Spatial and Seasonal Variations in Water Quality Parameters of a Humid Tropical River, Niger Delta, Nigeria.

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Abstract: Studies on the spatial and seasonal variation in water quality parameters of a humid tropical river within the Niger Delta was investigated for 10 months from November 2017, to August, 2018. water samples were collected from three stations along the river course and analyzed using standard methods. All the parameters analyzed varied across stations which was attributed the levels of human activities within each of the station and proximity to land. However, there was no significant spatial variation in all the parameters exception of temperature. Similarly, studied parameters showed significant difference for TSS and transparency. TSS, TDS, EC and Alkalinity exceeded the WHO permissible limit for portable water indicating the presence of human mediated impacts on the river system. Therefore, constant monitoring of the River is recommended to forestall any changes that might deteriorate the quality of water making it unfit for domestic and other usage.

Keywords: Spatial, Temporal, Variation, Water Quality, Human Mediated Impacts.

1.0 Introduction

Water is the most important natural resource for the existence of life on earth. It is a medium in which all living processes take place. Water supports all forms of biological resources including plant and animal life. A complete assessment of a water body is however based on appropriate monitoring of its hydrology, physico-chemistry and biology (Meybeck and Helmer, 1996). In river systems, nutrients, sediment and organisms move according to the water current. This flow is a controlling factor in the distribution and abundance of organisms. Variation in hydrologic regime are undoubtedly of great importance, and responsible for main changes in a great number of environmental factors related to each other and to the plankton, such as current velocity, turbidity and suspended solids (Olawale, 2016).

However, the quest for technological advancement and increasing industrial activities to satisfy the growing need of human and improve on civilization has created unexpected damages to our environment (Salim, 2002). These damages are potential threats to the water quality and several biological activities of the ecosystem. Man-induced environmental damages resulting from these activities have created various problems in recent times to most water bodies (Rolph and David, 2004). Mbo River is not an exception to these threats.

Estuaries are partially enclosed bodies of water along coastlines, where fresh water and salt water meet and mix. They act as transition zones between oceans and continent. An estuary has a free connection to the ocean and fresh water inputs from rivers dilute the estuarine salt content. Estuaries are vital habitat for thousands of marine species and they have been called the "nurseries of the sea" because of the protected environment and abundant of food in this ecosystem provide an ideal location for fish to reproduce. Most commercially important fish species spend some part of their life cycles in the estuaries.

The seasonal variations in precipitation, surface runoff interflow, groundwater flows and out flows, have a strong effect on river discharge and subsequently on the concentration of the dissolved and non-dissolved matter in rivers (Shrestha and Kazama, 2007). River pollution is a growing problem in developing countries such as Nigeria, as much as 70 percent of industrial waste and 80 percent of domestic waste water flow untreated into rivers. In Nigeria, the input of environmental pollutants in aquatic system is a common phenomenon (Olatayo, 2014).

The aquatic ecosystems are the final sink to every human activity on land. The impacts of anthropogenic activities on the aquatic ecosystem are devastating. All pollutants, atmospheric and land based invariably enter water bodies, by direct discharge, precipitations and run-offs (George and Atakpa, 2015). Water bodies, thus become sink as well as carriers of pollutants. Water pollution has wide ecological

impact, as it is an important raw material in photosynthesis and hydrological processes (George and Atakpa, 2015).

The quality of water may be described according to their physical and chemical characteristics. For effective maintenance of water quality through appropriate control measures, continuous monitoring a large number of these parameters is essential (George and Atakpa, 2015). This paper therefore provides information to complement the existing data in the management of Mbo River.

2.0 Materials and Methods
2.1 Study Area

Fig. 1 depicts Mbo River. It is one of the major rivers in Akwa Ibom State, traversing across two local government areas; Mbo and Udung Uko Local Government Areas and lies within latitude $4°30°$ to $5°30$ North and longitude $7°30°$ to $8°30$ West on the south eastern Nigeria coastline. It is a near coastal river located within the Cross-River Basin and drains into the Cross-River Estuary at Ibaka in the Bight of Bonny, with which it maintains a permanent mouth thus exposing the river system to tidal ebb and flood. It forms part of the Atlantic Drainage system (Anukam, 1997) east of the Niger which comprises the Cross, Imo, Qua Iboe and Kwa Rivers. Mbo River which is within the Niger Delta Zone of Nigeria is located within tropical rain forest region characterized by tropical humid climate with distinct dry (November-March) and wet (April-October) seasons. The dry season is characterized by prevalence of dry tropical continental winds from the Sahara Desert while the wet season is typified by moist tropical wind from the Atlantic Ocean.

