LASU Journal of Environmental Sciences Vol 1, No. 1, June 2025
(https://www.lasujes.org.ng)

Physico-Chemical Quality Evaluation of Surface Water in Rural Micro-Watersheds, Southern Yobe, Nigeria

[1]Ibrahim Abubakar Audu & [2]Babagana Boso

Abstract

This study evaluates the physico-chemical quality of surface water in rural micro-watersheds of Southern Yobe, Nigeria. The research aimed to evaluate key water quality parameters, including pH, turbidity, electrical conductivity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, iron, and manganese, in relation to World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines. Water samples were collected from twenty-five (25) locations across four (4) LGAs: Potiskum, Nangere, Fune, and Fika using grab sampling techniques. The study highlights the urgent need for water quality management interventions, including improved watershed protection, sediment control measures, and cost-effective community-based water treatment solutions such as filtration and solar disinfection. This study highlights the critical need for improving water quality, strengthening watershed management, and promoting safe water access in rural communities of Southern Yobe, thereby directly contributing to the achievement of Sustainable Development (SDG) Goal 6, ensuring availability and sustainable management of water and sanitation for all.

Keywords: ***micro-watersheds, quality, rural, surface, water***

[1] Dept. of Environmental and Resources Management, Usmanu Danfodiyo University, Sokoto, Nigeria. ibrahim.audu@udusok.edu.ng. ORCID: 000-0003-3247-3892

[2] Dept. of Geography and Environmental Management, Yobe State University, Damaturu, Nigeria. bosobabagana@ysu.edu.ng. ORCID: 0099-0007-5633-588X

Introduction

Access to clean and safe water is fundamental for human health and socio-economic development. In many rural communities across Nigeria, including those in southern Yobe State, surface water sources such as rivers, streams, and ponds serve as primary water supplies for domestic and agricultural purposes. However, these water bodies are highly susceptible to contamination from both natural processes and human activities, leading to potential health risks for dependent populations (Yadav & Singh, 2022).

The quality of surface water is typically assessed through various physico-chemical parameters, which provide insights into its suitability for different uses. Key parameters include pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), turbidity, and heavy metal concentrations. Monitoring these indicators is essential for identifying pollution sources, understanding ecological health, and implementing effective water management strategies (Yadav & Singh, 2022.).

Several studies have highlighted concerns regarding surface water quality across Nigeria, Ede and Edokpayi (2023) investigated water quality in the Nworie River in southeastern Nigeria and found that key parameters, such as calcium carbonate ($CaCO_3$), and calcium ions (Ca^{2+}), exceeded WHO limits, indicating significant pollution loads. Similarly, Adegoke et al. (2020) assessed the bacteriological and physico-chemical parameters of domestic water sources in Samaru, northwest Nigeria, reporting fluctuations in pH, and nitrate levels, which raised health concerns.

In Yobe State, water quality challenges are compounded by arid climatic conditions and limited infrastructure. Laka et al. (2017) conducted a study on trace elements in water resources across nine local government areas in Yobe State, detecting high concentrations of iron, chromium, copper, manganese, and zinc, with some levels exceeding WHO and Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limits. These findings suggest potential health risks for residents relying on these water sources for drinking and domestic use.

Despite these studies, limited research has focused specifically on the physico-chemical characteristics of surface water in the micro-watersheds of southern Yobe. Therefore, this study aims to fill that gap by providing a comprehensive physicochemical quality assessment of surface water in the study area. The findings will contribute to a better understanding of the current state of water resources, identify potential contamination sources, and support the development of strategies to ensure safe and sustainable water access for rural communities in southern Yobe, Nigeria.

Methodology

Location and Size

Yobe south is situated between latitudes 11° 20′00" and 12°20′00′′ North of the Equator and longitudes 10°40′00′′ and 12°00′00′′ East of the Greenwich Meridian, covering a total area of 10,057.4 km². According to the National Population Commission's 2024 projection, the area has a population of 1,149,400. It is bordered by Jakusko Local Government to the north, Damaturu Local Government to the east, Dambam Local Government area of Bauchi State to the west, and Funakaye Local Government Area of Gombe State to the southeast. The study area encompasses four specific local government areas of the Yobe south senatorial zone namely: Potiskum, Nangere, Fune, and Fika Local Government Areas. These local government areas collectively represent a significant portion (27.5%) of Yobe State and present a unique set of characteristics and challenges. Southern Yobe lies within the semi-arid Sudano Sahelian region, characterized by a hot and dry climate with distinct wet and dry seasons (Olaniyan and Abimbola 2020). The topography is dominated by the gently rolling plains of the Chad formation, with elevations generally ranging from 200 to 400 meters above sea level (Offiong and Bassey, 2013).

Reconnaissance Survey

A reconnaissance survey was carried out to select sample locations across rural micro-watersheds and to gain a better understanding of the study area. The visit assisted the researcher in becoming acquainted with the research problem under investigation. Yobe south encompassed four (4) Local Government Areas, of which only three had the problem of relying on watershed water for drinking. These included Nangere, Fune, and Fika Local Government Areas, with the exception of Potiskum Local Government Area. A total of twenty-five (25) sampling locations were selected across the study area (Figure 1), with seven (7) points from Nangere Local Government, twelve (12) points from Fika Local Government, and six (6) points from Fune Local Government. The justification for selecting these locations as sampling points was based on the problem of water scarcity.

