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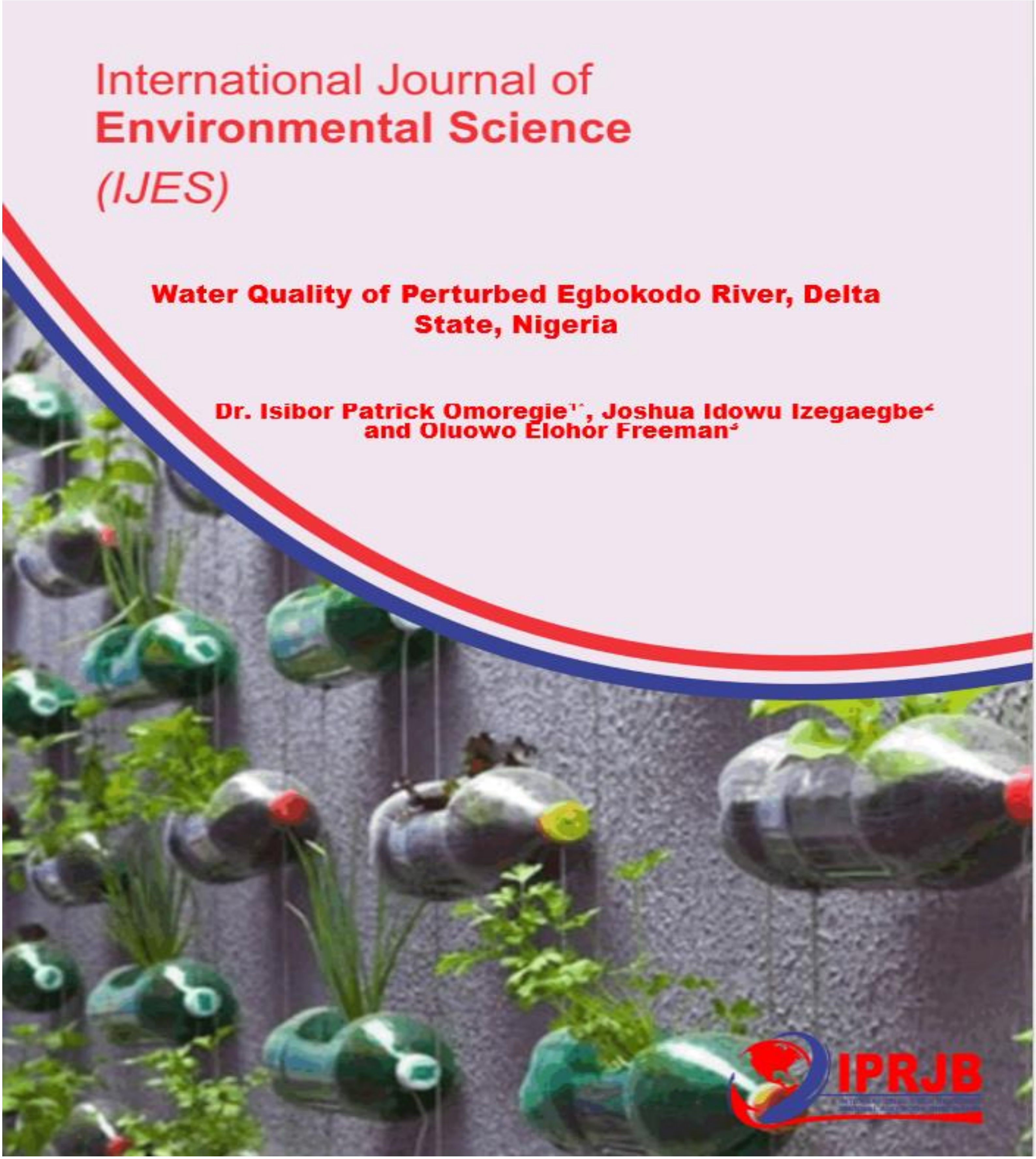

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Abstract

Purpose: An aquatic ecological survey was carried out across the stretch of Egbokodo River; located in Warri South Local Government Area of Delta State, Nigeria. Biomonitoring survey of the river was carried out around important sections along the river.

Methodology: 10 samples of surface water were collected at 10 sub-stations; marked using the Global Positioning System device (GPS); randomly around each station (1, 2, 3, 4, and 5) from November, 2014 to February, 2016 (16 months). The pH of water was taken and recorded in-situ using a WTW water sampler probe. All samples were transported immediately to the laboratory for analysis of the physico-chemical variables. The mean and standard error values of 10 samples collected from each station were subjected to a two-way analysis of variance (ANOVA) to analyse the differences across the stations and the months; using SPSS version 19.2 at probability level of 0.05. Duncan Multiple Range test (DMR) to ascertain the actual locations of the significant differences across the stations and among the months.

Results: Results show that anthropogenic activities around the river are of higher impacts on the ecological equilibrium than most neighbouring rivers. Data assures the suitability of the river for aquatic life, agriculture and domestic use. However, need for amelioration of the anthropogenic perturbations cannot be overemphasised. High conductivity in the dry season was coeval with high salinity; indicating a substantial contribution of the dissolved salts to the conductivity of the river. The high values of BOD observed at Station 2 was accompanied by low dissolved oxygen (DO). This can be attributed to disposal of organic wastes at this section of the river. The DO at Station 3 was significantly higher than other stations throughout the study period ($P < 0.05$). This can be attributed to the surface turbulence by dredging agitation and high standing aquatic macrophytes. The levels of the essential primary productivity nutrients such as nitrate, phosphate and sulphate in the river indicate that the river is oligotrophic.

Conclusion and Recommendations: The study has provided a proof of trophic stratification by anthropogenic perturbations. The study has also provided a general picture of the aquatic environment over an extended period of time; a database useful for reference in subsequent studies aimed at protecting the ecological integrity Egbokodo River.

Key words: *Allocthonous, authoctonous, anthropogenic activities, pollution, seasonal variation, physico-chemical properties.*

1. INTRODUCTION

The physico-chemical parameters of a water body is the basis of the aquatic ecosystem quality; hence a reflection of the conditions of the aquatic biota. However, the quality of rivers and lakes are in constant moderation by allocthonous and authoctonus influences. In the event of pollution of a water body, contaminants released into the aqueous phase are adsorbed on surfaces of particulate matter; which settle them quickly to the bottom of the river where they create the potential for continued environmental degradation, even when the concentrations in the water medium comply with established water quality criteria (DiToro *et al.*, 1991). The physico-chemical conditions of the river influence the metal bioavailability to the biota (i.e. finfish and shellfish); hence an impact on the health of the consumers. However, the variability of the physico-chemical parameters of an aquatic environment is a function of the varied degrees of anthropogenic activities. Hence, constant biomonitoring study of aquatic environments is very paramount in assessing the impacts of anthropogenic activities on the receiving water bodies and impact on public health.

Egbokodo River has been disturbed by several anthropogenic activities such as oil production, agricultural practices and domestic perturbations. These activities are potential allochthonous sources of contaminants which might have risen to concentrations of eco-toxicological significance (Oyewo & Don-Pedro, 2003). The fate of these contaminants can be monitored by measuring their concentrations in water at strategic locations (Camusso *et al.*, 1995).

There is dearth information on the baseline data of physico-chemical parameters of Egbokodo River. Ikejimba and Sakpa (2013) recommended a detailed study of the physico-chemical conditions of the river; with a view to providing a baseline data information of the aquatic environment. There is need for an extensive and intensive biological survey of this aquatic environment; which is of nutrition, ecological and economic importance to the public.

The research was aimed at surveying the aquatic environment with a view to assessing the spatial and temporal variations of the surface water quality of the river through rainy and dry seasons.

2. MATERIAL AND METHODS

2.1 Study Area

An aquatic ecological survey was carried out across the stretch of Egbokodo River; located in Warri South Local Government Area of Delta State, Nigeria. It lies between 5° 37' and 5° 42' N; 5°38I and 5°42' E (Figure 1). The study area is dominated by bamboo trees (*Bambusa species*), oil palm trees (*Elaeis guinensis*), water hyacinths (*Eichhornia crassipes*) and few grasses and shrubs. The area has tropical wet climate which is regulated by rainfall. The climate of the area comprises the wet season (April to October) and the dry season (November to March); followed by a cold harmattan spell from December to January. Occupations of the dwellers of the communities around the catchment areas include farming, fishing, trading and transportation of goods and passengers along the course of the river. There are settlements at the bank of the river.

