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ANALYSIS OF THE PHYSICO-CHEMICAL CHARACTERISTICS OF MBIAKONG RIVER IN SOUTH EAST NIGERIA

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ABSTRACT

The investigation into the Physico-Chemical characteristics of Mbiakong River in South East Nigeria spanned from March 2021 to February 2022. The study employed standard analytical methods to assess selected water quality parameters, and the resulting data underwent various statistical analyses. Microsoft Excel was utilized for graphical representations, while SPSS facilitated descriptive statistics. Analysis of Variance (ANOVA) was employed to determine spatial and seasonal variations in physico-chemical parameters. The mean values for key parameters were as follow: Air Temperature (30.93 ± 0.72 °C), Water Temperature (25.29 °C ± 1.12 °C), pH (6.45 ± 0.17), Electrical Conductivity (EC) (361.78 ± 19.02 µS/cm), Total Dissolved Solids (TDS) (192.22 ± 13.24 mg/l), Dissolved Oxygen (DO) (7.31±0.98 mg/l), Biochemical Oxygen Demand (BOD) (3.42 ± 0.37 mg/l), Hardness (35.93 ± 1.02 mg/l), Alkalinity (39.64 ± 01.63 mg/LCaCO3), Chloride (24.82 ± 0.72 mg/l), Phosphate (27.28 ± 4.11 mg/l), Turbidity (18.64 ± 1.04 NTU), Transparency (34.67 ± 4.64 cm), Sulphate (4.51 ± 0.51 mg/l), and Nitrate (138.10 ± 10.19 mg/l). Significance was observed in all measured Physico-Chemical parameters except for Turbidity, Chloride, and Phosphate. The elevated nutrient levels identified in the study indicate a rich aquatic environment that greatly supports primary and secondary productivity.

KEY WORDS: Water Quality, Physico-Chemical, Variations, Mbiakong River, Parameters, Season

INTRODUCTION

Water is a crucial element for the sustenance of all known life forms, and its quality is a matter of utmost importance to humanity due to its direct connection to metabolic processes supporting human health (WHO, 2012). According to Tyagi *et al.* (2013), water quality encompasses the physical, chemical, and biological factors influencing species composition, diversity, stability, production, and physiological conditions of indigenous populations. The concentration of Physico-chemical parameters in water bodies can vary seasonally, daily, or even hourly. Several researchers, including Asuquo and Uko, (2019), Ekwu (2007), Essien-Ibok *et al.* (2010), Nkwoji *et al.* (2010) and Joydas and Damodaran (2009) have advocated for the use of invertebrates as bio-indicators to assess water quality. Top of Hashim *et al.* (2021) employed the use of The Mann- Kendall Test and Send's Slope method in assessing Water Quality. The interaction among the physical, chemical, and biological attributes of water frequently results in the generation of phytoplankton, and their compositions are shaped by these factors, as highlighted by Ekwu and Sikoki (2010) and Samuel *et al.* (2015). Consequently, any disruptions in these elements may influence the arrangement of phytoplankton, potentially impacting both water quality and the aquatic ecosystem's fish population, as noted by (Asuquo and Uko, 2019, Mustapha and Nabegu, 2011, Ekwu and Awakessien, 2013, Essien-Ibok *el al*, 2010)

Otogo *et al*. (2021) conducted a study examining the spatiotemporal variations in PO_4, NO_3, and SO_4, along with various physicochemical parameters in the Cross River estuary, Nigeria. The obtained values for Physico-Chemical parameters fell within ranges supportive of life and ecosystem health. Despite the ecosystem being deemed unpolluted, the study identified elevated nutrient concentrations, reduced dissolved oxygen (DO), and increased biochemical oxygen demand (BOD_5) compared to earlier research in the estuary. This suggests an augmented influx of extraneous substances. The higher water temperatures recorded may be linked to marine heat waves, potentially exacerbated by global warming, posing detrimental effects on the estuarine living resources. This will expose basic data on the present fauna of the river basin and equally provide information on the basin's health status.

MATERIALS AND METHODS

Study Area

The study was conducted in Mbiakong River (Fig. 1). Mbiakong river lies between latitude 5o 2′ 57.84"N and longitude 8o 3′5.04"E within the tropical rainforest of Niger Delta region, Nigeria. The Cross River estuary is regarded as an extension of the shallow continental shelf region of Nigeria, classified as a drowned river-mouth type of estuary. The annual rainfall received here is about 2500 mm with a mean annual temperature of 32 °C and a relative humidity of 75 %. The banks of the river were mostly covered with grass and other tropical riparian vegetation (Esenowo *et al.*, 2017).