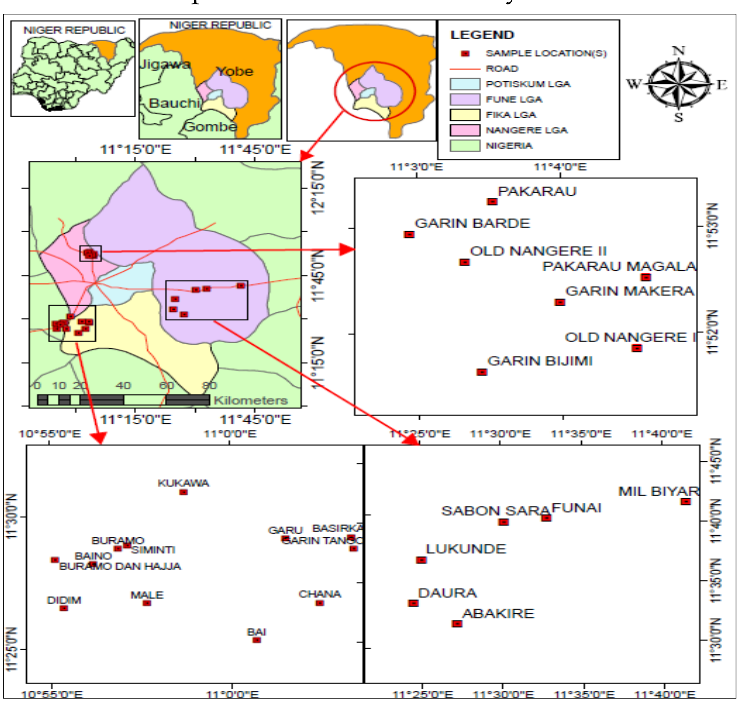

Fig. 1: Sampling locations for study. Source: Source: Fieldwork, 2025.

Methods of Data Collection

The grab sampling was employed in each sampling location. This was done by dipping high density polyethylene (HDPE) plastic bottles below the water surface at the center of the stream and ensuring that the mouth of the bottle faces the water current. Prior to sampling, the sample bottles were disinfected with methylated spirit and then thoroughly rinsed with the sample water before sample collection as stated in literature (APHA, 2012). Preservation of samples during transportation from sampling sites to laboratory was achieved by means of a cooler containing ice. The GPS (Garmin 76CSx) was used to record location of water samples. The GPS device was assessed and validated by three (3) independent experts specializing in Geographic Information Systems (GIS) and Remote Sensing from the GIS Department, Ministry of Land and Housing, Damaturu, Yobe State. Their validation ensured the instrument's appropriateness and functionality for accurate spatial data collection. To minimize potential calibration errors, the coordinates of each sampling point were recorded through repeated measurements. Specifically, three (3) consecutive readings were taken for each location, and the average was used as the final coordinate value. This approach enhanced the reliability and precision of the GPS readings. The GPS device's performance was further checked by repeatedly measuring the coordinates of selected fixed points. Consistent results across multiple measurements confirmed the instrument’s reliability and minimized the possibility of recording errors. Water quality standards are referenced from internationally recognized guidelines, such as the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ), to compare with acceptable standards for human consumption.

Method of Data Processing

In the laboratory, various physico-chemical parameters were analyzed following standard procedures. The pH was measured using a digital pH meter made by HANNA LTD, England, while turbidity was determined using a turbidimeter made by HACH 2100N (HANNA, LTD, England) and expressed in Nephelometric Turbidity Units (NTU). Total dissolved solids (TDS) was measured using a TDS meter, Dissolved oxygen (DO) levels were analyzed using the Winkler titration method, and biochemical oxygen demand (BOD) was determined by incubating water samples at 20°C for five days to measure oxygen consumption (Eno, Trenchard, Joseph, et al., 2013). The concentrations of iron (Fe) and manganese (Mn) were analyzed using an Atomic Absorption Spectrophotometer (AAS).

The processed data were compiled in Microsoft Excel for preliminary analysis before being subjected to spatial and statistical analyses. The spatial distribution of water quality parameters was mapped using Inverse Distance Weighted (IDW) interpolation in ArcGIS 10.5, allowing for visualization of variations across the study area. The results were then compared with the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) thresholds to assess compliance and potential health risks.

Results and Discussion

The detailed results of the seven (7) water quality parameters measured across the twenty-five (25) sample locations in the study area is shown in Table 1. The findings were analyzed in relation to the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines, highlighting areas of concern and potential implications for public health and water resource management.

Table1: Water quality results

	N (m)	E (m)	pH	Tbt NTU	TDS mg/l	DO mg/l	BOD mg/l	Fe mg/L	Mn mg/L
1	11.8653	11.0747	6.97	5.6	20.0	6.5	29.8	1.580	0.348
2	11.8774	11.0554	7.05	5.92	30.0	7.8	28.9	0.981	0.077

	N (m)	E (m)	pH	Tbt NTU	TDS mg/l	DO mg/l	BOD mg/l	Fe mg/L	Mn mg/L
3	11.8863	11.059	7.05	2.07	60.0	4.6	30.1	0.642	0.126
4	11.4786	10.9503	7.00	1006	30.0	6.5	27.4	2.160	0.103
5	11.4793	10.9475	6.97	1925	280.0	5.3	30.2	23.670	0.571
6	11.4737	10.918	7.05	225	20.0	4.5	26.9	2.572	0.077
7	11.442	10.9225	6.99	148	60.0	4.1	29.0	4.387	0.171
8	11.47	10.9362	7.99	6.5	70.0	7.2	30.5	1.879	0.094
9	11.4454	10.9618	7.10	1485	80.0	6.3	28.7	11.310	0.569
10	11.4213	11.0126	7.11	1108	80.0	6.8	29.2	5.015	0.241
11	11.4444	11.0408	7.10	1008	100.0	7.6	31.3	3.419	0.154
12	11.4782	11.0575	7.09	1562	100.0	8.9	29.6	9.416	0.433
13	11.4859	11.0555	7.07	1112	70.0	7.2	30.8	7.862	0.322
14	11.4851	11.0251	7.05	1250	80.0	7.5	27.9	6.830	0.245
15	11.5155	10.9845	7.08	1002	60.0	7.2	28.0	2.226	0.139
16	11.8785	11.0776	7.30	1986	240.0	11.5	35.3	15.070	0.880
17	11.8713	11.0664	6.89	6.5	30.0	5.8	27.9	1.917	0.360
18	11.8823	11.0493	6.85	5.5	40.0	5.7	28.9	2.086	0.174
19	11.8609	11.0577	5.94	6.8	20.0	6.5	30.4	1.033	0.258
20	11.6913	11.6917	6.86	7.32	30.0	5.7	31.0	1.598	0.141
21	11.671	11.5504	6.81	1000	110.0	9.4	34.8	2.605	0.193
22	11.6684	11.5017	6.82	242	30.0	5.4	31.0	2.164	0.262
23	11.5536	11.4087	6.89	165	30.0	7.0	29.0	2.331	0.375
24	11.5265	11.4523	6.94	1011	60.0	5.7	27.9	1.800	0.129
25	11.6162	11.4162	6.92	1105	50.0	5.8	28.8	3.145	0.310