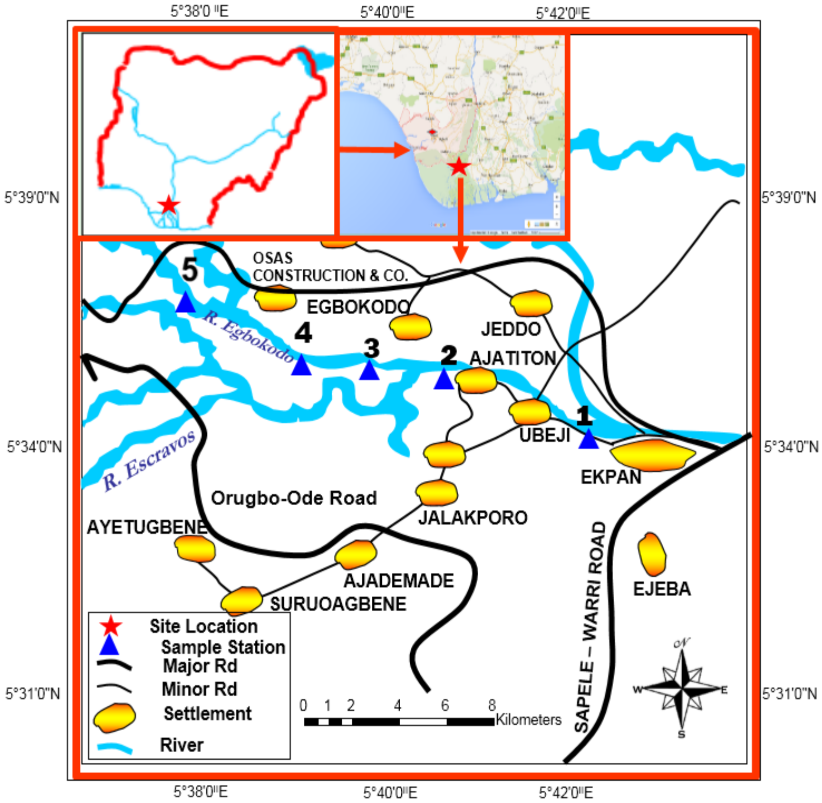

Figure 1. Map of study area showing sampling sampled stations

Five (5) stations were chosen at relevant points of anthropogenic activities along the stretch of the river. Station 1 was located far upstream; away from the disturbed locations. Minimal anthropogenic activities were observed at this location; hence labelled as the control station. Station 2 was located about 430 metres downstream from Station 1. Inhabitants of the surrounding communities use water of the river for washing, bathing and laundering. It was observed that the dwellers of the surrounding communities also dump faeces, kitchen wastes, and other organic domestic wastes at this section of the river. Station 3 was located about 180 metres downstream from Station 2. Manual dredging activities was constantly carried out by a company called Osas Construction Company at this section of the river during the period of sampling. Station 4 was located about 150 metres downstream from Station 3. A vandalized oil pipline (point source pollution) is located at this section of the river. Station 5 was chosen about 430 metres downstream from Station 4. Immense fishing activities predominate this section of the river.

2.2 Sample collection and Analysis

Biomonitoring survey of the river was carried out around important sections along the river. 10 samples of surface water were collected at 10 sub-stations; marked using the Global Positioning System device (GPS); randomly around each station (1, 2, 3, 4, and 5) using 250 litres sampling bottles which were rinsed with distilled water, and then with water from each sampling point. The sampling regime was from November, 2014 to February, 2016 (16 months); on monthly basis

between 0700 h and 1100 h of each sampling day. The pH of water was taken and recorded in-situ using a WTW water sampler probe. All samples were transported immediately to the laboratory for analysis of the physico-chemical variables using standard methods (APHA, 1998).
Turbidity was measured with the aid of a DR/2000 HACH spectrophotometer and was recorded in Nephelometric Turbidity Units (NTU). Conductivity was determined using conductivity meter and was recorded in µS/cm. Total dissolved solid was determined using a total dissolved meter and was recorded in mg/L. Salinity was determined spectrophotometrically and recorded in mg/L. Dissolved oxygen (DO) was determined using Winkler's method. Water samples were fixed immediately after collected at the field with 1ml each of Winkler's solution A (MnSO4) and B (alkali- iodide-azide) and determined titrimetrically in the laboratory using Azide modification method (APHA, 1998) and recorded in mg/L. Water samples for biological oxygen demand (BOD) were incubated at 200 ºC for five days, after when BOD_5 was determined using Winkler's method and recorded in mg/L.

2.3 Statistical Analysis

The mean and standard error values of 10 samples collected from each station were subjected to a two-way analysis of variance (ANOVA) to analyse the differences across the stations and the months; using SPSS version 19.2 at probability level of 0.05. Duncan Multiple Range test (DMR) to ascertain the actual locations of the significant differences across the stations and among the months.

3. RESULTS AND DISCUSSION

3.1 Spatial and temporal variation in pH

The pH of an aquatic environment is a vital physico-chemical parameter. It determines the bioavailability of contaminants to the aquatic biota; hence it is worthy of much attention. Table 1 shows no significant difference occurred in the pH of Station 1 throughout the study period ($P > 0.05$). The values observed were within established standard limit of 6 – 8 (FEPA, 1993). This is quite supportive of aquatic ecological system and shows the suitability of the station as control. At Station 2, significantly higher pH was recorded in February, 2015 than the remaining part of the study period ($P = 0.04$). Slightly acidic pH was recorded at this Station in the months of May and October, 2015 and January, 2016 (Table 1). These periods may expose the finfish and shell fish of the river to higher bioavailability of metals; which may culminate in higher bioaccumulation of the metals in their tissue. At Station 3, there exists a proportionate fluctuation of the pH with the amount of rain. The pH was within regulatory limits during January, March and December, 2015; and January, 2016; and became slightly acidic in August, 2015. There was no discernible pattern in the temporal rhythmic fluctuations in the pH at Station 4. After Station 1, Station 5 was the most stable in terms of the pH levels throughout the period of study. The overall pH (4.12 – 7.07) of the river was wider in range than that observed in Ovia River: 6.58- 6.60 (Imoobe & Adeyinka, 2009) and Ikpoba River: 5.44 – 6.67 (Ekhator *et al.*, 2012). The high variability in the pH of the river; coupled with the apparent spatial heterogeneity can be attributed to variability in perturbations across the stations.

Table 1. Seasonal variation in pH (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	6.89±0.23*(5.23- 8.75)	6.81±0.43^{B*}(1.23- 8.75)	5.08±0.23^{B**}(4.23- 7.75)	4.44±0.03^{C***} (4.03- 5.75)	5.11±0.23^{B***}(4.23- 6.75)
	DEC	6.12±0.23* (5.23- 8.75)	6.8±0.23^{B}* (5.23- 8.75)	5.07±0.23^{B}** (4.23- 6.75)	5.34±0.23^{B**} (4.23- 6.75)	5.67±0.22^{A*} (4.23- 7.71)
2015	JAN	6.05±0.33 (6.00- 7.75)	6.78±0.03^{B} (5.23- 8.75)	6.86±0.23^{A} (5.23- 8.75)	5.78±0.23^{A} (4.03- 6.97)	6.11±0.21^{A} (5.23- 7.75)
	FEB	6.78±0.22 (5.23- 7.02)	7.07±0.03^{A} (5.23- 8.75)	5.84±0.03^{A} (4.23- 6.75)	6.78±0.23^{A} (5.23- 8.75)	6.44±0.24^{A} (5.23- 8.75)
	MAR	6.81±0.12* (5.85- 8.75)	5.67±0.23^{C*} (3.23- 7.25)	6.08±0.23^{A*} (5.23- 8.75)	5.23±0.43^{B**} (4.23- 7.75)	6.22±0.25^{A*} (5.23- 7.25)
	APR	6.21±0.04 (5.88- 8.65)	5.81±0.33^{C} (4.23- 7.75)	5.86±0.01^{A} (4.23- 6.75)	6.44±0.23^{A} (5.23- 8.75)	5.87±0.23^{A} (4.23- 7.75)
	MAY	6.01±0.06* (5.23- 8.85)	4.77±0.23^{C**} (3.23- 5.75)	5.67±0.13^{A*} (4.23- 6.95)	6.86±0.22^{A*} (5.23- 8.72)	5.67±0.23^{A*} (4.23- 6.75)
	JUN	6.25±0.03* (6.13- 7.95)	5.72±0.13^{C*} (4.23- 7.75)	5.77±0.23^{A*} (4.23- 6.75)	6.23±0.23^{A*} (5.23- 7.71)	5.22±0.23^{B**} (4.83- 6.75)
	JUL	6.23±0.03* (5.72- 8.95)	6.81±0.23^{B*} (5.23- 8.75)	5.79±0.23^{A*} (4.23- 7.75)	4.21±0.01^{C**} (4.03- 5.55)	6.66±0.23^{A*} (5.23- 8.75)
	AUG	6.08±0.23* (5.34- 6.95)	5.46±0.33^{C**} (4.23- 7.75)	4.82±0.43^{C**} (4.02- 5.75)	6.87±0.23^{A*} (5.23- 8.75)	6.75±0.11^{A*} (5.23- 8.71)
	SEP	6.22±0.23* (5.02- 7.95)	5.39±0.23^{C**} (4.23- 8.75)	5.81±0.23^{A*} (4.23- 7.75)	6.34±0.21^{A*} (5.23- 7.75)	6.02±0.23^{A*} (5.01- 7.75)
	OCT	6.03±0.13* (5.13- 7.95)	4.58±0.13^{C**} (4.01- 5.75)	5.8±0.43^{A*} (4.13- 8.75)	5.41±0.23^{B**} (4.23- 6.75)	5.88±0.23^{A*} (4.23- 6.75)
	NOV	6.06±0.53* (5.63- 8.95)	5.78±0.23^{C*} (4.23- 7.75)	5.81±0.33^{A*} (4.23- 8.75)	5.67±0.26^{A*} (4.23- 7.42)	5.12±0.23^{B**} (4.23- 6.65)
	DEC	6.02±0.03* (5.13- 7.95)	5.67±0.33^{C*} (4.23- 8.75)	6.09±0.23^{A*} (5.03- 8.75)	4.77±0.03^{C**} (4.01- 5.75)	6.12±0.23^{A*} (5.23- 7.75)
2016	JAN	6.01±0.23* (5.73- 8.95)	4.81±0.23^{C**} (4.02- 7.75)	6.12±0.23^{A*} (5.23-8.75)	5.02±0.23^{B**} (4.23- 7.75)	6.02±0.23^{A*} (5.07- 8.75)
	FEB	6.01±0.02* (4.13- 7.95)	5.59±0.13^{C*} (4.73- 7.75)	5.58±0.13^{B*} (4.23- 8.75)	4.12±0.23^{C**} (4.01- 6.75)	6.34±0.23^{A*} (5.23- 7.75)
P- VALUE		*P*= 0.08	*P*= 0.04	*P*= 0.05	*P*= 0.04	*P*= 0.05

