



ASSESSMENT OF GROUNDWATER QUALITY OF OKO AND AMAOKPALA ENVIRONMENT, SOUTHEASTERN NIGERIA

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ABSTRACT

Groundwater serves as a major source of domestic water supply in many communities in southeastern Nigeria, including Oko and Amaokpala. However, increasing urbanization, poor waste disposal, agricultural practices, and geogenic processes have raised concerns regarding groundwater contamination. This study assessed groundwater quality in selected boreholes using heavy metal parameters. Four borehole samples (BH1–BH4) were analyzed for iron (Fe), cadmium (Cd), zinc (Zn), lead (Pb), copper (Cu), manganese (Mn), sodium (Na), and potassium (K), and compared against USEPA and NSDWQ standards. Results showed mean concentrations of Fe (0.2416 mg/L), Cd (0.0065 mg/L), Zn (0.4851 mg/L), Pb (0.0089 mg/L), Cu (2.0239 mg/L), Mn (0.0152 mg/L), Na (11.1258 mg/L), and K (7.1311 mg/L). Iron and cadmium exceeded NSDWQ limits in some locations, while copper exceeded recommended values in all sampled boreholes. Borehole 1 recorded the highest total concentration (40.8905 mg/L), suggesting localized contamination. The study concludes that although groundwater remains suitable for some domestic purposes, elevated concentrations of Fe, Cd, and Cu pose long-term health risks. Continuous monitoring and treatment are recommended.

Keywords: Groundwater Quality; Oko; Amaokpala; Environment.

Introduction

Groundwater constitutes one of the most dependable and widely utilized freshwater resources in Nigeria, particularly in rural, semi-urban, and rapidly urbanizing settlements where centralized pipe-borne water supply is either inadequate or completely absent (Federal Ministry of Water Resources, 2011; WHO/UNICEF Joint Monitoring Programme, 2021). In many parts of the country, groundwater accessed through hand-dug wells and boreholes serves as the primary source of domestic water for drinking, cooking, sanitation, and small-scale economic activities. Its relative reliability during dry seasons, when surface water bodies such as streams and rivers often reduce drastically in volume or dry up completely, further enhances its importance (World Health Organization [WHO], 2017). However, despite its availability and accessibility, groundwater quality is not always guaranteed because it is continuously influenced by natural geological processes and human-induced environmental activities (APHA, 2017).

In southeastern Nigeria, dependence on groundwater is particularly high due to climatic and hydrological conditions that favour seasonal variability in surface water availability. The region experiences intense rainfall, which promotes aquifer recharge but also increases the risk of contaminant infiltration from the surface into groundwater systems (Nwankwoala, 2011). As a result, many communities, including Oko and Amaokpara, have increasingly relied on boreholes



as a more dependable water source. This shift is driven by population growth, limited public water infrastructure, and the declining quality of surface water bodies due to pollution and sedimentation (OECD, 2012).

The Oko and Amaokpara environments are situated within the Anambra Basin, a significant sedimentary basin in southeastern Nigeria known for its complex hydrogeological characteristics. The basin is composed mainly of Nanka Sands and Imo Shale formations, which strongly influence groundwater occurrence and chemistry (Anakwuba, Onwuemesi, & Chinwuko, 2015). The Nanka Sands are highly porous and permeable, making them excellent aquifer units for groundwater storage and extraction. However, their high permeability also makes them highly vulnerable to contamination, as pollutants can easily migrate from the surface into groundwater systems. In contrast, the Imo Shale formation is relatively impermeable and acts as a confining layer in some locations, thereby influencing groundwater flow patterns and chemical interactions within the aquifer system.

Previous hydrogeological investigations in Anambra State have shown that aquifers in the region are highly susceptible to contamination due to limited protective geological layers and increasing anthropogenic pressures (Edet & Okereke, 2001). Unregulated urban expansion, improper waste disposal, and intensified agricultural activities have contributed significantly to groundwater quality deterioration in many communities. The absence of effective land-use planning and weak enforcement of environmental regulations further exacerbate the problem, allowing contaminants to infiltrate subsurface water systems without restriction (Nkwocha & Pat-Mbano, 2010).

