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Assessing Physicochemical Properties of Water: A Case Study of Rivers Flowing into River Benue in Loko Town, Nasarawa State, Nigeria

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ABSTRACT

This study focused on the analysis of nine water samples from three selected rivers across three towns in Nasarawa State, Nigeria. These rivers are Antau River, Kotto River, and Loko River. The primary aim was to assess various physiochemical properties of these water samples, including pH, turbidity, electrical conductivity (EC), total dissolved solids, total organic Sulphur, total organic nitrogen (TON), and total organic carbon (TOC). Conventional methods were used to evaluate the physical and chemical characteristics of the water samples. The results from this research reveal that the water exhibits moderate alkalinity in some areas and moderate acidity in others, and it contains organic and ionizable substances. In addition, the analysis of pH (4.389), EC (398.1 µS/cm), TDS (424.7 mg/L), TOS (200.9 mg/L), TON (5.222 mg/L), and TOC (0.975 mg/L) falls within the recommended standards set by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA), with the exception of turbidity (0.7 NTU), which exceeds the recommended levels. Based on the findings of this study, it is advisable to continue using these three rivers, but regular monitoring is strongly recommended

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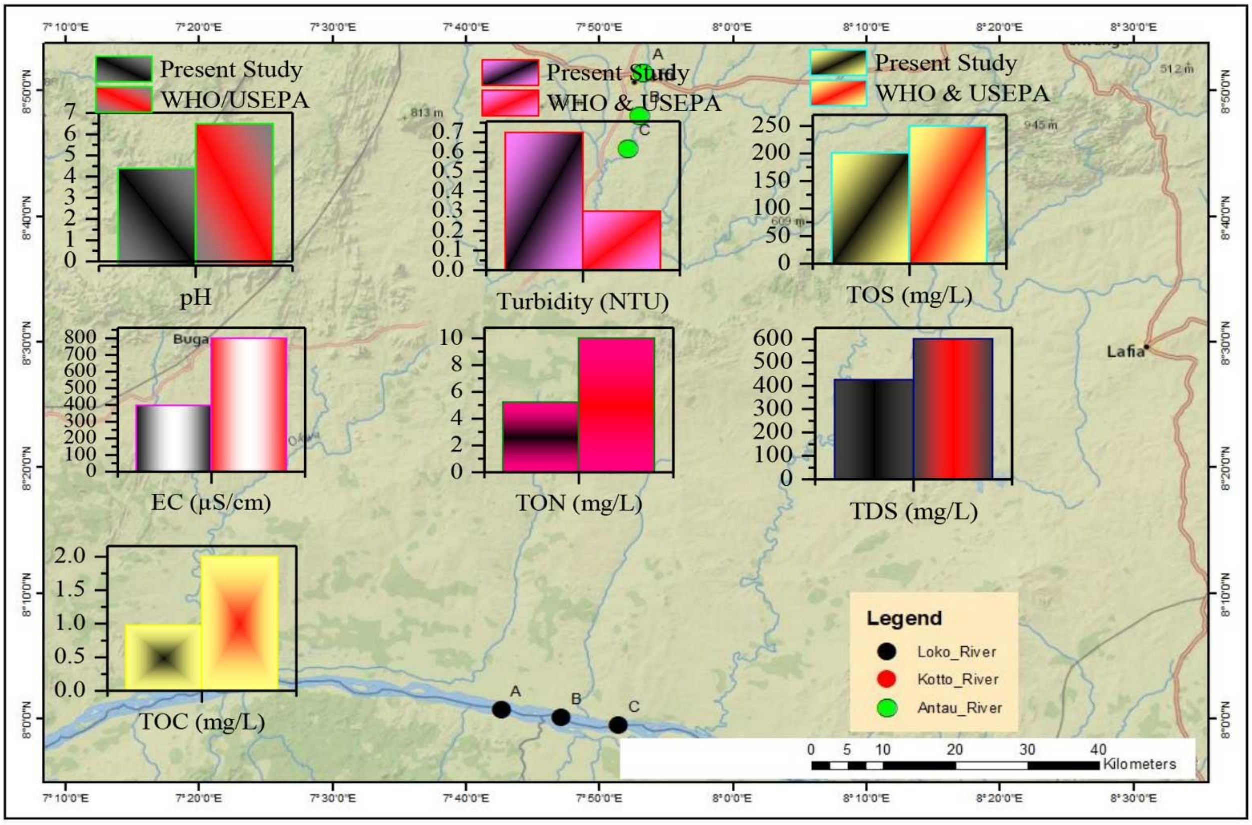
GRAPHICAL ABSTRACT



