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Investigating the Influence of Surface Runoff and Human Activities on the Seasonal Characterization of Physicochemical Properties of the upper segment of Qua Iboe River Water, Niger Delta, Nigeria

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ABSTRACT: The objective of this paper was to investigate the influence of surface runoff and human activities on the seasonal characterization of physicochemical properties o of the upper segment of Qua Iboe River Water, Niger Delta, Nigeria, using the protocols described in standard methods for the examination of water and wastewater. The values of physicochemical parameters assessed in water samples gave the following ranges: Water Temperature (22.0-31.6 ^{o}C), Dissolved Oxygen (1.5-7.42 mg/L), Total Dissolved Solids (48.6-130.6 mg/L), Electrical Conductivity (72.5-195.0 mg/L), Turbidity (5.14-48.0 NTU), Sulphate (42.8-158.3 mg/L), Nitrate (1.76-17.48 mg/L),Phosphate (1.85-17.95 mg/L), Biochemical Oxygen Demand (0.62-6.51 mg/L), Chloride (22.29-80.36 mg/L) and Total Suspended Solids (22.1-91.5 mg/L). The mean values of Dissolved Oxygen, Nitrate and Biochemical Oxygen Demand in wet season exceeded the standard limits while Turbidity, Phosphate and Total Suspended Solids in both seasons exceeded the standard limits. ANOVA at $P < 0.05$ reveals significant variation in some parameters between the seasons. The findings revealed that surface runoff and anthropogenic activities influence the concentrations of some parameters.

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Pollution in aquatic systems is so devastating, connected with human induced activities and climate change (Taiwo *et al*., 2012; George *et al*., 2020; Akpan *et al*., 2023; Jacob *et al*., 2023).Climate change, currently, represents one of the biggest environmental threats, causing water pollution and has a great impact on human's health. It can lead to greater fluctuations in the occurrence and extent of precipitation, air temperatures and a corresponding increase in water temperatures (Whitehead *et al*., 2009). Air temperature influence the temperature values in water (Mohseni and Stefan, 1999;Webb *et al*., 2003) while the water temperature in other hand influence the solubility of dissolved oxygen in water bodies (George *et al*., 2007; Whitehead *et al*.,2009; Jonah *et al*., 2020b). The alteration in hydro-parameters due to excessive rainfall and anthropogenic activities has a pessimistic

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consequence on ecological balance since the aquatic productivities are equally based on water quality conditions (Conlan *et al*., 2007).In contrast, drought leads to the concentration of existing pollution, when the water level in the rivers drops. Reduction in water dilution affects organic pollutant concentrations, with increased biological oxygen demand, and hence, lower dissolved oxygen concentrations in rivers (Whitehead *et al*., 2009). More so, flooding could increase the level of organic loads and inorganic pollutants (Jonah *et al*., 2020a), suspended solids (Lane *et al.*, 2007), and contaminant metal fluxes (Longfield and Macklin, 1999). However, the concentrations of suspended solids of a water body are sometimes influenced by sand dredging, indiscriminate dumping of solid wastes and excessive growth of aquatic plants (Jonah *et al*., 2019). Studies (Jonah *et al*., 2020b; Jonah *et al*., 2020e; Anyanwu *et al*., 2022) has shown that values of some water parameters are often increased with an increase rainfall while some are increased with less precipitation. Intense rainfall leading to runoffs could transfer all sorts of pollutants from houses, industries, farmland and dumping sites into the water bodies (Izonfuo and Bariweni, 2001).Water pollution through surface run-off has been reported in literatures with subsequent effects on nutrient enrichment and water quality impairment (Ekpo *et al*., 2012; Ayobahan *et al.*,2014; Amah-Jerry *et al*., 2017; Jonah and Akpan, 2024).The Qua Iboe river is one of the major tropical rainforest rivers in Niger delta that traverses over 100 communities from its origin covered three Local Government Areas in Abia State and ten in Akwa Ibom State. The water body is vulnerable to various anthropogenic activities which might hamper the ecological integrity.More so, the agricultural activities within the catchment area are a source of concern as a result of consistent used of fertilizers, pesticide, and insecticides that are highly toxic, and other synthetic organic compounds widely used in agriculture.These substances might get into the adjoining water bodies, and subsequently Qua Iboe River through surface runoff, and there is paucity of information concerning the physiochemical properties of this river. Hence, the objective of this paper was to investigate the influence of surface runoff and human activities on the seasonal characterization of physicochemical properties of the upper segment of Qua Iboe River water, Niger delta, Nigeria.

