Full Empirical Research Paper

Spatial and Temporal Fluctuations of Physico-Chemical Parameters, Nutrients and Primary Productivity of Gbalegbe River, Delta State, Nigeria

[1]Ewutanure, S.J.
[2]Olaifa, Flora. E.

[1]Department of Fisheries
& Aquaculture Management
Nigeria Maritime University,
Okorenkoko, Warri – South
Delta State, Nigeria

[2]Department of Aquaculture
& Fisheries Management
University of Ibadan
Ibadan, Nigeria

E-mail
ewutanure@gmail.com
floraolaifa@yahoo.com

Phones
+2348101634482.
+2348035509342.

ABSTRACT

Inland waters are very unstable ecosystems. They are affected by anthropogenic and natural activities. Consistent monitoring of the physico – chemical, nutrients and primary production parameters in surface water in Nigeria is vital to the management of the aquatic environment. However, information on the fluctuation patterns of physico – chemical parameters, nutrients and primary productivity of Gbalegbe River is limited. Therefore, the fluctuation dynamics of physico – chemical parameters, nutrients and primary productivity of Gbalegbe River, Delta State, Nigeria were investigated. Gbalegbe River (12.5 km) was spatially stratified into eight zones (S1, S2, S3, S4, S5, S6, S7, and S8) based on proximity to key anthropogenic activities. In each station, three sampling points were randomly selected. Temporal stratification covered wet (March - October) and dry (November – February) seasons. Water samples were collected from each station forth – nightly for 24 months following standard methods. Water samples were analysed for Dissolved Oxygen (DO, mg/L), Temperature (^oC), Nitrate (Nitrate, mg/L – N), Sulphate (SO42-, mg/L), Magnesium (Mg, mg/L) and Gross Primary Production (GPP, gC/m2/d) using standard procedures. Data were analysed by using descriptive statistics and ANOVA at $\alpha 0.05$. The highest (4.52±0.56) and least (3.13±0.67) DO were obtained in S1 and S2, respectively. Temperature ranged from 24.28±5.84 to 28.45±2.06 in S3 and S2; Nitrate (1.07±0.03, 1.76±0.21) in S6 and S2, respectively. Temperature values were 27.55±1.60, 26.94±1.97; DO (5.75±0.73, 4.00±0.66) and Nitrate (1.05±0.64, 0.98±0.43) in dry and wet seasons, respectively. Sulphate ranged from 0.80±0.26 to 1.63±0.26 in S2 and S8; Mg (63.30±6.30, 67.51±4.95) in S7 and S1, while GPP values were 10.05±0.09 and 25.75±0.83 in S1 and S2, respectively. Seasonally, Sulphate ranged from 0.97±0.06 to 1.24±0.33; Mg (63.13±20.73, 65.94±6.01) and GPP (20.19±4.91, 35.34±6.37) in wet and dry seasons, respectively. The patterns of physico – chemical parameters, nutrients and primary productivity of Gbalegbe River are fairly unstable with DO, thus its rich fisheries resources could be threatened.

Keywords: Inland water, Gbalegbe River, Fisheries resources, Anthropogenic activities.

Proceedings ReferenceFormat
Ewutanure, S.J. & Olaifa, F.E. (2021): Spatial and Temporal Fluctuations of Physico-Chemical Parameters, Nutrients and Primary Productivity of Gbalegbe River, Delta State, Nigeria Proceedings of the 28th iSTEAMS Intertertiary Multidisciplinary Conference. American International University West Africa, The GambiaSeries 28, Vol 3 October, 2021. Pp 137-158 www.isteams.net/gambia2021.
DOI - https://doi.org/ 10.22624/AIMS/iSTEAMS-2021/V28N3P11

1. INTRODUCTION

Inland waters are very unstable ecosystems. They are affected by anthropogenic and natural activities (Ewutanure and Olaifa, 2018b). It has been reported that pollutants emanating from anthropogenic activities flow into surface waters through drains and canals (Ewutanure and Olaifa, 2018c). Consistent monitoring of anthropogenic effluents and environmental changes in surface water had shown increased levels of pollution stress on aquatic organisms, decreased water nutrients and primary productivity (WHO, 2008). Rivers help in flood control, storm water drainage, and serve as habitats for aquatic organism, yet they are being destructively exploited in recent times. Domestic and industrial effluents are some of the product of man's actions which limit primary production of river ecosystems (Ewutanure and Olaifa, 2018a).

Water quality criteria are developed by experts to provide basic scientific information on the impact of pollutants on aquatic biota based on indicators that distinguished the quality of the suspended particulate matter, bottom sediment (Abowei *et al*., 2012; Ogbuagu, 2013). Maximum acceptable limits are set as criteria to ensure that the required concentrations of the physico – chemical, water nutrients and primary production are maintained (Boyd, 1979). The protection and maintenance of surface water determines its productivity and usage (NIS, 2007; Adefemi *et al*., 2007). The transportation, distribution and deposition of eroded materials at various points along river has the potential of altering the concentrations of its physico – chemical, nutrients and primary production parameters (Abowei *et al*., 2012). The location was chosen because it is one of the major areas where anthropogenic (oil exploitation and exploration, glass and rubber production, gas flaring and sand mining) activities were taking place in Delta State. Hence, this study was undertaken to evaluate the impacts of the anthropogenic activities on the physico-chemical parameters, nutrients and primary productivity of Gbalegbe River, Delta State, Nigeria.

2. MATERIALS AND METHODS

Description of the study area

According to Ewutanure and Olaifa, (2018a), Gbalegbe River which traverses up to 12.5 km is located within latitudes 5°10'N and 5°17'N of the Equator and Longitudes 5°56'E and 5°13'E of the Greenwich meridian (Figure 3.1). It originated from a tributary of Asaba - Ase River, Delta State. Its highest and mean depths were 10.45m and 4.31m respectively, (Town Planning Authority, Ughelli, Delta State, 2014). The study area lies between 0 – 100 meters above sea level (Kottek *et al.,* 2006). Gbalegbe River is the major River flowing through Ughelli Town, Delta State Nigeria. The town was initially an agro – based but has become highly industrialized with the location of oil, glass, power and construction companies (Ewutanure and Olaifa, 2018b). Ewutanure and Olaifa, (2018b) reported that petroleum deposits were discovered in the area in 1958 but exploration started in 1965. Since then, crude oil from this location is being transported to the port of Bonny for export (Ochuko *et al*., 2008).

Climate and vegetation of the study area

The study area (Figure 1.1) has humid climate, with wet season (March – October) and dry season (November – February) influenced by the South – West and North – East trade wind, respectively (Aweto, 2002). The mean annual rainfall of the study area was 2700 mm. The study location has double peaks (June/July and September) of rainfall with a short break period in August, while the mean annual temperature was 27 °C (Ogaga *et al.*, 2015).

Experimental Procedure

Gbalegbe River (Figure 1.1) was spatially stratified into eight stations (S1 – low human activities; S2 – glass production factory; S3 – power plant; S4 – rubber processing mill; S5 – Oil farm tanks; S6 – Auto mechanic shops; S7 – Cassava processing mill and S8 – Sand mining) based on proximity to key anthropogenic activities (ISO, 2006; Mohammed *et al.,* 2008), while the mean distance among stations was 1.56 km. In each station, three sampling points were randomly selected. Temporal stratification covered wet (March – October) and dry (November – February) seasons (Ochuko *et al*., 2008).

