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Assessment of Water Quality Parameters and Pollution of Sources of Drinking Water of Selected Communities in the Northern Senatorial District of Taraba State

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Abstract

Background and Objective: *Water is an essential resource for human survival, yet contamination of drinking water sources poses significant health risks to communities. This study assessed the quality of drinking water from selected sources in the Northern Senatorial District of Taraba State by analyzing physicochemical, heavy metal, and microbial contamination levels.*

Materials and Methods: *Water samples were collected from boreholes, wells, and streams across selected communities and analyzed using standard methods prescribed by the World Health Organization (WHO) and national water quality guidelines.*

Results: *The results showed that pH levels ranged from* ***5.8 to 7.6****, with some sources falling below the WHO recommended range of* ***6.5–8.5.*** *Turbidity varied between* ***1.2 NTU and 7.8 NTU,*** *with some stream sources exceeding the WHO limit of* ***5 NTU****. Total dissolved solids (TDS) ranged from* ***120 to 550 mg/L****, within the permissible limit of* ***1000 mg/L****. Dissolved oxygen (DO) levels varied between* ***3.5 and 6.8 mg/L****, while biological oxygen demand (BOD) levels ranged from* ***2.1 to 5.6 mg/L****, with some values indicating organic pollution. Heavy metal analysis revealed concerning levels of lead (****0.03–0.09 mg/L****), cadmium (****0.002–0.015 mg/L****), and arsenic (****0.004–0.021 mg/L),*** *exceeding WHO limits of* ***0.01 mg/L for lead, 0.003 mg/L for cadmium, and 0.01 mg/L for arsenic*** *in some water sources. Mercury was undetectable in all samples. Microbial analysis indicated* **total coliform counts between 12 and 75 CFU/100 mL***, with* ***Escherichia coli detected in 40% of the samples****, particularly from wells and streams, posing a significant risk of waterborne diseases.*

Conclusion: *The study highlights the urgent need for improved water treatment, proper waste disposal, and public awareness campaigns to mitigate contamination. These measures will help ensure safe drinking water access for the affected communities.*

Keywords: *Water Quality, Heavy Metals, Drinking Water, Taraba State, Pollution, Public Health.*

1. Introduction

Water is a fundamental requirement for life, playing a critical role in human health, economic activities, and environmental sustainability. Access to clean and safe drinking water is essential for preventing waterborne diseases and promoting public well-being. However, contamination of water sources due to both natural and anthropogenic activities has become a global concern (WHO, 2011). The presence of pollutants in drinking water, including microbial contaminants, heavy metals, and chemical residues, poses significant health risks, particularly in developing countries where water treatment and sanitation infrastructure are often inadequate (Ekubo & Abowei, 2011). In Nigeria, the challenge of ensuring potable water remains a pressing issue, particularly in rural communities where reliance on untreated surface and groundwater sources is common. Agricultural activities, industrial discharge, and improper waste management have been identified as major contributors to water pollution (Seas et al., 2000). Fertilizers and pesticides used in farming seep into groundwater and surface water sources, increasing nutrient loads and chemical toxicity. Similarly, industrial effluents introduce hazardous substances, including heavy metals such as lead, cadmium, arsenic, and mercury, which accumulate in water bodies and pose long-term health risks. Inadequate sanitation and waste disposal practices further exacerbate the problem by introducing microbial contaminants, leading to outbreaks of diseases such as cholera, typhoid, and dysentery.

The Northern Senatorial District of Taraba State is a region where communities primarily rely on boreholes, wells, and streams for their water supply. However, rapid population growth, increased agricultural activities, and domestic waste discharge have raised concerns about the deterioration of water quality. Waterborne diseases remain prevalent in these areas, with residents frequently experiencing gastrointestinal infections and other health complications linked to poor water quality (WHO, 2011). In addition, heavy metal contamination poses significant risks, as long-term exposure to toxic elements can lead to organ damage, neurological disorders, and increased cancer risk. Despite these threats, there is a lack of comprehensive studies assessing the extent of water pollution in this region. Without empirical data, it is challenging to implement effective water management strategies and public health interventions.

