 2004)

4.3.1.2 SULPHATE (SO₄²⁻): Sulfates may be leached from the soil into water bodies.

The sulfate concentrations range from 0.27mg/L to 4.79 mg/L with a mean concentration of 1.79 mg/L (Table 4.4 and Figure 4.5). These values are below NSDWQ and WHO maximum permissible limit of 100 mg/L and 200 mg/L.

4.3.1.3 NITRATE (NO₃²⁻): Nitrates in water are from fertilizers, agricultural run-off and gunpowder . The concentrations of nitrate range from 9.25 mg/L to 22.40 mg/L with mean concentration of 12.66 mg/L (Table 4.4 and Figure 4.5). The values were below the WHO recommended value of 50 mg/L but the NSDWQ 10 mg/L value. This does not conform to the NSDWQ standard. High nitrate doses cause cyanosis and asphyxia (blue baby syndrome) in infants NSDWQ (2007)

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study assessed the quality of borehole water from selected locations in Ekpoma, Esan West Local Government Area, Edo State, Nigeria, and compared the results with the standards established by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). The findings revealed that most of the physicochemical parameters, including total dissolved solids (TDS), electrical conductivity, hardness, chloride, sulphate, sodium, and most heavy metals, were within the permissible limits for drinking water.

However, variations were observed among the sampled boreholes. Boreholes A and B exhibited acidic pH values below the recommended range, while Borehole A recorded turbidity above the permissible limit. Elevated nitrate concentration was observed in Borehole C relative to the NSDWQ guideline value. Microbiological analysis further indicated the presence of total coliforms and fecal coliforms in Borehole C, suggesting possible contamination resulting from poor sanitary conditions, shallow groundwater influence, or inadequate borehole construction. Heavy metals such as arsenic, nickel, and chromium were not detected in any of the samples, while manganese exceeded the WHO guideline value only in Borehole A.

Overall, the study indicates that groundwater in Ekpoma is generally suitable for domestic use; however, localized contamination issues require attention to ensure the continued

safety of drinking water supplies. Regular monitoring and effective groundwater protection measures are therefore essential for safeguarding public health and promoting sustainable water resource management.

5.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Routine physicochemical and microbiological monitoring of borehole water should be conducted to ensure compliance with WHO and NSDWQ standards.
2. Boreholes should be properly designed, constructed, and maintained to minimize contamination from surface runoff, septic systems, and other pollution sources.
3. Appropriate water treatment methods such as chlorination, filtration, or ultraviolet (UV) disinfection should be adopted where microbial contamination is detected.
4. Public awareness programs should be implemented to educate residents on safe water handling, sanitation practices, and groundwater protection.
5. Regulatory agencies and local authorities should strengthen enforcement of drinking water quality standards and establish periodic inspection programs for private boreholes.
6. Further studies should investigate seasonal variations in groundwater quality and the influence of land-use activities on groundwater contamination in Ekpoma.

Implementation of these measures will contribute to improved groundwater quality, reduced public health risks, and sustainable management of water resources in the study area.

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