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

3.2 Spatial and temporal variation in conductivity

Conductivity; which is the measure of the amount of matter in the water; which can conduct electricity was generally higher in the dry season compared to the rainy season in all the stations; except Stations 2 and 4 (Table 2). The higher conductivity in dry season can be attributed to lower water volume due to reduced water input form rain; hence higher concentration of aqueous ions. The general conductivity was Stations 2 > Station 5 > Station 3 > Station 4 > Station 1 ($P < 0.05$). The entire conductivity was below the Federal Ministry of Environment regulatory limit (80 mg/L) throughout the study period. The conductivity of the entire river ranged from 2.4 µS/cm (Station 1 in June and July, 2015) to 48.9 µS/cm (Station 2 in November, 2014). This range is however lower than the conductivities observed by Ekhator et al. (2012) in Okhuaihe River (51 – 78 µS/cm), Ikpoba River (38 – 83 µS/cm), Ossiomo River (41 – 94 µS/cm), Siluko River (28 – 68 µS/cm) and Ogba River (46 – 85 µS/cm). High conductivity in the dry season was coeval with high salinity (Table 7) i.e. the levels of conductivity was directly proportional to the salinity throughout the period of study. This indicates a substantial contribution of the dissolved salts to the conductivity of the river. The implication of the numerous emboldened figures is that there is generally high spatio-temporal variability of conductivity in the river. The only exception is in August, 2015 at all stations; where stability in conductivity was apparent.

3.3 Spatial and temporal variation in total dissolved solids

Total dissolved solids (TDS); which is the amount of non-filterable components of the water was higher across the length of the river in the rainy season than the dry season; contrary to the seasonal rhythm of the conductivity. This suggests that the total dissolved solids in the water is not associated with the high conductivity observed in dry season. However the levels of total dissolved solid (Table 3) was directly proportional to the turbidity (Table 4); especially at Station 3; which recorded significantly higher concentrations in both parameters than other stations. This shows that the total dissolved solids can be attributed to the dredging activity that takes place at Station 3. The turbidity across the river is in the order of Station 3 > Station 4 > Station 2 > Station 1. The general total dissolved solids (15- 52.3 mg/L) was far lower than the FEPA regulatory limit (2000 mg/L). It was quite higher than that observed in Mbo River (0.92 – 0.99 mg/L). However, the general total dissolved solids across the entire study area is quite similar to that observed in many neighbouring rivers such as Ossiomo River: 18.4- 45 mg/L, Ogba River: 21.50 – 42.50 mg/L, Siluko River: 15.5 – 34 mg/L. Inferences; in correlation with available data show that the River has not been disrupted beyond background level in terms of the total dissolved solids.

3.4 Spatial and temporal variation in turbidity

Outstandingly high turbidity was recorded at Station 3; particularly in February, March, May, August, October and November, 2015; and January, 2016. At all stations, most of the high turbidity months were months of rainy season; hence the turbidity of the river could be a function of particulate loads from surface runoff. The general sequence of the turbidity across the study area is: Station 3 > Station 2 > Station 4 > Station 1. This spatially heterogeneous turbidity can be attributed to distinct anthropogenic perturbations at the various sampled stations. Turbidity was higher at Station 2 than FEPA limit (30 NTU) particularly towards ending of each year i.e. outstandingly high level was observed in November (31.2 NTU) and December (36.2 NTU), 2014; and January (22.2 NTU), November (21.72 NTU), December (38.6), 2015. This can be attributed to attendant release of organic waste into the river at this station; particularly in the period of festivity (end of the year), due to upsurge wastes generated from kitchens in the catchment area. Much algal growth, alongside proliferation of other hydrophytes was observed at this station, especially in the months of observed high turbidity. On these grounds, the high turbidity during this period can be attributed to increased organic waste loads, coupled with increased concentration due to low water volume in dry season. On the other hand, concentrations than standard limit were observed at Station 3 in the rainy season i.e. in June, 2015 (52.7 NTU) and September, 2015 (48.8 NTU). However, high concentrations were also observed in most of other rainy season months; though above standard regulatory limit. This can be attributed to the dredging activities; coupled with increased particulate influx during reason as a result of surface run-off. Given that to some extent turbidity is a function of anthropogenic activities, a comparative analysis of turbidity of Egbokodo River with other rivers in the Niger Delta areas and regulatory standard suggests given that dredging activities at Station 3 had impacts on the river. The turbidity range at Station 1 (0.21- 4.52 NTU), Station 4 (2.24-5.23 NTU), and Station 5 (2.12- 3.82 NTU) were all lower than FEPA regulatory limit (30 NTU) for aquatic environment. The turbidity levels at these stations are quite comparable to that observed in Okhuaihe River (0.5- 4.64 NTU) and Ogbese River (5.20- 5.9 NTU) by Ekhator *et al.* (2012); and Ovia River (0.47- 0.57 NTU) by Imoobe and Adeyinka (2009). However, distinctively high turbidity ranges observed at Station 2 (2.11- 38.6 NTU) and Station 3 (5.31- 48.8 NTU) in the current study is quite higher than highly perturbed Ikpoba River: 3.74- 19.48 NTU (Ogbeibu *et al.*, 2014), Ossiomo River: 5.38- 18.56 NTU (Ekhator *et al.*, 2012); but lower that the level observed in Mbo River: 52.89- 58.39 NTU (Mandu & Ekpo, 2015).