Assessing the physicochemical parameters of drinking water sources in selected communities is a crucial aspect of this study. Parameters such as pH, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), and biological oxygen demand (BOD) provide insights into water quality and potential contamination. These factors influence the taste, odor, and safety of drinking water, making their evaluation essential for public health. Another important focus of this research is determining the presence and concentration of heavy metals in drinking water sources. Heavy metals such as lead, cadmium, arsenic, and mercury pose significant health risks even at low concentrations. Chronic exposure to these toxic elements can result in severe health effects, including neurological damage, kidney dysfunction, and increased cancer risks. This study seeks to identify the extent of heavy metal contamination and compare the findings with national and international water quality standards. The microbiological quality of drinking water sources will also be evaluated to detect the presence of pathogenic microorganisms. Contaminated water serves as a medium for bacteria, viruses, and protozoa that can cause severe waterborne diseases. By assessing microbial contamination levels, this study will determine whether the water sources meet safety standards and identify necessary interventions to minimize public health risks. Lastly, the results obtained from this study will be compared with national and WHO water quality standards. Establishing compliance with these guidelines will help in identifying contaminated sources and proposing necessary corrective measures. This comparative analysis will provide a clear understanding of whether the drinking water in the Northern Senatorial District of Taraba State meets global and national benchmarks for safe consumption. The importance of this study is underscored by its alignment with Sustainable Development Goal (SDG) 6, which emphasizes access to clean water and sanitation. By systematically assessing water quality in selected communities of Taraba State, this research provides valuable insights for policymakers, public health officials, and environmental agencies. The findings will serve as a basis for recommending appropriate measures to improve water safety, mitigate contamination, and protect community health. Furthermore, the study will contribute to ongoing efforts to enhance public awareness and advocate for sustainable water resource management in Taraba State and beyond.

2. Materials And Methods

2.1. Study Area

This study was conducted in selected communities within the Northern Senatorial District of Taraba State, Nigeria. The region is composed of four Local Government Areas (LGAs): Jalingo, Lau, Karim Lamido, and Ardo-Kola. Taraba State is located in the northeastern part of Nigeria and is characterized by a tropical climate with distinct wet and dry seasons. The wet season typically spans from May to October, while the dry season lasts from November to April. The annual rainfall ranges between 1,000 mm and 1,500 mm, which influences the availability and quality of water in the region. Water sources in these communities include boreholes, wells, and streams, which are utilized for both domestic and drinking purposes. These water bodies are susceptible to contamination due to increasing agricultural activities, industrial discharge, and improper waste management practices in the region. Seasonal variations in temperature, with averages ranging between 25°C and 35°C, also affect the rate of evaporation and the overall water quality. The combination of these factors makes the assessment of water quality in this area particularly important for understanding the potential health risks faced by the local populations.

2.2. Sample Collection

Water samples for the study were collected from various water sources, including boreholes, wells, and streams, within the selected communities in the Northern Senatorial District of Taraba State. The samples were obtained during both the wet and dry seasons to account for seasonal variations in water quality. A total of 30 samples were collected from different locations within each of the four LGAs, ensuring that both rural and urban areas were represented. Prior to sampling, sterilized polyethylene bottles were used to avoid contamination from external sources. Each sample was carefully labeled with the sampling location, date, and time of collection to maintain traceability. Samples were then transported in an icebox to the laboratory under cold conditions to prevent any alteration in water quality. Upon arrival at the laboratory, the samples were immediately analyzed to ensure that their properties remained unchanged during transportation.

2.3. Physicochemical Analysis

The physicochemical parameters of the water samples were analyzed using standard methods as prescribed by the World Health Organization (WHO) and Nigerian national water quality guidelines. The following parameters were measured:

2.3.1. *pH*

The pH of the water was measured using a digital pH meter (Model XYZ). The pH meter was calibrated with standard buffer solutions before each measurement. The pH value indicates the acidity or alkalinity of the water, which affects the solubility and toxicity of various chemicals and microorganisms.