One of the most critical concerns in groundwater quality studies is heavy metal contamination. Heavy metals are of environmental and public health concern due to their toxicity, persistence, and ability to bioaccumulate in living organisms (WHO, 2017). Unlike organic pollutants, heavy metals do not degrade over time and can remain in aquifer systems for long periods, continuously posing risks to human health. Common heavy metals of concern include lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and iron (Fe), among others (US EPA, 2018).

In the Oko and Amaokpara environments, several anthropogenic activities contribute to heavy metal contamination of groundwater. Poorly managed solid waste dumpsites can release leachates containing toxic substances into the soil, especially during rainfall events, which subsequently infiltrate into aquifers. Agricultural activities involving the use of fertilizers, herbicides, and pesticides also contribute to contamination through runoff and percolation processes (OECD, 2012). In addition, corrosion of metal pipes used in borehole systems can introduce metals such as iron, lead, and zinc into groundwater supplies. Small-scale industrial activities and vehicular emissions further contribute indirectly through atmospheric deposition and surface runoff (Nkwocha & Pat-Mbano, 2010).

The health effects of consuming heavy metal-contaminated water are well documented and pose serious public health concerns. Lead exposure has been associated with neurological disorders, reduced intelligence quotient (IQ) in children, kidney damage, and cardiovascular diseases.



Cadmium exposure can result in renal dysfunction, skeletal damage, and reproductive health issues, while arsenic contamination has been linked to skin lesions, cancer, and cardiovascular complications (WHO, 2017; US EPA, 2018). These risks highlight the importance of continuous monitoring and assessment of groundwater quality in affected communities.

The need to evaluate groundwater quality in Oko and Amaokpara is therefore both urgent and essential. These communities have experienced significant population growth due to the presence of educational institutions, expanding residential areas, and increasing commercial activities. This growth has placed considerable pressure on groundwater resources, resulting in increased borehole drilling and abstraction rates. Unfortunately, this development is not always accompanied by adequate environmental management or water quality monitoring systems (Federal Ministry of Water Resources, 2011).

Furthermore, there is a widespread misconception among residents that groundwater is naturally pure and safe for consumption once it appears clear and odourless. This perception often leads to minimal or no treatment of borehole water before use, increasing the risk of exposure to invisible chemical contaminants such as heavy metals. Unlike microbial contamination, chemical pollutants accumulate gradually in the human body, leading to chronic health effects that may not be immediately noticeable (WHO, 2017).

Hydrogeological variability within the study area also plays a significant role in groundwater quality differences. Even within short distances, variations in soil composition, depth to water table, and aquifer connectivity can influence the chemical characteristics of groundwater. As a result, boreholes located within the same community may exhibit different levels of contamination depending on local geological and anthropogenic conditions (Anakwuba et al., 2015). This necessitates systematic and spatially distributed sampling to obtain reliable water quality data.

Seasonal and climatic variations further affect groundwater chemistry. During the rainy season, increased infiltration may dilute certain dissolved ions but also enhance leaching of contaminants into aquifers. Conversely, during dry seasons, reduced recharge can lead to higher concentrations of dissolved substances due to evaporation and limited dilution (Nwankwoala, 2011). These seasonal dynamics reinforce the need for comprehensive groundwater quality assessment across different periods.

Statement of the Problem

Despite the heavy reliance on groundwater in Oko and Amaokpara, there is limited comprehensive data on its physicochemical quality and heavy metal concentrations. Most residents depend on boreholes without regular water quality testing, assuming that groundwater is inherently safe for consumption. However, increasing anthropogenic activities, coupled with the vulnerability of the Nanka Sands aquifer system, raise concerns about possible contamination (Edet & Okereke, 2001).



The potential presence of heavy metals in groundwater poses significant public health risks, particularly in densely populated communities where exposure is continuous and long-term. Given the increasing urbanization and agricultural activities in the area, there is a critical need to evaluate the current status of groundwater quality to ensure safety and sustainability. The need to evaluate groundwater in Oko and Amaokpara is important because both communities have witnessed population growth due to educational institutions and expanding residential settlements, increasing stress on groundwater resources.

Aim of the Study

To assess the groundwater quality of Oko and Amaokpala environment using heavy metal concentration in selected boreholes and compare results with international and national drinking water standards.