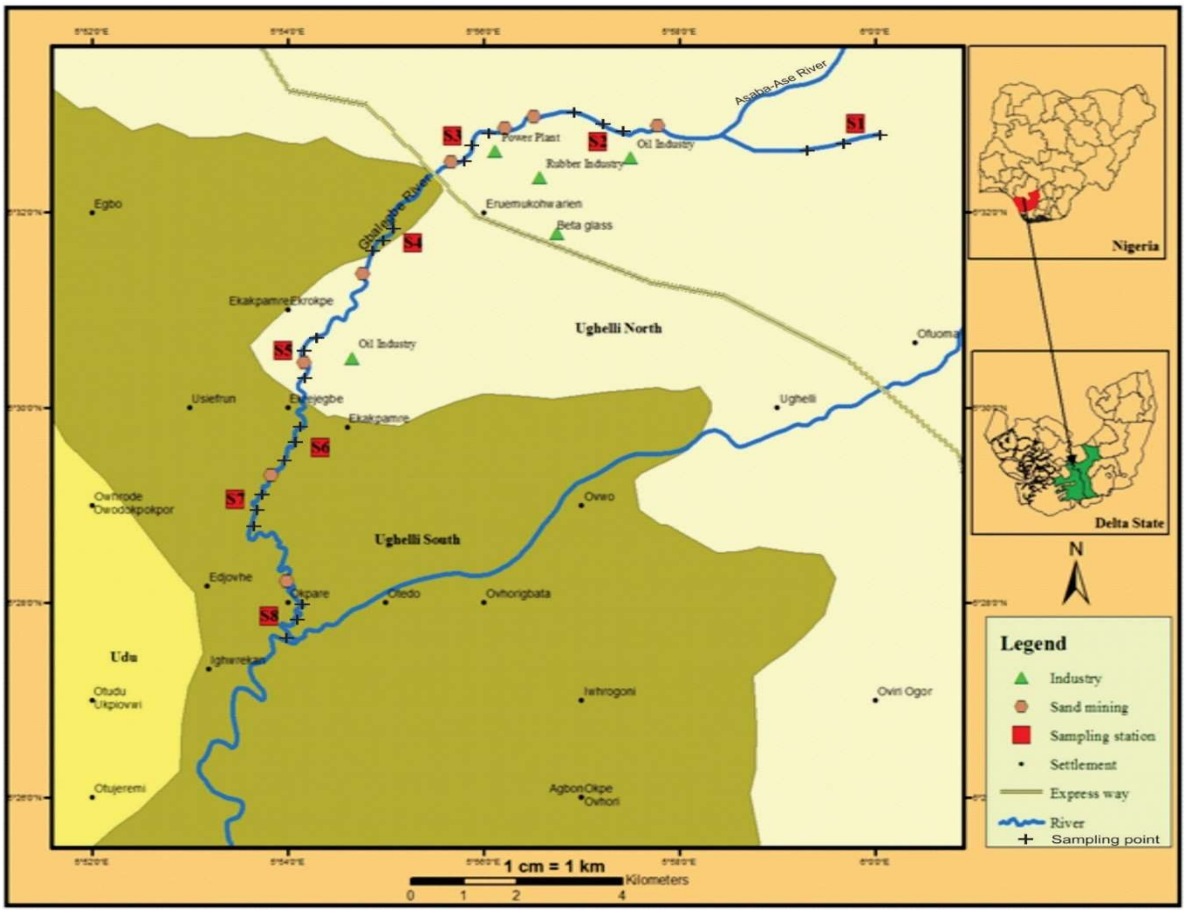

Figure 1.1. Gbalegbe River, Delta State, Nigeria
Source: Ewutanure and Olaifa, (2018a)

Sampling Techniques

The background weather data (rainfall, temperature and relative humidity) of the study area were obtained from the Metrological Station of Ughelli North Local Government Area, Delta State, Nigeria, while bi-weekly field trips were made to collect water samples. Parameters monitored were Total Dissolved Solids, Total Suspended Solids, Electrical Conductivity, pH, Dissolved Oxygen, Biological Oxygen Demand, Transparency, Alkalinity, Nitrate, Nitrite, Ammonia, Sulphate, Phosphate-Phosphorus, Chlorophyll a, Gross primary production and Net primary production.

Pre – treatment of sampling equipment and storage containers

Before sampling, all samplers and glass bottles were washed using detergent and rinsed in distilled water. Polypropylene and glass bottles were rinsed with 1N nitric acid but 95% Acetone was used to rinse glass wares (APHA, 1998). Prior to collection of water samples, polypropylene and glass bottles were rinsed twice with the environmental sample.

2.6 Collection of water samples for analyses

Samples of water were collected bi – weekly between 0700 and 0900hours from each point by dipping the sample bottles to a depth of 10 – 50 cm through inversion to avoid trapping air bubbles. Samples for BOD and DO analyses were collected in 300 ml and 250 ml glass bottles, stoppered and fixed immediately at the points of collection with Winkler A and B solutions and preserved as recommended by AOAC, (1990).

2.7 Analytical techniques

Dissolved Oxygen (DO)

The DO was evaluated ex-*situ* by titration – Winkler's method (Gupta, 2001). Water samples were fixed with Winkler A (manganous sulphate) and Winkler B (alkaline potassium iodide). The DO was calculated using the formula;

$$DO\ (mg/L) = \frac{V1 \times N \times 8 \times 1000}{V2 - V3}$$ (Gupta, 2001).

Where:

V_1 = Volume of titrant (ml)

N = Normality of titrant (0.025N

V_2 = Volume of Sampling bottle after placing the stopper (ml)

V_3 = Volume of manganous sulphate + potassium iodide solutions added (ml)

Biological oxygen demand (BOD_5)

Samples for BOD_5 were incubated for five days in the laboratory at 20°C (Trivedy and Goel, 1984) and determined by Winkler method (APHA, 1998). BOD_5 was calculated by using the formula stated below:

$$BOD_5 = (D1 - D2)\ X\ \frac{\text{Volume of BOD bottle}}{\text{ml of sample used}}$$ (Gupta, 2001).

Where

D1 = Initial dissolved oxygen in sample

D2 = Sample dissolved oxygen after 5 days of incubation.

Sulphate was analysed according to standard method (USEPA, 1978a).

Total suspended solids (TSS)

Measurement of TSS was through filtration method followed by oven drying method as described in (AOAC, 1990). Calculation:

TSS (mg/L) $= \frac{A-B}{C}\ X\ 1000{,}000$ (AOAC, 1990)

Where:
A = Dry weight of residue + filter paper
B = Dry weight of filter paper alone
C = Total ml of water filtered.