Table 2. Seasonal variation in conductivity (µS/cm) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	25.5±0.33^{A**}(4.23- 7.75)	48.9±0.33^{A*}(4.23- 7.75)	21±0.33^{A**} (4.23- 7.75)	14.5±0.33^{B***}(4.23-7.75)	21.6±0.33^{B**} (4.23- 7.75)
	DEC	15.2±0.33^{B***}(4.23-7.75)	26±0.33^{B**} (4.23- 7.75)	35±0.33^{A*} (4.23- 7.75)	22.1±0.33^{A**}(4.23- 7.75)	23.3±0.33^{B**} (4.23- 7.75)
2015	JAN	16.3±0.33^{B***}(4.23-7.75)	42.8±0.33^{A*}(4.23- 7.75)	21±0.33^{A**} (4.23- 7.75)	12.8±0.33^{B***}(4.23-7.75)	15.5±0.33^{C***} (4.23- 7.75)
	FEB	7.5±0.33^{C***} (4.23- 7.75)	6.5±0.33^{D***}(4.23- 7.75)	5.6±0.33^{B***} (4.23- 7.75)	22±0.33^{A*} (4.23- 7.75)	13.5±0.33^{C**} (4.23- 7.75)
	MAR	4.2±0.33^{D***} (4.23- 7.75)	12.6±0.33^{C**}(4.23-7.75)	7.5±0.33^{B***} (4.23- 7.75)	11.3±0.33^{C**}(4.23- 7.75)	22.2±0.33^{B*} (4.23- 7.75)
	APR	5.5±0.33^{C***} (4.23- 7.75)	12±0.33^{C**} (4.23- 7.75)	5.3±0.33^{B***} (4.23- 7.75)	6.8±0.33^{D***} (4.23- 7.75)	21±0.33^{B*} (4.23- 7.75)
	MAY	6.5±0.33^{C**} (4.23- 7.75)	8.5±0.33^{D**} (4.23- 7.75)	8.2±0.33^{B**} (4.23- 7.75)	4.6±0.33^{D**} (4.23- 7.75)	15±0.33^{C*} (4.23- 7.75)
	JUN	2.4±0.33^{D**} (4.23- 7.75)	5.8±0.33^{D**} (4.23- 7.75)	12.5±0.33^{B*} (4.23- 7.75)	4.1±0.33^{D**} (4.23- 7.75)	12.5±0.33^{C*} (4.23- 7.75)
	JUL	8.2±0.33^{C*} (4.23- 7.75)	6.7±0.33^{D**} (4.23- 7.75)	5.2±0.33^{B**} (4.23- 7.75)	4.2±0.33^{D**} (4.23- 7.75)	11.2±0.33^{C*} (4.23- 7.75)
	AUG	2.4±0.33^{D} (4.23- 7.75)	5.7±0.33^{D} (4.23- 7.75)	4.8±0.33^{C} (4.23- 7.75)	7.4±0.33^{D} (4.23- 7.75)	8.8±0.33^{D} (4.23- 7.75)
	SEP	5.5±0.33^{C***} (4.23- 7.75)	22±0.33^{B*} (4.23- 7.75)	4.2±0.33^{C***} (4.23- 7.75)	4.1±0.33^{D***} (4.23- 7.75)	11±0.33^{C**} (4.23- 7.75)
	OCT	4.5±0.33^{C***} (4.23- 7.75)	24±0.33^{B*} (4.23- 7.75)	2.6±0.33^{C***} (4.23- 7.75)	8.2±0.33^{C**} (4.23- 7.75)	22±0.33^{B*} (4.23- 7.75)
	NOV	5.6±0.33^{C**} (4.23- 7.75)	13.9±0.33^{C*}(4.23- 7.75)	4.6±0.33^{C**} (4.23- 7.75)	12.7±0.33^{B*} (4.23- 7.75)	11.1±0.33^{C*} (4.23- 7.75)
	DEC	32.2±0.33^{A**}(4.23- 7.75)	48±0.33^{A*} (4.23- 7.75)	22±0.33^{A**} (4.23- 7.75)	17.7±0.33^{B***}(4.23-7.75)	31±0.33^{A**} (4.23- 7.75)
2016	JAN	4.8±0.33^{C***} (4.23- 7.75)	41±0.33^{A*} (4.23- 7.75)	4.5±0.33^{C***} (4.23- 7.75)	15.8±0.33^{B**}(4.23- 7.75)	42±0.33^{A*} (4.23- 7.75)
	FEB	13.6±0.33^{B**}(4.23- 7.75)	19.5±0.33^{B*}(4.23- 7.75)	5.8±0.33^{B***} (4.23- 7.75)	4.2±0.33^{D***} (4.23- 7.75)	12.1±0.33^{C**} (4.23- 7.75)
P- VALUE		*P* = 0.02	*P*= 0.05	*P*= 0.04	*P*= 0.05	*P*= 0.05

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

Table 3. Seasonal variation in total dissolved solids (mg/L) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	18.5±0.33^{B} (16.2-20.7)	17.2±0.33^{B} (4.23- 7.75)	17.2±0.33^{B} (15.23- 19.5)	25.8±0.33^{A} (24.2- 27.7)	24.8±0.33^{B} (20.2- 26.7)
	DEC	16.1±0.33^{B***} (14.23-17.7)	23.3±0.33^{A**} (4.23- 7.75)	23.3±0.33^{A**} (20.2- 25.5)	28.2±0.33^{A*} (24.2- 33.7)	28.9±0.33^{A*} (24.2- 30.7)
2015	JAN	15.0±0.33^{B**} (13.23-18.7)	26.8±0.33^{A**}(4.23-7.75)	26.8±0.33^{D**} (24.2- 28.7)	26.7±0.33^{A**} (24.2-28.7)	33.2±0.33^{A*} (30.2-34.7)
	FEB	16.7±0.33^{B**} (14.23-18.7)	27.4±0.33^{A*} (4.23-7.75)	27.4±0.33^{A*} (25.2- 29.7)	32.4±0.33^{A*} (30.2- 34.5)	29.7±0.33^{A*} (26.2- 31.7)
	MAR	21.3±0.33^{A} (18.23- 23.7)	18.4±0.33^{B} (4.23- 7.75)	18.4±0.33^{B} (67.2- 20.7)	18.5±1.33^{B} (14.2- 22.7)	25.5±1.33^{A} (24.2-26.7)
	APR	22.5±0.33^{A} (19.23- 24.7)	22.3±0.33^{A} (4.23- 7.75)	52.3±0.33^{A*} (20.2- 24.7)	28.7±2.33^{A} (14.2- 32.7)	27.8±0.33^{A} (24.2- 30.7)
	MAY	28.2±0.33^{A} (26.23- 27.7)	32.5±0.33^{A} (4.23- 7.75)	42.5±0.33^{A} (30.2- 34.7)	33.8±0.33^{A} (30.2- 35.7)	31.2±0.33^{A} (28.2- 33.7)
	JUN	22.4±0.33^{A} (20.23- 23.7)	31.3±0.33^{A} (4.23- 7.75)	31.3±0.33^{A} (30.2- 34.7)	32.6±0.33^{A} (30.2- 34.7)	28.7±0.33^{A} (24.2- 30.7)
	JUL	28.6±0.63^{A} (24.23- 31.7)	36.7±0.33^{A} (4.23- 7.75)	36.7±0.33^{A} (34.23- 38.7)	34.3±0.33^{A} (32.2- 36.7)	26.8±0.33^{A} (24.2- 28.7)
	AUG	26.7±0.73^{A***} (24.23-28.7)	38.2±0.33^{A*} (4.23- 7.75)	48.2±0.33^{A*} (37.2- 39.7)	36.7±0.33^{A*} (34.2- 38.7)	22.4±0.73^{B***}(30.2-34.7)
	SEP	23.4±0.33^{A**} (21.23- 25.7)	33.2±0.33^{A*} (4.23- 7.75)	33.2±0.33^{A*} (31.2- 35.7)	38.7±0.33^{A*} (34.2- 40.7)	33.2±1.33^{A*} (31.2- 35.7)
	OCT	24.6±0.33^{A} (22.23- 26.7)	23.5±0.33^{A} (4.23- 7.75)	23.5±0.33^{A} (21.2- 25.7)	31.5±0.33^{A} (30.2- 33.7)	22.8±0.43^{B} (20.2- 24.7)
	NOV	32.1±0.33^{A} (30.23- 34.7)	34.4±0.33^{A} (4.23- 7.75)	34.4±0.33^{A} (30.2- 36.7)	28.7±0.33^{A} (26.2- 31.7)	31.5±1.33^{A} (28.2- 33.7)
	DEC	21.3±0.33^{A***} (20.23-24.7)	28.9±0.33^{A**} (4.23- 7.75)	28.9±0.33^{A**} (27.2- 29.7)	26.9±0.33^{A**} (24.2- 28.7)	18.1±0.43^{c***}(31- 36.7)
2016	JAN	22.4±0.33^{A} (20.23- 24.7)	18.5±0.33^{B} (4.23- 7.75)	18.5±0.33^{B} (17.2- 19.7)	21.3±0.33^{A} (20.2- 23.7)	25.9±1.33^{B} (22.2- 27.7)
	FEB	29.3±0.33^{A*} (26.23- 31.7)	19.7±0.33^{B***} (17.2-21.7)	19.7±0.33^{B***} (18.2-21.7)	17.9±0.33^{B***} (14.2-19.7)	24.3±2.33^{B**} (20.2-27.7)
P- VALUE		*P* = 0.02	*P*= 0.05	*P*= 0.04	*P*= 0.05	*P*= 0.05