MATERIALS AND METHODS

Description of the study area: The Qua Iboe River is among the major rivers in Niger Delta, Nigeria. The river flows in south eastern direction towards the Atlantic Ocean, from Ikwuano Local Government Area of Abia State into Usaka Community in Akwa Ibom State. The river receives wastes from point and non-point sources. The river water serves as source of water for irrigation, industrial and domestic use. The region is characterized by having two climatic seasons (April - September) and dry season (October - March). Five locations were selected along the stretch of the river between Obot Akara and Ukanafun Local Government Area; lies from Latitude $04^o53^'$ to 05^o9'North and Longitude 07^o39' to 07^o47' East (Fig.1). The locations were selected based on the ecological setting; geological features, land use, nearest to communities and the levels of anthropogenic activities. The 1st location is upstream (Ikot Amba); 3km from Obot Akara L. G. Headquarter. The location is characterized by slow water current, higher penetration of sunlight intensity, substrate is sandy and muddy at the right hand side of the river, and human activities (bathing, laundry and farming) are minimal. The 2nd location (Head Bridge at Ikot Osurua) is 6km from location 1. The location is characterized by higher human activities ranging from extensive farming, intense sand dredging, bathing, laundry, sand loading, stone mining, and other domestic activities. The water is also extracted for drinking, domestic, and for industrial uses. The river receives wastes from nearby communities, markets, municipal run-off, direct dumping and from road construction. The 3rd location (Ekpenyong Attai 1) is 5km from location 2; anthropogenic activities are high, which include extensive farming, sand dredging, bathing, laundry, sand loading. The substratum is muddy and sandy. The location is near to human habitations. The 4th location (Uruk Ata Ikot Isemin) is 5km from location 3; human activities were farming at the wetland behind the river, fishing and laundry. The water current is slow especially during the dry season. The 5th location (Head Bridge at Nkek Idim) is 4km downstream away from location four. The area is characterized by slow water current; sandy substrate while the edge is muddy. Human activities were intense sand dredging, farming, bathing, and laundry. The river at this point also receives wastes from nearby community through run-off.

*Samples collection and Analysis:*The water samples were collected in monthly basis in five sampling locations, between January 2020 and June 2021 (eighteen months) for physicochemical analysis using sterilized plastic bottles (one litre). Samples for biochemical oxygen demand (BOD_5) were collected using 250mL reagent bottles. Before collection, the plastic bottles were rinsed with the river water to be sampled. Samples collected were placed in ice chests and transported to the Laboratory Unit of Akwa Ibom

State Ministry of Science and Technology, Uyo, and kept frozen at 4^{o}C prior to analysis. Parameters like water temperature, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC) and turbidity (NTU) were determined at the sampling locations while others were analyzed *ex-situ*. The DO was measured using portable DO Meter (Hanna H 19146 - 04 Model); TDS and EC were determined with portable TDS/EC meter (HACH CO.150 model); turbidity was determined using turbidity meter (DT 138 Model); sulphate (SO_4^-) was by turbidemetric method; nitrate (NO_3^-) was by cadmium reduction method; phosphate (PO_4^-) by molybdenum blue method; biochemical oxygen demand (BOD_5) by acid modification method; chloride (Cl^-) by Argentometric method while total suspended solids (TSS) by gravitation method. The measurements were made following protocols described in the text "Standard Methods for the Examination of Water and Wastewater" (APHA, 2017).