The vegetation cover of the drainage basin is dominated by dense nipa palm (*Nypa fruticans*) which seems to have displaced the mangrove trees (Rhizophora spp) (Orok *et al.,* 2010). Mbo River is an important ecosystem because it supports the local economic activities such as agriculture, fishery, eco-tourism and water supply for domestic use (at the upstream reaches).
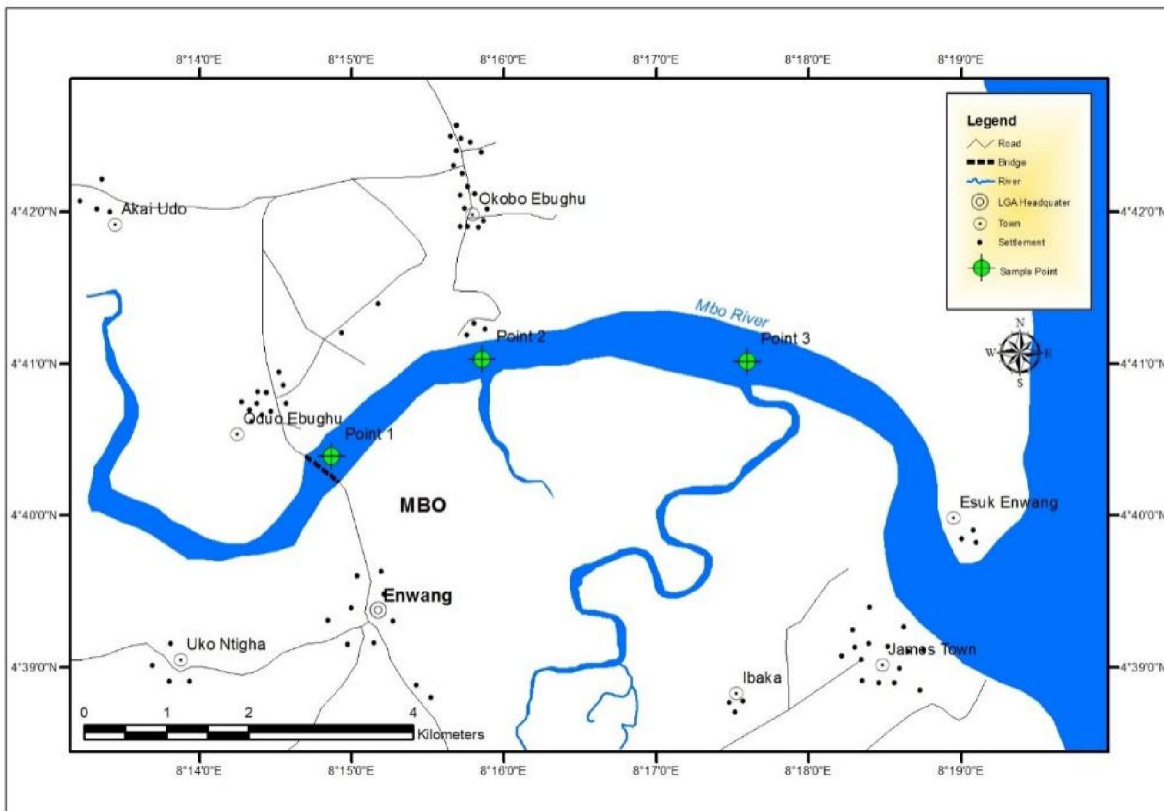

Figure 1: Mbo River showing the Sampling Locations

2.2 Sampling Locations

The experimental site were selected in such a way that the represent areas with high, medium and low human activities respectively. Three sampling locations were identified. The stations were chosen along the river gradient. Station 1 is located at Esuk Uloh. Station 2 is located between the bridge head and the defunct fishing terminal, at Esuk Egbughu where the virgin forest energy is located which is suspected to be highly contaminated (mid-stream). The average depth of this site is about 4.1m. The fringing vegetation is mainly *Nypa fruiticans* because mangrove species have been either replaced by the nypa palm or felled for construction and fire wood for smoking of fish and for domestic use. This station records intense human activities such as inflow of domestic sewage, intense fishing and faecal discharge which could impact negatively on this location along the river. Other endeavours here include the use of motorized boat for commercial services and a small landing port for medium sized sea faring boats, with lots of mechanical repairs going on here. Station 3 (Esuk Ukontenge Creek) is located about upstream of Mbo Bridge. The average depth for this station is about 3.5m. The fringing vegetation is mainly of red mangrove (Rhizophora spp).