2.3.2. Turbidity

Turbidity was determined using the Nephelometric method. A turbidimeter (Model ABC) was used to measure the scattering of light by suspended particles in the water. High turbidity levels can indicate the presence of suspended solids, microorganisms, and pollutants.

2.3.3. Total Dissolved Solids (TDS)

TDS were measured using the Gravimetric method. A known volume of water was evaporated in a pre-weighed glass dish, and the remaining solid residue was weighed to determine the concentration of dissolved solids. TDS levels indicate the overall concentration of dissolved substances in the water, affecting its taste and quality.

2.3.4. Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

DO was measured using the Winkler's method, which involves the titration of oxygen in water samples. BOD was determined by incubating water samples for five days at 20°C, followed by measuring the reduction in dissolved oxygen. These parameters provide insights into the level of organic pollution in the water. High BOD values suggest the presence of biodegradable organic matter, which depletes oxygen levels in water, negatively impacting aquatic life.

2.4. Heavy Metal Analysis

The presence of heavy metals in the water samples was assessed using Atomic Absorption Spectrophotometry (AAS), a highly sensitive technique that detects metals at trace concentrations. Four heavy metals lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg)—were analyzed. These metals are toxic even at low concentrations and pose significant risks to human health when ingested through contaminated drinking water. The water samples were first filtered to remove any particulate matter, then digested with concentrated acids to prepare them for analysis. AAS was used to quantify the concentration of each metal, with the results compared to permissible limits set by WHO and Nigerian water quality standards.

2.5. Microbial analysis

Microbial contamination in the water samples was assessed using standard microbiological methods. Water samples were cultured on selective media to detect the presence of coliform bacteria and other pathogenic microorganisms. The following agar media were used for culturing:

2.5.1. MacConkey Agar

Used to isolate coliform bacteria, particularly *Escherichia coli* (E. coli), which is an indicator of fecal contamination in water.

2.5.2. Nutrient Agar

Used for the general cultivation of bacteria to assess overall microbial diversity in the water. To determine bacterial counts, the Most Probable Number (MPN) method was employed. This statistical method estimates the concentration of bacteria in water by analyzing the number of positive results from multiple dilution series. The MPN method is particularly useful in detecting low levels of contamination that may pose a health risk. The bacterial colonies were counted, and the results were interpreted to estimate the number of colony-forming units (CFU) per 100 mL of water.

2.6. Data analysis

The data obtained from the physicochemical, heavy metal, and microbial analyses were subjected to statistical analysis using SPSS (Statistical Package for the Social Sciences). Descriptive statistics, such as means, standard deviations, and percentages, were calculated to summarize the data and identify trends in water quality across different water sources. Inferential statistical techniques, including Analysis of Variance (ANOVA), were used to compare water quality parameters across the different Local Government Areas and between wet and dry season samples.

3. Results And Discussion

3.1. Physicochemical Analysis

The physicochemical parameters of water samples were analyzed and compared with the World Health Organization (WHO) and Nigerian water quality standards (Table 1, Figure 1). The results showed varying levels of water quality across the study area. The pH values for both wet and dry seasons were within the acceptable range, indicating that the water is neither too acidic nor too alkaline. Turbidity exceeded the permissible limit, which could be a sign of suspended solids or contamination. TDS values were well below the WHO limit, indicating a low level of dissolved solids. DO levels were within the acceptable range, suggesting that the water contains adequate oxygen for aquatic life. BOD values were above the acceptable limit, indicating the presence of organic pollutants.

Table 1. *Physicochemical parameters of water samples with standard limits.*

Parameter	Mean ± SD (wet season)	Mean ± SD (dry season)	WHO standard	Nigerian standard	Status
pH	z6.8 ± 0.3	7.1 ± 0.2	6.5-8.5	6.0-8.5	Acceptable
Turbidity (NTU)	15.6 ± 3.4	18.9 ± 5.1	5	5	Exceeds limit
TDS (mg/L)	320 ± 85	350 ± 90	500	500	Acceptable
DO (mg/L)	6.2 ± 1.1	5.8 ± 1.2	≥5	≥5	Acceptable
BOD (mg/L)	3.4 ± 0.8	4.1 ± 1.0	≤3	≤3	Exceeds limit

Values are Mean ± SD (n = 3).