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

Table 4. Seasonal variation in turbidity (NTU) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	0.82±0.33^{C***}(0.66- 3.8)	31.2±0.33^{A**}(0.66- 7.75)	7.21±0.83^{D*} (3.66- 9.75)	4.41±0.33^{B**} (0.66- 8.75)	3.63±0.33^{A**}(0.66- 5.75)
	DEC	0.21±0.01^{D***}(0.06- 1.2)	36.2±1.33^{A*} (0.66- 10.5)	5.31±0.33^{D*} (2.66- 8.75)	2.32±0.33^{D**} (1.66- 5.75)	2.23±0.33^{B**}(0.66- 4.71)
2015	JAN	1.61±0.33^{C***}(0.66- 2.7)	22.2±0.33^{B**}(1.66- 8.75)	26.8±0.33^{A*} (22.6- 28.5)	3.42±0.33^{C**}(1.66- 7.72)	3.42±0.33^{A**}(0.66- 6.72)
	FEB	1.72±0.33^{C****}(0.66-3.7)	3.11±0.33^{C**}(0.46- 7.71)	17.2±0.73^{B*}(12.6- 22.7)	3.81±0.32^{B**} (0.66- 8.75)	2.24±0.33^{B**}(0.66- 5.75)
	MAR	1.82±0.33^{C***}(0.16-3.7)	2.62±0.33^{D**}(0.36- 4.75)	16.2±0.33^{B*} (13.6- 22.5)	2.24±0.33^{D***} (0.66- 6.75)	3.22±0.33^{A**}(0.66- 6.09)
	APR	1.22±0.33^{C***}(0.26-3.5)	3.31±0.33^{C**}(0.26- 6.75)	8.2±0.33^{D*} (2.66- 10.75)	3.44±0.13^{C**}(0.66- 6.25)	3.72±0.33^{A**}(0.61- 6.75)
	MAY	4.52±0.33^{A**} (0.86- 7.5)	2.11±0.33^{D***}(1.6- 5.5)	15.6±0.33^{B*} (11.6- 18.7)	3.54±0.13^{B**}(0.66- 5.75)	2.62±0.09^{A***}(0.66- 4.5)
	JUN	3.21±0.33^{B***}(0.26-5.7)	4.11±0.22^{C**}(1.66- 6.7)	52.7±0.33^{D*}(2.66- 7.75)	4.24±1.53^{B**}(0.9- 7.75)	3.22±0.83^{A***}(1.6- 6.22)
	JUL	3.21±0.63^{B***}(0.6- 4.5)	4.11±0.43^{C**}(1.6- 6.75)	5.71±0.63^{D*}(0.66- 8.25)	4.24±0.33^{B**}(0.66- 6.15)	2.14±0.33^{B****}(0.6- 3.5)
	AUG	2.82±0.33^{B**}(0.3- 3.75)	3.41±0.33^{C**}(0.6- 7.25)	18.8±0.43^{B*}(12.6- 23.5)	4.23±0.33^{B**}(2.66- 7.75)	3.52±0.03^{A**}(0.6- 5.75)
	SEP	2.21±0.13^{B***}(0.4- 4.5)	3.62±0.33^{C***}(0.26-5.5)	48.8±0.13^{D*}(5.66- 9.75)	5.23±0.23^{A**}(1.66- 8.75)	3.42±0.02^{A***}(0.26- 6.5)
	OCT	3.32±0.53^{B***}(0.2- 6.5)	4.52±0.33^{C**}(1.6- 7.72)	15.8±0.33^{B*}(12.6- 19.5)	4.32±0.13^{B**}(2.66- 8.75)	3.82±0.01^{A***}(0.16- 4.5)
	NOV	2.61±0.39^{B**}(0.16- 4.1)	21.72±0.33^{B**}(0.6- 3.5)	15.2±0.33^{B*}(12.6- 17.5)	3.83±0.33^{B**}(0.66- 3.85)	2.12±0.07^{B**}(0.26- 3.1)
	DEC	1.22±0.23^{C****}(0.01- 3)	38.6±0.33^{A**}(1.76- 5.1)	12.9±1.33^{C*}(8.6- 16.75)	3.63±0.33^{B**}(1.06- 5.75)	2.21±0.08^{B***}(0.66- 3.4)
2016	JAN	1.21±0.33^{C****}(0.4-3.5)	18.3±0.33^{B**}(1.6- 8.75)	16.8±0.33^{B*}(11.6- 20.5)	4.23±0.83^{B**}(1.66- 5.75)	2.42±0.02^{B***}(0.26- 3.5)
	FEB	1.32±0.33^{C****}(0.3-4.5)	6.52±0.73^{C*}(1.66- 12.7)	7.5±1.33^{D*}(3.66- 13.75)	4.31±0.13^{B**}(1.66- 7.75)	2.23±0.03^{B***}(0.6- 3.11)
P- VALUE		$P = 0.02$	$P= 0.05$	$P= 0.04$	$P= 0.05$	$P= 0.05$

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

3.5 Spatial and temporal variation in BOD and DO

The lowest biological oxygen demand (BOD) was recorded at Station 1 throughout the study period (Table 5). There was stability in the BOD at Station 3; which had a significant reduction only in November and December, 2014; and August, 2015 ($P < 0.05$). Stability was also observed in Station 5; which also showed significant drop only in November, 2014; and May and November, 2015 ($P < 0.05$). Highest BOD was observed in Station 2, particularly in December, 2015; January and February, 2016 ($P < 0.05$) during which extreme BOD levels were observed. This abrupt upsurge in BOD can be attributed to disposal of organic wastes at this section of the river; which is the predominant activity during the end of the year; a period of festivity when much organic wastes are generated from nearby kitchens. The high values of BOD observed at Station 2 was accompanied by low dissolved oxygen (DO) (Table 5). The BOD of Egbokodo River at Station 1 ranged from 1.21 mg/L to 3.82 mg/L, Station 2 ranged from 3.18 mg/L to 48 mg/L, Station 3 was 4.8 mg – 6.86 mg/L, Station 4 was 4.12 mg/L – 6.87 mg/L, while Station 5 was 5.11 mg/L – 6.75 mg/L. The BOD at Station of Egbokodo River (except control); especially at Station 2 (3.18 – 48 mg/L) is much higher than that of Ovia River which was 1.97 to 3.46 mg/L within the period of April, 2005 to June, 2006 (Imoobe & Adeyinka, 2009) and that of Ikpoba River which was 2.92 to 3.13 mg/L between January and July, 2007 (Ogbeibu et al., 2014), that of Mbo River which was from 2.8 to 2.85 mg/L (Mandu & Imaobong, 2015). This is an indication that Egbokodo River (particularly at Station 2) is stressed with organic wastes; which are oxygen demanding. The DO at Station 3 was significantly higher than other stations throughout the study period ($P = 0.05$). This can be attributed to the dredging disturbances; which may lead to exchange of oxygen gas between the air-water interface through diffusion of oxygen at water surface due to surface water agitation and turbulence (Omaigberale & Ogbeibu, 2007). The numerous standing aquatic macrophytes at this station might have also contributed to the substantially higher oxygen observed at the station. Only Station 1 (control) and Station 4 maintained DO concentrations within regulatory limits. The overall dissolved oxygen of the river (1.2 – 8.8 mg/L) was within close range with that observed in Siluko River: 5.6 – 8.8 mg/L (Ekhator et al., 2012). However, the general level of dissolved oxygen observed at Egbokodo River is quite lower than that observed in Mbo River: 7.4 – 7.7 mg/L (Mandu & Imaobong, 2015). The general BOD of Egbokodo River is lower in the wet season while DO is higher and the reverse was the trend in the dry season. This observation is in conformity with the observation of Mandu and Imaobong (2015) in Mbo River. This can be attributed to the dilution of the water body during rainy season; consequently the concentration of the oxygen demanding organic waste is sequestered.

