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WATER QUALITY STATUS OF LOWER RIVER NIGER, AGENEBODE, EDO STATE, NIGERIA

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ABSTRACT

Freshwater is often exposed to pollution due to rapid industrialization and population resulting in epidemics. Lower River Niger, Agenebode, Edo State, Nigeria is impacted by anthropogenic activities of over two-hundred thousand communities, necessitating an assessment of its quality. The study evaluated the spatio-temporal variations in physical and chemical parameters of the River as a vital resource for fishery and domestic uses. Lower River Niger (LRN) was stratified downstream (DNS), midstream (MDS) and upstream (UPS) zones based on hydrological features and two sampling points each were randomly selected. Water samples were collected bi-monthly over two wet and dry seasons and analyzed for Dissolved-Oxygen (DO, mg/l), Chemical-Oxygen-Demand (COD mg/l), Total Suspended Solids (TSS mg/l), Alkalinity(mg/l), Phosphate(mg/l), conductivity(S/cm), Biochemical-Oxygen-Demand (BOD,mg/l), and temperature (^{0}C) following standard methods. Highest (84.46±24.95) and lowest (75.45±24.23 mg/l) alkalinity was recorded for MDS and DNS respectively. Temperature and DO ranged from 27.52±1.48^{o}C (DNS) to 28.32±1.56^{o}C (MDS) and 4.27±0.42 (UPS) to 6.06±10 mg/l (DNS) respectively, TSS varied between 51.68±8.81mg/1 to 84±19.8mg/1, with maximum value in UPS and MDS. The seasonal variation showed that mean DO values, COD, transparency, temperature, conductivity, ammonia, phosphate, chloride, TDS, TSS, calcium, magnesium, sulphate, and depth vary significantly. Conductivity were 60.28±6.1 and 58.67±6.52 mg/l, phosphate (3.89±1.63;0.52±0.09) mg/l, temperature (28.20±2.34; 25.52±1.74) ^{o}C and DO (5.25±0.56; 5.5±0.61) mg/l in dry and wet seasons respectively. The mean values for BOD (68.52±61.21mg/l), temperature (27.52±1.48)^{o}C, conductivity (59.55±25.19)mg/l, alkalinity (79.03±22.61) mg/l and ions were within desirable limits for aquatic life. However, TSS 101.49 ±105.27, Transparency 49.88±12.46, Sulphate 5.30±4.40 and COD 84.03±25.37 (mg/l) were above the recommended level for aquatic life. These findings are indicative of warning signs for pollution which impact not only aquatic organisms but also drinking water. Crucial restorative steps are needed therefore to reduce direct discharges of agricultural and anthropogenic effluents into LRN

Keywords: Lower River Niger, Agenebode, Water Pollution; Water Quality, Spatio-temporal variation.

INTRODUCTION

Water, the matrix of life is exposed to pollution, unhealthy environment resulting in human afflictions and disease transmission due to rapid industrialization and population. Nigeria is one of the tropical countries endowed with immerse natural resources including freshwater resources. One of these natural resources is Lower River Niger Water at Agenebode, Edo State, Nigeria. Physical and chemical parameters are known to affect the biotic components of the aquatic environment (Chia *et al*., 2011). The quality of water is closely associated with sustainable fish production in the aquatic system (Ajani, 2011).

The role water play in human life cannot be quantified. Despite the importance of water to man and his animals, little attention is often paid to the quality of this resources and sustenance of life; therefore a lot of the water consumed on daily basis is often polluted and in some extreme cases unfit for human consumption and unhealthy for the organisms living in the water body. Some of the diseases humans suffer today are inherent in polluted water. The people of Agenebode, a major fish commercial town depends almost solely on the water of the Lower River Niger. A state-owned Water Board is unable to supply drinking water for household use. Private boreholes cannot meet the demand of the community. This river is a major destination for industrial waste, human excrement, wastes from abattoirs, heavy metals as well as sewage (Plates a – c). Due to the difficulties in getting easy access of portable water, the residents have no choice but to draw the water from the river for domestic use. This poses a lot of health dangers and could make the children predisposed to illness such as cholera and other water borne diseases.