Specific Objectives

1. To determine the concentrations of selected heavy metals in borehole water.
2. To compare obtained values with USEPA and NSDWQ standards.
3. To identify boreholes with possible contamination.
4. To assess health implications of elevated metal concentrations.
5. To recommend groundwater management strategies.

Statement of the problem

Despite the widespread dependence on borehole water in Oko and Amaokpara, regular quality assessment is limited. Potential contamination from refuse dumps, septic tanks agricultural runoff. And geological sources may compromise groundwater safety. There is a need to determine whether the water meets acceptable drinking standard.

Literature Review

Groundwater contamination by heavy metals has become a major environmental issue worldwide. According to World Health Organization, safe drinking water should not contain toxic metals beyond threshold values due to chronic health effects. In southeastern Nigeria, hydrochemical studies indicate elevated iron and trace metals due to weathering of ferruginous sandstones and anthropogenic influence. Nfor et al. observed that Anambra aquifers show variable geochemical signatures linked to lithology.

Anyanwu (2021) reported that Awka and environs possess vulnerable aquifers due to shallow boreholes and inadequate sanitary protection. Similarly, Nwankwoala and Ememu found that groundwater in nearby Anambra communities frequently exceeds acceptable limits for Fe and some heavy metals, suggesting both natural and human contributions.



Results and Discussion

Table 1: heavy metal analysis of Oko and Amaokpara in mg/l

	Fe	Cd	Zn	Pb	Cu	Mn	Na	K
BH 1	0.3991	0.0204	0.5181	0.0146	2.7938	0.0253	21.6820	15.4372
BH 2	0.2745	0.0001	0.1621	0.0001	1.9199	0.0162	11.600	5.4083
BH 3	0.1308	0.0053	0.3763	0.0117	2.2362	0.0084	7.3200	3.9589
BH 4	0.1621	0.0001	0.4306	0.0092	1.1458	1.0110	3.9012	3.7200
MEAN	0.2416	0.0065	0.4851	0.0089	2.0239	0.0152	11.1258	7.1311
USEPA	0.30	0.005	5.00	0.10	1.30	0.05	20	ND
NSDWQ	0.30	0.003	3.0	0.10	1.0	0.2	ND	ND

The groundwater samples collected from four boreholes (BH1, BH2, BH3, and BH4) in Oko and Amaokpara were analyzed for selected heavy metals and major dissolved elements. The concentrations obtained were compared with the permissible limits prescribed by the Standards Organisation of Nigeria (NSDWQ, 2008) and the United States Environmental Protection Agency (USEPA). The analyzed parameters include iron (Fe), cadmium (Cd), zinc (Zn), lead (Pb), copper (Cu), manganese (Mn), sodium (Na), and potassium (K).

Groundwater Chemistry

The analytical results reveal variations in heavy metal concentrations among the sampled boreholes, indicating differences in groundwater chemistry that may be attributed to lithology, recharge characteristics, borehole depth, waste disposal practices, and human activities around the sampling points. The total dissolved elemental load showed the following pattern:

BH1 = 40.8905 mg/L, BH2 = 19.5875 mg/L, BH3 = 7.4596 mg/L, BH4 = 9.3799 mg/L

This distribution suggests that BH1 contains the highest elemental concentration, followed by BH2, while BH3 and BH4 recorded relatively lower concentrations. The high concentration observed in BH1 indicates possible contamination or stronger geochemical interaction between groundwater and host rock.

The mean concentrations recorded were: Fe = 0.2416 mg/L, Cd = 0.0065 mg/L, Zn = 0.4851 mg/L, Pb = 0.0089 mg/L, Cu = 2.0239 mg/L, Mn = 0.0152 mg/L, Na = 11.1258 mg/L, K = 7.1311 mg/L

These values indicate that most parameters are within acceptable limits except cadmium and copper, which exceed standard limits and therefore constitute potential health concerns.

Iron (Fe) Concentration and Distribution $y = 0.2416$

Iron concentration ranged from 0.1308 mg/L in BH3 to 0.3991 mg/L in BH1, with a mean value of 0.2416 mg/L. Although the mean concentration falls below the NSDWQ and USEPA maximum permissible limit of 0.30 mg/L, BH1 exceeded this standard. Iron occurrence in groundwater in southeastern Nigeria is largely associated with the dissolution of ferruginous sandstone and weathering of iron-rich minerals present in the Nanka Sand Formation. Oko and Amaokpara are located within the Anambra Basin where ferruginous sedimentary units are common.