Data Collection

The research spanned 12 months, from March 2021 to February 2022, and involved sampling during morning hours from 8:00 to 10:00 am, encompassing both the wet and dry seasons. One-litre containers were used to collect water samples.Water sample for biochemical oxygen demand was collected in Amber glass stopper bottles. The bottles were carefully filled without trapping air bubbles (APHA, 2005). Secchi Disc transparency was measured at each station using a Secchi Disc and the depth expressed as Zsd in meters. Some parameters such as temperature, pH, electrical conductivity and total dissolved solids were also determined in-situ using Hanna Instrument (model HI 98129) while others were transported to the laboratory for the analysis of Physico-Chemical parameters.

RESULTS

Air temperature of Mbiakong River ranged from

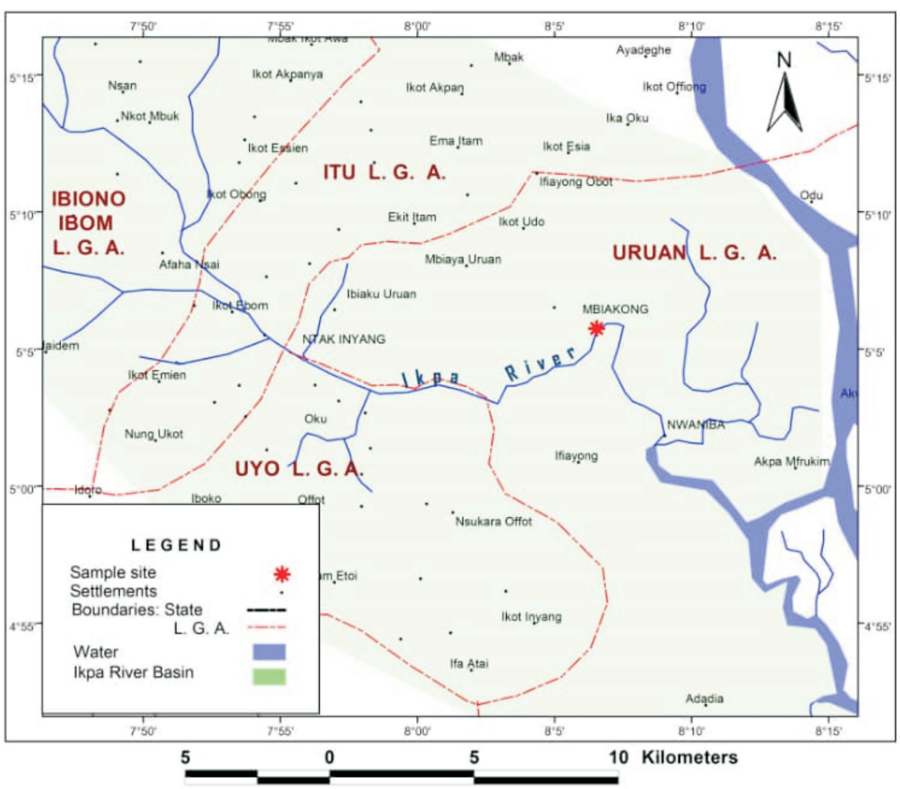

Fig. 1. Map showing Mbiakong River

23.00 °C to 37.30 °C. The maximum value of 37.30 °C occurred in December 2021 with the highest mean value of 31.15 ± 1.29 (Table 1). The mean air temperature for the wet season (28.02 ± 1.06 °C) was lower than the dry season value 35.54 ± 0.54°C and there was a significant difference between seasons at ($p < 0.05$). The water temperatures ranged from 17.00 °C - 34.90 °C with a mean value of 24.50 °C ± 1.77 °C during the study period (Table 1). The lowest water temperature of 17.00°C was recorded in July, 2021 while the highest water temperature of 35.00 °C was recorded in the month of November, 2021. The monthly variations in water temperatures of Mbiakong River are as presented in Fig. 2. The mean water temperature for the wet season 28.02 ± 1.06 °C was lower than the dry season value 35.54 ± 0.54 °C and there was a significant difference between seasons ($p < 0.05$). The monthly variations in the hydrogen ion concentration (pH) are presented in Fig. 2. The river was mostly in the range of 5.00 - 7.90 with a mean of 6.4 ± 0.31. The lowest pH 5.00 was recorded in September, 2021 while the highest 8.0 was recorded in December, 2022. The mean pH for the wet season 6.23 ± 0.38 was higher than the dry season value of 6.80 ± 0.51 and there was a significant difference between seasons ($p > 0.05$). Monthly variations showed no significant difference in pH ($p > 0.05$). The Dissolved Oxygen fluctuated