Agenebode community is fast growing and developing into a big city in Edo State. The human influx and other acssociated anthropogenic activities, including unrestricted dumping therefore of pollutants into the river calls for concern. The construction of a new bridge across the river at Agenebode to link Idah village has further perturbed the aquatic ecosystem. Thus, a comprehensive update on the physico-chemical parameters of this important river with respect to its pollution status is necessary. The study, in addition provided baseline data for monitoring changes in its physico-chemical parameters.

Plates a – c : Anthropogenic activities around Lower River Niger at Agenebode, Edo State, Nigeria

MATERIALS AND METHODS

Agenebode community is a water-side town located by the banks of the river Niger in Edo state, South-South geo-political zone of Nigeria. It is located on latitude $7^0$06'N and longitude of $6^0$42'E as shown in Figure 1. The area is characterized by a typical rainforest climatic condition of rainy season from April to November and dry season from December to March.

The Spatial stratification of the River was adopted according to Southwood and Henderson, (2006), in which the river was divided into three zones (Down stream (DNS), Middle stream (MDS) and Upper stream (UPS)) and two stations were randomly selected in each zone (Figure 2).

Sampling of the physico-chemical parameters was done bimonthly for in two dry and rainy seasons. Water sample was collected early hours of the morning (6.00am) at a depth of 20cm below the water surface at each station. The water sample for dissolved oxygen (DO) was collected using DO bottles and fixed with Winkler's solution in situ before taking it to the laboratory, Amber, biological oxygen demand (BOD), bottles were used to collect water samples for BOD for analysis. Calibrated rope line attached to lead sinker was used to ascertain depth, Mercury in glass thermometer was used to measure temperature, Secchi disc attached with calibrated rope was used for the measurement of depth and transparency, Digital pH meter Suntex (Model TS-2) calibrated using 2 buffer solutions of pH 4.7 and 10 at 25ºC was used for pH. DO was measured using Dissolved oxygen meter standardized by using saturated Potassium Chloride and zero oxygen solution. Intelligent meter (AD. 33915) for conductivity and total dissolved solid, HANNA meter (HI3811) for total alkalinity while chloride, total hardness, calcium, magnesium, sodium, potassium, total dissolved solids, biochemical oxygen demand, chemical oxygen demand, sulphate, phosphate, nitrate, and ammonia were analyzed according to APHA [2022]. Data generated were subjected to both descriptive (means and standard deviations) and inferential statistics (ANOVA) at $\alpha_{0.05}$ and presented as seasonal and spatial mean variances.