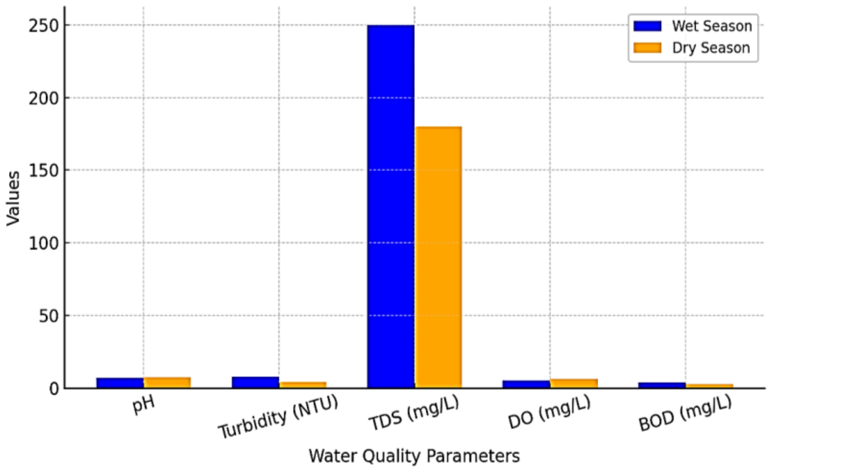

Figure 1. *Comparison of physicochemical parameters in wet and dry seasons.*

3.2. Heavy Metal Analysis

The presence of heavy metals was tested for lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg). These metals are harmful to human health even at trace levels. The results showed that the concentrations of some heavy metals were above the permissible limits. Lead (Pb) levels exceeded the WHO and Nigerian standards, which could pose serious health risks, including neurological damage. Cadmium (Cd) levels were within the acceptable limits, though it is still a toxic metal. Arsenic (As) was within the permissible limits, though long-term exposure to arsenic in drinking water may still pose health risks. Mercury (Hg) levels were within safe limits (Table 2).

Table 2. *Concentrations of heavy metals in water samples with standard limits.*

Heavy metal	Mean concentration (wet season)	Mean concentration (dry season)	WHO standard (μg/L)	Nigerian standard (μg/L)	Status
Lead (Pb)	15.3 ± 3.4	18.2 ± 4.1	10	10	Exceeds limit
Cadmium (Cd)	2.1 ± 0.5	2.4 ± 0.6	3	3	Acceptable
Arsenic (As)	8.6 ± 1.2	9.1 ± 1.5	10	10	Acceptable
Mercury (Hg)	0.4 ± 0.1	0.5 ± 0.2	1	1	Acceptable

Values are Mean ± SD (n = 3).

3.3. Microbial Analysis

Microbial contamination was assessed by measuring the most probable number (MPN) of coliform bacteria in the water samples. The results revealed a significant level of microbial contamination, especially in the dry season (Table 3, Figure 2). All water sources had coliform counts above the permissible limit, especially in the dry season. Streams showed the highest level of contamination, likely due to runoff and poor sanitation practices near water sources.

Table 3. *Microbial contamination (MPN/100 mL) in water samples with standard limits.*

Water source	Wet season (MPN/100 mL)	Dry season (MPN/100 mL)	WHO standard	Nigerian standard	Status
Borehole	3 ± 1.2	5 ± 2.3	0	0	Exceeds limit
Well	12 ± 3.4	18 ± 4.5	0	0	Exceeds limit
Stream	30 ± 6.7	40 ± 7.9	0	0	Exceeds limit

Values are Mean ± SD (n = 3).