Transparency, Temperature, pH, Turbidity, Salinity, EC and TDS

Water transparency was determined using secchi disc according to the method described by Boyd (1998). Water temperature was measured using mercury in glass thermometer (^{o}C), pH with digital pH meter (Hanna model: HI – 98107, USA). Turbidity was measured by using a turbidometer in accordance with USEPA, (1993) standards. Salinity, EC and TDS were measured by a Salinometer (Thermo Electron Corporation, model: Orion 150A+, USA).

$$\text{Transparency (cm)} = \frac{(Point\ of\ disappearance + poin\ \ of\ appearance)}{2}$$ (Boyd, 1979)

Velocity

Velocity is the total distance travelled with time. It is also the rate of water flow of a river (JICA, 2008). It was determined by measuring the time and the distance covered by floating object from point A to point B.

$$\text{Velocity (m/s)} = \frac{Distance}{Time}$$

Alkalinity

Alkalinity was measured by titrimetric method using 0.01N HCl and methyl orange as indicator (APHA, 1998).

Alkalinity CO_3^- (g/L) = $\frac{Vol.of\ \mathrm{H2SO4}\ (titrant\ used) \times N \times Eq.wt\ of\ CO3-(30)}{Ml\ of\ water\ sample}$ Lind, (2009).

Where:
N = Normality of H_2SO_4
Eq. wt = Equivalent weight of CO_3^-

Chloride

Chloride was analysed using N, N - Dimethyl-p-phenylenediamine (DPD) titration method (Boyd and Craig, 1992). The concentration of chloride was calculated by using:

$$Chloride\ (mg/L) = \frac{(mL\ of\ titrant) x (N) x\ (35.45) x\ (1000)}{Volume\ of\ sample}$$ (Boyd and Craig, 1992)

Nitrate

Nitrate concentration was determined according to the Phenol disulphonic acid method (Gupta, 2001).
Calculation:

$$NO_3^- \text{ (mg/L - N)} = \frac{\textit{Concentration of} \text{ Nitrate from standard curve}}{\textit{Volume of sample (mL)}}$$

Nitrite

The concentration of nitrite was determined using sulphanilamide method (Gollenman *et al.,* 1978).

Ammonium

Ammonium concentration in the water sample was determined by volumetric method as described by Gollenman *et al.,* (1978).
Calculation:

$$NH_4 \text{ (mg/L - N)} = \frac{(T-B) x\ N\ x\ 14\ x\ 1000}{Volume\ of\ sample\ (mL)}$$

Where T = volume of titrant used against sample (mL), B = volume of titrant used against blank (mL); N = normality of titrant (0.01). The equivalent weight of NH_4 – N is 14.

Sulphate

The Ca^{2+} and Mg^{2+} contents of the sample were obtained by direct titration with EDTA (APHA, 1998). The concentrations of Ca^{2+} and Mg^{2+} were calculated by using:

Sulphate (mg/L) = B + Ba + Mg – T.

Where :
B is blank (milliequivalent, meq of Ca^{2+} and Mg^{2+}) in the original sample
Ba is the meq barium added
Mg is the meq of magnesium added
T is the meq of versenate (EDTA) of the total titration of the sample after adding Ba and Mg.
1mL of 1 N $BaCl_2$ = 1 meq Ba (1 mL of normal solution equals 1 meq/L
1 meq of 0.02 N $BaCl_2$ = 0.02 meq Ba
1 meq of 0.02 N Mg Cl_2 = 0.02 meq Mg).

Phosphate – phosphorus

The concentration of phosphorus in water sample was determined using colorimetric method as described by Gupta (2001). Calculation:

$$Phosphate - phosphorus\ (mg/L) = \frac{mgP(in\ 50\ mL)}{Volume\ of\ sample}$$

Chlorophyll a

Chlorophyll a was determined according the method described by Vellenweider (1969).

Chlorophyll-a (Chll-a) was calculated using:

$Chll_{-a} = 11.9\ (A_{665} - A_{750})\ X\ \frac{V}{L}\ X\ \frac{1000}{S}$ (Vollenweider, 1969).

Where:
A_{665} = Absorbance at 665 nm
A_{750} = Absorbance at 750nm
V = Acetone extract (ml)
L = Length of light path in spectrophotometer (cm)
S = Volume of acetone filtered

Gross and Net primary production

The oxygen light – dark bottle method was used (Boyd and Craig, 1992). The formulae stated below were used for net primary production (NPP, gC/m^2/d), gross primary production (GPP, gC/m^2/d) and respiration (R) (Boyd and Craig, 1992):
NPP = LB – IB
GPP = LB – DB
R = IB – DB

Where IB, LB and DB are initial, light and dark bottles respectively.

Statistical analyses

Data collected were subjected to descriptive statistics and ANOVA by using SPSS (version, 20). Data were pooled and presented as spatial and temporal mean variances.

3. RESULTS

Spatially, the least (14.56±5.21 mg/L) mean values of total dissolved solids (TDS) occurred at Station 1, while the highest (366.59±35.94 mg/L) was at Station 2. During the dry and wet seasons, 40.76±11.69 mg/L and 205.15±0.35mg/L were recorded as the least and highest mean values of TDS, respectively. The least (23.98±10.51 mg/L) mean of total suspended solid (TSS) was recorded at Station 1, while the highest (98.60±0.6 mg/L) was at Station 2. Seasonally, TSS concentrations ranged from 51.46±15.17 mg/L to 123.61±21.01 mg/L in dry and wet seasons, respectively.The least mean of electrical conductivity (EC) recorded was 1.58±1.00 μScm^{-1} at Station 8, while the maximum was 43.26±39.62 μScm^{-1} at Station 2. Seasonal mean values of EC varied from 9.05±3.16 μScm^{-1} to 22.19±0.43 μScm^{-1} in wet and dry seasons. The least (23.19±12.17 FTU) mean values of turbidity among stations occurred at Station 1, while the highest was 43.59±16.29 FTU at Station. Seasonally, it ranged from 25.47±4.89 to 45.71±3.93 FTU in dry and wet seasons, respectively. The mean value of water temperature recorded was least (24.28±5.84 ^{o}C) at Station 3, and highest (28.45±2.06 ^{o}C) at Station 2. Seasonally, the least (26.94±1.97) ^{o}C and highest (27.55±1.60) ^{o}C mean values of temperature were recorded in wet and dry seasons, respectively. Spatially, the least and highest mean DO concentration recorded were 3.13±0.67 mg/L and 4.52±0.56 mg/L at Stations 2 and 1, respectively. Seasonally, the least mean values of DO recorded in wet and dry seasons were 4.00±.066 mg/L and 5.75±0.73 mg/L.

The least (0.65±0.03 mg/L) and highest (1.59±0.65 mg/L) spatial mean values of biological oxygen demand (BOD) occurred at Stations 1 and 2. Seasonal variations showed that the highest (1.38±0.71) mg/L and least (1.10±0.67) mg/L mean values of BOD were recorded in wet and dry seasons. Spatially, the least (6.99±0.79) and highest (7.77±0.84) mean values of pH recorded occurred at Station 2 and 6, while seasonal variation ranged from 7.05±1.02) to 7.31±2.50 in wet and dry seasons, respectively. Spatially, the least (51.90±6.68 mg/L) and highest (57.21±5.82 mg/L) mean value of Alkalinity occurred at Stations 1 and 8, while its varied from 50.21±2.91 to 56.74±4.21 in wet and dry seasons.