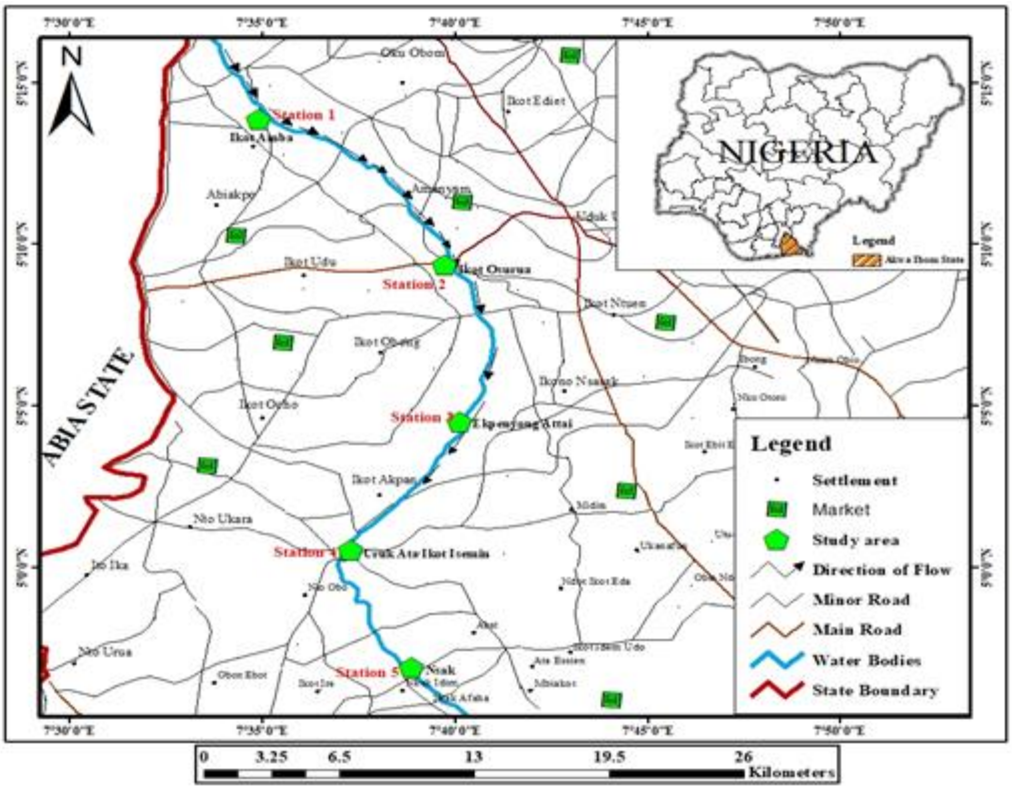

Fig. 1: A map showing the stretch of Qua Iboe River and sampling locations

Statistical analysis:The data obtained were grouped by seasons and subjected to One-way ANOVA using SPSS while Fisher's LSD was applied to compare the means of water variables, and Paired sample T-test was carried out for seasonal comparison with significant difference set at P <0.05. Pearson correlation co-efficient (r) of analysis was also carried out to establish the relationship among the physicochemical parameters in each season.

RESULTS AND DISCUSSION

The summary of seasonal variation of physicochemical parameters is presented in Table 1 while the correlation matrix for physicochemical parameters in during dry and wet season is shown in Table 2 and 3 respectively. Water temperature is an influential hydrological parameter that controlled the solubility of dissolved oxygen in the water, and it may affect the distribution of aquatic biota. Living things are sensitive to changes in WT (Özdemir *et al*., 2014; Jonah *et al*., 2024). Increase in atmospheric temperature significantly led to increase in rate of chemical reactions and formation of toxic complexes in aquatic ream and portrayed a profound effect on aquatic organisms (Okorafor *et al.*, 2014). The WT obtained ranged from 23.3 to 31.6 ^{0}C in dry season and 22.0 to 26.7 ^{0}C in wet season; maximum averages value (27.29 ^{0}C±0.15) was obtained in dry season while the minimum value (24.84 ^{0}C±0.26) was in wet season. ANOVA test showed significant difference (T = 8.317, P < 0.05) between the mean values for the two seasons.

Table 1: Seasonal variation of physicochemical parameters from upper segment of Qua Iboe River