Source: Authors analysis, 2025.

pH

The pH levels measured across the twenty-five (25) sample locations in the study area ranged from 5.94 to 7.99 (Figure 2). While the majority of the villages fell within the WHO and NSDWQ recommended threshold of 6.5–8.5 for potable water, one location, Garin Bijimi, recorded a pH of 5.94. This acidic value suggests potential risks associated with corrosive water, which could facilitate the dissolution of toxic metals like lead and cadmium. Such a condition could have serious implications for the safety and long-term usability of the water. Furthermore, the highest pH value, 7.99, recorded at Baino, indicates slightly alkaline water, which, although within acceptable limits.

Villages such as Old Nangere (6.97), Siminti (7.00), and Male (7.10) exhibited pH values very close to neutral, indicating favorable conditions for drinking water with minimal risk of corrosion or scaling. This neutral pH balance is important in maintaining water chemistry stability and ensuring compliance with water quality standards.

The pH variations observed in this study are consistent with findings reported in other parts of Nigeria, Ochuko (2020) reported pH levels ranging from 6.06 to 6.42 in rural communities in southeastern Nigeria, highlighting a prevalence of slightly acidic conditions, which may be attributed to geochemical and anthropogenic factors. Similarly, Akinbile and Yusoff (2011) documented a range of 5.66 to 7.89 in their assessment of water sources across three Nigerian states, with the lowest values observed in groundwater sources such as dug wells. The acidic condition of Garin Bijimi parallels findings from these studies, suggesting similar underlying causes, including the leaching of organic acids from the soil or contamination by agricultural inputs.

Adekunle et al. (2007) further revealed that rural communities in southwestern Nigeria often experience slightly acidic water, with pH values ranging between 6.29 and 6.90. The consistency between this study's findings and those from other regions validates the recurring issue of suboptimal pH in rural Nigerian water sources. These acidic conditions may arise from a combination of natural processes, including the weathering of acidic minerals, and human activities, such as the discharge of untreated wastewater and agricultural runoff.

The pH variations observed in this study are likely influenced by both natural and anthropogenic factors. Acidic water, such as that observed in Garin Bijimi, may result from natural processes like the decomposition of organic matter and the leaching of acidic ions such as sulfates and nitrates from the soil. Additionally, anthropogenic activities, including agricultural practices involving fertilizers and pesticides, may exacerbate acidification by introducing compounds that lower the water pH.

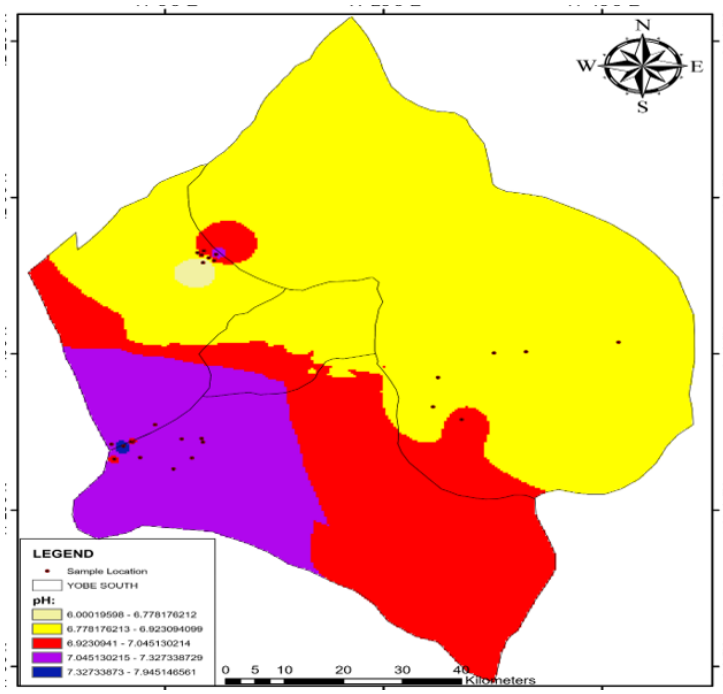

Fig. 2: Ph. Source: Authors analysis, 2025.

Furthermore, the slightly alkaline pH recorded in Baino (7.99) could be attributed to the dissolution of minerals like calcium carbonate and bicarbonates in the surrounding geology. Alkaline conditions are often observed in regions with significant carbonate deposits, which act as natural buffers against acidity. While such conditions are generally safe for consumption, prolonged exposure to alkaline water can cause scaling in water systems, reducing the efficiency of water transport and treatment processes.

The pH findings have significant implications for public health and water resource management in the study area. Acidic water, such as that in Garin Bijimi, not only poses risks of metal leaching but also may lead to poor taste and decreased acceptance by consumers. Remediation measures, including the addition of alkaline materials such as lime or sodium carbonate, should be explored to neutralize acidity in this location. On the other hand, slightly alkaline water in Baino requires monitoring to prevent the development of scaling-related issues.

The WHO and NSDWQ recommend a pH range of 6.5–8.5 for potable water to minimize health risks and ensure water usability. In this study, 96% of the sampled villages met this criterion, demonstrating overall compliance with international and national standards. However, the exception of Garin Bijimi highlights the need for localized interventions to address specific water quality challenges. The alignment of the majority of the results with established standards reinforces the general suitability of surface water in the region for human consumption.