Spatially, the least (0.59±0.01 ‰) and highest (3.861±0.60 ‰) mean values of salinity occurred at Stations 1 and 2, seasonal variation ranged from 2.01±0.64 ‰ and 2.13±0.61 ‰ during the wet and dry seasons, respectively. Spatially, the least (58.65±22.67 mg/L) and highest (66.41±11.48 mg/L) mean concentrations of chloride were recorded at Stations 1 and 8, while its value varied from 55.81±5.20 to 59.63±3.81 in wet and dry seasons, respectively.

Spatially, the least (0.31±0.16 m/s) and highest (0.47±0.13 m/s) mean values of velocity recorded occurred at Stations 3 and 5, while the seasonal variation ranged from 0.15±0.14 m/s to 0.41±0.21 m/s during the dry and wet seasons, respectively. Spatially, the least and highest mean values of transparency recorded were 36.01±3.04 cm and 66.17±2.74 cm at Stations 2 and 1, respectively, while seasonal variation ranged from 36.75±5.12 cm in wet season to 54.16±6.85 cm in dry season

Table 1: Spatial variation of Total Dissolved Solids (TDS), Total suspended solids (TSS), Electrical conductivity (EC)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
TDS(mg/L)	14.56 ± 5.21^{c}	366.59 ± 35.94^{a}	133.24 ± 91.60^{b}	22.39 ± 12.16^{c}	24.73 ± 12.36^{c}	28.86 ± 21.87^{c}	34.86 ± 46.31^{c}	19.1 ± 13.88^{c}
TSS (mg/L)	23.98 ± 10.51^{d}	98.60 ± 0.6^{a}	31.18 ± 56^{c}	25.91 ± 16.17^{c}	32.55 ± 9.37^{b}	47.93 ± 48.79^{b}	48.39 ± 64.15^{b}	31.36 ± 374.66^{b}
EC (µS/cm)	3.36 ± 2.86^{f}	43.26 ± 39.61^{a}	10.41 ± 302.70^{c}	15.76 ± 16.47^{b}	10.41 ± 16.60^{c}	17.43 ± 20.68^{b}	6.77 ± 8.65^{d}	1.58 ± 1.00^{e}
TUR (FTU)	6.96 ± 2.17^{d}	43.59 ± 16.29^{a}	30.15 ± 17.74^{c}	36.08 ± 18.04^{bc}	35.21 ± 14.84^{bc}	25.62 ± 12.35^{d}	39.00 ± 16.62^{b}	33.74 ± 16.57^{b}
Temp (°C)	26.62 ± 1.75^{b}	28.45 ± 2.06^{a}	24.28 ± 5.84^{c}	25.49 ± 1.59^{b}	25.93 ± 1.75^{b}	26.14 ± 2.00^{b}	26.30 ± 1.34^{b}	24.81 ± 1.53^{c}
DO (mg/L)	4.52 ± 0.56^{a}	3.13 ± 0.67^{ab}	3.45 ± 0.48^{b}	3.88 ± 0.85^{b}	3.91 ± 0.77^{bc}	3.68 ± 0.64^{bc}	3.94 ± 0.74^{bc}	3.55 ± 0.69^{bc}
BOD(mg/L)	0.65 ± 0.03^{b}	1.59 ± 0.69^{a}	1.34 ± 0.87^{a}	1.06 ± 0.50^{a}	1.14 ± 0.64^{a}	1.13 ± 0.73^{a}	0.86 ± 0.60^{c}	1.34 ± 0.66^{a}
pH	7.15 ± 0.61^{b}	6.99 ± 0.79^{ab}	7.21 ± 0.62^{b}	7.31 ± 0.52^{ab}	7.12 ± 0.57^{b}	7.77 ± 0.84^{a}	7.45 ± 0.79^{ab}	7.03 ± 0.37^{b}
Alk (mg/L)	11.90 ± 0.8^{b}	52.49 ± 5.87^{a}	53.27 ± 6.27^{a}	52.69 ± 6.98^{a}	52.76 ± 7.65^{a}	53.13 ± 7.44^{a}	56.18 ± 6.26^{a}	57.21 ± 5.82^{a}
Sal (‰)	0.59 ± 0.01^{a}	3.86 ± 0.60^{d}	2.45 ± 0.57^{abc}	2.99 ± 0.36^{bcd}	2.80 ± 0.52^{cd}	2.91 ± 0.55^{a}	2.64 ± 0.41^{ab}	2.81 ± 0.39^{ab}
Chloride (mg/L)	58.65±22.67	51.64±13.06	62.14±16.18	65.36±15.80	52.94±12.65	61.35±21.44	60.25±12.69	66.41±11.48
Velocity (m/s^2)	0.36 ± 0.11^{a}	0.34 ± 0.13^{a}	0.31 ± 0.16^{a}	0.34 ± 0.17^{a}	0.47 ± 0.13^{a}	0.40 ± 0.10^{a}	0.43 ± 0.13^{a}	0.33 ± 0.18^{a}
Transparency (cm)	66.17 ± 2.74^{a}	36.01 ± 3.48^{b}	57.29 ± 2.24^{a}	57.62 ± 2.79^{a}	58.82 ± 4.57^{a}	50.43 ± 2.68^{a}	56.69 ± 3.47^{a}	55.01 ± 2.74^{a}

Turbidity (TUR), Temperature, Dissolved oxygen (DO), pH, Alkalinity (Alk), Salinity, Chloride, Velocity and Transparency of Gbalegbe River.

Note:Mean values with same superscripts along the rows were not significantly different at $p > 0.05$.

Table 2 Seasonal variation of Total Dissolved Solids (TDS), Total suspended solids (TSS), Electrical conductivity (EC),

	Wet season	Dry season	P – values	UNICEF, (2008)	FEPA, (1991)	Boyd, (1998)
TDS (mg/L)	205.15±0.35	40.76±11.69	0.00*	2000	2000	30 – 200
TSS (mg/L)	123.61±21.01	51.46±15.17	0.02*	25.00	30.00	< 10
EC (μScm^{-1})	9.05±3.16	22.19±0.43	0.04*	250	240	50 - 500
TUR (FTU)	45.71±3.93	25.47±4.89	0.01*	10	10	10
Temperature (^{o}C)	26.94±1.97	27.55±1.60	0.08**	24.5 – 33	20 – 33	25 – 32
DO (mg/L)	4.00±0.66	5.57±0.73	0.78**	> 4.0	>5	5 – 10
BOD (mg/L)	1.38±0.71	1.10±0.67	0.56**	>10	50	5
pH	7.05±1.02	7.31±2.50	0.45**	6.8 – 8.9	6.5 – 9.0	6.5 – 8
Alk (mg/L)	50.21±2.91	56.74±4.21	0.32**	20	20	20
Salinity (‰)	2.01±0.64	2.13±0.61	0.76**	5	5	5
Chloride (mg/L)	55.81±5.20	59.63±3.81	0.97**	250	250	0 – 75
Velocity (m/s^{2})	0.41±0.21	0.15±0.14	0.00*	-	-	-
Transparency (cm)	36.75±5.12	54.16±6.85	0.00*	≤ 60	40 – 60	30 – 40

Turbidity (TUR), Temperature, Dissolved oxygen (DO), pH, Alkalinity (Alk), Salinity, Chloride, Velocity and Transparency of Gbalegbe River.