between 2.30 mg/l and 9.00 mg/l with a mean of 5.60 ± 0.68 mg/l throughout the study period. The lowest DO concentration was in the month of March, 2021 (2.30 mg/l) while the highest was in January, 2022 (9.00 mg/l). The monthly variations of DO are shown in Fig. 2. There was a significant difference ($p < 0.05$) between the DO concentrations (3.80 ± 0.31 mg/l) for the wet season and the dry season (8.12 ± 0.30 mg/l) (Table 2).

The conductivity ranged from 200.00 µS/cm - 548.00 µS/cm with a mean of 353.60 ± 34.81µS/cm. The lowest value (200.00 µS/cm) was recorded in the month of October, 2021 while the highest (548.00 µS/cm) was recorded in July, 2021 (Fig. 3). The mean conductivity of the river was higher during the wet season (402.00 ± 49.07/cm), than the dry season (284.72 ± 30.09µS/cm) with a significant difference between seasons ($p < 0.05$).The TDS values measured at Mbiakong River ranged from 90.50 mg/l - 313.20 mg/l with a mean of 173.20 ± 20.14 mg/l during the study period (Table 1). The lowest TDS value of 90.50 mg/l was recorded in March, 2021 while the highest value of 313.20 mg/l was recorded in December, 2021. The mean TDS for the wet season 124.20 ± 11.90 mg/l was lower than the dry season value 241.68 ± 19.19 mg/l which showed a significant difference ($p < 0.05$). Hardness ranged from 29.00 mg/l - 45.00 mg/l with a mean of 35.93 ± 1.02 mg/l during the study period August, 2021 recorded the lowest value of 29.00 mg/l while the highest value of 45.00 mg/l was recorded in January 2022. The mean hardness for the wet season 31.36 ± 0.61 mg/l was lower than the dry season value of 42.42 ± 0.88 mg/l and there was a significant difference between seasons ($p < 0.05$). Alkalinity ranged from 28.30 mg/l $CaCO_3$ - 59.00 mg/l $CaCO_3$ with an overall mean of 44.92 ± 2.55 mg/l $CaCO_3$ (Table 1). December, 2021 recorded the highest value of 59.00 mg/l $CaCO_3$ and March, 2021 recorded the lowest value of 28.30 mg /l $CaCO_3$. The mean value for the wet season 39.66 ± 2.06 mg/l $CaCO_3$ was lower than the dry season 52.29 ± 3.27 mg/l $CaCO_3$ (Table 2).

The Transparency values ranged from 9.20 cm - 72.00 cm with a mean of 32.83 ± 7.91 cm (Table 1). The lowest value of 9.20 cm was recorded in July, 2021 in while the highest value of 72.00 cm was recorded in January, 2022 (Fig 3). The mean