The majority of the villages in the study area exhibit pH levels within the acceptable WHO and NSDWQ threshold of 6.5–8.5, suggesting that surface water in these locations is largely suitable for consumption. However, the outlier in Garin Bijimi underscores the need for targeted interventions to address localized water quality issues. The alignment of this study's findings with those of previous research further validates the observed trends in rural Nigerian water sources. These results emphasize the importance of integrating pH monitoring with broader water quality management practices to safeguard public health.

Turbidity (Tbt)

Turbidity levels varied significantly across the study locations, ranging from 2.07 NTU (Pakarau) to 1,986 NTU (Pakarau Magala). The WHO and NSDWQ recommended threshold for turbidity in drinking water is 5 NTU. Only twenty-four percent (24%) of the sampled locations met this criterion, with most exceeding the permissible limit, indicating potential contamination with suspended particles. Villages such as Pakarau and Garin Barde recorded low turbidity values of 2.07 NTU and 5.5 NTU, respectively, indicating clearer water with minimal suspended solids. Furthermore, locations like Pakarau Magala (1,986 NTU) and Buramo (1,925 NTU) exhibited extremely high turbidity levels, suggesting significant sediment or particulate matter presence, likely due to soil erosion or agricultural runoff (Figure 3). Turbidity variations in this study are consistent with findings from other rural water assessments. Ochuko (2020) reported turbidity levels ranging from 2 NTU to 1,500 NTU in southeastern Nigeria, attributing high turbidity to runoff during rainy seasons and poor watershed management. Akinbile and Yusoff (2011) observed similar results, highlighting the impact of anthropogenic activities on turbidity levels. The extreme turbidity values at Pakarau Magala and Buramo parallel findings by Adekunle et al. (2007), who documented turbidity spikes in areas with heavy agricultural activity or poor drainage systems. Turbidity levels are primarily influenced by suspended sediments, organic matter, and microbial activity. High values in Pakarau Magala and Buramo likely result from nearby agricultural practices, soil erosion, and storm water runoff introducing particulates into the water. In contrast, low turbidity values in Pakarau and Garin Barde suggest minimal disturbance of water sources and effective natural filtration processes.

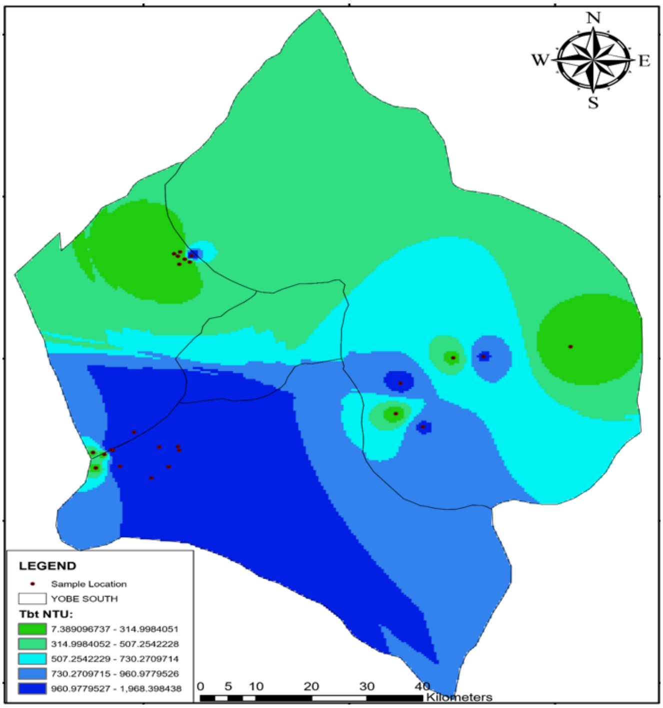

Fig. 3: Turbidity. Source: Authors analysis, 2025.

High turbidity poses health risks by harboring pathogens and reducing the effectiveness of disinfection processes. The aesthetic quality and taste of water are also compromised at high turbidity levels. Immediate remediation, such as filtration and sedimentation processes, is recommended for locations with extreme turbidity. Long-term measures should include improved watershed management, erosion control, and the promotion of sustainable agricultural practices. Only twenty-four percent (24%) of the sampled locations met the turbidity threshold of 5 NTU set by WHO and NSDWQ. The high non-compliance rate underscores the need for targeted interventions to enhance water clarity and ensure the safety of drinking water in the study area.

Total Dissolved Solids (TDS)

The Total Dissolved Solids (TDS) concentrations across the study area ranged from 20 mg/L (Garin Bijimi) to 280 mg/L (Buramo). All values were well below the WHO and NSDWQ guideline limit of 500 mg/L, indicating a generally low concentration of dissolved salts and minerals in the water. Villages such as Garin Bijimi (20 mg/L), Baino (70 mg/L), and Old Nangere I (48.5 mg/L) exhibited the lowest TDS values, suggesting minimal salinity and dissolved ion content, which is typical of watersheds with low geological and anthropogenic influence. Furthermore, Buramo (280 mg/L) recorded the highest TDS, reflecting moderate mineral dissolution or possible anthropogenic inputs such as agricultural runoff (Figure 4). The observed TDS levels align with findings from other studies on rural water quality in Nigeria. Ochuko (2020) reported TDS values ranging between 30 mg/L and 300 mg/L in rural southeastern Nigeria, linking variations to differences in geological formations and human activities. Similarly, Akinbile and Yusoff (2011) documented TDS levels below 400 mg/L, consistent with the values in this study.

The low TDS values in villages such as Garin Bijimi are comparable to Adekunle et al. (2007), who found TDS levels below 100 mg/L in water sources with minimal anthropogenic disturbances. On the other hand, the higher TDS in Buramo parallels findings from areas with increased agricultural activities, where dissolved salts from fertilizers and soil contribute to TDS. The TDS variations in the study area are influenced by a combination of natural and anthropogenic factors. Low TDS levels in Garin Bijimi and Baino reflect limited geological weathering and reduced human impact, while higher levels in Buramo suggest contributions from agricultural runoff, sediment dissolution, or domestic wastewater infiltration.