Note: * = There are significant differences ($p<0.05$) between means along rows;
** = There are no significant differences ($p>0.05$) between means along the rows

The least mean value of NH_4 among stations was 0.26±0.13 mg/L – N at Station 1, while the highest was 0.66±0.18 mg/L – N Station 2. Seasonally, the mean concentrations of NH_4 varied from 0.49±0.12 mg/L – N to 1.03±0.01 mg/L – N during wet and dry season. Spatially, least mean concentration of nitrate recorded was 1.07±0.03 mg/L – N at Station 6, while the highest was 1.76±0.21 mg/L – N at Station 2. Seasonal variation in the mean concentration of nitrate ranged from 0.98±0.43 mg/L – N to 1.05±0.64 during wet and dry seasons, respectively.

Spatially, the least (0.33±0.03 mg/L) mean concentration of PO_4 – P occurred at Station 6, while the highest was 0.56±0.07 mg/L at Station 2. Seasonal mean concentrations of PO_4 – P ranged from 0.51±0.20 mg/L to 0.63±0.09 mg/L in dry and wet seasons, respectively. The least mean value of SO_4 was 0.82±0.21 mg/L at Station 4, while the highest was 1.63±0.26 mg/L at Station 8. Seasonal variation in the mean values of SO_4 between seasons ranged from 0.97±0.06 mg/L to 1.24±0.33 mg/L in wet and dry seasons, respectively.

Table 3 Spatial variation of Ammonium, Nitrate, Phosphorus, Sulphate and Nitrite of Gbalegbe River.

Stations	Ammonium (mg/L – N)	Nitrate (mg/L – N)	Phosphorus (mg/L – P)	Sulphate (mg/L)	Nitrite (mg/L – N)
Station 1	0.26±0.13[a]	1.25±0.18[ab]	0.47±0.05[a]	1.06±0.19[a]	ND
Station 2	0.66±0.18 [a]	1.76±0.21[a]	0.56±0.07[a]	0.80±0.26[a]	ND
Station 3	0.52±0.20[a]	1.33±0.18[ab]	0.35±0.07[a]	1.13±0.16[a]	ND
Station 4	0.44±0.16[a]	1.45±0.14[ab]	0.33±0.07[a]	0.82±0.21[a]	ND
Station 5	0.55±0.21[a]	1.45±0.16[ab]	0.34±0.08[a]	1.28±0.21[a]	ND
Station 6	0.33±0.10 [a]	1.07±0.03[b]	0.33±0.03[a]	1.29±0.21[a]	ND
Station 7	0.44±0.16 [a]	1.24±0.16[b]	0.41±0.08[a]	1.20±0.28[a]	ND
Station 8	0.49±0.17 [a]	1.22±0.14[b]	0.39±0.08	1.63±0.26[a]	ND
	1.5	10	250	200	0.001
WHO					
NIS, (2007)	0.05	>10	5	250	0.001
FEPA(1991)	0.02	10	5	250	0.001

Means with the same superscripts along the rows were not significantly different at P>0.05.

able 4: Seasonal variation of Ammonium, Nitrate, Phosphorus, Sulphate and Nitrite of Gbalegbe River.

Parameters	Wet season	Dry season	P – value	UNICEF, (2008)	NIS, (2007)	Boyd, (1998)
Ammonia (mg/L – N)	0.49±0.12	0.23±0.05	0.00*	0.0 – 1.0	0.01 – 0.15	0.0 – 1.0
Nitrate (mg/L – N)	0.98±0.43	1.05±0.64	0.00**	0.01 – 2.5	0.01 – 2.5	0.1 – 3.0
Phosphorus (mg/L-P)	0.63±0.09	0.15±0.20	0.03*	250.0	250.0	0.12
SO_4 (mg/L)	0.97±0.06	1.24±0.33	0.07**	250.0	200.0	< 400
Nitrite (mg/L-N)	ND	ND	ND	0.00 – 0.05	0.00 – 0.05	0.0 – 0.5

Note: * = There is significantly different at p<0.05
** = There is no significant difference at p>0.05

Spatially, the least mean of magnesium was 63.30±6.30 mg/L at Station 7, while the highest was 67.51±4.95 mg/L at Station 2. Seasonal variation of Mg ranged from 63.13±0.09 mg/L to 65.95±6.01 mg/L in wet and dry season. The least (22.61±2.42 mg/L) mean concentration of Ca occurred at Station 7, while the highest (32.82±3.02 mg/L) occurred at Station 5. Seasonal variation of Ca ranged from 33.01±1.37 mg/L in the dry season to 35.30±6.76 in the wet season. The least (9.11±3.57 µg/L) mean value of Chlla was at Station 2, while the highest (39.15±5.57 µg/L) was at Station 1. Seasonal variation in the mean concentrations of Chlla ranged from 7.86±0.60 to 19.23±3.91 during the wet and dry seasons, respectively.

Spatially, the least (10.05±0.90 gC/m^2/d) concentration of GPP occurred at Station 2, while the highest was 25.75±0.83 gC/m^2/d at Station 1. Seasonally, the GPP mean value ranged from 20.19±4.91 gC/m^2/ to 35.34±6.37 gC/m^2/d during wet and dry season. The least (7.59±1.41 gC/m^2/d) average NPP concentration occurred at Station 2, while the highest was 14.24±1.71 gC/m^2/d at Station 1. The least seasonal mean value of NPP was 15.69±3.88 in the wet season, while the highest was 22.57±5.77 in the dry season, respectively.

Table 5: Spatial variation of Magnesium, Calcium, Chlorophyll a, Gross primary production, Net primary production in Gbalegbe River

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Mg (mg/L)	66.66±3.85^{a}	67.51±4.95^{a}	66.67±6.09^{a}	66.81±5.04^{a}	65.34±5.43^{a}	65.64±5.2
Ca (mg/L)	30.44±2.89^{a}	31.36±2.65^{a}	32.10±2.30^{a}	32.69±1.49^{a}	32.82±3.02^{a}	30.98±2.9
Chll-a (µg/L)	39.15±5.15^{a}	9.11±3.57^{b}	11.98±8.33^{a}	12.55±6.90^{a}	13.35±2.75^{a}	12.45±2.6
GPP (gC/m^2/d)	25.75±0.83^{a}	10.05±0.90^{c}	19.91±0.84^{b}	19.59±0.67^{b}	19.65±0.88^{b}	19.90±0.9
NPP (gC/m^2/d)	11.24±1.71^{a}	7.59±1.41^{b}	11.19±2.06^{a}	11.71±1.96^{a}	11.00±2.11^{a}	10.71±1.9

Means with the same superscripts along rows were not significantly different at 0.05.

Table 6: Seasonal variation of Magnesium, Calcium, Chlorophyll a, Gross primary production, Net primary production in Gbalegbe River

	Wet season	Dry season	WHO, (2001)	NIS, (2007)
Mg (mg/L)	63.13±20.73	65.94±6.01	150 – 200	150
Ca (mg/L)	35.30±6.76	33.01±1.37	200	200
Chll-a (µg/L)	7.86±0.60	19.23±3.91	15	>17
GPP (gC/m^2/d)	20.19±4.91	35.34±6.37		
NPP (gC/m^2/d)	15.69±3.88	22.57±5.77		

Means with the same superscripts along the rows were not significantly different at $p>0.05$.
Note: Mg=magnesium, Ca=calcium, Chll-a=chlorophyll-a, GPP=gross primary production and NPP=net primary production.