Parameters	Unit	Dry Season (Octo. – March)	Wet Season (April – Sept.)	P value	WHO (2017)	FMEnv (2011)
WT	^{0}C	27.29±0.15^{a} (23.3 – 31.6)	24.84±0.26^{b} (22.0 – 26.7)	$P< 0.05^{*}$	24 – 30	NI
DO	mg/L	6.19±0.12^{a} (3.0 – 7.42)	4.40±0.16^{b} (1.5 – 6.22)	$P< 0.05^{*}$	>5	6.0
TDS	mg/L	86.34±0.87^{a} (48.6 – 129.8)	53.87±1.63^{b} (48.6 – 130.6)	$P< 0.05^{*}$	500	NI
EC	μS/cm	138.70±1.14^{a} (72.5 – 194.0)	92.17±1.62^{b} (72.5 – 195.0)	$P< 0.05^{*}$	1500	NI
Turb.	NTU	14.48±1.09^{a} (5.14 – 39.6)	38.43±0.72^{b} (9.13 – 48.0)	$P< 0.05^{*}$	<5	NI
SO^{-}_{4}	mg/L	79.36±3.03^{a} (45.8 – 136.4)	92.16±4.36^{b} (42.8 – 158.3)	$P< 0.05^{*}$	250	100
NO^{-}_{3}	mg/L	5.93±0.27^{b} (1.76 – 6.13)	13.34±9.61^{a} (3.10 – 17.48)	$P< 0.05^{*}$	<50	9.1
PO^{-}_{4}	mg/L	4.05±0.18^{a} (1.85 – 6.64)	6.04±0.29^{a} (2.18 – 17.95)	$P> 0.05^{ns}$	<5	3.5
BOD_5	mg/L	2.35±0.09^{a} (0.62 – 3.82)	3.58±0.11^{a} (1.22 – 6.51)	$P> 0.05^{ns}$	3	3
Cl^{-}	mg/L	49.07±2.04^{a} (26.63 – 80.36)	40.90±1.86^{a} (22.29 – 77.64)	$P> 0.05^{ns}$	250	300
TSS	mg/L	48.33±2.44^{b} (22.1 – 91.5)	68.65±2.41^{a} (32.6 – 91.5)	$P< 0.05^{*}$	50	0.25

± Standard error; * = Significant at $p < 0.05$; ^{ns} = not significant; NI = not indicated

The mean values obtained in both seasons were within the optimum concentration (24 – 30 ^{0}C) recommended by WHO (2017).The maximum mean value recorded in dry season suggests periodic changes in climatic condition, intense solar radiation, implying that sunlight imposes a rise in water temperature in the dry season compared to the wet season where rainfall is predominant with consequent reduction in water temperature.

Table 2: Pearson correlation matrix for physicochemical parameters in during dry season

	WT	DO	TDS	EC	Turb.	SO^{-}_{4}	NO_3^{-}	PO^{-}_{4}	BOD_5	Cl^{-}	TSS
WT	I										
DO	-.113	I									
TDS	-.683	-.511	I								
EC	-.541	-.022	.928*	I							
Turb.	-.521	-.196	-.153	.273	I						
SO^{-}_{4}	-.317	.582	-.414	.789	.690	I					
NO_3^{-}	-.440	.695	.819*	-.97**	.376	-.423	I				
PO^{-}_{4}	-.331	-.918*	-.555	-.92**	.250	.358	-.032	I			
BOD_5	-.624	.590	.210	-.210	.197	-.591	-.063	-.738	I		
Cl^{-}	-.369	.690	.331	.816*	.424	-.925*	-.739	.943**	-.018	I	
TSS	-.032	-.876*	-.479	-.573	-.431	-115	-.321	-.583	-.599	.133	I

** Correlation is significant at 0.05 level (2-tailed); ** Correlation is significant at 0.01 level (2-tailed)*

Table 3: Pearson correlation matrix for physicochemical parameters in during wet season

	WT	DO	TDS	EC	Turb.	SO^{-}_{4}	NO_3^{-}	PO^{-}_{4}	BOD_5	Cl^{-}	TSS
WT	I										
DO	-.426	I									
TDS	-.621	-.733	I								
EC	-.721	-.484	.507	I							
Turb.	-.170	-.822*	.710	.636	I						
SO^{-}_{4}	-.641	.583	-.573	.408	-.686	I					
NO_3^{-}	-.451	-.984*	-.714	.872**	-.145	.924*	I				
PO^{-}_{4}	.528	-.440	-.913*	-.725	-.260	.813*	.918*	I			
BOD_5	.492	-.839*	-.081	-.308	-.102	-.89**	.746	.832*	I		
Cl^{-}	-.672	-.624	-.125	-.453	-.198	.007	.862**	.169	-.765	I	
TSS	-.419	.973**	-.761	.677	.961**	.259	.228	.468	.691	-.748	I

* Correlation is significant at 0.05 level (2-tailed); ** Correlation is significant at 0.01 level (2-tailed)

The level of DO in aquatic systems is essential to determine whether the water can support aquatic life (Joshua and Nazrul, 2015).The DO levels ranged between 1.5 and 7.4 mg/L; having the maximum mean level (6.19mg/L±0.12) in dry period while minimum mean level (4.40 mg/L±0.16) was obtained in wet period. ANOVA reveals a significant difference (T = 5.945, $P < 0.05$) among the seasons.