2.3 Collection of Water Samples / Analysis

Water Samples were collected from November 2017 to August 2018 on monthly interval. Surface water samples were collected from three different Stations. Water samples were collected in a one (1) liter capacity of plastic rubber for physico-chemical analysis. All the sampling bottles were thoroughly washed and sun dried after which the sampling bottles were labeled with dates and collection stations before use for collection of water samples. Collected water samples were stored in a cool box containing ice blocks and transported to the laboratory. Physicochemical parameters, such as temperature, pH, dissolved oxygen, conductivity, transparency as well as total dissolved solids were measured in situ using test kits. Water samples for Total suspended solids, alkalinity, biological oxygen demand, nitrate, phosphate and sulphate were collected using sample bottles and transported to Ministry of Science and Technology laboratory, Uyo. In the laboratory the parameters were determine based on the principles and procedures outlined in standard methods for the examination of physico-chemical parameters in wastewater (APHA, 1998).

2.4 Data Analysis

The water quality parameters were tabulated per stations to enable the examination of the water quality with the aim of comparing the values with WHO standards. Descriptive statistics was employed in computing means and standard deviations for both stations and seasons. Significant different in means were established using analysis of variance while significant seasonal variations were established using paired sample t-test using SPSS version 20. 0.

3. 0 Results

3.1 Physico-chemical Parameters of Surface Water Samples of Mbo River, Nigeria

The physico-chemical parameters of Mbo River showed spatial variation (Table 1). The water temperature variation indicated mean value of 28.40 ±0.16^{o}C and ranged between 26.80-30.40^{o}C. Total suspended solids in the River had peak value of 510.00 mg/l which was recorded in Station 1 with mean value 177.54 ± 25.9. Total dissolved solids ranged from 136.00- 718.00 mg/l with overall mean value 528.93 ± 38.76 mg/l. The electrical conductivity ranged from 910.00- 6560.00 μS/cm with mean of 1675.97 ± 200.0 μS/cm. Transparency of the River fluctuated from 4.10 -20.00 m with mean value of 11.66 ± 2.41 m. The pH values ranged between 5.10-6.75 with mean value of 5.99±0.95. The total alkalinity showed mean of 153.67±6.04 mg/l (CaCO$_3$) with range of 90.10-196.0mg/l. The study revealed spatial variations in the concentration levels of physico-chemical concentrations in Mbo River but were not significantly ($p > 0.05$) different among the stations in the river during the study period except for water temperature ($p < 0.05$).

3.2 Dissolved Oxygen and Nutrients of Surface Water Samples of Mbo River, Nigeria

Summary of dissolved oxygen and nutrients analyzed in this study are shown in Table 2. The dissolved oxygen values in the River ranged from 4.10-10.20 mg/l; with mean of 5.80 ± 0.23mg/l. The biochemical oxygen demand revealed spatial variation with mean value of 3.39 ± 0.14mg/l. Nitrate indicated mean value of 4.98 ±0.32mg/l and ranged from 3.50-5.70 mg/l during the period of study. Mean value of Phosphate-phosphorus was 0.23± 0.0 mg/l. Sulphate levels in the river had range of 2.0-2.80 mg/l with mean value of 2.31± 0.04 mg/L.

3.3 Comparison of Physico-chemical Parameters of Mbo River with WHO Standards

Comparing the physico-chemical parameters of Mbo River with the WHO standard limits (Table 1 and Table 2) showed that the parameters that indicated lower values than the WHO standard limits were: mean water

temperature (28.39^oC) < 35^oC, mean pH (5.99) < 6.5-8.5 and mean transparency (11.66m) < 40m. Parameters that indicated higher values than the WHO standards limits were: mean TDS (528 mg/l) >500 mg/l; Electrical conductivity (1675 μS/cm) > 1000 μS/cm, mean TSS (177.53 mg/l) > 50mg/l and total alkalinity (153.67 mg/l) > 100mg/l. On the other hand, the comparison of dissolved oxygen and nutrient analyzed in this study showed that the mean values of these parameters: DO (5.80 mg/l) < 6.0 mg/l; BOD (3.39 mg/l) < 4.5 mg/l; Nitrate (4.98 mg/l) < 10.0 mg/l; Phosphate (0.23 mg/l) < 5.0 mg/l and Sulphate (2.31 mg/l) < 25.0 mg/l were considerably lower than the WHO standards for surface water (Table 1 and 2).