Introduction

Water is not merely a necessity for life; it constitutes life itself. Its distinctive characteristics and ubiquitous presence render it a precious resource that upholds ecosystems, promotes human well-being, and drives the operations of the natural world. The preservation and responsible management of this invaluable resource are of paramount importance for the welfare of our planet and future generations [1-4].

River water holds a position of great significance for various ecological, social, and economic reasons. Rivers serve as critical habitats for a diverse array of plant and animal species. Healthy river ecosystems foster biodiversity and help maintain ecological equilibrium. They represent a primary source of freshwater for drinking, agriculture, and industrial purposes. Their indispensability in human survival and economic activities underscores their pivotal role in irrigation for crop cultivation, ensuring food security and supporting agriculture [5-8].

Historically, rivers have served as vital trade and transportation routes. Even in contemporary times, they continue to play a role in the transportation of goods and people in many regions. Rivers provide recreational opportunities such as fishing, boating, and tourism, which contribute to local economies and enhance the quality of life. Furthermore, they are harnessed for hydropower generation, thus providing a source of renewable energy [9-12].

The pH of water is recognized as one of the principal factors influencing the concentration of metals in water solutions, their availability to plants, and their mobility [13-16]. An increase in the concentration of hydrogen ions is one of the factors that hinder the mobilization of heavy metals [17-20]. For example, Cadmium becomes mobile below a pH value of 6.5, while Lead becomes more active at a pH value of 4.00 [21,22].

Extreme pH levels can influence the taste and corrosiveness of water. Highly acidic or alkaline water can lead to digestive discomfort. Typically, pH is regulated for aesthetic reasons and often falls within the range of 6.5 to 8.5. Elevated turbidity may indicate the presence of other contaminants, affecting water aesthetics without posing direct harm. The USEPA recommends turbidity levels below 0.3 NTU (monthly average) for treated drinking water. Electrical Conductivity (EC) measures water's capacity to conduct electricity and, while not directly affecting health, can signal the presence of dissolved minerals. Elevated Total Dissolved Solids (TDS) can influence water taste but are not typically a health concern at normal levels between 800 µS/cm to 1000 µS/cm. TDS limits are often determined for taste-related reasons, with the WHO recommending levels below 600 mg/L for drinking water. Elevated sulfate levels can have a laxative effect at concentrations exceeding 500 mg/L but are generally not a health concern at lower levels. The EPA has a secondary SMCL of 250 mg/L for sulfate. Elevated nitrate levels can be harmful, particularly to infants, leading to methemoglobinemia (blue baby syndrome). The EPA sets a maximum contaminant level (MCL) of 10 mg/L for nitrate as nitrogen in drinking water. Total Organic Carbon (TOC) can suggest the presence of organic matter but is not directly harmful at typical levels. TOC limits (2 mg/L) vary according to water source and treatment [23, 24].

It is imperative to routinely monitor and regulate the physiochemical properties of river water to safeguard public health and the environment. Water treatment and strict regulatory standards are indispensable to ensure that the pH and other physiochemical properties in drinking water fall within acceptable limits. Initiatives aimed at reducing industrial pollution and promoting sustainable land use practices are also vital to safeguard river ecosystems and water quality [25-28].

The primary objective of this study was to assess various physiochemical properties of these samples, including water pH, turbidity, electrical conductivity, total dissolved solids, sulphate, SO_4, nitrate, NO_3, and total organic carbon. These three rivers were selected due to the prevalence of numerous anthropogenic activities in the area without a clear understanding of the physiochemical properties of the water they utilize.

This study contributes valuable insights into water properties and their alignment with international standards. This knowledge has the potential to benefit both local farmers and the broader community by enhancing agricultural practices, promoting environmental sustainability, and improving overall well-being in the study area.