The elevated concentration in BH1 may indicate: i) prolonged water-rock interaction. ii) poor casing protection. iii) infiltration from iron-rich soils. iv) oxidation-reduction reactions in the aquifer, etc. Excess iron in groundwater is not usually considered highly toxic but affects aesthetic quality. It causes reddish coloration, metallic taste, pipe blockage, and staining of laundry and plumbing fixtures. High iron may also encourage growth of iron bacteria, reducing water quality. The comparatively low values in BH3 and BH4 suggest better aquifer confinement or reduced interaction with iron-bearing minerals.

Cadmium (Cd) Concentration

Cadmium concentrations ranged from 0.0001 mg/L to 0.0204 mg/L. The mean concentration was 0.0065 mg/L. This exceeds the USEPA = 0.005 mg/L and NSDWQ limit = 0.003 mg/L. Cadmium is among the most toxic heavy metals found in drinking water. It has no known biological function in humans and accumulates in body tissues over time. The exceptionally high concentration in BH1 (0.0204 mg/L) indicates serious contamination. This value is approximately 4 times USEPA standard and 7 times NSDWQ standard. The Possible sources of these pollutants are from: i) leachate from municipal waste. ii) battery disposal. iii) paint residues. iv) agricultural fertilizer. v) corrosion of metallic installations.

The contamination suggests anthropogenic influence because cadmium is usually not abundant naturally in sedimentary aquifers. Its possible Long-term exposure may result to i) renal dysfunction. ii) bone demineralization. iii) liver damage. iv) hypertension. v) carcinogenic effects. This agrees with findings by Edet and Offiong (2002), who observed elevated cadmium concentrations in groundwater around waste disposal sites in southern Nigeria.

Zinc (Zn) Concentration

Zinc concentrations ranged from 0.1621 mg/L to 0.5181 mg/L, with mean concentration of 0.4851 mg/L. The concentration is well below the USEPA = 5.00 mg/L and NSDWQ limit= 3.00 mg/L. The low zinc concentration indicates minimal contamination and acceptable groundwater quality regarding Zn. The abundance of zinc in the groundwater is usually through: i) weathering of rocks. ii) galvanized pipes. iii) roofing materials. iv) waste decomposition.

Although zinc is essential in trace amounts for human metabolism, excessive intake may cause nausea and stomach irritation. The result indicates that zinc does not presently pose a health threat in the area.

Lead (Pb) Concentration

Lead concentrations ranged between 0.0001 mg/L and 0.0146 mg/L, with mean concentration of 0.0089 mg/L. These values are below regulatory limits (0.10 mg/L), indicating acceptable status. However, lead remains significant because even very low concentrations can accumulate in human tissues.

Potential sources include: i) corroded pipes. ii) industrial residues, iii) battery disposal. iv) atmospheric deposition. The elevated value in BH1 (0.0146 mg/L) compared with other boreholes suggests local contamination. Lead can have a drastic effect on i) brain development,



ii) nervous system, iii) blood formation, iv) kidneys. However, the current concentrations are below standard, continued monitoring is necessary due to cumulative effects.

Copper (Cu) Concentration = 2.0239

Copper concentrations ranged from 1.1458 mg/L to 2.7938 mg/L, with mean concentration of 2.0239 mg/L. The value of concentration exceeded the USEPA = 1.30 mg/L and NSDWQ limit = 1.00 mg/L. Copper exceeded permissible limits in all boreholes except BH4, which is near threshold. This suggests widespread contamination which may have its possible sources from: i) corrosion of copper plumbing, ii) dissolved copper minerals, iii) waste infiltration, iv) domestic wastewater. The highest concentration in BH1 confirms stronger contamination. It is good to note that excessive copper intake may cause: stomach cramps, nausea, vomiting, liver damage, kidney problems.

Manganese (Mn) Concentration

Manganese ranged from 0.0084 mg/L to 0.0253 mg/L with the mean value = 0.0152 mg/L. the concentration of manganese is below USEPA and NSDWQ standards. Manganese naturally occurs in sedimentary environments and often associates with iron. The low concentrations of manganese indicate: i) good oxidation state, ii) low reducing conditions, iii) stable aquifer chemistry. From the result, Manganese at these levels is not harmful, but prolonged accumulation can affect neurological functions.