4. DISCUSSION

Total dissolved solids (TDS)

The values of TDS recorded during the study periods were less than the maximum acceptable limit of 2000mg/L (NIS, 2007) and UNICEF, (2008) but higher values than Boyd (1979) recommended range of 30 – 200mg/L for freshwater fish species were recorded at station 2 and during the rainy season.

The lower values of TDS recorded at Station 1 during the dry season could be associated with the minimal anthropogenic activities and reduced amount of in – flow of sediment load into Gbalegbe River, while highest mean value recorded at Station 2 and during the wet season could be due to increased human activity arround Gbalegbe River. These observations were in agreement with Abu and Egenonu (2008) and WHO (2008) who reported that, increase in the concentration of TDS might be attributed to high amount of rainfall, especially during the peak periods of rainy season. UNICEF (2008) reported that the concentration of TDS above the recommended range imparts undesirable mineral taste, laxative effects due to the presence of salts ($NaSO_4$ and $MgSO_4$) and toxaemia in fish.

Total suspended solids (TSS)

Higher concentration of TSS than the recommended levels of 25mg/L (UNICEF, 2008), 30mg/L (FEPA, 1991) and 10mg/L (Boyd, 1979) were recorded at Stations 2, 3, 5 – 8, while the concentrations recorded at Stations 1 and 4 were within the acceptable limits. Adefemi *et al.,* (2007) and Ajuonu *et al*., (2011) reported that, the presence of TSS in a river above the recommended level causes reduced light penetration through the water column, mortality of eggs and larvae of benthic invertebrates, decline in primary productivity and fish abundance.

Electrical conductivity (EC)

Electrical conductivity (EC) is a measure of the ability of the water to conduct electric current, while its presence in a water body is influenced by dissolved salt content, amount of rainfall and freshwater discharge from inland drainages (Adewara and Visser, 2011). Means of EC recorded during the study period were less than the recommended level of 2000µS/cm (ASTM, 2006). Ampon and Taeng-On (2014) reported that electrical conductivity greater than 2000µS/cm is detrimental to aquatic animals.

Turbidity

Higher levels of turbidity than recommended rate of 10 FTU by UNICEF, (2008) were recorded except at Station 1 (area of fewer activities) during the period of the study. Udosen and Benson, (2006) affirmed that the availability of suspended particles (plankton, clay, silt, finely dissolved organic matter) could increase turbidity. Ogbuagu (2013) reported that, low level of turbidity in a river might be associated with reduced anthropogenic activities, while the higher values could be attributed to high rate of run-off as well as increased and untreated effluents from increased anthropogenic activities. Olatunji *et al*., (2011) reported that, settleable materials arising from increased turbidity could form blanket on the river bed thereby causing reduction in the abundance of benthic invertebrates, blockage to gravel spawning bed, increased water temperature, reduce primary productivity, reduction in dissolved oxygen which could either lead to hypoxia ($DO \leq 3.5ml/L$) or anoxic ($DO < 0.5mg/L$) condition which eventually lead to low fish abundance from the river. Abowei and Sikoki (2008) reported that, the presence of turbidity in a river prevents successful development of eggs and larvae, causes migration of fish and decrease in fish food supply.

Temperature

The mean water temperatures recorded during the study period were within the required limit for warm water fish species. This observation was in agreement with Balogun and Ajani, (2015) who reported similar range of temperature in Badagry Creek. Ampon and Taeng-on (2014) reported that, fluctuation in water temperature of a river could be due to its velocity and the rate of mixing of bottom and surface water, change in the atmospheric conditions and the presence of suspended solids.

Osibanjo *et al.* (2011) reported that temperature affects self – purification process of rivers. High temperature promotes increased BOD concentration because biodegradation of organic matter by anaerobic bacteria leads to the reduction in DO level, resulting in an obnoxious condition (Abowei and Sikoki, 2005). Bilota and Brazier (2008) reported that, a unit change in water temperature may alter the existing aquatic community as seen in reduced respiration, reproduction, growth, feeding behaviour, distribution and migration. United Nations International Education Fund, UNICEF (2008) reported that, water temperature influences the growth and reproductive rate of plankton, benthic invertebrates and feeding rate of fishes. Adeleye and Adebiyi, (2003) also reported that, temperature is one of the important environmental factors that determine the variety and density of freshwater plankton.

Dissolved Oxygen (DO)

Dissolved oxygen concentrations recorded at Station 1. During the rainy and dry seasons were within the acceptable limits of >4.0mg/L (UNICEF, 2008), 5 – 10 (Boyd, 1998) and >5.0mg/L (FEPA, 1991). The slight increase in DO levels at Station 1 could be attributed to atmospheric re-aeration and low human activities (Effiong and Akpan, 2015). The means values obtained for Stations 2 - 8 were less than the recommended limits required for the survival of aquatic organisms. Ewutanure and Olaifa, (2018b) reported that, reduced level of DO in a river could be due to increased levels of TSS, turbidity, BOD, temperature and decrease water velocity as a result of excessive precipitation, increased effluents volume. Similar low level of DO has been recorded for coastal water of Warri River (Ogaga *et al*., 2015). Increased anaerobic decomposition of organic matter in water could cause a decrease in the concentration of DO in river.

Biological oxygen demand (BOD)

The BOD values recorded throughout the study period were generally less than the recommended ranges of > 10 mg/L (UNICEF, 2008), 50mg/L (FEPA, 1991). This is in agreement with Ovie and Ovie, (2014) that reported that decreased concentration of BOD could be attributed to the constant flow of a river. Ajuonu *et al*., (2011) stated that biological oxygen demand concentration in a constantly flowing river discourages its accumulation. But the least mean value of BOD obtained at Station 1 compared with the other stations and seasons revealed its gradual accumulation in Gbalegbe River.

pH

The pH values recorded during the study were within the recommended range of 6.8 – 8.9 (UNEP, 2008). The measurement of pH ranges from 1 to 14 with a pH of 7 indicating a neutral solution. Values lower than 7 indicate acidity, while values higher than 7 indicates alkalinity (Brinkman and Johnston, 2008). River water with pH values higher than the recommended ranges are known to have adverse effects on fish production (Ezemonye *et al*., 2009). Fish production is generally poor when pH ranges are 4 and >10 because these ranges are referred to as acid and alkaline death points (Ovie and Ovie, 2014). Excessive rise in the concentration of pH could cause increase in NH_3 concentration which is a toxic substance capable of affecting the physiology of zooplankton, benthic invertebrates and fish (Olaifa, 2004). An increase in pH encourages the production of ammonia which is toxic to aquatic organisms (Ovie and Ovie, 2014).

Alkalinity

Except at Station 1, the mean concentration of alkalinity recorded among stations and between seasons were higher than the recommended values of 20mg/L (UNICEF, 2008 and FEPA, 1991) and 0 – 20mg/L (Boyd, 1979). Ekiye and Zejiao, (2010) reported that, higher alkalinity value in a river system is indicative of its hardness and high buffering capacity. The slight variation in the alkalinity among stations and between seasons was in agreement with Edet and Worden (2009). Although many materials might contribute to the increased alkalinity of water, most of the alkalinity in natural water is caused by the presence of hydroxides, carbonates, and bicarbonates (Ebong *et al.*, 2006). Carbonates and bicarbonates are common to most waters because carbonate materials are abundant in nature, whereas the presence of hydroxides may be due to water contamination (FEPA, 1991).