Materials and Methods

Materials

The materials used for this study are pH meter, electrical conductivity meter, and Shimadzu TOC-VCPH with a THM-1 Model, and also a sample changer, ASI-V,

Method

Study Area

This study was conducted in Antau River, Kotto River, and Loko River, all located in Nasarawa west in Nasarawa State, Nigeria. The coordinates of the study area presented in Table 1. The map of Nasarawa state showing sampling Local Governments is depicted by Fig. 1, while that of sampling Local Governments showing sample points is depicted by Fig. 2.

The study area lies in the tropical climate that accounts for the persuading moist rainforest vegetation. The area's climate is characterized by a sonny (dry season) from November to March and a wet (rainy) season from April to October with average annual rainfall of almost 1805 mm. The rivers are the most important feeder of the river Benue which flows 210 kilometres (130 miles) into the Benue River before lastly being allowed into the Atlantic Ocean through several outlets [29-33]. The fishing and crop farming activities in the community are of paramount economic importance as most of the dwellers are fisherfolks and crop farmers who cultivate mainly rice, as well as other crops (yam, cassava, vegetables corn, guinea corn, millet, melon, and cocoyam) and also engage actively in daily fishing activities.

Measurement of Water pH

The assessment of water's pH followed established and approved methods. Water pH was determined using a 1:2:5 ratio [34]. Initially, a liter of the water sample was accurately measured. Subsequently, 25 cm^3 of distilled water was added to the sample, and the mixture was allowed to equilibrate for 5 minutes, followed by an additional hour without any disturbance. The pH was measured by immersing the electrode of a pH meter into the sample solution, and all readings were duly recorded.

Water Salinity (Electrical Conductivity Procedure)

To evaluate water salinity, a liter of water was weighed into a 125 cm^3 beaker. Distilled water (20 cm^3) was added to the beaker and stirred until a thorough mix was achieved, typically taking around 30 minutes. The electrical conductivity (EC) of the water was measured at 25 °C using a conductivity meter. Before and after each reading, the conductivity meter probe was rinsed with distilled water [35].

Total organic carbon (TOC) analysis

To ascertain the total organic carbon content, 5 g of the water sample underwent a 30-minute heating process at 20 °C. The heated water samples were then shaken. An acid treatment involving hydrochloric acid was employed to eliminate inorganic carbon, followed by passing the test through a catalyzer to eliminate carbonic acid, which is non-carbon dioxide. The resulting solution was quantified using a Shimadzu TOC-VCPH with a THM-1 Model and a sample changer, ASI-V [36].

Table 1. Geographical coordinates of the study area

Location Names	Sample Code	Longitude (E)	Latitude (N)
Antau River 1	A	7°53'15.42"	8°51'26.09"
Antau River 2	B	7°53'9.06"	8°51'7.36"
Antau River 3	C	7°53'24.09"	8°50'52.97"
Kotto River 1	A	7°42'7.70"	8°31'10.13"
Kotto River 2	B	7°42'26.11"	8°31'8.21"
Kotto River 3	C	7°42'44.54"	8°31'9.73"
Loko River 1	A	7°46'17.59"	8° 0'15.94"
Loko River 2	B	7°47'7.72"	8° 0'5.17"
Loko River 3	C	7°48'19.70"	7°59'54.85"