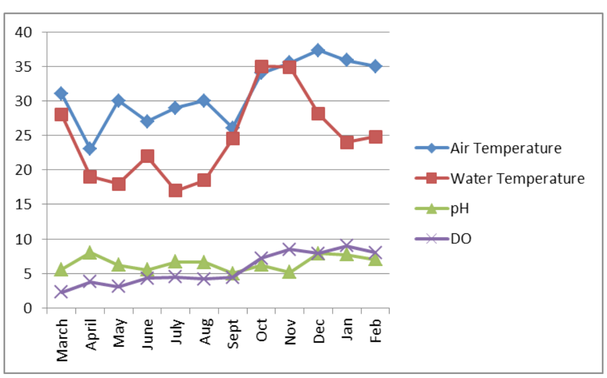

Fig. 2. Monthly variations in Air temperature, Water temperature, pH & DO

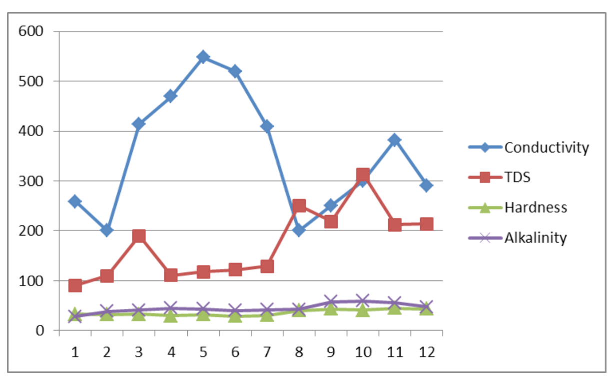

Fig. 3. Monthly variations in Conductivity, TDS, Hardness & Alkalinity

transparency for the wet season 11.53 ± 1.08 cm was lower than the dry season value 62.66 ± 5.31 cm. The Turbidity values ranged from 13.00 NTU - 33.20 NTU with a mean of 20.78 ± 2.00 NTU. The lowest value of 13.00 NTU was recorded in January, 2022 while the highest value of 33.20 NTU was recorded in September, 2021. The mean turbidity for the wet season 23.30 ± 2.97 NTU was higher than the dry season value 17.26 ± 1.68. The value for Chloride fluctuated throughout the study period and it ranged from 20.00 mg/l - 34.00 mg/l with a mean of 25.57 ± 1.44 mg/l (Table 1). The lowest value of 20.00 mg/l was recorded in November, 2021 while the highest value of 34.00 mg/l was recorded in the month of June, 2021. The mean value for the wet season (25.96 ± 2.21 mg/l) was higher than the dry season value of 25.02 ± 1.82 mg/l with no significant difference ($p > 0.05$) between seasons (Table 2). The phosphate values ranged from 15.20 mg/l - 81.00 mg/l with a mean of 51.10 ± 6.95 mg/l (Table 1). The month of October, 2021 recorded the lowest value of 15.20 mg/l while the highest value of 81.00 mg/l was recorded in the month of September, 2021 (Fig 3). The mean value for the wet season 67.30 ± 6.10 mg/l was higher than the dry season value of 28.42 ± 4.54 mg/l and there was no significant difference ($p > 0.05$) between seasons (Table 2).

The sulphate values ranged from 0.21 mg/l - 8.50 mg/l with a mean of 4.63 ± 0.81 mg/l (Table 1). The month of March, 2021 recorded the lowest value of 0.21 mg/l in while the highest value of 8.50 mg/l was recorded in the month of February, 2022 (Fig. 4). The mean value for the wet season 2.54 ± 0.46 mg/l was lower than the dry season value of 7.56 ± 0.47 mg/l which showed a significant difference between seasons ($p < 0.05$)(Table 2). The value for Nitrate in fluctuated throughout the study period and it ranged from 71.00 mg/l - 240.30 mg/l with a mean of 144.29 ± 18.44 mg/l (Table 1 & 2). The lowest value of 71.00 mg/l was recorded in the month of October, 2021 while the highest value of 240.30 mg/l was recorded in the month of June, 2021(Fig. 4). The mean value during the wet season (190.51 ± 14.32 mg/l) was higher than the dry season (79.59 ± 4.31 mg/l) and showed a significant difference ($p < 0.05$) between seasons. The value for BOD fluctuated throughout the study period and it ranged from 0.80 mg/l - 6.50 mg/l with a mean of 3.36 ± 0.66 mg/l (Table 1). The lowest value of 0.80 mg/l was recorded in the month of April, 2021 while the highest value of 6.50 mg/l was recorded in the month of February, 2022. The mean value for BOD during the wet season (1.66 ± 0.26 mg/l) was lower than the dry season (5.82 ± 0.33 mg/l) with a

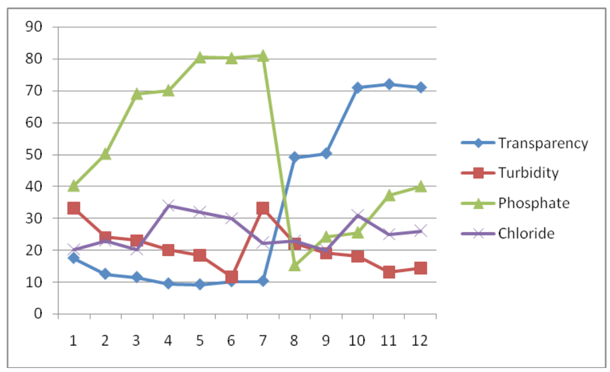

Fig. 4. Monthly variations in Transparency, Turbidity, Phosphate & Chloride

Table 1. Mean and Standard Error values of Physico-Chemical parameters of Mbiakong River March 2021 – February, 2022