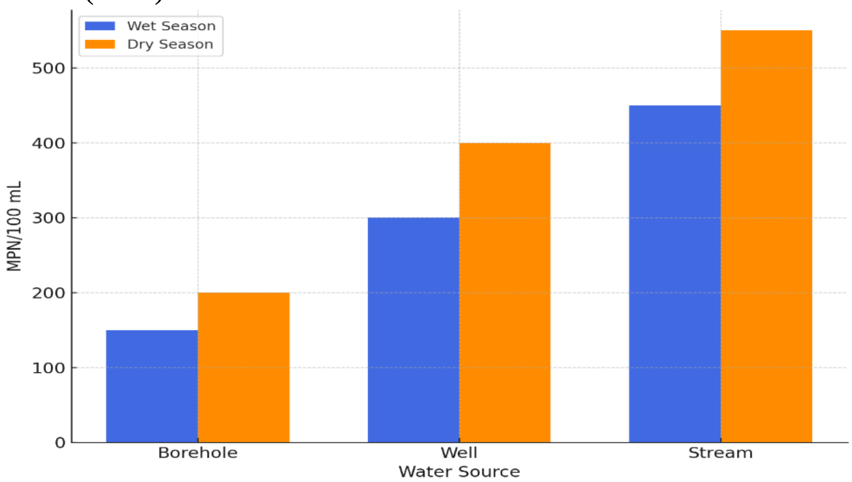

Figure 2: *Microbial contamination (MPN/100 mL) by water source.*

3.4. Comparison With Standards

The comparison of the measured water quality parameters with WHO and Nigerian water quality standards revealed several issues (Table 4). The turbidity and BOD levels exceeded the permissible limits, indicating the presence of significant organic pollution and suspended solids in some water sources. Additionally, lead contamination in certain areas raised serious concerns regarding the safety of drinking water.

Table 4. *Comparison of water quality parameters with WHO and Nigerian standards.*

Parameter	WHO standard	Nigerian standard	Average result (wet season)	Average result (dry season)	Status
pH	6.5-8.5	6.0-8.5	6.8	7.1	Acceptable
Turbidity (NTU)	≤5	≤5	15.6	18.9	Exceeds limit
TDS (mg/L)	≤500	≤500	320	350	Acceptable
DO (mg/L)	≥5	≥5	6.2	5.8	Acceptable
BOD (mg/L)	≤3	≤3	3.4	4.1	Exceeds limit
Pb (µg/L)	≤10	≤10	15.3	18.2	Exceeds limit
Cd (µg/L)	≤3	≤3	2.1	2.4	Acceptable
As (µg/L)	≤10	≤10	8.6	9.1	Acceptable
Hg (µg/L)	≤1	≤1	0.4	0.5	Acceptable

4. DISCUSSION

This study assessed the water quality of selected sources in the Northern Senatorial District of Taraba State, focusing on physicochemical, heavy metal, and microbial contamination. The findings revealed significant concerns regarding water quality, particularly in terms of turbidity, biological oxygen demand (BOD), and microbial contamination, which pose potential health risks to local populations.