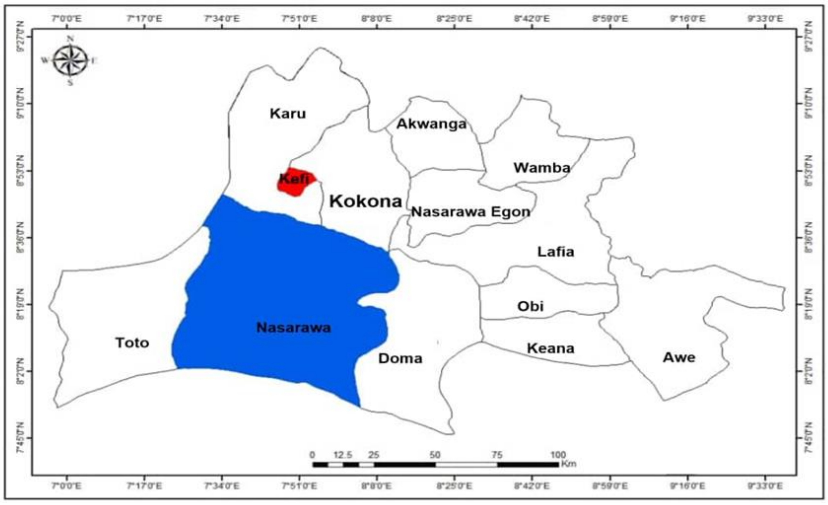


Fig 1. Map of Nasarawa State Showing Keffi and Nasarawa Local Government Area

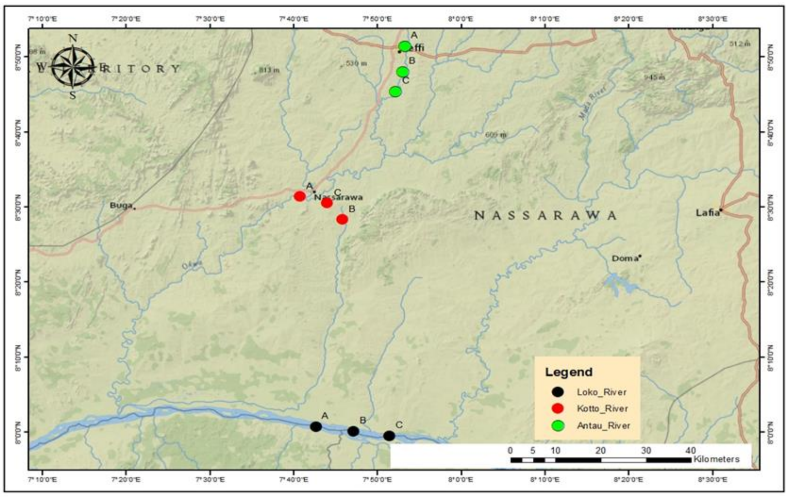


Fig 2. Map of Keffi and Nasarawa Local Government Area Showing Sample Points

Total organic nitrogen (TON) analysis

In the assessment of total organic nitrogen using the Kjeldahl technique, 0.62 g of organic compound were heated with sulfuric acid. This process converted the organic nitrogen into ammonium sulfate. The formed ammonium sulfate was further heated with an excess of sodium hydroxide (NaOH) to release ammonia (NH_3). The liberated ammonia was absorbed in a standard sulfuric acid solution. The quantity of ammonia produced was determined through titration, measuring the amount of sulfuric acid used for the reaction and estimating the remaining sulfuric acid after ammonia absorption. Standard alkali solution was used for titration [37]. The difference between the initial quantity of sulfuric acid recorded and the amount that remained after the reaction provides the quantity of acid that reacted with the ammonia reaction, as indicated by Mohammad *et al.* (2017) [38], through Equations (1) to (3).

$$N_2 + H_2S0_4 \rightarrow (NH_4)_2SO_4 \quad (1)$$

$$(NH_4)_2SO_4 + NaOH \rightarrow 2NH_3 + NaSO_4 + 2H_20 \quad (2)$$

$$\%\ of\ N = 1.4\,m \times 2\,(V - V_1)/\ Mass\ of\ organic\ compound \quad (3)$$

Where, V = volume of H_2SO_4, V_1 = Volume of NaOH, M = Molarity of H_2SO_4

Table 2. Physiochemical parameters of different points from Antau, Kotto, and Loko rivers