Table 5. Seasonal variation in biological oxygen demand (mg/L) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	1.81±0.33 (0.83- 2.75)	6.82±0.53^{D*} (4.23-7.75)	5.08±0.33^{B**} (4.23- 7.75)	4.44±0.33^{C***} (4.23- 7.75)	5.11±0.33** (4.23- 7.75)
	DEC	1.21±0.23 (0.73- 3.75)	6.81±0.13^{D*} (4.83- 7.85)	5.07±0.33^{B**} (4.23- 7.75)	5.34±0.33^{B**} (4.23- 7.75)	5.67**±0.33 (4.23- 7.75)
2015	JAN	2.61±0.73 (1.23- 4.75)	6.71±0.23^{D*} (4.28- 7.75)	6.86±0.33^{A*} (4.23- 7.75)	5.78±0.33^{B*} (4.23- 7.75)	6.11±0.33* (4.23- 7.75)
	FEB	2.72±0.43 (0.93- 4.75)	7.11±0.03^{D*} (6.83- 7.75)	5.84±0.33^{A**} (4.23- 7.75)	6.78±0.33^{A*} (4.23- 7.75)	6.44±0.33** (4.23- 7.75)
	MAR	3.82±0.33 (1.43- 5.75)	5.63±0.33^{D**} (4.2- 7.75)	6.08±0.33^{A} *(4.23- 7.75)	5.23±0.33^{B**} (4.23- 7.75)	6.22±0.33* (4.23- 7.75)
	APR	2.22±0.33 (1.53- 4.05)	5.83±0.33^{D*} (4.23- 6.75)	5.86±0.33^{A*} (4.23- 7.75)	6.44±0.33^{A*} (4.23- 7.75)	5.87±0.33* (4.23- 7.75)
	MAY	2.52±0.22 (1.23- 3.75)	4.23±0.33^{E***} (2.23- 7.7)	5.67±0.33^{A**} (4.23- 7.75)	6.86±0.33^{A*} (4.23- 7.75)	5.67±0.33** (4.23- 7.75)
	JUN	2.21±0.33 (1.23- 4.75)	5.2±0.63^{E*} (2.23- 7.75)	5.7±0.33^{A*} (4.23- 7.75)	6.23±0.33^{A*} (4.23- 7.75)	5.22±0.33* (4.23- 7.75)
	JUL	3.21±0.33 (1.23- 5.75)	4.21±1.73^{E**} (2.23- 7.5)	5.79±0.33^{A*} (4.23- 7.75)	4.21±0.33^{C**} (4.23- 7.75)	6.66±0.33* (4.23- 7.75)
	AUG	1.81±0.33 (0.83- 2.75)	3.18±0.33^{E**} (1.23- 4.7)	4.8±0.33^{C**} (4.23- 7.75)	6.87±0.33^{A*} (4.23- 7.75)	6.75±0.33* (4.23- 7.75)
	SEP	2.21±0.73 (0.73- 4.75)	3.16±0.73^{E**} (1.23- 5.7)	5.81±0.33^{A*} (4.23- 7.75)	6.34±0.33^{A*} (4.23- 7.75)	6.02±0.33* (4.23- 7.75)
	OCT	1.31±0.33 (0.33- 2.75)	4.15±0.33^{E**} (1.23- 6.7)	5.8±0.33^{A*} (4.23- 7.75)	5.41±0.33^{B*} (4.23- 7.75)	5.88±0.33* (4.23- 7.75)
	NOV	2.61±0.33 (1.03- 4.75)	8.17±1.33^{C*} (4.23- 7.75)	5.81±0.33^{A**} (4.23- 7.75)	5.67±0.33^{B**} (4.23- 7.75)	5.12±0.33** (4.23- 7.75)
	DEC	3.22±0.33 (1.23- 5.75)	22.6±0.33^{B*} (18.2-27.7)	6.09±0.33^{A**} (4.23- 7.75)	4.77±0.33^{C*} (4.23- 7.75)	6.12±0.33** (4.23- 7.75)
2016	JAN	1.22±0.33 (0.66- 3.75)	42.3±3.33^{A*} (31.2- 52.7)	6.12±0.33^{A**} (4.23- 7.75)	5.02±0.33^{B***} (4.23- 7.75)	6.02±0.33** (4.23- 7.75)
	FEB	1.23±0.33 (0.73- 4.75)	48±2.33^{A*} (28.23- 57.7)	5.58±0.33^{A**} (4.23- 7.75)	4.12±0.33^{B***} (4.23- 7.75)	6.34±0.33** (4.23- 7.75)
P- VALUE		*P* = 0.24	*P*= 0.05	*P*= 0.04	*P*= 0.05	*P*= 0.15

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

Table 6. Seasonal variation in dissolved oxygen (mg/L) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	3.8±0.23^{C**} (1.23- 5.75)	1.2±0.33^{C***} (4.23- 7.75)	7.2±0.33^{A*} (4.23- 7.75)	4.4±0.33^{B**} (4.23- 7.75)	3.6±0.33^{D**} (4.23- 7.75)
	DEC	4.2±0.33^{C**} (1.23- 7.75)	2.2±0.33^{B***} (4.23- 7.75)	5.3±0.33^{C*} (4.23- 7.75)	5.3±0.33^{A*} (4.23- 7.75)	5.2±0.33^{B*} (4.23- 7.75)
2015	JAN	3.6±0.23^{C**} (1.23- 5.75)	2.7±0.33^{B**} (4.23- 7.75)	6.8±0.33^{B*} (4.23- 7.75)	3.4±0.33^{C**} (4.23- 7.75)	3.4±0.33^{D**} (4.23- 7.75)
	FEB	4.7±0.38^{B***}(2.23- 6.75)	2.1±0.33^{B****}(4.23- 7.75)	8.2±0.33^{A*} (4.23- 7.75)	3.8±0.33^{C***} (4.23- 7.75)	6.4±0.33^{A**} (4.23- 7.75)
	MAR	3.8±0.43^{C**} (1.23- 5.75)	2.6±0.33^{B***} (4.23- 7.75)	6.2±0.33^{B*} (4.23- 7.75)	4.2±0.33^{B**} (4.23- 7.75)	6.2±0.33^{A*} (4.23- 7.75)
	APR	6.2±0.33^{A**} (4.23- 7.75)	1.3±0.33^{C****}(4.23- 7.75)	8.2±0.33^{A*} (4.23- 7.75)	3.4±0.33^{C***} (4.23- 7.75)	5.7±0.33^{A**} (4.23- 7.75)
	MAY	4.5±0.32^{B**} (2.23- 7.75)	2.1±0.33^{B****}(4.23- 7.75)	5.6±0.33^{C*} (4.23- 7.75)	3.5±0.33^{C***} (4.23- 7.75)	4.6±0.33^{C**} (4.23- 7.75)
	JUN	3.2±0.33^{C***}(1.23- 6.75)	3.1±0.33^{A***} (4.23- 7.75)	5.7±0.33^{C*} (4.23- 7.75)	4.2±0.33^{B**} (4.23- 7.75)	4.2±0.33^{C**} (4.23- 7.75)
	JUL	3.2±0.63^{C***}(1.29- 5.75)	2.1±0.33^{B} (4.23- 7.75)	5.7±0.33^{C*} (4.23- 7.75)	4.2±0.33^{B**} (4.23- 7.75)	3.4±0.33^{D***} (4.23- 7.75)
	AUG	4.8±0.53^{B***}(1.23- 7.75)	1.4±0.33^{C****}(4.23- 7.75)	8.8±0.33^{A*} (4.23- 7.75)	6.2±0.33^{A**} (4.23- 7.75)	4.5±0.33^{C***} (4.23- 7.75)
	SEP	5.2±0.33^{B**} (4.23- 7.75)	3.6±0.33^{A***} (4.23- 7.75)	7.8±0.33^{A*} (4.23- 7.75)	5.2±0.33^{A**} (4.23- 7.75)	6.4±0.33^{A*} (4.23- 7.75)
	OCT	3.3±0.31^{C**} (2.23- 4.75)	4.5±0.33^{A*} (4.23- 7.75)	5.8±0.33^{C*} (4.23- 7.75)	4.2±0.33^{B*} (4.23- 7.75)	5.8±0.33^{A*} (4.23- 7.75)
	NOV	5.6±0.33^{A*} (4.23- 7.75)	1.7±0.33^{C***} (0.23- 3.75)	5.2±0.33^{C*} (4.23- 7.75)	3.8±0.33^{C**} (4.23- 7.75)	5.1±0.33^{B*} (4.23- 7.75)
	DEC	6.2±0.13^{A*} (4.23- 7.75)	2.6±0.33^{B***} (1.23- 5.75)	6.9±0.33^{B*} (4.23- 7.75)	3.6±0.33^{C**} (4.23- 7.75)	6.1±0.33^{A*} (4.23- 7.75)
2016	JAN	5.2±0.38^{B**} (4.23- 7.75)	2.3±0.33^{B****}(1.23- 4.75)	6.8±0.33^{B*} (4.23- 7.75)	4.2±0.33^{B***} (4.23- 7.75)	4.4±0.33^{C***} (4.23- 7.75)
	FEB	3.3±0.23^{C**} (0.83- 5.75)	1.5±0.34^{C***} (0.23- 3.75)	7.5±0.33^{A*} (4.23- 7.75)	4.1±0.33^{B**} (4.23- 7.75)	3.3±0.33^{D**} (4.23- 7.75)
P- VALUE		*P* = 0.02	*P*= 0.05	*P*= 0.04	*P*= 0.05	*P*= 0.05

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

3.6 Spatial and temporal variation in primary productivity nutrients

The trophic status of an aquatic system determines health of the entire aquatic biota and growth rate of the aquatic ecological system; as it relates to its carrying capacity. In the pyramid of biomass, the fate of the organisms at the top of the trophic strata is a function of the amount of nutrients available to the primary producers at the bottom. There may be shortage in supply of these nutrients, they may also be in excess. Carrying capacity which varies from one lake and stream to another; is a determining factor in growth rates aquatic fauna. However for ease comparative analysis, as a general rule a stream may be oligotrophic, mesotrophic or eutrophic.