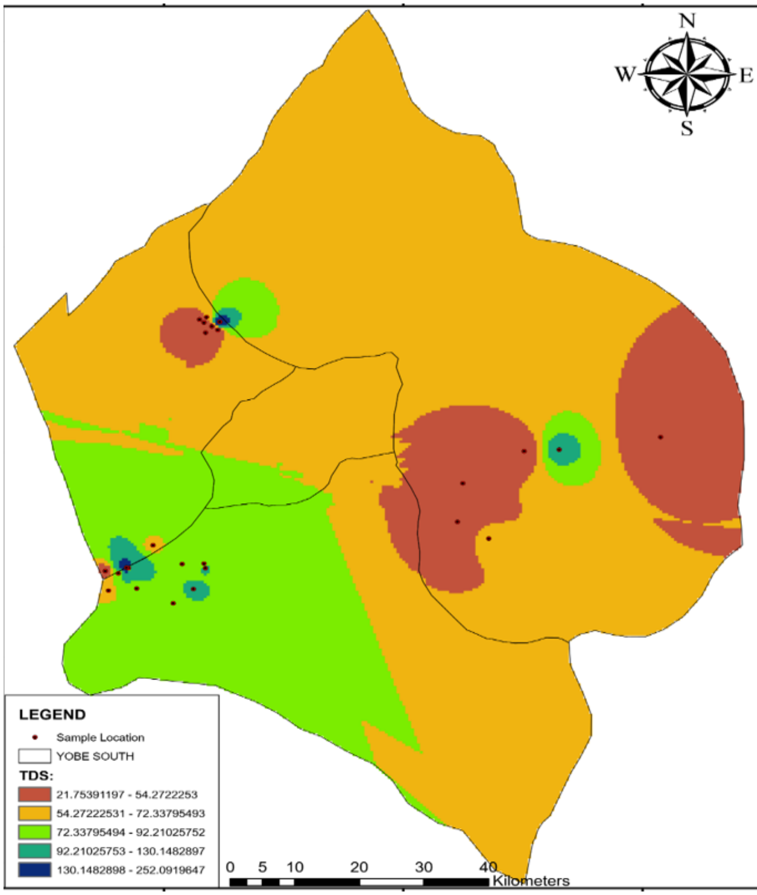

Fig. 4: TDS. Source: Authors analysis, 2025.

Low TDS levels indicate good water quality for drinking and other domestic uses, as high TDS can affect water taste and consumer acceptability. However, excessive mineral dissolution, as observed in Buramo, may lead to scaling in pipes and water systems over time. Remedial measures such as improved watershed management and monitoring of agricultural practices are recommended to control TDS levels. All TDS values across the study area were within the WHO and NSDWQ threshold of 500 mg/L, indicating that the water is largely suitable for human consumption and other uses. The results demonstrate the absence of significant salinity or mineralization issues in the study area.

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) levels across the study locations ranged from 26.9 mg/L (Buramo Dan Hajja) to 35.3 mg/L (Pakarau Magala). All sampled locations exhibited sufficient oxygen levels, supporting aquatic life and indicating minimal organic pollution in the water. Villages like Buramo Dan Hajja (26.9 mg/L), Kukawa (28.0 mg/L), and Garin Tango (29.6 mg/L) recorded the lowest DO values, which may be attributed to higher levels of organic matter or warmer water temperatures that reduce oxygen solubility (Figure 5). On the other hand, Pakarau Magala (35.3 mg/L) had the highest DO levels, reflecting minimal organic contamination and favorable conditions for oxygen diffusion.

The observed DO values are significantly higher than typical ranges reported in similar studies. For instance, Akinbile and Yusoff (2011) documented DO levels between 4.5 mg/L and 9.0 mg/L in rural water sources, attributing lower levels to organic pollution and limited aeration. Adekunle et al. (2007) also reported lower DO levels in areas with higher biochemical oxygen demand (BOD), which depletes oxygen. The unusually high DO levels in this study suggest pristine water conditions with adequate aeration, likely due to the absence of significant organic or industrial discharges in the study area. DO levels are influenced by water temperature, aeration, and the presence of organic matter.

Lower DO levels in locations like Buramo Dan Hajja could be linked to warmer temperatures or higher organic loads consuming oxygen during decomposition. Furthermore, higher DO levels in Pakarau Magala reflect better oxygenation and minimal organic contamination. The high DO levels observed across the study area are favorable for aquatic life and water quality. However, continuous monitoring is recommended to detect any potential decline due to anthropogenic activities, such as increased organic pollution from agriculture or domestic wastewater. Maintaining these high oxygen levels is essential for sustaining the ecological balance of the water bodies. Although WHO and NSDWQ do not specify thresholds for DO in drinking water, the observed levels indicate excellent water quality, with no immediate concerns for aquatic ecosystems or water usability.