Parameters	Seasons	Antau River			Kotto River			Loko River		
		A	B	C	A	B	C	A	B	C
pH	Rainy	5.322	5.263	5.243	5.023	5.007	4.983	5.110	5.130	5.147
	Dry	3.643	3.787	3.870	3.290	2.527	3.323	4.123	4.063	4.140
Turbidity (FNU)	Rainy	0.970	0.567	0.607	0.803	0.330	0.590	0.432	0.657	0.557
	Dry	0.470	0.820	0.877	0.993	0.670	0.760	0.734	0.963	0.800
EC (µS/cm)	Rainy	666.34	532.34	501	215	221	263.67	486.34	507.34	489.34
	Dry	254	169	152	134	119.34	120.34	761.67	786	786.67
TDS (mg/l)	Rainy	436.3	428.3	426.6	413.6	415.6	417.6	430.9	427.9	426.3
	Dry	416.6	411.3	410.9	410.3	409.3	409.3	451.3	451.3	450.3
TOS (mg/l)	Rainy	201.2	200.9	201.2	200.2	200.5	200.3	200.7	200.5	200.9
	Dry	199.9	199.9	200.0	199.9	200.9	200.9	202.6	203.6	201.6
TON (mg/l)	Rainy	5.078	5.044	5.278	5.044	5.144	5.211	5.278	5.078	5.178
	Dry	5.178	5.144	5.244	5.211	5.311	5.378	5.344	5.478	5.378
TOC (mg/l)	Rainy	0.920	0.810	0.920	0.920	0.920	1.100	0.920	0.920	1.400
	Dry	0.920	0.920	1.100	0.920	1.100	0.820	0.920	1.100	0.920

Results and Discussion

Results

The results of the physicochemical analysis for Antau River, Kotto River, and Loko River are presented in Table 2. Accordingly, it is evident that the pH values during the rainy season in all the rivers are higher than those during the dry season. This can be attributed to the dilution from rainwater and increased leaching of alkaline substances from the soil [39,40]. However, specific pH fluctuations can vary depending on local conditions and factors such as organic matter input or pollution [41].

The turbidity of Antau River (A) is higher during the rainy season than in the dry season, which may be attributed to factors like increased soil erosion, runoff, and sediment transport caused by heavy rainfall [42,43]. The turbulent flow can carry more suspended particles and sediments into the river, leading to greater turbidity [44,45]. On the other hand, the values for turbidity in all other investigated rivers are higher in the dry season compared to the rainy season, which could be due to reduced water flow, allowing sediments and particles to settle and accumulate in the river [46]. In addition, lower rainfall may lead to less surface runoff, decreasing the input of sediments and suspended matter [47,48]. It is also noticeable that, in Antau Rivers (A, B, and C) and Kotto Rivers (A, B, and), the rainy season has higher electrical conductivity (EC) compared to the dry season. This could be attributed to the input of ions, minerals, and pollutants from various sources, as well as the increased flow rate and mixing of materials in the water [49,50]. On the other hand, the dry season has higher electrical conductivity compared to the rainy season in Loko Rivers (A, B, and C), which could be attributed to reduced dilution, higher evaporation, longer contact time with sediments, and potential human activities during the dry season compared to the rainy season [51,52]. It is equally evident that, in Antau

Rivers (A, B, and C) and Kotto Rivers (A, B, and), the rainy season has higher total dissolved solids (TDS) compared to the dry season. This could be due to the input of dissolved solids, minerals, and pollutants from various sources, as well as the increased flow rate and mixing of materials in the water [53,54]. On the other hand, the dry season has higher total dissolved solids (TDS) compared to the rainy season in Loko Rivers (A, B, and C), which could be attributed to increased evaporation, reduced dilution, longer contact time with sediments, and potential human activities that concentrate dissolved solids in the water [55,56]. The total organic Sulphur in the rainy season, as observed in the same table, is higher compared to the dry season in Antau Rivers (A, B, and C) and Kotto River (A), which could be due to the increased input of organic matter, enhanced microbial activity, fertilizer runoff, and leaching of Sulphur compounds from the environment into the water [57]. In contrast, the dry season exhibits higher values of total organic Sulphur compared to the rainy season in Kotto Rivers (B and C) and Loko Rivers (A, B, and C), which may be due to reduced dilution, prolonged contact with organic matter, and potential inputs of organic Sulphur compounds from various sources [58].