The DO content obtained during wet season suggests high accumulation of organic and inorganic pollutants in the water body through surface runoff (Jacob *et al.*, 2023). The DO showed negative correlation relationship with PO_4^- (r = -0.918, *P* < 0.05) and TSS (r = 0.876, *P* < 0.05) in dry season (Table 2). On the other hand, DO indicated negative correlation with turbidity (r = -0.822, *P* < 0.05), NO^-_3 (r = -0.984, *P* < 0.05), BOD_5 (r = -839, *P* < 0.05) and inverse relationship with TSS (r = 0.973, *P* < 0.01) during wet season (Table 3). The mean level obtained in wet period was dropped below the limit (> 5 mg/L) recommended by WHO (2017) for drinking and 6.0 mg/L for aquatic life as set by FMEnv (2011). The seasonal trend is corroborating with findings of Jonah *et al*. (2020c) in previous study from the upper Qua Iboe River. The findings contradict with the report of Silas *et al*. (2018) for Mkomon River, having maximum DO content in wet season. The maximum mean value observed during dry season could be due to low contents of inorganic, organic wastes, and decaying organic matter that could have used much of DO by bacteria for decomposition (Jonah *et al.*, 2023; Jacob *et al.*, 2023) while the minimum value obtained during the wet season may be attributed to high accumulation of organic and inorganic pollutants in the water body couple with intense anthropogenic activities.The low content of DO recorded during wet season was precisely influenced by the concentrations of turbidity, NO^-_3 and $BOD_{5.}$

The TDS contents exhibited differences between the seasons, which occurred from 48.6 to 129.8mg/L (dry season) and 48.6 to130.6mg/L (wet season); with the maximum mean level (86.34mg/L±0.87) in dry season. The mean levels were in accordance with the limit (500mg/L) recommended by WHO (2017). ANOVA showed significant difference (T = 4.072, *P* < 0.05) between the seasons.The TDS correlate positively with EC (r = 0.928, *P* < 0.05) and NO^-_3 (r = 0.819, *P* < 0.05) in dry season and inverse relationship with PO^-_4 (r = -0.930, *P* < 0.05) during wet period. The seasonal mean values obtained are higher than the 9.62 to 22.65mg/L (wet season) and 10.45 to 13.12mg/L(dry season) reported by Jonah *et al.* (2019) in Ikpe Ikot Nkon River, Nigeria and further contrast with the earlier report of Jonah *et al*. (2020c) for upper segment of Qua Iboe River; Arazu *et al*. (2015) for River Niger at Onistsha Stretch; Silas *et al*. (2018) for River Mkomon, Nigeria. The maximum mean content during dry season attributed to higher precipitation that possibly dilutes the influx allochthonous substances during the wet season (Essien-Ibok *et al.*, 2010). The observed correlations reveals that higher concentration of EC and NO_3^- associated with the increased value of TDS level during dry season while increase in PO_4^-decrease the TDS recorded in wet season.

The EC content varied between the seasons, occurred between 72.5 and 194.0mg/L (dry season) and from 72.5 to195.0mg/L (wet season). The maximum mean level was obtained in dry season (138.70mg/L±1.14), with a robust significant differences (T = 4.694, *P* < 0.05) between the seasons.The mean values recorded were within the limit (1500µS/cm) recommended by WHO (2017).The correlation analysis showed that EC showed a positive correlation with NO_3^- (r = 0.872, *P* < 0.01) in wet season while negative correlation with PO^-_4 (r = -0.924, *P* < 0.01) and NO^-_3 (r = -0.972, *P* < 0.01) during dry period. This implies that the EC content was depends significantly on NO^-_3 during wet season while the PO^-_4 and NO^-_3 contents in dry months contributed to the lower concentration of EC. On the other hand, EC showed positive correlation with Cl^-. (r = 0.816, *P* < 0.05) in dry season, indicating that the levels of Cl^- were influenced the concentration of EC in both seasons.The seasonal contents contrast with the reports Akaahan *et al*. (2016) for River Benue; Ajegena *et al*. (2020) for Amba River and affirmed the report George and Efiom (2018) for Imo River. The EC minimum mean level recorded in wet season suggests dilution of ionic concentrations by rain water during the wet season months. This result is evident to the fact that during the rainy season there is an increase in precipitation and hence decreased the levels of EC (Kosten *et al*., 2011).