Table 1: Spatial Variation of the Physico-chemical Parameters of Surface Water Samples of Mbo River, Nigeria.

Parameters	Station 1		Station 2		Station 3		F-value between stations	P	WHO 2011 Standard limits
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE			
Temperature (^oC)	26.8-29.0	27.86 ± 0.22	27.6-30.4	28.93 ±0.25	26.8-29.2	28.4 ± 0.28	4.331	0.023**	35
TSS (mg/l)	15.00-510.00	167.85±57	101.3-420.0	183.56± 38.2	100.0-440.0	181.2± 42.1	0.033	0.967	50
TDS (mg/l)	136.0-710.0	556.5± 57.8	139.00-718.0	502.8± 74.0	137.0-715.0	527.50±73.7	0.151	0.861	500
Electrical Conductivity (μS/cm)	910.0-1420.0	1242.5±59.0	912.0-3110.0	1615.2±32.4	1112.0-6560.0	2170.2± 52.9	1.932	0.164	1000
Transparency (m)	5.50-20.00	11.35± 1.71	5.70-19.80	12.59±1.29	4.10-20.0	11.03±2.03	0.232	0.794	20-40
pH	5.20-6.72	6.02±0.14	5.10-6.70	5.92±0.18	5.20-6.75	6.03±0.18	0.129	0.879	6.5-8.5
Alkalinity (Mg/L CaCO$_3$)	120.0-196.0	160.1± 9.2	90.10-193.00	146.6± 12.29	105.20-192.0	154.32±10.33	0.401	0.673	100

Source of Standard limits: WHO, 2011. Key: TSS= Total Suspended Solid, TDS = Total Dissolved Solid, pH = Hydrogen ion content
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Table 2: Spatial Variation of the Dissolved Oxygen and Nutrients of Surface Water Samples of Mbo River.

Parameters	Station 1		Station 2		Station 3		F-value between stations	P	WHO 2011 Standard Limits
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE			
DO (mg/L)	4.50-10.20	6.14± 0.53	4.10-7.20	5.61± 0.32	4.50-7.04	5.66 ±0.31	0.494	0.615	≥ 6.0
BOD (mg/L)	2.30-4.90	3.42 ±0.23	2.10-5.80	3.45 ±0.32	2.20-4.50	3.31 ±0.21	0.079	0.925	4.5
Nitrate(mg/L)	3.70-4.00	5.44 ± 0.96	3.50-5.70	4.74 ±0.22	4.10-5.53	4.78 ± 0.15	0.460	0.636	10.0
Phosphate(mg/L)	0.20-0.25	0.23± 0.00	0.20-0.26	0.22± 0.0	0.20-0.25	0.22± 0.0	0.647	0.531	≤ 5.0
Sulphate(mg/L)	2.0-2.80	2.23± 0.08	2.0-2.80	2.43± 0.07	2.0-2.80	2.29± 0.08	1.488	0.244	25.0

Source of Standard limits: WHO, 2011. Key: DO = Dissolved Oxygen, BOD = Biological Oxygen Demand

3.4   Spatial Variation of the Physico-chemical Parameters

The spatial variation of the physico- chemical parameters of surface water samples of Mbo River (Table 1) indicated that temperature and TSS generally showed higher values in Station 2 > Station 3 > Station 1; TDS and alkalinity had higher values in Station 1> Station 3> Station 2; while electrical conductivity showed higher values in Station 3> Station 2> Station 1; transparency showed higher values in station 2 > station 1> station 3 and pH followed a different pattern in the order station 3 > station 2 > station 1. On the other hand, spatial variation of dissolved oxygen and nutrients indicated in Table 2 revealed that dissolved oxygen, nitrate and phosphate showed higher values in Station 1> Station 3 > Station 2. Biological Oxygen Demand (BOD) showed preference of Station 2 > Station 1> Station 3 while sulphate was higher in station 2 > station 3 > station 1. All parameters studied were not significantly different among the stations investigated (P>0.05) except temperature (p< 0.05)

3.5   Seasonal Variation
3.5.1   Seasonal Variation of the Physical Parameters of Surface Water Samples of Mbo River (Nigeria).