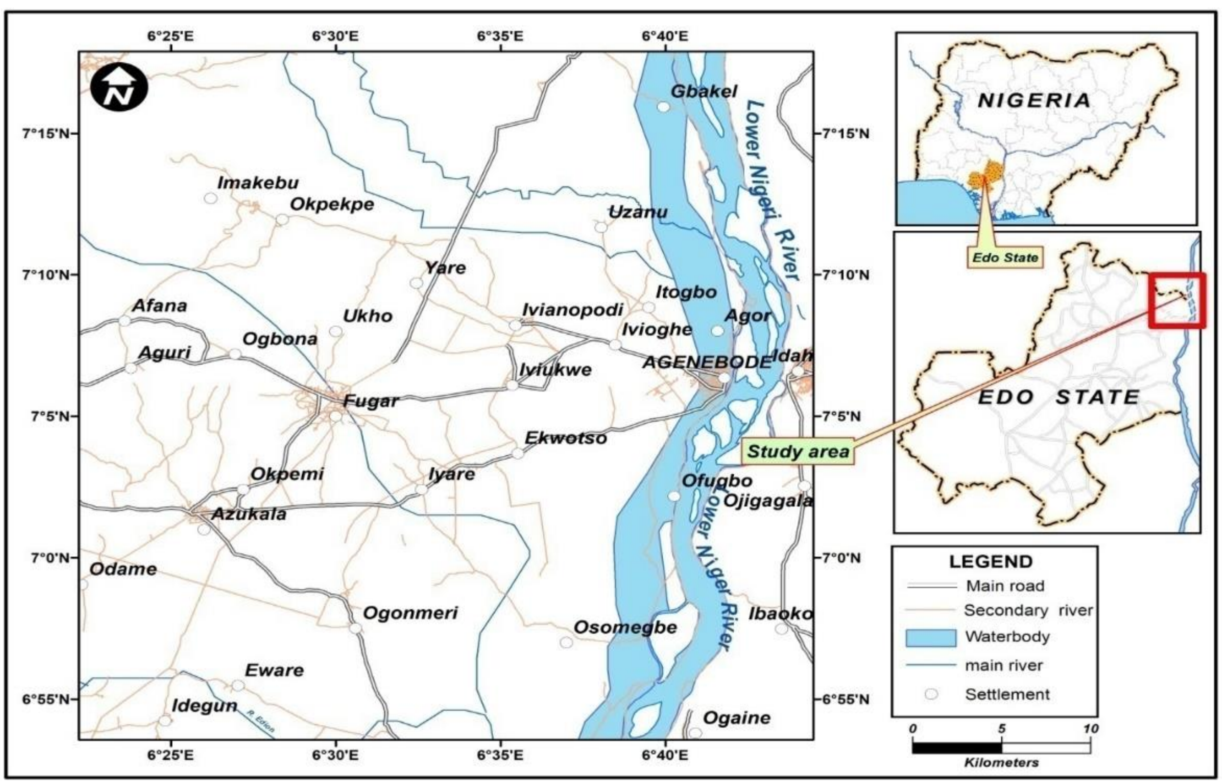

Fig. 1: Map of Edo state showing the location of the study area

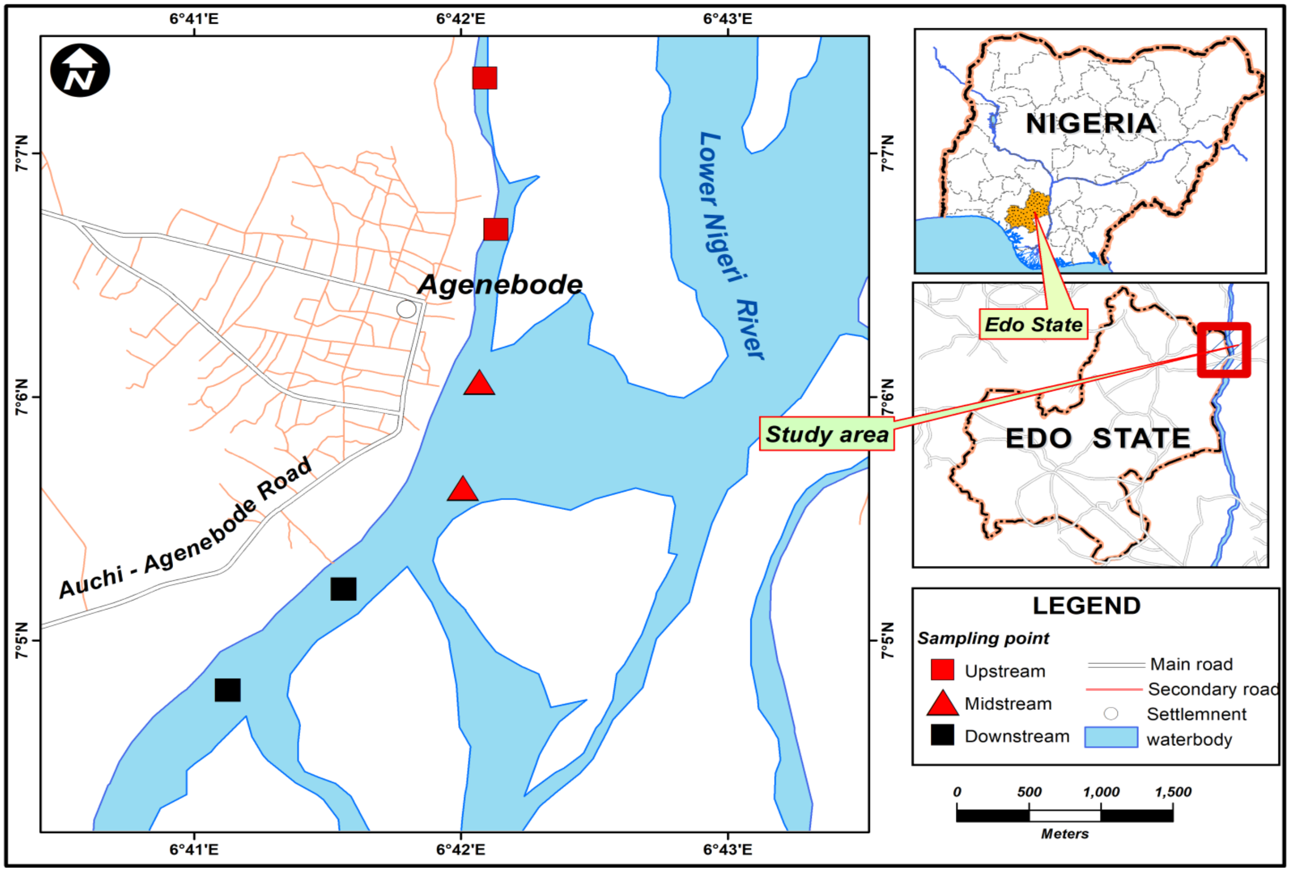

FIG. 2: MAP OF EDO STATE SHOWING THE LOCATION OF THE STUDY AREA

RESULTS

Temporal and Spatial Variations in Physico-chemical Parameters of Lower River Niger

The mean depth of Lower River Niger recorded during the period of study was 264.00cm, the highest (401.36cm) mean depth was obtained for UPS while DNS recorded the lowest (174.45cm) mean depth. Spatially, water depth was highly significant (P< 0.01) among the sampling stations using Analysis of variance (ANOVA) as represented in Table 1. Result of follow up t-test shows that downstream and midstream are not significantly different. There are no significant differences among the three sampling stations in terms of the water temperature and Transparency (Table 2).

The mean water temperature was 27.51 °C and there were no significant difference (P>0.05) among the sites; There were no significant difference (P>0.05) for pH, Suspended Solids (SS), Turbidity, Phosphate, Phosphorus, Sulphate, Nitrate, Ammonia-N, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chloride among the sampling stations while the Electrical Conductivity was highly significant (P<0.01) among the sampling stations during the study period (Table 2).

Seasonally, there were no significant difference (P>0.05) for Conductivity, Phosphate, Phosphorus, Sulphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chloride between the sampling stations while Total Suspended Solids (TSS), Turbidity, pH and Nitrate showed significant difference (P<0.05) among the sampling stations and Ammonia-N was highly significant (P<0.01) (Table 3).

Table 1: Water Depth, Temperature and Transparency of Lower River Niger, Agenebode, Edo State, Nigeria

	DNS	MDS	UPS	Mean ± Std. Deviation	F-value	P-value
Water Depth	174.45±119.12[a]	216.18±99.38[a]	401.36±191.78[b]	264.00±170.42	7.9106	0.002
Water Temperature	27.36±1.29[a]	27.36 ±1.69[a]	27.81 ± 1.54[a]	27.52 ± 1.48	0.330	0.721
Water Transparency	45.55 ± 15.21[a]	53.73±12.12[a]	50.36 ± 9.03[a]	49.88 ±12.46	1.214	0.314

Table 2: The spatial variation of the physico-chemical parameters of the Lower River Niger at Agenebode, Edo State, Nigeria