Parameters	Range	Mean ± Standard error
Air temperature (°C)	23.00 - 37.30	31.15 ± 1.29
Water temperature (°C)	17.00 - 34.90	24.50 ± 1.77
pH	5.00 - 7.90	6.4 ± 0.31
DO (mg/l)	2.30 - 9.00	5.60 ± 0.68
Conductivity (µS/cm)	200.00 - 548.00	353.60 ± 34.81
TDS (mg/l)	90.50 - 313.20	173.20 ± 20.14
Hardness (mg/l $CaCO_3$)	29.00 - 45.00	35.93 ± 1.02
Alkalinity (mg/l $CaCO_3$)	28.30– 59.00	44.92 ± 2.55
Transparency (cm)	9.20- 72.00	32.83 ± 7.91
Turbidity (NTU)	13.00- 33.20	20.78 ± 2.00
Chloride (mg/l)	20.20- 34.00	25.57 ± 1.44
Phosphate (mg/l)	15.20 – 81.00	51.1 ± 6.95
Sulphate (mg/l)	0.21 - 8.50	4.63 ± 0.81
Nitrate (mg/l)	71.00 – 240.30	144.29 ± 18.44
BOD (mg/l)	0.80 – 6.50	3.36 ± 0.66

significant difference ($p < 0.05$) between seasons (Table 2).

DISCUSSION

This result of this investigation is similar to the findings of Ekwu and Awakessien (2013) and Ekpo *et al.* (2012) who reported a range of 23.00 °C - 37.50 °C in Ikpa River in their separate studies. Rise in air temperature results in corresponding rise in water temperature. According to WHO (2011), high water temperature enhances the growth of micro-organisms and may increase problems related to taste, odor, color and corrosion Seasonal variability of water temperature showed highertemperatures during the dry than the wet season. The result of this finding is similar to the findings documented by Ekpo *et al.* (2012) who reported a range of 15.30 °C - 35.20 °C but slightly different from the reports of Esenewo *et al*. (2017) with the range of 26.00 - 31.00 °C in Nwaniba River and Asuquo and Uko (2019) who recorded a range of 26.3 - 26.5 °C Ikot Okoro River. The temperature of river water may be influenced by a whole lot of factors including latitude, altitude, and degree of insulation, substrate composition, turbidity, ground/rain water inflows, wind, and vegetation cover (Ekpo *et al*., 2012; Asuquo and Ukoh, 2019). In this study, the temperature could have been influenced by vegetation cover. The river was mostly in the neutral/alkaline range of 5.00 - 7.90, with a mean of 6.4 ± 0.31. The lowest pH 5.00 was recorded in September, 2021 while the highest 8.0 was recorded in December, 2022. Similar trends documented by Ekpo *et al.* (2012); Ebigwai *et al*. (2014); Esenewo *et al*. (2017); Salisu, 2017; and Essien-Ibok *et al*. (2010). This might be due to high photosynthetic activities because during photosynthesis, aquatic plants remove carbon dioxide from the water.

Jayalakshmi *et al.* (2011) reported that electric conductivity is a measurement of water's current and is directly related to the concentrations of ionized substance in the water and the levels affected by the EC of water are a direct function of its total dissolved solids, organic compounds and temperature (Jayalakshmi *et al*., 2011). The lowest value (200.00 µS/cm) was recorded in the month of October, 2021 while the highest (548.00 µS/cm) was recorded in July, 2021. The mean conductivity of the river was higher during the wet season (402.00 ± 49.07/cm), than the dry season (284.72 ± 30.09µS/cm). Similar result was reported by Ekpo *et al*. (2012), according to their findings, it was recorded that the high wet season conductivity value may be caused by the positive effect of rainfall and