Seasonal variation of the physico-chemical parameters of surface water samples of Mbo River are presented in Table 3. Temperature fluctuated between the dry and rainy seasons with higher values recorded in dry season months of February and March. Temperature exhibited narrow amplitude of variation between dry and rainy season (1.1^oC) and thus the dry and rainy season variation was not significant (p> 0.05). However, the spatial variations of temperature were significant (p < 0.05).

Total Suspended Solids (TSS) variation was significant in favour of dry season but Total Dissolved Solid (TDS) was higher in the rainy season and difference between the dry and the rainy season variations was not significant. Higher values of electrical conductivity were observed in the dry season than the rainy (p > 0.05).

Transparency was higher in the dry season than in the rainy season and the difference was significant (p< 0.05). pH was observed to be higher in the dry season than in the wet season with no significant difference while total alkalinity was higher in the rainy season than in the dry season with no significant difference between the seasons. Generally, two physical parameters (TSS and transparency) showed significant differences between seasons (p< 0.05), while the other five parameters (temperature, TDS, conductivity, pH and total alkalinity) did not reveal significant differences between seasons.

3.5.2   Seasonal Variation of the Dissolved Oxygen and Nutrients of Surface Water Samples of Mbo River, Nigeria

Seasonal variation of the dissolved oxygen and nutrients of surface water samples of Mbo River are recorded in Table 4. The Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Nitrate were higher in the dry season months than in the rainy season but the differences were not statistically significant (p > 0.05). The highest values of DO and BOD were observed in February and March. The nutrients (Phosphate and Sulphate) had higher values in the rainy season than in the dry season but the differences were not statistically significant (p > 0.05).

Table 3: Seasonal Variation of the Physico-chemical Parameters of Surface Water Samples of Mbo River (Nov, 2017-Aug, 2018)

Parameters	Dry Season		Rainy Season		Overall		t-value between stations	P
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE		
Temperature (^{o}C)	27.3-30.4	28.9 ± 0.74	26.8-29.0	27.89 ±0.76	26.80-30.4	28.40 ±0.16	0.345	0.562
TSS (mg/L)	15.0-510.00	250.16±71.9	101.3-129.0	104.9± 30.18	15.00-510.00	177.54 ± 25.9	17.049	0.000**
TDS (mg/L)	136.0-710.0	483.2± 21.1	163.00-718.0	574.66± 20.00	136.00- 718.0	528.93 ± 38.76	0.602	0.444
Electrical Conductivity (µS/cm)	1100-3110.0	1730.0±59.0	901.0-6560.0	1621.93±137.4	901.0- 6560.0	1675.97 ± 200.0	0.004	0.949
Transparency (m)	4.10-11.40	7.76± 2.42	7.60-20.0	15.55±4.35	4.10 -20.00	11.66 ± 2.41	12.577	0.001**
pH	5.50-6.72	6.19±0.41	5.10-6.75	5.80 ±0.56	5.10-6.75	5.99±0.95	1.956	0.173
Alkalinity (Mg/L CaC0$_3$)	90.10-194.0	134.55± 32.5	130.0-196.00	172.80± 20.54	90.10-196.0	153.67±6.04	1.730	0.199

Table 4: Seasonal Variation of the Dissolved Oxygen and Nutrients of Surface Water Samples of Mbo River (Nov, 2017-Aug, 2018).

Parameters	Dry Season		Rainy Season		Overall		t-value between stations	P
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE		
DO (mg/l)	4.80-10.20	6.49± 1.29	4.10-6.80	5.11 ±0.91	4.10-10.20	5.80 ± 0.23	0.171	0.638
BOD (mg/l)	2.10-5.80	3.52±0.99	2.20-3.90	3.26 ±0.56	2.10-5.80	3.39 ± 0.14	1.698	0.203
Nitrate (mg/l)	4.10-5.70	5.01 ± 0.44	3.50-5.10	4.96 ± 2.54	3.50-14.00	4.98 ±0.32	2.518	0.124
Phosphate(mg/l)	0.20-0.26	0.22± 0.02	0.20-0.25	0.23± 0.02	0.20-0.26	0.23± 0.0	0.651	0.426
Sulphate(mg/l)	2.0-2.90	2.48± 0.38	2.0-2.80	2.66± 0.53	2.0-2.80	2.31± 0.04	1.117	0.300