Parameters	DNS Mean ± SE	MDS Mean ± SE	UPS Mean ± SE	P-value	Significance
PH	6.64 ± 0.18	6.66 ± 0.21	6.88 ± 0.25	0.682	P>0.05
Conductivity (Mg/l)	76.36[a] ± 9.82	58.64[b] ± 3.76	43.64[b] ± 4.53	0.006	**P<0.01
Total Suspended Solids (Mg/l)	69.86 ± 23.83	84 ± 19.8	51.68 ± 8.81	0.477	P>0.05
Turbidity (NTU)	98 ± 35.55	113.09 ± 32.86	93.36 ± 29.3	0.905	P>0.05
Phosphate (Mg/l)	4.06 ± 2.4	0.45 ± 0.11	2.57 ± 1.35	0.286	P>0.05
Phosphorus (Mg/l)	1.31 ± 0.77	0.2 ± 0.04	0.89 ± 0.43	0.314	P>0.05
Sulphate (Mg/l)	30.41 ± 7.73	35.05 ± 7.38	24.45 ± 3.11	0.513	P>0.05
Nitrate (Mg/l)	6.87 ± 1.68	4.93 ± 1.17	4.09 ± 1.0	0.323	P>0.05
Ammonia-N	0.68 ± 0.37	0.55 ± 0.27	0.36 ± 0.15	0.715	P>0.05
Chloride (Mg/l)	17.32 ± 2.06	16.49 ± 2.41	16.15 ± 2.76	0.94	P>0.05
Dissolved Oxygen (Mg/l)	6.06 ± 1	5.75 ± 0.49	4.27 ± 0.42	0.162	P>0.05
B.O.D. (Mg/l)	4.11 ± 1.05	2.7 ± 0.57	3.22 ± 0.43	0.399	P>0.05
TDS (Mg/l)	87.10 ± 20.37	89.55 ± 32.42	87.00 ± 38.65	0.612	P>0.05
Alkalinity (Mg/l)	75.45 ± 24.23	84.46 ± 24.95	77.18 ± 0.43	0.261	P>0.05
Calcium (Mg/l)	43.64 ± 13.28	38.00 ± 14.93	34.55 ± 14.29	0.422	P>0.05
Magnesium (Mg/l)	2.43 ± 1.70	3.89 ± 1.81	4.84 ± 1.33	0.120	P>0.05
COD (Mg/l)	86.55 ± 26.97	90.12 ± 22.18	75.44 ± 26.66	0.524	P>0.05
Water temp. (^{0}C)	27.36 ± 1.86	27.36 ± 1.68	27.82 ± 1.54	0.425	P>0.05

Note: P>0.05- Not Significant, *P<0.05-Significant, **P<0.01- Highly Significant

Table 3: The seasonal variation of the physico-chemical parameters of the Lower River Niger at Agenebode, Edo State, Nigeria

Parameters	Wet season	Dry season	t-value	p-value	Significance
pH	6.5±0.12	7±0.21	-2.15	0.04	*P<0.05
Conductivity (Mg/l)	60.28±6.1	58.67±6.52	0.18	0.86	P>0.05
Total Suspended Solids (Mg/l)	89.67±17.56	43.13±6.1	2.32	0.03	*P<0.05
Turbidity (NTU)	136.19±30.54	59.83±10.13	2.2	0.04	*P<0.05
Phosphate (Mg/l)	3.89±1.63	0.52±0.09	1.88	0.07	P>0.05
Phosphorus (Mg/l)	1.29±0.52	0.21±0.04	1.89	0.07	P>0.05
Sulphate (Mg/l)	33.33±5.73	25.93±4.22	1	0.32	P>0.05
Nitrate (Mg/l)	6.81±0.92	3.48±1.12	2.32	0.03	*P<0.05
Ammonia-N	0.87±0.26	0.12±0.03	2.6	0.01	**P<0.01
Chloride (Mg/l)	14.98±1.65	18.67±2.19	-1.37	0.18	P>0.05
Dissolved Oxygen (Mg/l)	5.25±0.56	5.5±0.61	-0.3	0.77	P>0.05
B.O.D. (Mg/l)	3.08±0.53	3.66±0.7	-0.67	0.51	P>0.05