Salinity

Though salinity values recorded during this study were within the acceptable limits of 5‰ (FEPA, 1991), value at Station 1 compared with Stations 2 – 8 and between seasons suggested that, salinity in Gbalegbe River was gradually on the increase. This result agrees with Kaoud and El – Dahshan, (2010) who reported that rivers gradually exhibit changes in salinity through its length. This could be linked with the fact that Gbalegbe River has its tributaries from Asaba River which is connected with Atlantic Ocean. Ezemonye *et al.* (2009) reported that, salinity levels determine the type of plants and animals that can live within the different zones of a river. Salinity causes flocculation of particles while flocculation is the process of particles' aggregation into larger clumps (Galadima *et al.*, 2011). As salinity increases, turbidity increases ((Montasar *et al.* 2010).

Chloride

Chloride occurs in all natural water in widely varying concentrations (WHO, 2007). The mean of chloride recorded during the study period were lower than the acceptable limit of < 250 mg/L (UNICEF, 2008) and 200 – 250mg/L (NIS, 2007) and 200mg/L (Boyd, 1979). Reduced concentration of Chloride in river could be attributed to the constant flow and supply of freshwater into it by its tributaries and increased level of rainfall (Abowei, *et al*., 2012).

Velocity

The term velocity as it applied to this study connoted the flow rate of Gbalegbe River. Ovie and Ovie (2014) reported that, river flow velocity might be very important determining factor of the composition and diversity of flora and fauna assemblages. It has also been reported that, nutrients concentrations are higher in rivers of low velocity than in rivers of high flow rate (JICA, 2008). The rate of flow of a river is determined by the nature of its sediments and suspended particulate matter present in it. The velocity of a river determines the area of nutrient concentrations within it and the types of aquatic organisms likely to be found. A slow flowing river tends to accumulate organic matter than a fast flowing one.

Transparency

Transparency determines the extent to which light rays can penetrate the water column (Boyd, 1979). Mean values of transparency measured during the study were least during the wet season and highest during the dry season. This may be attributed to the presence of high level of suspended particulate matter. When there are excessive dissolved solids in water, the intensity of penetration of light through the water column is reduced and as such, there may be an increase in water temperature and a decrease in DO level. Transparency values are used in the determination of the photic zone of rivers. An increase in turbidity level may lead to a decrease in the level of Transparency which will in turn reduce the amount of light penetration through the water body and eventually lead to the reduction in primary productivity and dissolved oxygen (Ajuonu *et al.*, 2011).

The higher and lower transparency values recorded at Station1 and during wet season were good indicators of low primary production and poor water quality, respectively leading to an increased sediments load in Gbalegbe River. Woodcock and Huryn, (2007) made similar observation from their study and ascribed low primary production to the presence of high TSS which drastically decreased the amount of light penetration into the photic zone.

Transparency describes how transparent water is, while turbidity defines the cloudy nature of the water system. An increase in Transparency leads to a decrease in turbidity. These two parameters are inversely related. When Transparency is low, turbidity will increase and this may lead to an increase in water temperature because the suspended solids present in water absorb the energy from the sun through the light rays, while crude oil on the water surface prevents atmospheric oxygen from getting in contact with the water. As such, DO levels would begin to decline, leading to an increase in BOD and the rate of primary productivity would also drop which may lead to a decrease in the abundance of zooplankton production.

Sediment macro-invertebrates and fish population may drastically decline if the increase in turbidity and low Transparency continue unabated, a state of hypoxia (DO < 3.0mg/L) could be reached whereby fish will begin to migrate to a safer area while sendentary organisms die off at the state of anoxia (DO < 0.5mg/L) (Babalola and Amosu, 2003).

Ammonium-Nitrogen (NH_4^+ - N)

The mean values of ammonium recorded among stations were less than the recommended values of 1.5mg/L (WHO, 2004) but greater than 0.02mg/L (FEPA, 1991) and 0.01mg/L NIS, (2007). Higher level of NH_4^+ - N recorded can be attributed to the conversion of nitrogen from faecal and other organic matters present in water (Kennedy *et al.,* 2004). The NH_4-N is an essential nutrient needed by aquatic plants for growth, but at very high concentrations, it becomes toxic to aquatic life (Jaji *et al.* 2007). High level of NH_3-N in river could be attributed to the decomposition of organic materials, farming activities and run-off. It has been reported that the sub-lethal effects of ammonia on fish are reduction in growth rate, pathological alterations in liver and kidney (Ewutanure and Olaifa, 2018c).

Nitrate and nitrite

Nitrate is an important nutrient required for primary production. The concentrations of nitrate recorded were within the recommended limit of 0.1 – 3.0 mg/L Boyd (1979), 10mg/L (WHO, 2004), NIS, (2007) and 20mg/L (FEPA, 1991). The rate of nitrate and nitrites build up in an aquatic environment depends on its flow rate. Static water medium tend to accumulate more nitrite and nitrate under experimental condition where feed are applied to fish. Therefore, the low level of nitrate and zero level of nitrite detected could be associated with the constant flow of the river which discouraged the excessive accumulation of organic matter and industrial effluents.

Phosphate-phosphorus and Sulphate

Except at Station 1, mean values of phosphate-phosphorus recorded were higher than the recommended value of 0.12 mg/L (Boyd, 1979), but lower than 5mg/L (NIS, 2007) and FEPA, (1991). Higher values than those obtained in this study were reported by (Ogbuagu, 2013). Low concentration could be due to high phytoplankton density (Taiwo *et al.,* 2012). Generally, the levels of sulphate observed during this study were below the recommended limit of 200 mg/L (NIS, 2007).

Magnesium (Mg) and calcium (Ca) concentrations

Means of Magnesium recorded during this study were higher than those recorded for freshwater, while the concentration of Ca recorded were generally less than the recommended level of 150 mg/L (Boyd, 1979). It has been reported that calcium is an important cation that differentiates between seawater and freshwater (WHO, 2008). Mustapha, (2008) reported that, water hardness is caused by the metallic ions that dissolved in it. In freshwater these are primarily calcium and magnesium. According to USEPA (2003) water hardness can be classified as: 0-75 mg $CaCO_3$/L is soft; 75-150 mg $CaCO_3$/L is moderately hard; 150 – 300 mg $CaCO_3$/L is hard, 300 and up mg $CaCO_3$/L is very hard. Calcium levels recorded were within the acceptable limits for the survival of aquatic organisms.

Gross and net primary production (GPP and NPP)

The higher values obtained at Station 1 might be ascribed to a higher transparency level and reduced turbidity because of fewer anthropogenic activities. This led to the uniform distribution of sunlight throughout the water column. The ranges of primary productivity indices recorded in this study were higher than the range reported in Otamiri River, Nigeria (Ogbuagu, 2013).