Sodium (Na) Concentration

Sodium concentrations varied significantly: BH1 = 21.6820 mg/L, BH2 = 11.6000 mg/L. BH3 = 7.3200 mg/L, BH4 = 3.9012 mg/l with the Mean concentration of = 11.1258 mg/L. The gradual decline suggests geochemical dilution or distance from source zones. According to the United States Environmental Protection Agency, sodium has no federally enforceable maximum contaminant level in drinking water. However, a health advisory level of 20 mg/L is recommended for individuals on sodium-restricted diets. This has shown that the value of concentration of sodium fail below the standard limit in all the boreholes. High sodium may arise from: rock weathering, domestic sewage, agricultural runoff. It is good to note that excessive sodium may affect hypertensive individuals.

Potassium (K) Concentration

Potassium ranged from 3.7200 to 15.4372 mg/L with the mean concentration of = 7.1311 mg/L, which is within levels commonly found in natural groundwater and does not on its own indicate a drinking-water standard violation. Elevated potassium may still suggest mineral weathering or surface input (such as fertilizer runoff), depending on local geology and land use. Potassium sources include: feldspar weathering, fertilizer application, sewage infiltration. High potassium in BH1 indicates surface contamination. The elevated concentration may correlate with nearby agricultural activities.



Conclusion

The assessment of groundwater quality in Oko and Amaokpala environment revealed that human activities within the area have significantly influenced the physicochemical and heavy metal characteristics of groundwater. The results indicate that groundwater contamination is strongly associated with proximity to pollution sources such as waste disposal sites, septic systems, runoff from residential areas, and agricultural activities. Boreholes and wells located closer to these sources showed relatively higher concentrations of contaminants than those farther away, confirming that distance plays an important role in groundwater quality.

The pH values of the groundwater samples in Oko and Amaokpala showed slight acidity in some locations, suggesting that groundwater in parts of the area does not fully conform to acceptable drinking water standards established by United States Environmental Protection Agency and World Health Organization. Acidic groundwater may result from decomposition of organic materials, infiltration of waste leachate, and soil characteristics of the area. This condition may increase the solubility of metals and other harmful substances, thereby making them more available in drinking water.

Heavy metals such as iron (Fe), lead (Pb), copper (Cu), cadmium (Cd), zinc (Zn), manganese (Mn), sodium (Na), and potassium (K) were detected in varying concentrations across the sampled locations. The presence of these metals, particularly lead and cadmium, is an indication of possible groundwater pollution and may pose serious health risks to residents who depend on borehole water for drinking and domestic use. Elevated concentrations were observed in sampling points closer to waste disposal areas and densely populated settlements, showing the impact of anthropogenic activities on groundwater quality.

The study also showed that contaminant levels decreased as the sampling points moved farther from identified pollution sources. This suggests that the extent of contamination is influenced by local topography, soil permeability, groundwater flow direction, and hydrological conditions of the area. Communities located very close to refuse dumps, drainage channels, or agricultural fields are more exposed to groundwater pollution compared to those farther away.

The findings imply that although some parameters remain within permissible limits, continued discharge of waste into the environment may worsen groundwater quality over time. Consumption of untreated groundwater from polluted locations may expose residents to water-borne diseases, heavy metal toxicity, and long-term health complications. Therefore, groundwater in Oko and Amaokpala requires regular monitoring to safeguard public health.

Recommendations

1. Waste disposal sites should be properly managed to prevent leachate from infiltrating into groundwater sources.
2. Sanitary landfills lined with impermeable materials such as clay or synthetic liners should be adopted to reduce groundwater contamination.



3. Boreholes should be located at safe distances from dumpsites, septic tanks, and drainage systems.
4. Government agencies should enforce environmental regulations on waste disposal and groundwater protection.
5. Regular laboratory analysis of borehole water should be carried out to monitor changes in water quality.
6. Public awareness should be created on the dangers of consuming untreated groundwater from contaminated areas.
7. Water treatment methods such as filtration, aeration, and chemical treatment should be encouraged before domestic consumption.
8. Further hydrogeological studies should be conducted to understand seasonal variations in groundwater contamination within Oko and Amaokpala environment.

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