4.0 Discussion
4.1 Physico-chemical Parameters of Surface Water Samples of Mbo River
The overall mean of water temperature recorded in this study was 28.4^{o}C± 0.16 and the range was between 26 - 30°C. These values represent tropical humid equatorial climate of Southern Nigeria. Similar values had been reported by Arazu and Ogbeibu (2017) in River Niger at Onitsha Stretch; Iloba (2019) in Aghalokpe Wetland in Delta State, Nigeria. A closer range of 26.9±1.1 to 32.1±0.5 was previously recorded by Dimowo (2013) in River Ogun, Southwestern Nigeria and another close range of 29.5^{0}C to 32.67^{0}C was recorded by Oboh and Agbala (2017) in River Siluko. However, the temperature values recorded in this study was higher than a lower water temperature range 26.50°C to 27.00 °C reported by Dirisu and Olomukoro (2015) in Agbede-wetland in Southern Nigeria, lower than the mean water temperature of 26.21 ± 0.63 mg/L recorded by Oseji, *et. al.* (2019) in surface water from River Niger, Illushi, Edo State, Nigeria and lower than the maximum temperature limit of 35°C recommended by WHO, 2004 for surface water utilization.

The values of TDS and TSS recorded in this study was higher than total dissolved solids of 6.14 to

7.78mg/L in Agbede-wetland in Southern Nigeria as reported by Dirisu and Olomukoro (2015) and TDS (34.9±4.78mg/L) and TSS (71.7±21.17 mg/L) recorded by Oseji, *et. al.* (2019) from River Niger, Illushi, Edo State. The high values of TSS could result from weathered suspended materials in the water. Total dissolved solids are natural pollutants in the river water and it imparts the color, total alkalinity, and conducting nature of water. Thus, the impact of dissolved and suspended load in Mbo River was found to be greater than the impact in Agbede-wetland in Southern Nigeria and River Niger, Illushi, Edo State. The maximum TDS value recorded in this study is higher than the most desirable value of 500 mg/L as recommended by WHO, 2004. These higher values in the study area may be due to anthropogenic activities such as oil drilling and surface runoffs from surrounding land which may generally impede the portability and suitability of the water body for general purposes.

Higher value of conductivity was recorded in Mbo River compared to lower electrical conductivity of 7.99 to 25.55 µS/cm recorded by Dirisu and Olomukoro (2015) in Agbede-wetland in Southern Nigeria and 57.08±8.29 recorded by Oseji, *et. al.* (2019) in River Niger, Illushi, Edo State. The higher

conductivity recorded in all the stations of this study is as a result of intrusion of seawater due to the proximity of the study area to the sea. The conductivity of water is affected by the suspended impurities and also depends upon the number of ions in the water. The water samples from the study area could be regarded as saline (maximum conductivity > 6000μS/cm. The mean conductivity value of 3752.74 μS/cm recorded in New Calabar River (Agbugui and Deekae, 2014) is higher than 1675.96 μS/cm recorded in this present study. However, conductivity in this study was higher than the recommended limit of 500-1000 μS/cm by WHO (2004). The values obtained in this study suggest complete estuarine water, characterized by the very high conductivity levels. Conductivity of salt waters is usually higher than freshwater because the former contains more electrically charged ions than the latter.

The pH range of 5.10 - 6.75 with mean of 5.99±0.95 recorded in this study was lower than 6.5 to 8.5 recommended by WHO (2004) indicating that the River is generally acidic. This slightly acidic status of Mbo River is typical condition of tropical forest river due to the release of humic acid from plant leaches. The slightly acidic value is similar to the value from Osse river 6.31±0.08 to 6.52±0.14 (Ekhator, *et. al,* 2012) and a mean value from Surface Water from River Niger, Illushi, Edo State 6.27±0.1 (Oseji, *et. al.* 2019). This is an indication that the rivers were not well buffered and this was seen from the fluctuating pH condition across the stations of the study area. The apparent spatial heterogeneity can be attributed to variability in perturbations across the stations. However, a neutral pH value of 7.05 to 7.15 was reported by Dirisu and Olomukoro (2015) in Agbede-wetland in Southern Nigeria and these values are higher than the values obtained in the present study.

Higher value of alkalinity was recorded in Mbo River compared to lower alkalinity of 26.62±4.78 mg/L from River Niger, Illushi, Edo State. The mean alkalinity recorded in the study area is greater than (153.67mg/L > 100mg/L) value recommended by WHO standards. Again, high values in the study area are due to the proximity of the river to the Atlantic Ocean and the susceptible intrusion of salty water which is influenced by physical oceanographic factors such as waves, ocean current, tides and precipitation. These factors hail and proclaim higher value of alkalinity recorded in this study.