The turbidity content exhibited differences between the seasons, which occurred from 5.14 to 39.6 NTU (dry season) and 9.13 to 48.0 NTU (wet season). All values exceeded < 5 NTU limit recommended by WHO (2017). The maximum level of turbidity in aquatic ecosystems impaired the maximum capacity of primary productivity and reduction in amount of photosynthetic activities by green plants (Jonah *et al.*, 2020a).The maximum mean level (38.43NTU±0.72) was obtained in wet season while the minimum level (14.48 NTU±1.09) was in dry season. The mean level recorded in wet period was significantly (T =3.016, *P* < 0.05) higher than the dry season. Turbidity showed a positive correlation with TSS (r = 0.961, *P* < 0.01) and inverse relationship with DO (r = -0.822, *P* < 0.05) in wet period; indicating that increases in TSS results in an increases concentration of turbidity, while the negative value with DO implies that higher turbidity hindered the amount of DO during the wet season. The maximum level for turbidity obtained in wet season could be linked to the prevalent large volume of surface runoff, couple with sand mining activities in the river (Wickramarchchi *et al*., 2010; Jonah *et al*., 2020d; Hettige *et al*., 2022). Similar trend was recorded by Emurotu and Habib (2019) for Obuburu River.

The SO^-_4 occurred between 42.8 and 158.3mg/L; the maximum mean level (92.16mg/L±4.36) was recorded in wet season ascribed to significant influence of inundation, carrying miscellaneous wastes and other pollutants from the land use into the water.The minimum mean value (79.36mg/L±3.03) in dry season suggests low or absent the above mentioned factor.The mean levels obtained were within the permissible limit (200 mg/L) set by WHO (2017) for drinking and 100mg/L acceptable by FMEnv (2011).ANOVA test showed significant difference between the mean levels obtained in both seasons (T = 2.411, *P* < 0.05). The findings are in line with the concentrations reported by Ekpo *et al*. (2012) in a tropical rainforest riverand Jonah *et al.* (2015) for Ohii Miri River in Abia State, Nigeria. However, SO^-_4 was positively correlated with NO^-_3 (r = 0.924, *P* < 0.05), PO^-_4 (r = 0.813, *P* < 0.05) and inverse correction with BOD_5 (r = -0.896, *P* < 0.01) in wet season, and negatively with Cl^- (r = -0.925, *P* < 0.05) during dry season. This could be implies that in wet session, NO^-_3 and PO^-_4 contents contributed to the high concentration of SO^-_4while the observed relationship with Cl^- in dry season could implies that low content decrease the concentration of SO^-_4 in dry season.

The NO_3^- mean values exhibited significant differences (T = 0.771, *P* < 0.05) among the seasons; with the maximum mean level (13.34mg/L±9.61) obtained in wet season while the minimum value (5.93mg/L±0.37) was recorded in dry season. The mean levels recorded were at the acceptable limit (<50 mg/L) set by WHO (2017) for drinking. On the other hand, the wet mean value exceeded the permissible limit (9.1mg/L) of FMEnv (2011) for aquatic life. Nitrate concentration indicate positive coexistent with PO^-_4 (r = 0.918, *P* < 0.05) and Cl^- (r = 0.862, *P* < 0.01) in wet season; indicating that PO^-_4 and Cl^- contents increases the concentration NO_3^- during the wet season. Water body with high concentrations of NO_3^- could be detriment to aquatic ecosystems since it induces eutrophication.Nitrate entering aquatic ecosystems arise from a variety of sources which are mostly contributing to aquatic pollution (Ishaq and Khan, 2013).The NO_3^- mean level obtained in wet period indicated moderate pollution that could affect aquatic life, suggests domestic waste discharge and effect of runoffs from land used and the nearby dumpsite.