The study area is spatially heterotrophic and seasonal variation was also observed in the nutrients levels (Figures, 7, 8 and 9). There was stability in the level of nitrate at Station 1 throughout the study period. The primary productivity nutrients levels are typical of an oligotrophic river i.e. Station 1 (1.21- 3.82), Station 3 (5.07- 6.86 mg/L), Station 4 (4.12- 6.87 mg/L), Station 5 (5.11- 6.67 mg/L); except for unusually high levels observed at Station 2 (3.16- 48 mg/L). A comparative analysis with neighbouring rivers gives a clearer picture of the spatial heterotrophy at this river i.e. the levels of nitrate at Stations 1, 3, 4 and 5 are quite higher than that observed in Ovia River (0.66- 0.76 mg/L) by Imoobe and Adeyinka (2009), Ekpan River (0.02 mg/L) by Iloba and Ruejoma (2014), Okhuaihe River (0.03- 0.07 mg.L), Ikpoba River (0.05- 0.1 mg/L), Ossiomo River (0.04- 0.1 mg/L), Siluko River (0.05- 0.14), Ogba River (0.02- 0.7 mg/L) as pointed out by Ekhator *et al.*, (2012). However, the relatively high level at Station 2 is yet much lower than that of Mbo River (308.2- 318.08 mg/L); which was reported to be eutrophic by Mandu and Imaobong (2015).

Similarities were observed in the spatial and temporal behaviour of nitrate, phosphate and sulphate. Similar trends were detected in these primary nutrients across the stations i.e. nitrate and phosphate: Station 2 > Station 5 > Station 4 > Station 3 > Station 1 (Figure 7 and 8 respectively), sulphate: Station 2> Station 3> Station 4> Station 5> Station 1 (Figure 9). Dominance of Station 2 in all cases is an evidence of impact of the anthropogenic perturbations. Generally, there were indiscernible patterns of the nutrients at Station 1 in some cases and stability was observed in other cases.

Nitrate concentration ranged from 3.16- 8.17 mg/L between the period of November, 2014 and November, 2015. After a complete calendar (12 months), there was a significant rise to a range 22.6- 48 mg/L ($P = 0.05$) between December, 2015 and February, 2016. Significantly higher phosphate concentrations were observed in November, 2014, December, 2015 and January, 2016 at Station 2. Station 3 also exhibited a significant rise in phosphate concentration in December, 2015, Station 4 was in December, 2014 and Station 5 was in December, 2015 and January, 2016. As for sulphate, significantly higher concentrations were observed at Station 2 in November, 2014, November and December, 2015. Significant rises in sulphate were also observed at Station 3 in January, 2016, Station 4 from December, 2014 to January, 2015, and November, 2015 to February, 2016. Rise at Station 5 was observed from November, 2015 to February, 2016. It is quite glaring and observable that a recurring mechanism is influencing the levels of nutrients in Egbokodo River. A vital observation is the recurring rise in nutrient levels towards the end of every year and in some cases it was extended to the beginning of the following year. This trend was most severe at Station 2; hence it is attributable to the predominant activities of domestic waste disposal at this station i.e. disposal of organic wastes such as waste foods was predominant during the end of the year; a period of general merriments which is associated with rise in kitchen activities. This completely conforms to the analysis of the biological oxygen demand and dissolved oxygen (section 3.5).

Table 7. Seasonal variation in nitrate (mg/L) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	1.81±0.33 (0.83- 2.75)	6.82±0.53^{D*} (4.23-7.75)	5.08±0.33^{B**} (4.23- 7.75)	4.44±0.33^{C***} (4.23- 7.75)	5.11±0.33** (4.23- 7.75)
	DEC	1.21±0.23 (0.73- 3.75)	6.81±0.13^{D*} (4.83- 7.85)	5.07±0.33^{B**} (4.23- 7.75)	5.34±0.33^{B**} (4.23- 7.75)	5.67**±0.33 (4.23- 7.75)
2015	JAN	2.61±0.73 (1.23- 4.75)	6.71±0.23^{D*} (4.28- 7.75)	6.86±0.33^{A*} (4.23- 7.75)	5.78±0.33^{B*} (4.23- 7.75)	6.11±0.33* (4.23- 7.75)
	FEB	2.72±0.43 (0.93- 4.75)	7.11±0.03^{D*} (6.83- 7.75)	5.84±0.33^{A**} (4.23- 7.75)	6.78±0.33^{A*} (4.23- 7.75)	6.44±0.33** (4.23- 7.75)
	MAR	3.82±0.33 (1.43- 5.75)	5.63±0.33^{D**} (4.2- 7.75)	6.08±0.33^{A} *(4.23- 7.75)	5.23±0.33^{B**} (4.23- 7.75)	6.22±0.33* (4.23- 7.75)
	APR	2.22±0.33 (1.53- 4.05)	5.83±0.33^{D*} (4.23- 6.75)	5.86±0.33^{A*} (4.23- 7.75)	6.44±0.33^{A*} (4.23- 7.75)	5.87±0.33* (4.23- 7.75)
	MAY	2.52±0.22 (1.23- 3.75)	4.23±0.33^{E***} (2.23- 7.7)	5.67±0.33^{A**} (4.23- 7.75)	6.86±0.33^{A*} (4.23- 7.75)	5.67±0.33** (4.23- 7.75)
	JUN	2.21±0.33 (1.23- 4.75)	5.2±0.63^{E*} (2.23- 7.75)	5.7±0.33^{A*} (4.23- 7.75)	6.23±0.33^{A*} (4.23- 7.75)	5.22±0.33* (4.23- 7.75)
	JUL	3.21±0.33 (1.23- 5.75)	4.21±1.73^{E**} (2.23- 7.5)	5.79±0.33^{A*} (4.23- 7.75)	4.21±0.33^{C**} (4.23- 7.75)	6.66±0.33* (4.23- 7.75)
	AUG	1.81±0.33 (0.83- 2.75)	3.18±0.33^{E**} (1.23- 4.7)	4.8±0.33^{C**} (4.23- 7.75)	6.87±0.33^{A*} (4.23- 7.75)	6.75±0.33* (4.23- 7.75)
	SEP	2.21±0.73 (0.73- 4.75)	3.16±0.73^{E**} (1.23- 5.7)	5.81±0.33^{A*} (4.23- 7.75)	6.34±0.33^{A*} (4.23- 7.75)	6.02±0.33* (4.23- 7.75)
	OCT	1.31±0.33 (0.33- 2.75)	4.15±0.33^{E**} (1.23- 6.7)	5.8±0.33^{A*} (4.23- 7.75)	5.41±0.33^{B*} (4.23- 7.75)	5.88±0.33* (4.23- 7.75)
	NOV	2.61±0.33 (1.03- 4.75)	8.17±1.33^{C*} (4.23- 7.75)	5.81±0.33^{A**} (4.23- 7.75)	5.67±0.33^{B**} (4.23- 7.75)	5.12±0.33** (4.23- 7.75)
	DEC	3.22±0.33 (1.23- 5.75)	22.6±0.33^{B*} (18.2-27.7)	6.09±0.33^{A**} (4.23- 7.75)	4.77±0.33^{C*} (4.23- 7.75)	6.12±0.33** (4.23- 7.75)
2016	JAN	1.22±0.33 (0.66- 3.75)	42.3±3.33^{A*} (31.2- 52.7)	6.12±0.33^{A**} (4.23- 7.75)	5.02±0.33^{B***} (4.23- 7.75)	6.02±0.33** (4.23- 7.75)
	FEB	1.23±0.33 (0.73- 4.75)	48±2.33^{A*} (28.23- 57.7)	5.58±0.33^{A**} (4.23- 7.75)	4.12±0.33^{B***} (4.23- 7.75)	6.34±0.33** (4.23- 7.75)
P- VALUE		*P* = 0.02	*P*= 0.05	*P*= 0.04	*P*= 0.05	*P*= 0.05