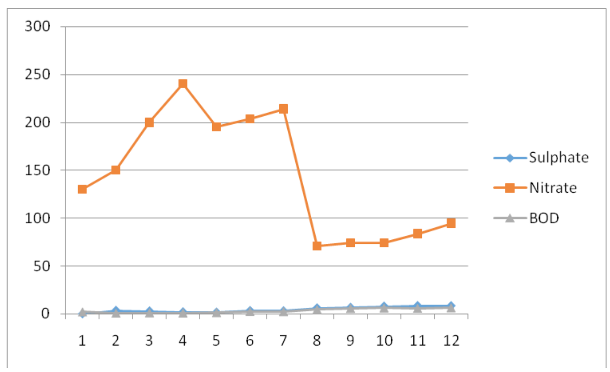

Fig. 5. Monthly variations in Sulphate, Nitrate & BOD

Table 2. Seasonal variations of Physico-Chemical Parameters of Mbiakong River

Parameters	Mean		
	Wet	Dry	Total
Air Temp. (°C)	28.02 ± 1.06	35.54 ± 0.54	31.15 ± 1.29
Water Temp. (°C)	21.00 ± 1.52	29.36 ± 2.38	24.50 ± 1.77
pH	6.23 ± 0.38	6.80 ± 0.51	6.4 ± 0.31
EC (µS/cm)	402.80 ±49.07	284.72 ± 30.07	353.60 ± 34.81
TDS (mg/l)	124.21 ± 11.90	241.68 ± 19.19	173.20 ± 20.14
DO (mg/l)	3.80 ± 0.31	8.12 ± 0.30	5.60 ± 0.68
BOD (mg/l)	1.60 ± 0.26	5.82 ± 0.33	3.36 ± 0.66
Hardness (mg/l)	31.36 ± 0.31	8.12 ± 0.30	35.93 ± 1.02
Alkalinity (mg/l$CaCO_3$)	39.66 ±2.06	52.29 ± 3.27	44.92 ± 2.55
Sulphate (mg/l)	2.54 ± 0.46	7.56 ± 0.47	4.63 ± 0.81
Chloride (mg/l)	25.96 ± 2.21	25.02 ± 1.82	25.57 ± 1.44
Phosphate (mg/l)	67.30 ± 6.10	28.42 ± 4.54	51.1 ± 6.95
Nitrate (mg/l)	190.51 ± 14.32	79.59 ± 4.31	144.29 ± 18.44
Turbidity (NTU)	23.30 ± 2.97	17.26 ± 1.63	20.78 ± 2.00
Transparency (cm)	11.53 ± 1.08	62.66 ± 5.31	32.83 ± 7.91

subsequent nutrient-load of surface runoffs together with the high organic matter contents brought into the aquatic system. Higher conductivities during the dry season have been reported by many authors, example, Ibuya River (Akponine, 2016) and River Saye (Salisu, 2017) which they attributed to high evapo-transpiration rates resulting in concentration of ions (dissolved solids) in the water bodies. Ewa *et al.* (2011) reported that high level of EC could be corresponding with high value of TDS as affirmed in this study. Ekwu and Awakessien (2013) also reported elevated levels of Turbidity and TDS in Ikpa River, from sand dredging activities by humans. Environmental Stressors have also been documented in Ugbalo River by Olatunji *et al.* (2023).

The highest TDS obtained in dry season December (313.20 mg/l) might be as a result of increased rate of evaporation thereby increasing the concentration of dissolved solutes in the water column (Samuel *et al.,* 2015). The lowest wet season TDS in March (90.50 mg/l) could be attributed to low wet season temperature, which promoted poor dissolution of solute in water and reduced evaporation rate temperature as well as low precipitation in the wet season. In this study, TDS values in dry season was similar to those of Ekpo *et al.* (2012) and Ndimile *et al.* (2017) with high TDS levels in the dry season when compared with the wet season.This possibly explains increase in solubility at high temperature. The lowest DO concentration was recorded in the month of March (2.30 mg/l) while the highest was in December (22.50 mg/l). The DO values for the first few months were considerably low. This could be as a result of anthropogenic activities from surrounding areas into the water during the period of collection. This result corroborates with the findings of Ayobahan *et al.* (2014) who reported that fluctuations of dissolved oxygen level is attributed to the presence of organic pollutants in water body majorly through human activities. The decrease in dissolved oxygen observed during wet season could also be due to phytoplankton bloom and decomposition of allochthonous organic materials taking place at this time of the year. Similar observation was made by Saksena and Kaushik (2011).