Note: P>0.05- Not Significant, *P<0.05-Significant, **P<0.01- Highly Significant

Correlation (r) between different Physico-chemical Parameters of Lower River Niger at Agenebode

The correlation coefficient (r) between every parameter pair was computed by taking the average values as shown in table 4 below. Correlation coefficient (r) between any two parameters, x & y was calculated for PH, water temperature, dissolved oxygen, electro-conductivity, nitrates, calcium of the Lower River Niger. The degree of line association between any of the water quality parameters measured by the simple correlation coefficient (r) is presented in table 4.14 as correlation matrix. The PH has been found to show positive correlation with water temperature (r=0.037), conductivity (r=0.087), nitrate (r= 0.121), BOD (r= 0.396), and transparency (r=0.142). dissolved oxygen(r=-0.305), has been found to show strong correlation with conductivity (r=0.104), turbidity (r=0.062), phosphate (r=0.090), phosphorus (r=0.086), and correlated significantly Biochemical oxygen demand (r=0.590). Water temperature showed had a negative correlation with BOD (r= -0.072) and positive correlation with pH (r= 0.037). However, conductivity showed positive significant with transparency (r= -0.117) and dissolved oxygen (r= -0.104) as represented in Table 4.

Table 4: Correlation of Physical and Chemical Parameters of Lower River Niger, Agenebode, Edo State, Nigeria

	pH	EC	Turb.	PO_4	P	SO_4	NO_3	NH_3	Chloride	DO	BOD	TSS	TDS	Alk	Ca	Mg	COD	Depth	WT	Trans.
pH	1																			
EC	.087	1																		
turbidity	-.493**	-.321	1																	
phosphate	-.263	-.145	.713**	1																
phosphorus	-.247	-.163	.737**	.998**	1															
sulphate	-.352*	-.133	.770**	.556**	.576**	1														
nitrate	.121	.496**	.102	.284	.280	.310	1													
ammonia	-.327	-.119	.886**	.770**	.792**	.809**	.431*	1												
chloride	-.508**	-.076	-.140	-.206	-.224	-.136	-.525**	-.347*	1											
DO	-.005	.104	.062	.090	.086	-.095	.183	.105	.060	1										
BOD	.396*	.322	-.383*	-.211	-.213	-.340	.330	-.164	-.176	.590**	1									
TSS	-.494**	-.236	.928**	.648**	.674**	.797**	.191	.923**	-.110	.135	-.318	1								
TDS	-.077	.088	-.053	-.188	-.176	-.044	.021	-.027	-.067	.144	.286	-.014	1							
Alk	-.022	-.173	.213	.093	.099	.086	.052	.198	-.162	.095	-.080	.194	-.092	1						
Ca	.050	.030	-.013	.073	.082	.120	.010	.043	.069	-.173	-.056	-.013	-.087	.016	1					
Mg	.379*	-.276	-.285	-.299	-.293	-.223	-.252	-.380*	-.107	-.315	-.130	-.381*	.184	-.084	-.077	1				
COD	.117	.046	-.184	-.180	-.183	-.002	-.079	-.162	-.088	-.168	-.032	-.234	-.142	.194	.142	.219	1			
depth	-.338	-.459**	.606**	.431*	.446**	.287	-.194	.395*	.046	-.026	-.283	.434*	.220	.108	-.250	.147	-.439*	1		
WT	.037	-.165	-.479**	-.317	-.326	-.295	-.475**	-.506**	.474**	-.234	-.072	-.418*	.048	-.150	.143	.158	.069	-.193	1	
trans	.142	.117	-.244	-.094	-.102	-.319	.144	-.190	-.016	.060	.113	-.174	-.347*	.067	.061	-.114	-.184	-.227	-.095	1

Keys:
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

The Nigeria climate is tropical, characterized by high temperatures and humidity as well as marked wet and dry seasons. Previous studies on limnological investigations of some Nigerian reservoirs, lakes, springs and streams have also been reported (Chia *et. al*, 2011).