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

Table 8. Seasonal variation in phosphate (mg/L) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	2.5±0.33^{A**}(4.23- 7.75)	48.9±0.33^{A*}(4.23- 7.75)	21±0.33^{A**} (4.23- 7.75)	14.5±0.33^{B***}(4.23-7.75)	21.6±0.33^{B**} (4.23- 7.75)
	DEC	15.2±0.33^{B***}(4.23-7.75)	26±0.33^{B**} (4.23- 7.75)	35±0.33^{A*} (4.23- 7.75)	22.1±0.33^{A**}(4.23- 7.75)	23.3±0.33^{B**} (4.23- 7.75)
2015	JAN	16.3±0.33^{B***}(4.23-7.75)	42.8±0.33^{A*}(4.23- 7.75)	21±0.33^{A**} (4.23- 7.75)	12.8±0.33^{B***}(4.23-7.75)	15.5±0.33^{C***} (4.23- 7.75)
	FEB	7.5±0.33^{C***} (4.23- 7.75)	6.5±0.33^{D***}(4.23- 7.75)	5.6±0.33^{B***} (4.23- 7.75)	22±0.33^{A*} (4.23- 7.75)	13.5±0.33^{C**} (4.23- 7.75)
	MAR	4.2±0.33^{D***} (4.23- 7.75)	12.6±0.33^{C**}(4.23-7.75)	7.5±0.33^{B***} (4.23- 7.75)	11.3±0.33^{C**}(4.23- 7.75)	22.2±0.33^{B*} (4.23- 7.75)
	APR	5.5±0.33^{C***} (4.23- 7.75)	12±0.33^{C**} (4.23- 7.75)	5.3±0.33^{B***} (4.23- 7.75)	6.8±0.33^{D***} (4.23- 7.75)	21±0.33^{B*} (4.23- 7.75)
	MAY	6.5±0.33^{C**} (4.23- 7.75)	8.5±0.33^{D**} (4.23- 7.75)	8.2±0.33^{B**} (4.23- 7.75)	4.6±0.33^{D**} (4.23- 7.75)	15±0.33^{C*} (4.23- 7.75)
	JUN	2.4±0.33^{D**} (4.23- 7.75)	5.8±0.33^{D**} (4.23- 7.75)	12.5±0.33^{B*} (4.23- 7.75)	4.1±0.33^{D**} (4.23- 7.75)	12.5±0.33^{C*} (4.23- 7.75)
	JUL	8.2±0.33^{C*} (4.23- 7.75)	6.7±0.33^{D**} (4.23- 7.75)	5.2±0.33^{B**} (4.23- 7.75)	4.2±0.33^{D**} (4.23- 7.75)	11.2±0.33^{C*} (4.23- 7.75)
	AUG	2.4±0.33^{D} (4.23- 7.75)	5.7±0.33^{D} (4.23- 7.75)	4.8±0.33^{C} (4.23- 7.75)	7.4±0.33^{D} (4.23- 7.75)	8.8±0.33^{D} (4.23- 7.75)
	SEP	5.5±0.33^{C***} (4.23- 7.75)	22±0.33^{B*} (4.23- 7.75)	4.2±0.33^{C***} (4.23- 7.75)	4.1±0.33^{D***} (4.23- 7.75)	11±0.33^{C**} (4.23- 7.75)
	OCT	4.5±0.33^{C***} (4.23- 7.75)	24±0.33^{B*} (4.23- 7.75)	2.6±0.33^{C***} (4.23- 7.75)	8.2±0.33^{C**} (4.23- 7.75)	22±0.33^{B*} (4.23- 7.75)
	NOV	5.6±0.33^{C**} (4.23- 7.75)	13.9±0.33^{C*}(4.23- 7.75)	4.6±0.33^{C**} (4.23- 7.75)	12.7±0.33^{B*} (4.23- 7.75)	11.1±0.33^{C*} (4.23- 7.75)
	DEC	3.2±0.33^{A**}(4.23- 7.75)	48±0.33^{A*} (4.23- 7.75)	22±0.33^{A**} (4.23- 7.75)	17.7±0.33^{B***}(4.23-7.75)	31±0.33^{A**} (4.23- 7.75)
2016	JAN	4.8±0.33^{C***} (4.23- 7.75)	41±0.33^{A*} (4.23- 7.75)	4.5±0.33^{C***} (4.23- 7.75)	15.8±0.33^{B**}(4.23- 7.75)	42±0.33^{A*} (4.23- 7.75)
	FEB	13.6±0.33^{B**}(4.23- 7.75)	19.5±0.33^{B*}(4.23- 7.75)	5.8±0.33^{B***} (4.23- 7.75)	4.2±0.33^{D***} (4.23- 7.75)	12.1±0.33^{C**} (4.23- 7.75)
P- VALUE		*P* = 0.02	*P*= 0.05	*P*= 0.04	*P*= 0.05	*P*= 0.05

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

Table 9. Seasonal variation in sulphate (mg/L) (October, 2014 to March, 2016)

YEAR	MONTH	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
2014	NOV	1.81±0.3^{B}(0.83- 2.75)	47.81±2.33^{A*}(21.8- 22.81)	4.81±0.33^{C}(0.83- 10.75)	11.81±0.33^{A**}(7.83- 22.7)	3.81±0.2^{B}(0.83- 6.25)
	DEC	1.21±0.23^{B}(0.73- 3.75)	31.21±1.2^{B*}(20.73- 43.25)	6.21±0.23^{C***}(2.73- 11.75)	11.21±0.23^{A**}(2.73- 23.5)	2.12±0.23^{B}(0.73- 5.15)
2015	JAN	2.61±0.73^{A} (1.23- 4.75)	18.61±0.7^{D*}(11.23- 27.7)	2.61±0.73^{C}(1.23- 4.75)	12.61±1.73^{A**}(1.3- 34.75)	3.61±0.3^{B***}(0.23- 8.66)
	FEB	2.72±0.43^{A} (0.93- 4.03)	24.72±0.43^{C}(10.93- 34.75)	2.72±0.43^{C}(0.93- 4.75)	2.72±0.43^{C}(0.93- 4.21)	4.72±0.43^{B}(1.93- 8.77)
	MAR	3.12±0.1^{A}**(1.43- 5.75)	33.82±0.8^{B*}(11.43- 45.75)	3.82±0.33^{C**}(1.43- 5.75)	3.02±0.33^{C**}(1.43- 5.75)	3.2±0.33^{B**}(1.43- 5.75)
	APR	2.02±0.12^{B} (1.53- 4.05)	22.22±0.3^{C*}(14.53- 28.05)	8.22±1.3^{C**}(1.53- 24.05)	5.2±0.1^{B***}(1.53- 12.05)	3.22±0.3^{B}(1.53- 6.05)
	MAY	2.52±0.22^{A} (1.23- 3.12)	12.52±2.2^{D*}(1.23- 33.75)	2.12±0.22^{C}(1.23- 3.15)	2.2±0.22^{C}(1.23- 3.75)	2.32±0.02^{B}(1.23- 3.75)
	JUN	2.21±0.33^{B} (1.23- 4.75)	15.21±1.3^{D*}(11.23- 24.75)	2.21±0.33^{C}(1.23- 4.75)	2.21±0.33^{C}(1.23- 4.75)	5.21±0.33^{B}(1.23- 9.55)
	JUL	3.21±0.33^{A} (1.23- 5.74)	12.21±0.1^{D*}(4.23- 25.75)	3.21±0.33^{C}(1.23- 5.25)	3.21±0.33^{C}(1.23- 5.07)	8.21±0.33^{B**}(3.23- 15.75)
	AUG	1.81±0.33^{B} (0.83- 2.75)	11.81±4.3^{D*}(4.83- 28.55)	4.81±0.33^{C**}(0.83- 7.75)	1.81±0.33^{C}(0.83- 2.22)	5.81±0.1^{B}**(1.83- 9.14)
	SEP	2.21±0.73^{B} (0.73- 4.25)	12.21±1.51^{D*}(5.73- 24.45)	2.21±0.73^{C}(0.73- 4.75)	2.21±0.73^{C}(0.73- 4.33)	3.21±0.73^{B} (0.73- 4.75)
	OCT	1.31±0.33^{B} (0.33- 2.75)	31.31±20.1*(40.3- 2.75)	4.31±0.33^{C**}(0.33- 8.85)	1.31±0.33^{C}(0.33- 2.75)	4.31±0.33^{B} (0.33- 7.75)
	NOV	2.61±0.33^{A} (1.03- 4.15)	42.61±2.33^{A*}(21.0- 64.75)	2.61±0.33^{C}(1.03- 4.75)	12.61±0.01^{A**} (3.03- 24.09)	6.61±0.33^{A***} (1.03- 12.11)
	DEC	3.22±0.33^{A} (1.23- 5.75)	43.22±0.33^{A*} (31.3- 53.8)	12.22±1.33^{B**}(5.23- 25.75)	13.22±0.03^{A**} (7.23- 22.75)	7.22±0.33^{A****} (1.23- 15.75)
2016	JAN	1.22±0.33^{B} (0.66- 3.75)	31.22±0.33^{B*}(21.6- 43.75)	14.22±0.83^{A**}(2.66- 31.8)	11.22±0.33^{A} (6.66- 26.15)	5.22±0.33^{A} (0.66- 8.75)
	FEB	1.23±0.33^{B***}(0.73- 4.5)	11.23±0.33^{D*}(8.1- 14.75)	2.23±0.33^{C***}(0.73- 4.75)	12.23±0.3^{A*} (9.73- 44.78)	6.23±0.33^{A**} (3.73- 9.41)
P- VALUE		*P* = 0.02	*P*= 0.05	*P*= 0.04	*P*= 0.05	*P*= 0.05

NOTE: P< 0.05= significant difference,> 0.05= no significant difference. N=number of samples collected from each stations=10.

4. CONCLUSION

The study has provided a proof of trophic stratification by anthropogenic perturbations. The study has also provided a general picture of the aquatic environment over an extended period of time; a database useful for reference in subsequent studies aimed at protecting the ecological integrity Egbokodo River; which is of immeasurable services to inhabitants of nearby communities and neighbouring water bodies. Results show that anthropogenic activities around the river are of higher impacts on the ecological equilibrium than most neighbouring rivers. Data assures the suitability of the river for aquatic life, agriculture and domestic use. However, need for amelioration of the anthropogenic perturbations cannot be overemphasised.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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