4.2 Dissolved Oxygen and Nutrients Load in Surface Water Samples of Mbo River

The mean Dissolved Oxygen concentrations in this study were consistently below 11 mg/L in all the stations and the range was 4.10 to 10.20mg/L. This is higher than the low oxygen levels (0.05- 3.5 mg/L) reported by Iloba (2019) in Aghalokpe Wetland in Delta State, Nigeria and 4.47±0.46 mg/L in River Niger, Illushi, Edo State. The higher DO may be as a result of the presence of phosphorus and nitrates in the river which may had triggered tremendous growth of algae and aquatic plants which may in-turn release large amounts of DO into the water during photosynthetic activities. Comparatively low Mean DO (5.80 ± 0.23) content in the study area showed mild pollution as a result of organic waste in the volume of the water. However, the overall mean value of Dissolved Oxygen recorded in this study can support biotic diversity because it has been established that tropical aquatic ecosystem should have oxygen concentration of at least 5mg/L in order to support biotic diversity.

The Biochemical Oxygen Demand value recorded in this study is higher than the BOD value of 0.88 to 2.42mg/L in Agbede – Wetlands in Southern Nigeria but lower than 7.29±3.25 mg/L in River Niger, Illushi, Edo State. The low BOD could be due to the huge load of organic constituents from the surrounding farmlands which require a high level of oxygen to break down. The BOD has been widely used to determine the strength of organic pollution of wastewaters and as well as the quality of surface water bodies. Thus, the Biochemical Oxygen Demand (BOD) values recorded in this study were far below the value that defines pollution and the river may have the ability to exercise self -purification because the maximum BOD value was lower than the recommended WHO (2004) value of 4mg/L. The pollution status of Mbo River is far better than the outrageous maximum BOD value of 520.0 mg/L and mean value of (182.5 mg/L) recorded in Nairobi River, Kenya (Dulo, 2008) which explained that the water quality index of Nairobi River, Kenya portrayed bad condition and badly polluted environment.

From the mean concentrations of nutrient compounds, their order of hierarchy in Mbo river was Nitrate> Sulphate > phosphate and several values had been reported by several authors across the globe. For instance, Oseji, *et. al.* (2019) recorded Phosphate value of 2.20±0.09 mg/L and Sulphate value of 25.81±10.78 mg/L in River Niger, Illushi, Edo State. These values are higher than 0.23±0.01 and 2.31± 0.04 recorded in this study and indicated that the nutrient load in River Niger, Illushi, Edo State is higher than the load in Mbo River. Higher maximum value of phosphate (5.7mg/L) was reported in Tidal Creek, Lagos, Nigeria (Taofikat, 2012) which was higher than the value recorded in this study. However, the low Phosphate recorded in this study is higher than (0.01- 0.34 mg/l) recorded by Iloba (2019) in Aghalokpe Wetland in Delta State, Nigeria. Ewebiyi,

et. al. (2015) within Kaduna Metropolis posited that the excessive amount of nutrients in water bodies along with higher temperature favors the growth of algae and aquatic weeds. The nitrate value recorded in this study is slightly higher than 3.19±0.94 mg/L reported in River Niger, Illushi, Edo State. The nitrate values were above the 1.00mg/L limit which heralds algal bloom or eutrophication but the possibility of eutrophication taking place in the river is limited by the corresponding lower phosphate. However, the levels of the essential nutrients such as nitrate, phosphate and sulphate in Mbo river indicate that the river is not oligotrophic. This assertion is true because the nitrate values were above the 1.00 mg/l limit which signals, discloses and announces algal bloom and the concentration of phosphate is higher than the 0.1mg/L enrichment threshold beyond which algal bloom will likely manifest (Ewebiyi *et al.*, 2015).

All parameters studied were not significantly different among the stations investigated (P>0.05) except temperature. This is different from the result of Ekhator, *et. al.* (2012) in Osse River, Edo State, Nigeria that all parameters studied were significantly different among the stations investigated (P<0.05) except pH. The insignificant differences among majority of the physicochemical parameters across the stations may be due to the diversity of the sampling locations.