The temperature for all the sampling sites were normal for a tropical water body and this is in line with values between 26.5 and 32.8 ^0C recorded by APHA (2022) for tropical rivers. The temperature is within the recommended level (24-31 ^0C) for warm water fish (World Health Organization, 2019). Dissolved Oxygen in water is an important factor that determines the occurrence and abundance of aerobic aquatic organisms. Thus, the more dissolved oxygen available in water, the more the organisms it will support (Hassan, *et.al*. 2014). All the DO values were within the range ($\geq$4mg/L) recommended for warm water fish (Boyd, 2020)

The pH values recorded in all the stations fall within the International Standard for freshwaters APHA, (2022), and are optimum for fish culture Boyd, (2020). This is supported by the findings of World Health Organization (2019) that pH of 5.5 to 10 is recommended for tropical fishes. However, they all tend towards alkalinity which is in line with some researchers (Ioryue, *et. el.*, (2018), and Chia, *el. al*. (2011),. The relatively high values of electrical conductivity observed are due to the evaporation of water, leaving a higher concentration of salt within a smaller volume of water.

Agenebode has distinct wet and dry seasons. The wet season spans from April to October while the dry season extends from November to March. The rainfall data showed a seven month wet season period with five months dry season cycle though the months of rains are not high in rainfall as observed in other parts of the state, The highest ambient air temperature and lowest relative humidity were recorded in the middle of the dry season due to the characteristic cool dry tropical wind and intense sunlight between November and February. Water temperature regulates activities (both abiotic and biotic) of an aquatic ecosystem (Lintern, *et..al* 2018; Medudhula *et al*., 2012). It remains as a major factor that determines primary production in reservoirs

(Adeniyi, 2018). The surface temperatures of 23.3^{0}C to 31.0^{0}C fall within the range documented for typical tropical lakes and reservoirs. Hassan et al., (2014) and Adeniyi (2018)' corroborated this observation. The spatial difference in temperature is as a result of inflowing water, vertical mixing of water as well as processes like exchange of heat with the atmosphere and other localized phenomena (Adeniyi, 2019). Higher water temperature during the dry season can be attributed to high atmospheric temperature, low relative humidity and high transparency. The present result also agreed with previous reports that temperatures in tropics vary between 21^{0}C and 32^{0}C (NESREA, 2011). Boyd (2017) recommended temperature range of 20 – 30^{0}C for optimum fish growth. Therefore, the temperature range of 25.3^{0}C – 31.0^{0}C observed in Lower River Niger at Agenebode during the course of this study falls within the optimal range for fish growth.

Seasonally, variations among the investigated parameters were not statistically significant ($p<0.05$) except for Total Suspended Solids (TSS). TSS are solid materials, including organic and inorganic, that are suspended in water. These would include silt, planktons and industrial waste. The marked higher TSS recorded during the rainy season months, could be attributed to periods of high rainfall and subsequent erosional over flooding; when particulate materials from within and outside the river's geographical boundaries are carried into the water body. Also the ongoing sand excavation activities by the local inhabitants and dredging could contribute suspended particulate materials along the river channel. Pooja (2018) classified water with TSS of 278mg/l and above as grossly polluted, while NESREA (2011) recommends value not greater than 0.25mg/l for aquatic life in surface waters. This therefore makes the Lower River Niger at Agenebode a polluted water body and unsuitable for both aquatic life and drinking water. Total suspended Solids is an important water quality parameter in assessing water pollution (EPA, 2022). Suspended solids can harbor pathogens which contribute to water borne diseases that can infect aquatic or human life.

The BOD concentrations values were within the regulated limits of <4mg/L by Boyd (2015) and WHO (2019). Transparency is a parameter of water quality that varies with the combined effect of colour and turbidity. Turbidity is influenced by suspended solid materials such as clay, silt, colloidal organic matter, planktons and remains a major cause of low transparency. Increase in turbulence of waters usually increases all the suspended materials, especially in shallow waters. Transparency was lowest during the month of September, which coincides, with the peak of the raining season due to over flooding. The higher transparency observed during the dry season could also be due to reduction in allochthonous substances that find their ways into the river with flood. Water transparency was higher during the dry season than the rainy season. The lower transparency observed during the raining season could be attributed to high water run-off from the water shed into the reservoir.