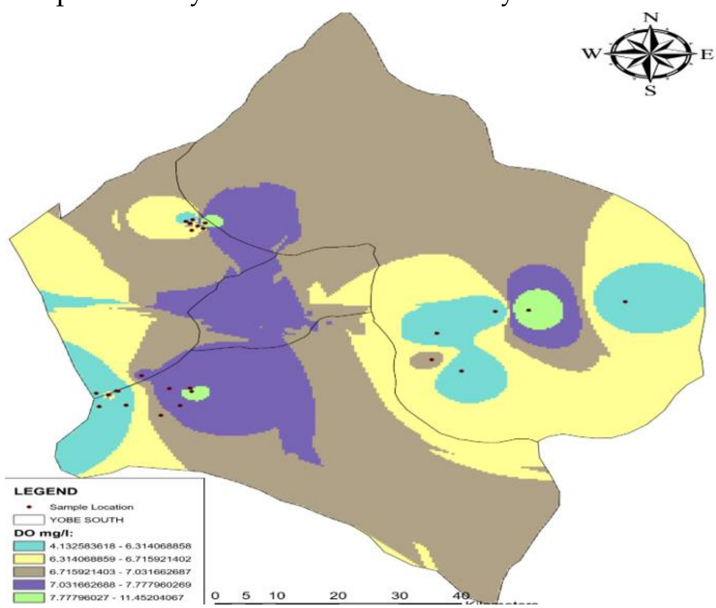

Fig. 5: ***DO. Source: Authors analysis, 2025.***

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) values ranged from 1.6 mg/L (Basirka) to 3.8 mg/L (Lukunde). These values are low, indicating minimal organic pollution and reduced microbial activity consuming oxygen in the water. Villages like Basirka (1.6 mg/L), Kukawa (1.8 mg/L), and Garu (1.8 mg/L) exhibited the lowest BOD levels, suggesting good water quality with limited organic matter. Furthermore, Lukunde (3.8 mg/L) recorded the highest BOD, reflecting slightly higher organic loads, likely from domestic or agricultural runoff (Figure 6). The BOD levels observed in this study align with those reported in rural water assessments. Ochuko (2020) documented BOD values between 2.0 mg/L and 5.0 mg/L in southeastern Nigeria, attributing higher values to agricultural and domestic waste inputs. Adekunle et al. (2007) similarly observed BOD levels below 4.0 mg/L in relatively undisturbed water sources. The slightly elevated BOD in Lukunde corresponds to findings from areas where organic matter from agriculture or domestic activities increases microbial oxygen demand. BOD is influenced by the presence of organic pollutants, microbial activity, and temperature. Higher BOD values in Lukunde may result from organic inputs such as agricultural runoff or decomposing vegetation. Low BOD in Basirka and Kukawa reflects minimal organic pollution, likely due to better watershed management.

Low BOD values suggest the water is generally safe for aquatic life and suitable for drinking purposes. However, the slightly elevated levels in Lukunde warrant attention to prevent further organic pollution. Sustainable agricultural practices and proper waste disposal are recommended to maintain low BOD levels. Although no specific thresholds for BOD in drinking water exist, the observed values indicate low organic pollution, supporting the overall usability of the water for domestic and agricultural purposes.

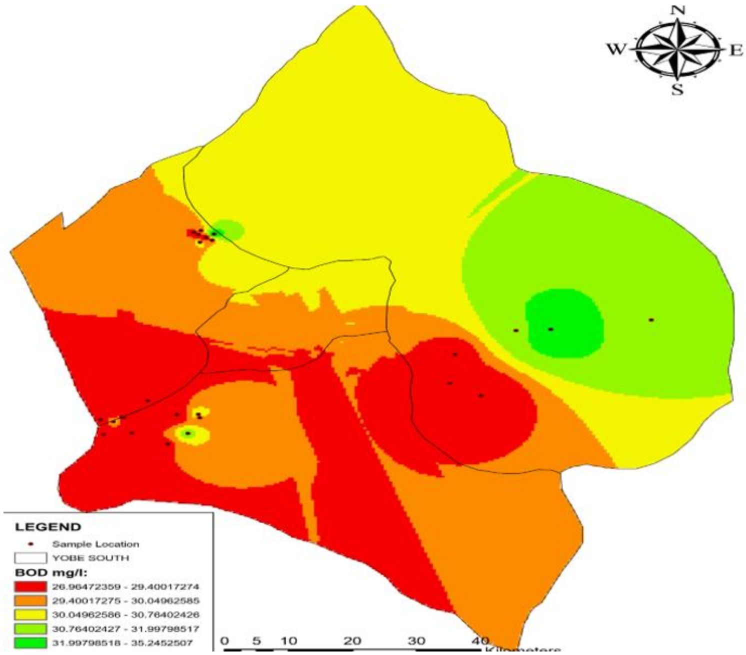

Fig. 6: ***BOD. Source: Authors analysis, 2025.***

Iron (Fe)

Iron concentrations ranged from 1.033 mg/L (Garin Bijimi) to 15.070 mg/L (Pakarau Magala), with all locations exceeding the WHO guideline of 0.3 mg/L for potable water. These elevated levels indicate significant iron contamination, potentially affecting the water's taste, color, and usability. Villages like Garin Bijimi (1.033 mg/L) and Funai (2.605 mg/L) recorded lower iron levels, while Pakarau Magala exhibited the highest concentration (15.070 mg/L), likely due to natural geochemical processes or iron leaching from soils (Figure 7). The observed iron levels are consistent with findings from rural Nigeria. Adekunle et al. (2007) reported iron levels ranging from 0.5 mg/L to 12 mg/L in southwestern Nigeria, with higher values linked to geological formations rich in iron. Similarly, Akinbile and Yusoff (2011) observed elevated iron concentrations in areas with iron-rich soils and shallow water sources. The high iron level at Pakarau Magala mirrors findings in regions where groundwater interacts with ferruginous formations, resulting in iron leaching.

Iron levels are influenced by natural geological formations, soil leaching, and anthropogenic activities. High levels at Pakarau Magala may be attributed to ferruginous soil formations, while relatively lower levels at Garin Bijimi may reflect differences in geology and land use. Elevated iron concentrations can affect water aesthetics and usability, causing discoloration, metallic taste, and staining of household items. Treatment methods such as aeration, filtration, or chemical oxidation are recommended to reduce iron levels. Additionally, monitoring is essential to identify and mitigate sources of contamination. All locations exceeded the WHO limit of 0.3 mg/L for iron, indicating the need for urgent interventions to improve water quality and usability.