Antau River (C) has higher total organic nitrogen (TON) in the rainy season than in the dry season, which may be caused by the increased input of organic matter, enhanced microbial activity, fertilizer runoff, and leaching of organic nitrogen compounds from the environment into the water [59]. On the other hand, all other investigated rivers have higher values of total organic nitrogen (TON) in the dry season compared to the rainy season, which could be attributed to reduced dilution, prolonged contact with organic matter, and potential inputs of organic nitrogen compounds from different sources [60]. The total organic carbon (TOC) in Kotto River (C) and Loko River (C) is higher in the rainy season compared to the dry season. This could be attributed to the increased input of organic matter, enhanced microbial activity, fertilizer runoff, leaching of organic carbon compounds, and algal growth [61]. The total organic carbon (TOC) was observed to be higher in the dry season compared to the rainy season for Antau River (B and C), Kotto River (B), and Loko River (B), which could be related to reduced dilution, prolonged contact with organic matter, and potential inputs of organic carbon compounds from various sources [62,63]. However, the values of total organic carbon (TOC) in Antau River (A), Kotto River (A), and Loko River (A) showed similar values in both rainy and dry seasons, indicating stable organic matter sources, uniform hydrology, effective dilution or treatment processes, and minimal human influence on the river's ecosystem [64]. Nevertheless, seasonal variations are more common due to changing environmental factors [65]. The mean of all the results in Table 2 was summarized and presented in Table 3. Figs. 2 to 8 were used to compare the summary of results presented in Table 3 with the guidelines provided by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

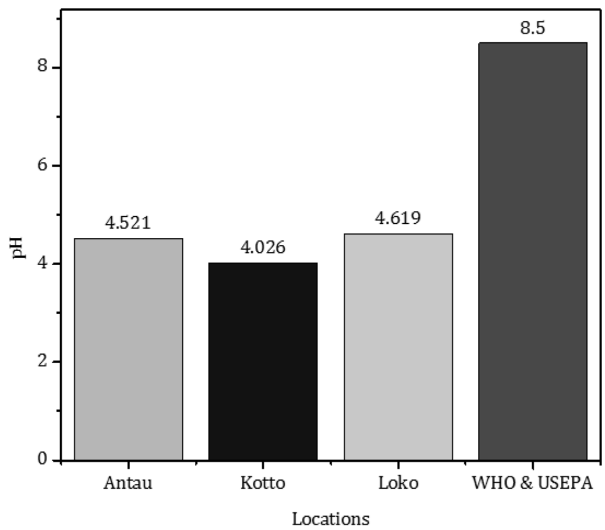


Fig 3. Comparison of the pH for the present work with the WHO/USEPA

Table 3. Summary of physiochemical parameters of River Antau, Kotto, and Loko

Parameters	Seasons	Antau	Kotto	Loko	Mean ± SD	CV	WHO & USEPA
pH	Rainy & Dry	4.521	4.026	4.619	4.389±0.318	7.243	6.5-8.5
Turbidity (NTU)	Rainy & Dry	0.719	0.691	0.691	0.700±0.016	2.308	0.3
EC (µS/cm)	Rainy & Dry	379.2	178.9	636.2	398.1±229.2	57.59	800-1000
TDS (mg/L)	Rainy & Dry	421.7	412.6	439.7	424.7±13.79	3.248	600
TOS (mg/L)	Rainy & Dry	200.5	200.5	201.7	200.9±0.693	0.345	250
TON (mg/L)	Rainy & Dry	5.161	5.217	5.289	5.222±0.064	1.229	10
TOC (mg/L)	Rainy & Dry	0.932	0.963	1.030	0.975±0.050	5.137	2

pH measurement

From Fig 3 and Table 3, it is evident that mean pH value is 4.389, with Loko River, having the highest pH value of 4.619, followed by Antau River with 4.521, and Kotto River with the lowest value at 4.026. Importantly, all the pH values fall within the recommended range of 6.5 to 8.5 as stipulated by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

Turbidity (NTU) Measurement

In terms of turbidity presented in Table 3 and Fig 4, with a mean of 0.7 NTU, Antau River records the highest value at 0.719 NTU, followed by Kotto and Loko Rivers at 0.691 NTU. Notably, these turbidity values exceed the recommended limit of 0.3 NTU set by both the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

Electrical Conductivity (EC) Measurement

Regarding electrical conductivity (EC) (see Table 3 and Fig 5), with a mean value of 398.1 µS/cm, it was observed that Loko River has the highest value at 636.2 µS/cm, followed by Antau River at 379.2 µS/cm, and Kotto River with the lowest value at 178.9 µS/cm. Importantly, all the EC values fall within the recommended range of 800 to 1000 µS/cm as specified by both the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