4.3 Seasonal Variation of the Physico-chemical Parameters of Surface Water Samples of Mbo River

Water temperature showed some asymmetric pattern in both the dry and rainy season. Temperature rose to 30.10°C in the dry season and lower during the months of rainy season. Mean temperatures were higher during the dry season months. Temperature was higher in the dry season when compared with the rainy season, this dissimilarity is influenced by the intensity of solar radiation, evaporation, freshwater influx, cooling and mixing up with ebb and flood from adjoining neritic waters whereas the minimum temperature was due to sea breeze and precipitation. These findings have been reported in previous studies elsewhere in Nigeria inland waters (Essien-Ibok *et al.,* 2010; Dirisu and Olomukoro, 2015; Ekhator *et al.,* 2012 and Oseji, *et. al.*, 2019). Temperature variation in the present study shows a fluctuation during the dry and rainy season with 27.3 - 30.4°C and 26.8 – 29.0°C respectively. This is higher than 25.39°C ±0.31 to 27.81°C ±0.41 recorded by Ekhator, *et. al.* (2012) in Osse River, Edo State, Nigeria.

Total Suspended Solid (TSS) variation was significant in favour of dry season but Total Dissolved Solid (TDS) was higher in the rainy season and difference between the dry and the rainy season variations was not significant. The influence of rainfall and tidal incursion might be responsible for the amplified value of TDS in the rainy season and higher value of TSS in the dry months.

Seasonal variations in conductivity were observed with high values in the dry months and low values in the rainy months. This contradicts earlier assertion by Essien-Ibok *et al.* (2010) for Mbo River; Agbugui and Deekae (2014) for New Calabar-Bonny River; Dirisu and Olomukoro (2015), for Agbede – Wetlands in Southern Nigeria; Oseji, *et. al.* (2019) for Surface Water from River Niger, Illushi, Edo State, Nigeria who reported high EC values in the rainy season than in the dry season. However, this report is in agreement with the findings of Ekhator *et al.* (2012) in Osse River, Edo State, Nigeria, who observed high conductivity values in the dry season than wet season. The higher level of EC during the dry season is attributed to evaporation which leads to increase in the concentrations of dissolved ions while the low value recorded in the rainy season is attributed to dilution due to precipitation and surface run-off from adjourning water bodies.

Transparency was higher in the rainy season than in the dry season and the difference was highly significant (p< 0.05). The episodic low transparency during the dry season may be attributed to the low content of organic load in the water surface while high values in the rainy season may be attributed to turbulence influence of rainfall which played a significant role in introducing high organic load to the water during the rainy season.

None uniformity was observed in the pH pattern in the river and the range of this parameter showed proportionate fluctuation in season. This is at variance with reports by Essien-Ibok *et al.* (2010), for Mbo River and Iloba (2019) in Aghalokpe Wetland in Delta State, Nigeria who reported high pH value in the rainy season. Total alkalinity was higher in the rainy season than in the dry season but with no significant difference between the seasonal values.

4.4 Seasonal Variation of the Dissolved Oxygen and Nutrients in Surface Water Samples of Mbo River

Dissolved oxygen showed prime pattern of fluctuation, with higher values recorded during the dry season. The dissolved oxygen (DO) was higher in the dry season months than in the rainy season but the difference was not statistically significant (p > 0.05). Thus, DO in the river is governed by photosynthetic activities during the dry months due to intense sunlight. This indicates the influence of seasonal climate in the study area. This supports the reports of previous authors (Essien-Ibok *et al;* 2010; Dirisu and Olomukoro, 2015; Oseji, *et. al.* 2019).

The biological oxygen demand (BOD) was higher in the dry season months than in the rainy season but the difference was not statistically significant ($p > 0.05$).

In this study, phosphate was detected in both dry and rainy season. This contradicts the report of Dirisu and Olomukoro (2015) in Agbede-wetland in Southern Nigeria where Phosphate was not detected during the dry season. However, phosphates provide the nutrient required for the growth of algae and aquatic plants. So, the dominance of phytoplankton in the dry season may be as a result of phosphorus in the water. However, excess release of phosphorus into the River may evidently increase the nutrient load in the system and create a pathway for eutrophication to thrive. Phosphate values rose in January and February when there was little or no rainfall at all. The phosphate value recorded in the dry months was higher than that of the rainy months. This favours the proliferation of diatoms in the study area. This observation is supported by earlier assertion by Taofikat (2012) who worked on Tidal Creek, Lagos and associated the decrease in nutrients in rainy season to high rainfall and proliferation of phytoplankton to the dominance of phosphate.

5.0 Conclusion

Studies revealed that the parameters studied showed low-moderate-high contamination level in Mbo River indicating a perturbed environment. However, it is important to note that the inhabitants of the study area primarily depend on the river for domestic purposes. Therefore, constant monitoring of Mbo River is recommended to forestall any changes that might deteriorate the quality of water making it unfit for domestic purposes.

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