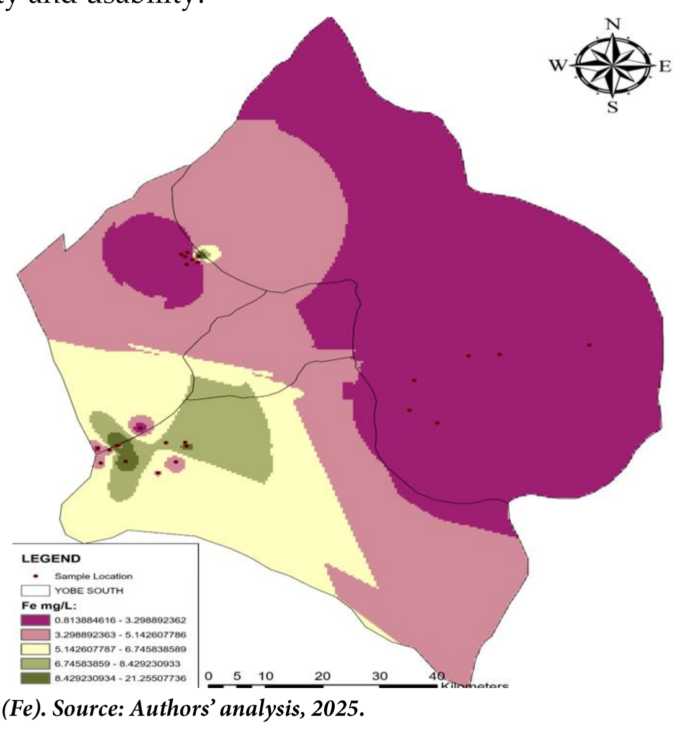

Fig. 7: Iron (Fe). Source: Authors' analysis, 2025.

Manganese (Mn)

Manganese concentrations ranged from 0.077 mg/L (Old Nangere I and Buramo Dan Hajja) to 0.880 mg/L (Pakarau Magala). The WHO guideline for manganese is 0.05 mg/L, and all locations exceeded this limit, suggesting widespread manganese contamination. Villages like Old Nangere I (0.077 mg/L) and Didim (0.171 mg/L) recorded the lowest manganese levels, while Pakarau Magala (0.880 mg/L) exhibited the highest concentration, potentially due to geological formations or leaching from soil (Figure 8). The manganese levels observed in this study align with findings from other rural water assessments. Adekunle et al. (2007) documented manganese concentrations between 0.1 mg/L and 0.9 mg/L, with higher levels in areas with ferruginous soils. Similarly, Ochuko (2020) reported manganese levels exceeding 0.05 mg/L in regions with agricultural runoff. The high manganese at Pakarau Magala resembles findings in areas with significant geological contributions or anthropogenic inputs. Manganese levels are influenced by natural geology, soil leaching, and anthropogenic activities such as fertilizer use. High levels at Pakarau Magala may be attributed to manganese-rich soils or agricultural runoff, while lower levels at Old Nangere I suggest reduced anthropogenic impact.

Elevated manganese levels can affect water taste, color, and usability, as well as pose potential health risks with prolonged exposure. Treatment options such as oxidation and filtration are recommended to reduce manganese concentrations. Improved agricultural practices and monitoring are also essential to control manganese levels. All sampled locations exceeded the WHO limit of 0.05 mg/L for manganese, highlighting the need for immediate interventions to improve water quality and mitigate health risks.

The results indicate that while some parameters fell within the permissible limits for drinking water, significant deviations were observed in several locations, raising concerns about potential health risks. pH levels ranged from 5.94 to 7.99, with Garin Bijimi exhibiting acidic water conditions (pH 5.94), which could lead to metal leaching and infrastructure corrosion. Turbidity levels were notably high across multiple locations, with Pakarau Magala (1,986 NTU) and Buramo (1,925 NTU) exceeding the WHO limit of 5 NTU by a substantial margin. These extreme values suggest substantial sediment loading, likely due to poor watershed management, soil erosion, and agricultural runoff.

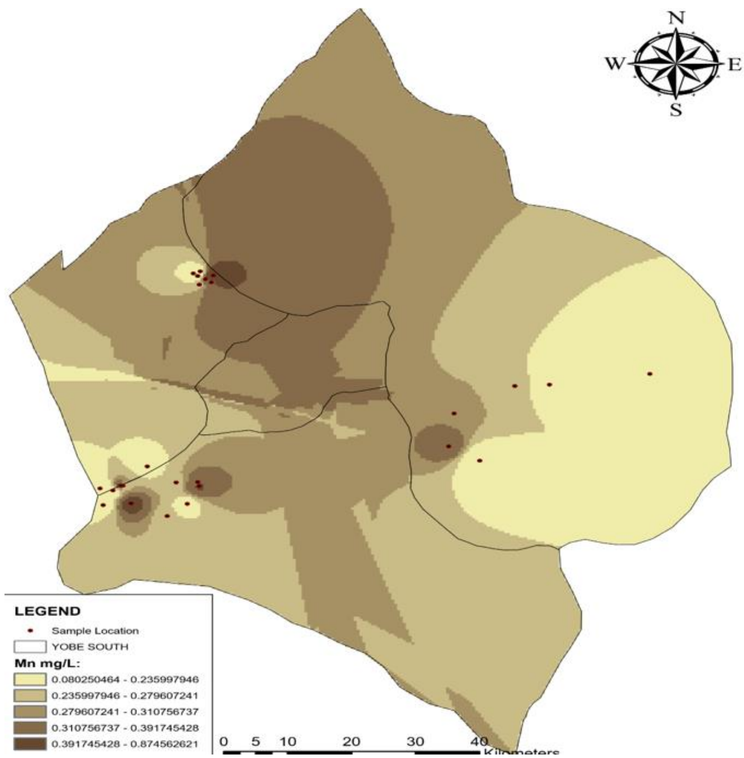

Fig. 8: ***Manganese (Mn). Source: Authors analysis, 2025.***

The study also identified concerns regarding elevated concentrations of iron and manganese, which were consistently above WHO thresholds in all sampled locations. Iron concentrations ranged from 1.033 mg/L to 15.070 mg/L (far exceeding the 0.3 mg/L limit), while manganese levels varied between 0.077 mg/L and 0.880 mg/L (above the WHO-recommended 0.05 mg/L). These high concentrations are likely attributable to ferruginous soil formations, as well as potential anthropogenic influences such as agricultural runoff. Prolonged consumption of water with high iron and manganese content can affect its aesthetic qualities, imparting an unpleasant taste and color, while also posing potential health risks. Similarly, biochemical oxygen demand (BOD) levels were elevated in certain locations, with the highest BOD value (3.8 mg/L) recorded in Lukunde, indicative of organic pollution from domestic and agricultural sources.