Little variations in PO^-_4 content were recorded between the seasons; with no significant differences (T = 2.741, *P* > 0.05). The maximum mean value (6.04mg/L±0.29) was recorded in wet season and exceeded limit (< 5mg/L) recommended by WHO for drinking as shown in Table 1. On the other hand, the mean values exceeded the permissible limit (3.5mg/L) set by FMEnv (2011) for aquatic life. Pearson correlation analysis showed that PO^-_4 corrected positively with BOD_5 (r = 0.832, *P* < 0.05), SO_4^- (r = 0.813, *P* < 0.05) and NO_3^- (r = 0.918, *P* < 0.05) in wet season and inverse correlation with Cl^- (r = -0.943, *P* < 0.01) in dry season. These denote that increased concentrations of BOD_5, SO_4^- and NO_3^- resulting in an increases of PO^-_4 content during the wet season.The PO^-_4 seasonal values obtained are in conformity with the reports of Clement *et al.* (2010) in Urban Draining Creek, Nigeria; Jonah *et al.* (2020c) for Qua Iboe River, and not in line with the findings of Ibrahim *et al.* (2009) in Kontagora Reservoir, Niger State, and Jonah *et al.* (2015) for Ohii Miri River, Nigeria where they recorded maximum mean value in dry season. Phosphate is considered to be the most significant among the nutrients, responsible for growth of aquatic plants (George *et al*., 2020; Jonah *et al*., 2020c; Anyanwu *et al.*, 2022; Jonah and Akpan, 2024). Indeed, there are various sources of PO^-_4 to the river water, such as firm rock deposit, runoff from surface catchments, and interaction between the water and sediment from dead plants and animal remains at the bottom of the river (Ishaq and Khan, 2013).However, the maximum mean value of PO^-_4 obtained during the wet season may be linked to higher rainfall, resulted in higher concentration of organic and inorganic wastes in the water (Akpan *et al*., 2023).

The BOD_5 showed higher variations between the study months, but little among the seasons. The maximum mean level (3.58 mg/L±0.11) was recorded in wet season and exceeded 3mg/L limit recommended by WHO (2017) for drinking and FMEnv (2011) for aquatic life. ANOVA showed no significant difference between the mean values (T=5.417, *P* > 0.05).The maximum BOD_5 content during wet season could be due to higher rate of decomposition of organic matter (Ishaq and Khan, 2013). According to Jacob *et al*. (2023), BOD_5 level <1.0mg/L is classified as unpolluted; values < 10.0mg/L is moderately polluted while value > 10.0mg/L regarded as heavily polluted water.

The Cl^- ranged between 26.63 and 80.36mg/L (dry season) and (22.29 and 77.64mg/L); with the maximum mean value (49.07mg/L±2.04) recorded in dry season. All values recorded were within the permissible limit (250mg/L) recommended by WHO (2017) for drinking and 300mg/L by FMEnv (2011) for aquatic life. ANOVA when applied showed no significant difference between the seasonal mean values (T = 2.959, *P* > 0.05).The seasonal trend in Cl^-

observed contradicts with the reports of Akaahan *et al*. (2016) for River Benue; Silas *et al*. (2018) for River Mkomon; Emurotu and Habib (2019) for Obuburu River and Anyanwu *et al*. (2022) for Ikwu River, Umuahia, Nigeria, where they obtained maximum levels of Cl^- during the wet months suggest runoff during rainy season from chloride sources and coincides with the findings Jonah *et al*. (2019) for Ikpe Ikot Nkon River and Ajegena *et al*. (2020) for Amba river, both in Nigeria. In this study, the minimum mean value recorded during the wet season suggests dilution of Cl^- concentration during rainfall.

The TSS mean level **(**48.33mg/L±2.44**)** recorded in dry season exceeded the mean level (68.65mg/L±2.41) obtained inwet period.The values recorded in both wet seasonsexceeded 0.25mg/L recommended by FMEnv (2011) for aquatic life while the mean content in dry period is within the desirable limit (50mg/L) set by WHO (2017) for drinking purpose. The seasonal patterns of TSS is in conformity with that of Akaahan *et al*. (2016) for River Benue and oppose the findings of Ekpo *et al*. (2012) and Jonah *et al.* (2019) reported maximum values during dry season.The maximum level obtained in wet season is due to high discharge of solid materials, sediments from the adjoining areas, and due to turbulent flow which stirred up the non-living matter like silt and sand at the bottom of the river, coupled with sand mining activities resulting in high turbidity.

Conclusion: The surface runoff is the leading causes of pollution in aquatic ecosystems. The study reveals that water qualities are varied, due to seasonal factors, precipitation and the level of anthropogenic activities. The higher mean values of dissolved oxygen, nitrate and biochemical oxygen demand in wet season could link to impacts of surface runoff, moving more pollutants into the water body during the wet season. This call for urgent attention by the Federal Ministry of Environment and other related agencies to address these issues in order to safeguard the aquatic ecosystem from continues degradation.

Declaration of Conflict of Interest: The author declares no conflict of interest.

Data Availability: Data are available upon request from the corresponding author.

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