The electrical conductivity value obtained in Lower Niger River was within the optimum value (Boyd, 2017). However, there was variation and significant difference in observed spatial conductivity, this could be attributed to utilization of the ions by flora and fauna. Similarly, the highest conductivity value obtained in DNS could be linked to its closeness to the most sand mining activity area of the river leading to high influx of flood water which contains suspended and dissolved materials. Enough storm water runoff from soil erosion and the washing of ions into the water channel in the rainy season were responsible for the higher values.

A pH range of 6 to 8.5 is normal according to the United States Public Health Association (APHA, 2022). The absence of marked spatial variation in pH at the locations in Lower River Niger at Agenebode indicates stable habitat, which could be linked to its stable photosynthetic rates measured as primary productivity. According to Adeniyi (2017), the pH of water is affected considerably as photosynthetic activities which remove carbon (IV) oxide from water and shifts the carbonate-bicarbonate equilibrium. The slightly acidic pH range of 6.00 – 6.88 recorded in this study conformed to values previously reported in Niger Delta freshwaters (Ighalo and Adeniyi, 2020). The pH range also falls within (6.5-8.5) recommended limits for aquatic life (USEPA, 2022). This pH makes it quite suitable for fish production in this river

The range obtained for nitrate fall within the optimum value (50mg/l) for drinking water by WHO (2019) and NESREA 9.10mg/l for aquatic life. .This value is higher than 0.02-0.03mgl^{-1} reported by Medudhula et al. (2012) in Lower Manair river in India. The variation in nitrate concentration reflects the effects of human activities on various sections of the river. The positive correlation observed between nitrate and TDS indicates that nitrate ions also contributed to the total dissolved components of the river. The non-significant spatial variation in nitrate concentrations at several sampling locations indicates homogeneity in natural and anthropogenic inputs at those locations. However, there was significant difference ($P<0.05$) in the mean values of nitrate obtained in Lower Niger River seasonally.

Like other nutrients, the sources of phosphate in aquatic environments has been identified as natural weathering of materials in the drainage basin, biological decomposition, and runoff from human activities in urban and agricultural areas (UNEP GEMS, 2022). The observed higher phosphate values recorded during the rainy season therefore could be attributed to increased leaching and surface runoff associated with rainfall and flooding from the catchment areas of the river.

The range of phosphate (PO_4^{2-}) ions in this study was within optimum limits for drinking water and aquatic life (Boyd, 2015). Values recorded in this study were also within the range of many Nigerian inland waters as reported by NASREA (2011). The absence of marked spatial variation in phosphate concentration in the study area implies homogenous natural and anthropogenic inputs at these stations. The positive correlations between phosphate, TDS and conductivity reveal the importance of nutrient ions in the overall dissolved and ionic compositions of an aquatic system.

CONCLUSION

All the physical and chemical parameters investigated fall within the limits required for sustainable ecosystem, however, total suspended solids, Transparency, Sulphate and COD were above the permissible level. Seasonally, there were no significant difference ($P>0.05$) for Conductivity, Phosphate, Phosphorus, Sulphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chloride among the sampling stations while Suspended Solids (SS), Turbidity, pH and Nitrate showed significant difference ($P<0.05$) among the sampling stations and Ammonia-N was highly significant ($P<0.01$). These findings are indicative of warning signs for pollution which impact not only aquatic organisms but also drinking water. Suspended solids can harbor pathogens which contribute to water borne diseases that can infect aquatic or human life. Crucial steps are needed urgently to reduce agricultural activities and anthropogenic discharges in the Lower River Niger at Agenebode to sustain the water body from further degradation. High levels of pollution will not only affect aquatic life but will also invite socio-economic disasters.

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