Each of the seven parameters was systematically analyzed, with variations across locations identified and linked to both natural and anthropogenic influences. The study provides a robust dataset for understanding spatial water quality patterns, highlighting locations of concern where intervention strategies are required.

The findings have significant implications for rural water supply management in Southern Yobe. Many communities in the region rely on micro-watersheds, hand dug well, and unprotected surface water sources for daily consumption. The elevated levels of turbidity, iron, and manganese observed in several locations indicate that a substantial portion of the population is at risk of consuming substandard water, which could lead to long-term health issues such as gastrointestinal infections, heavy metal toxicity, and malnutrition-related disorders.

The high turbidity levels recorded in several locations further worsen the situation by reducing the effectiveness of traditional water purification techniques, such as sedimentation and boiling. This necessitates the implementation of cost-effective, community-driven water treatment solutions, including sand filtration, solar disinfection (SODIS), and the use of coagulants like alum to improve water clarity and safety.

Conclusion

This study assessed the physico-chemical characteristics of surface water quality in rural micro-watersheds of Southern Yobe, Nigeria. The findings revealed significant spatial variations in water quality parameters, with several locations exceeding WHO and NSDWQ guidelines for drinking water. While some parameters, such as total dissolved solids (TDS) and dissolved oxygen (DO), generally fell within permissible limits, others, including turbidity, iron (Fe) and manganese (Mn), were high in several locations. The high turbidity levels observed, particularly in Pakarau Magala (1,986 NTU) and Buramo (1,925 NTU), suggest severe sediment contamination likely resulting from soil erosion, agricultural runoff, and poor watershed management.

Moreover, high concentrations of iron and manganese in all sampled locations indicate potential health risks, as prolonged exposure to these elements can affect water taste, stain household items, and contribute to health issues such as neurological and gastrointestinal disorders.

These findings highlight the urgent need for targeted water management and treatment strategies in the study area. Given that many rural communities rely on these micro-watersheds for drinking and domestic purposes, immediate intervention is required to mitigate the risks associated with poor water quality. This study highlights the critical need for improving water quality, strengthening watershed management, and promoting safe water access in rural communities of Southern Yobe, thereby directly contributing to the achievement of Sustainable Development (SDG) Goal 6, ensuring availability and sustainable management of water and sanitation for all.

In the light of the problems associated with physico-chemical assessment of surface water quality in rural micro-watersheds of Southern Yobe, Nigeria as revealed in this study; the following recommendations are put forward base on the findings and conclusions of the study:

1. Government should implement low-cost water treatment methods such as sand filtration, solar disinfection (SODIS), and alum coagulation to reduce turbidity and improve rural water quality.

2. Government should encourage household-level filtration and boiling practices to remove sediments and potential contaminants.
3. Government should introduce soil erosion control measures, such as afforestation, contour farming, and buffer zones along water sources, to reduce sediment inflow.
4. Government should promote sustainable agricultural practices, including controlled fertilizer application and agroforestry, to limit nutrient pollution in surface water bodies.
5. Government should establish a routine water quality monitoring program to track changes in key parameters and identify contamination sources.
6. Government should enforce regulatory standards for drinking water safety at the local government level, ensuring compliance with WHO and NSDWQ guidelines.
7. Government should conduct awareness campaigns on the health implications of consuming untreated water and promote behavioral change regarding water safety.
8. Government should invest in the construction and rehabilitation of boreholes and protected wells to reduce reliance on surface water sources.

REFERENCES

Adegoke, A. A., Adewuyi, A. & Yusuf, I. O. (2020). Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. PubMed Central. https://www.ncbi.nlm.nih.gov/pmc/

American Public Health Association (APHA). (2012). Standard methods for the examination of water and wastewater (22nd ed.). APHA, AWWA & WPCF.

Akinbile, C. O. & Yusoff, M. S. (2011). Environmental impact of leachate pollution on groundwater supplies in Akure, Nigeria. International Journal of Environmental Science and Development, 2(1), 81–86.

Ede, V. O. & Edokpayi, J. N. (2023). Environmental pollution loads on surface water chemistry and potential ecological risks of inland aquatic ecosystems in southeastern Nigeria. Environmental Systems Research. https://springeropen.com/

Laka, A., Ali, M., Lawan, M. & Mustapha, B. (2017). Preliminary ground and surface water resources trace elements concentration, toxicity and statistical evaluation in part of Yobe State, North Eastern Nigeria. Scientific & Academic Publishing. https://www.sapub.org/

Ochuko, S. (2020). A comparative assessment of Water Quality Index (WQI) and suitability of River Ase for domestic water supply in urban and rural communities in Southern Nigeria. International Journal of Environmental Studies and Sustainability, 7(2), 45–58. https://www.semanticscholar.org/

Offiong, O. E. & Bassey, D. E. (2013). Geographical analysis of the Chad Basin. Journal of Environmental Studies.

Olaniyan, O. S. & Abimbola, A. F. (2020). Water quality and sanitation challenges in rural communities: A review of the situation in sub-Saharan Africa. International Journal of Environmental Research and Public Health, 17(13), 4734. https://doi.org/10.3390/ijerph17134734

Yadav, R. & Singh, M. (2022). Physico-chemical parameters for water quality check: A comprehensive review. Academia.edu. https://www.academia.edu/