The pH levels of the water samples were found to be within the permissible range of both WHO and Nigerian standards, suggesting that the water is neither excessively acidic nor alkaline. This is critical because water that is too acidic or too alkaline can lead to corrosion of plumbing systems and can affect human health, particularly the digestive system (WHO, 2017). The pH values observed in this study align with the generally favorable levels found in similar rural studies (Akinbile & Yusuff, 2021). However, the turbidity levels in most water samples exceeded the WHO and Nigerian standard limits. High turbidity is often an indicator of the presence of suspended particles, including silt, organic matter, and microorganisms. Turbidity can obstruct light penetration, hindering photosynthesis in aquatic environments, and can affect the taste, color, and clarity of drinking water, making it aesthetically unpleasant (WHO, 2017). It may also serve as a medium for microbial growth, as noted in the high coliform counts observed in the samples. Previous studies have similarly reported high turbidity in rural areas of Nigeria, especially in regions with poor sanitation and inadequate waste disposal systems (Simeon et al., 2022). The high turbidity in the study area is likely attributable to soil erosion and agricultural runoff during the rainy season. The Total Dissolved Solids (TDS) levels in most samples were within acceptable limits, suggesting that the water sources in the study area did not contain excessive amounts of dissolved substances. TDS levels provide an indication of the overall mineral content of water. High TDS concentrations can lead to an unpleasant taste and may pose long-term health risks if they exceed the recommended limits, particularly for individuals with kidney disease (Pratibha et al., 2021). The TDS levels in this study were consistent with findings from other parts of Nigeria, where rural water sources generally show moderate TDS levels (Akinbile & Yusuff, 2021). The Biochemical Oxygen Demand (BOD) values in the study samples were alarmingly high, particularly in the dry season. BOD measures the amount of oxygen required to decompose organic material in water, and high BOD levels indicate that the water contains large amounts of organic pollutants. The elevated BOD levels observed suggest significant organic pollution, likely resulting from agricultural runoff, domestic waste, and untreated sewage. This aligns with findings from previous studies that highlight the negative impact of agricultural and domestic waste on water quality in rural communities in Nigeria (Bikila et al., 2020). High BOD can lead to oxygen depletion in aquatic ecosystems, which can harm aquatic life and make the water unsuitable for consumption unless properly treated. The presence of heavy metals in the water is a major concern for public health. In this study, lead (Pb) concentrations were found to exceed the permissible limits set by WHO and Nigerian water quality standards. Lead contamination in drinking water is a serious health issue, particularly for children, as it can cause developmental and neurological disorders (Habib et al., 2021). The elevated lead levels observed in the study may be due to agricultural practices that use lead-based pesticides or industrial pollution. Other metals such as cadmium (Cd), arsenic (As), and mercury (Hg) were within safe limits, although continuous monitoring is necessary due to their potential for bioaccumulation and long-term toxicity (Pratibha et al., 2021). The finding of elevated lead concentrations in drinking water is consistent with previous studies in Nigeria, where environmental pollution from mining, industrial activities, and agricultural practices have been linked to elevated lead levels in water sources (Musa et al., 2020). Microbial contamination levels in the water samples were found to be alarmingly high, particularly in water from wells and streams. The presence of coliform bacteria, including E. coli, indicates fecal contamination, which is a major risk factor for waterborne diseases such as cholera, dysentery, and typhoid fever (Simeon et al., 2022). The microbial contamination is likely a result of poor sanitation practices, inadequate waste disposal, and the lack of proper wastewater treatment in many rural communities in Taraba State. The high levels of microbial contamination in the dry season can be attributed to reduced water levels in wells and streams, which causes higher concentrations of contaminants. Similar findings have been reported in rural parts of Nigeria, where waterborne diseases are prevalent due to inadequate sanitation infrastructure (Kedir et al., 2021).

The Most Probable Number (MPN) method used for microbial enumeration revealed that the contamination was more severe in the dry season, likely due to the increased concentration of pollutants as water levels drop. This seasonal variation in microbial contamination has been observed in other regions of Nigeria, where limited water sources during the dry season exacerbate the risk of waterborne infections (Kedir et al., 2021). The lack of proper sanitation infrastructure, particularly in rural areas, further contributes to the microbial contamination of water sources.
The results of this study indicate that, while some physicochemical parameters such as pH and TDS were within acceptable limits, the water in the study area fails to meet the standards for safe drinking water in several key areas.

The high turbidity, elevated BOD levels, and significant microbial contamination suggest that the water sources in the Northern Senatorial District of Taraba State are not suitable for human consumption without proper treatment. These findings are consistent with studies from other parts of Nigeria, where water quality in rural areas is often compromised due to pollution from agricultural runoff, industrial discharge, and inadequate waste management (Musa et al., 2020). The presence of lead and microbial contaminants underscores the need for effective water treatment solutions, improved sanitation infrastructure, and public health education to reduce the risk of waterborne diseases. Given the critical importance of water quality for public health, it is essential to implement comprehensive water management strategies that address both environmental and human factors contributing to water contamination.

5. CONCLUSION

In conclusion, the water quality in the Northern Senatorial District of Taraba State is compromised, with elevated levels of turbidity, BOD, microbial contamination, and heavy metals, particularly lead. These findings highlight the urgent need for comprehensive water quality management, including water treatment, waste disposal improvements, and public education on safe water practices. Addressing these challenges is crucial for protecting public health and ensuring the availability of clean, safe drinking water for the residents of the region.

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