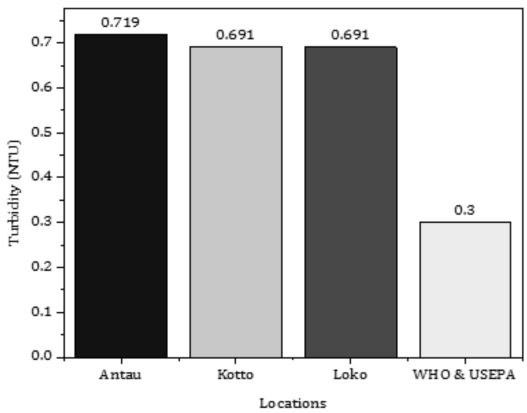


Fig 4. Comparison of the turbidity for the present work with the WHO/USEPA

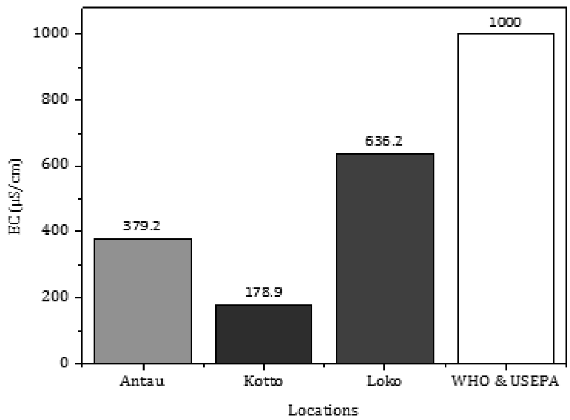


Fig 5. Comparison of the electrical conductivity for the present work with the WHO/USEPA

Total Dissolved Solids (TDS) Measurement

In terms of Total Dissolved Solids (TDS), with a mean value of 424.7 mg/L, it was observed that Loko River has the highest value at 439.7 mg/L, followed by Antau River at 421.7 mg/L, and Kotto River with the lowest value at 412.6 mg/L. Significantly, all the TDS values are well within the recommended limit of 600 mg/L as specified by both the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA), as shown in Table 3 and plotted in Fig 6.

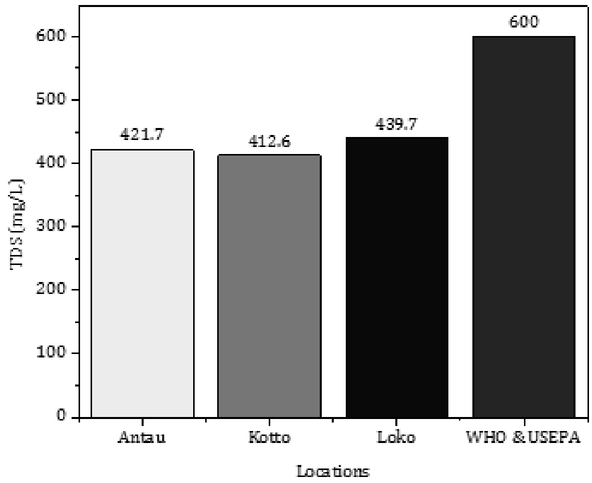


Fig 6. Comparison of the total dissolved solids for the present work with the WHO/USEPA

Total Organic Sulphur (TOS) Measurement

In the case of Total Organic Sulphur (TOS), with a mean value of 200.9 mg/L, it was observed that Loko River has the highest value at 201.7 mg/L, followed by Antau and Kotto Rivers with the lowest value at 200.5 mg/L. Importantly, all the TOS values are comfortably within the recommended limit of 250 mg/L as specified by both the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA), as provided in Table 3 and plotted in Fig 7.