The higher values of hardness during the dry season could be as a result of low water levels and the concentration of ions, and the lower wet season value could be due to dilution as reported in Kolo and Oladimeji (2004) for Shiroro Lake. Higher hardness values are mainly due to weathering of Ca and Mg-rich rocks in the area (Zeitoun and Mehana, 2014). Kiran (2010) reported that water can be categorized according to the degree of hardness, as soft (0 - 75 mg/l) moderately (75 - 150 mg/l) hard, hard (150-300 mg/l) and above 300 mg/l as very hard. The trend in hardness values in this study showed that the river was soft. The highest value of Alkalinity 59.00 mg/l $CaCO_3$ was recorded in the dry season while the lowest value of 28.30 mg/l $CaCO_3$ was recorded during the wet season. This is in conformity with the findings of Essien-Ibok *et al.*, (2010); Ekpo *et al.*, (2012) and Salisu, (2017). The higher alkalinity observed in dry season indicates low carbonate bicarbonate ions in the water reflecting the absence of limestone in the water basin. This seasonal trend is in line with electrical conductivity and salinity suggesting limiting role of freshwater discharge into the water body (Ekwu and Sikoki, (2010), Chindah and Braide, (2004). Relative increase in alkalinity and electrical conductivity in dry season could be due to the extended dry season period, high evaporation and more intrusion of point source effluents. This finding is similar to the studies of Wetzel and Liken (2001) and Michael and Lieberherr (2015).

The lowest value of transparency (9.20 cm) was recorded in July, 2021 in while the highest value of 72.00 cm was recorded in January, 2022. The higher value of transparency recorded during dry season compared to that of the wet season could be due to absence of floodwater, surface run-offs and settling effect of suspended materials that followed the cessation of rainfall (Akponine, 2016). The significantly higher turbidity recorded during the wet season compared to the dry season may be due to heavy rainfall leading to an increase in phytoplankton abundance and decay of organic matter in suspension in addition to surface runoff. Similar higher turbidity values were also recorded by many workers as compared to the limits set by WHO (Akan *et al.* (2008); Mebrahtu and Zerabruk, (2011); Pal *et al.* (2013}; Akponine, (2016). Higher value of chloride (34.00 mg/l) was recorded in wet season. This observation correlates with the findings of Farombi and Adelowo (2014) on the study of variation of biotic conditions of water Quality of river Osun, Osun State Nigeria. The mean value for the wet season (25.96 ± 2.21 mg/l) was higher than the dry season value of 25.02 ± 1.82 mg/l with no significant difference ($p > 0.05$) between seasons. The results of this study showed that maximum phosphate concentration was 81.00 mg/l and minimum was 15.20 mg/l. It is evident from this work that seasonally, phosphate concentration in the river was more in wet season and lower in the dry season. Highest seasonal values reported during wet season are in conformity with the findings of Verma *et al.* (2012). The recorded highest phosphate value in might be due to the biodegradation of organic matter by bacteria (Saksena and Kaushik, 2011).

From this study, it was noted that the highest value of nitrate (240.30 mg/l) was recorded in the wet season and could be attributed to the buildup of nitrate from extensive farming activities during the wet season. Lowest (71.00 mg/l) was recorded in the dry season. The low rainy season nitrate could be due to high dilution caused by the rains. Similar observation was made by Thilag *et al.* (2007) and Garg *et al.* (2006). The lowest Sulphate value was recorded during the wet season (0.21 mg/l) while the dry season had the highest value (8.50 mg/l). The higher values can be attributed to the discharge of Sulphate containing municipal waste from towns; and surface runoff that contain organic fertilizers from agricultural activities undertaken by the river side. BOD was recorded to be highest in dry season (6.50 mg/l) and lowest dry season (0.80 mg/l). Ekpo *et al.* (2012) and Soom *et al*. (2018) recorded similar results. The increased level during the dry season might have resulted from reduced water level due to increased evapotranspiration rate occasioned by the high temperature.

CONCLUSION

The study of Mbiakong River in the South East Nigeria revealed significant spatial and seasonal variations in Physico-Chemical parameters. While most parameters showed significance, turbidity, chloride, and phosphate did not. Elevated nutrient levels indicated near eutrophic water quality conditions, underscoring the need for protective measures against further nutrient loading. The findings underscore the importance of informed decision-making and environmental management strategies to ensure the health and sustainability of the Mbiakong River. Interdisciplinary collaboration and community engagement are crucial for successful conservation efforts in this river.

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