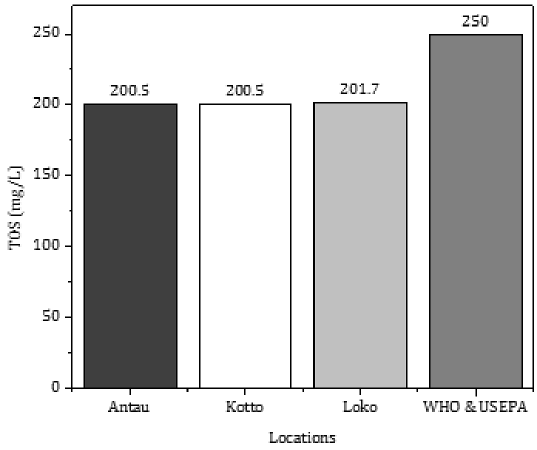


Fig 7. Comparison of the total organic sulphur for the present work with the WHO/USEPA

Total Organic Nitrogen (TON) Measurement

According to Table 3 and Fig 8, Total Organic Nitrogen (TON), with a mean value of 5.222 mg/L, was observed to be the highest in Loko River, with a value of 5.289 mg/L. It was followed by Kotto River, with a TON value of 5.217 mg/L, and Antau River had the lowest TON value at 5.161 mg/L. Significantly, all the TON values comfortably fall within the recommended limit of 10 mg/L set by both the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

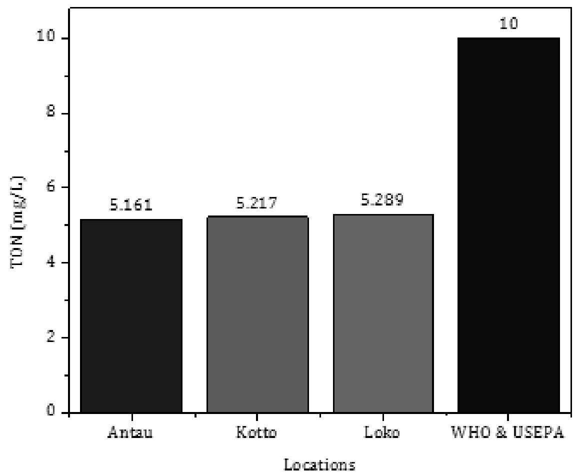


Fig 8. Comparison of the total organic nitrogen for the present work with the WHO/USEPA

Total Organic Carbon (TOC) Measurement

According to Fig 9, Total Organic Carbon (TOC), with a mean value of 0.975 mg/L, was found to be the highest in Loko River, with a value of 1.03 mg/L, followed by Kotto River with a value of 0.963 mg/L, then Antau River which had TOC values of 0.932 mg/L. Importantly, all these TOC values are well within the recommended limit of 2 mg/L, as outlined by both the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

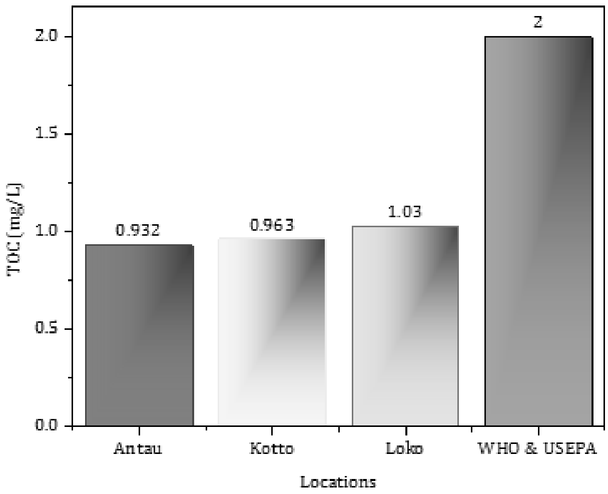


Fig 9. Comparison of the total organic carbon for the present work with WHO/USEPA

Conclusion

The study has furnished valuable data regarding the physicochemical attributes of water samples collected from selected rivers within Antau, Kotto, and Loko, Nasarawa State, Nigeria. The results of the physicochemical analysis indicate that the rivers exhibit pH levels that vary from moderately basic to moderately acidic, with a composition comprising a blend of organic, ionizable, and inorganic substances. Furthermore, the study acknowledges the potential environmental consequences linked to human activities. It is noteworthy that, in general, the findings of the physicochemical analysis of the water samples align with established standard limits, with the exception of turbidity. This implies that the water in the surveyed rivers complies with regulatory requirements for various parameters, signifying its suitability for agricultural purposes while upholding environmental standards.

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Declarations

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Consent to participate: Not applicable.
Consent for publication: Not applicable

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