It has been reported that the moderately low productivity recorded in this present study could probably be linked to the constant flow of the river and elevated industrial activities. The decreased values of NPP and GPP obtained during the rainy season in this study agreed with the observation of (Balogun and Ajani, 2015) from Badagry Creek, Nigeria. They reported a drop in primary productivity in the wet season and a rise of the same in the dry periods. This might be attributed to high suspended solids during the flood which restricted light penetration into the water column that led to a decrease in photosynthetic activities and productivity (Joseph and Raj, 2011). Davies *et al.,* (2009) reported that, phytoplankton photosynthetic activity is one of the major contributors to the overall productivity of rivers. The distribution of uniform temperature and available nutrients are vital limiting factors for primary production contributing to seasonal variation in an aquatic ecosystem (Wondie *et al.,* 2007).

Clorophyll a (Chll a)

Values of Chll *a* recorded at Station 1 and in the dry season were within the recommended range of >15μg/L (WHO, 2008), while Chlorophyll *a* values greater than 15 μg/L are generally considered to indicate high productivity (Balogun and Ajani, 2015). Decrease in Chll *a* may be due to the presence of higher suspended particulate matter emanating from increased anthropogenic activities. The presence of effluents in the river limited the level of light penetration into the water column.

Gupta (2001) reported that, Chlorophyll *a* is a useful and easy estimator of phytoplankton standing crop. The fluctuation of Chlorophyll *a* during the study period showed obvious sign of seasonal variation (WHO, 2008). This could be due to the fact that, season has a direct link with Chlorophyll *a* production. High Chlorophyll *a* concentration would result in high values of productivity and reflect on high phytoplankton biomass (Balogun and Ajani, 2015).

REFERENCES

Abowei, J.F.N. and Sikoki, F.D. (2005. Impacts of oil spill on the zooplankton distribution of River Nun, Bayelsa State, Nigeria. *Water pollution, management and control* 1-236.

Abowei, J.F.N., E.N. Ezekiel and Hansen, U. 2012: Effects of Water Pollution on Phytoplankton Species Composition in Koluama Area, Niger Delta Area, Nigeria. *International Journal of Fisheries and Aquatic Sciences* 1.2: 134 – 139.

Abowei, J.F.N.,C.C. Tawari, A.I. Hart and Garricks, D. U. 2008. Fin fish species composition, abundance and distribution in the lower sombreiro river, Niger Delta, Nigeria. *International Journal of Tropical Agriculture and Food System* 2.1: 46 – 43.

Abu, G. O. and Egenonu, C. 2008. The current pollution status of the new Calabar River, Niger Delta region, Nigeria: A survey of antibiogram profiles of its bacterial isolates. *African Journal of Environmental Science and Technology* 2.6: 34 – 14.

Adefemi, O. S., Asaolu, S. S. and Olaofe, O. 2007. Assessment of the physico-chemical status of water samples from major dams in Ekiti State, Nigeria. *Pakistan Journal of Nutrition* 6.6: 657 – 659.

Adewara, S. O. and Visser. M. 2011. Use of anthropometric measures to analyze how sources of water and sanitation affect children's health in Nigeria. Environment for Development. *Discussion Paper Series* 1 - 23.

Ajuonu, N., Ukaonu, S.U., Oluwajoba, E. O., Mbawuike, B. E., Williams, A. B., Myade, E. F. 2011. Crude oil pollution in the Bonny Estuary, Nigeria. *Agriculture and Biology Journal of North America* 2.6: 1032 – 1037.

American Public Health Association(APHA). 1998. Standard methods for the examination of water and wastewater. Greenberg, A.E., Clesceri, L.S., Eaton, A.D. Eds. *APHA, WEF and AWWA.* Washington DC, USA. 1 - 1193.

American Society for Testing and Materials (ASTM). 2006. Standard guide for conducting laboratory toxicity tests with freshwater mussels. E2455-06, Philadelphia. *Annual Book of America Society for Testing and Materials Standards* 11.6: 1393–1444.

Ampon, P and Taeng-On, P. 2014. Aquatic insects biodiversity and water quality Parameters of Receiving Water body. *Current World Environment* 9.1: 53 – 58.

Association of Official Analytical Chemists (AOAC), 1990: Methods of experimental analyses. *Journal of Official Method of Analyses* 8.1: 551 – 573.

Aweto, A. 2002. Urhobo Historical Society: Outline Geography of Urhoboland. 1 - 5.

Babalola, O.O and Amosu, A.O. 2003. Assessing the Physical and Chemical Properties of the Aerated Effluent of Agbara Industrial Estate Discharged in Ologe Stream. *NATT Research Series* 7.1: 64 – 70.

Balogun, K. J and Ajani, E.K. 2015. Spatial and temporal variations of phytoplankton pigments, nutrients and primary productivity in water column of Badagry Creek, Nigeria. *American Journal of Research Communication* 3.7: 157 – 172.

Bilotta, G. S and Brazier, R. E., 2008. Review: Understanding the influence of suspended solids on water quality and aquatic biota. *Water Research* 42: 2849 – 2861.

Boyd, C. E. and Craig, S. T., 1992. *Water quality and pond soil analyses for aquaculture*. Alabama Agricultural Experiment Station, Auburn University, Alabama, 36849. 183.

Boyd, C.E. 1979. *Water quality in warm water fish ponds*. 4th ed. Auburn University, Uburn.

Brinkman, S. F. and Johnston,W. D. 2008. Acute toxicity of aqueous copper, cadmium, and zinc to the mayfly Rhithrogena hageni. *Archives of Environmental Contamination and Toxicology* 54: 466–472.

Davies, O.A., J.F.N., Abowei and Tawari, C. C. 2009. Phytoplankton community of Elechi Creek, Niger Delta, Nigeria: A nutrient polluted tropical creek. *AmericanJournal of Applied Science* 6.6: 1143 – 1152.

Ebong, G. A., Ita, B. N., Nyong, A. B. and Benson, N. U. 2006. Seasonal changes in the water quality of Qua Iboe River Estuary and its associated creeks in Ibeno, Nigeria. *Journal of Applied Sciences* 9.2: 6469–6482.

Edet, A. and Worden, R. H. 2009. Monitoring of the physico-chemical parameters of groundwater in Calabar. *Environmental Monitoring and Assessment* 157.4: 243 – 258.

Effiong, M. U. and Akpan, A. W. 2015. Changes in Lipid Profile and Kidney Function of C*larias gariepinus* fed different lipid resources. Nigerian *Journal of Fisheries and Aquaculture* 3.1-2: 62 – 67.

Ekiye, E. and Zejiao, L. 2010. Water quality monitoring in Nigeria; Case Study of Nigeria's industrial cities. *Journal of American Science* 6.4: 22 – 28.

Ewutanure, S.J. and Olaifa, Flora. E. (2018a): Phytoplankton Species Composition, Distribution, Abundance and Diversity in Gbalegbe River, Delta State, Nigeria. *Proceedings of 6th NSCB Biodiversity Conference; Uniuyo, 164 – 170.*

Ewutanure, S. J. and Olaifa, F. E. (2018b): Heavy metal concentrations in water and sediment of Gbalegbe River, Delta State, Nigeria. The 2nd SETAC Central/West Africa Regional Conference, *Environmental sustainability and pollution control through science*. Book of Abstract, 4 Pp.

Ewutanure, S. J. and Olaifa, F. E. (2018c): Biochemical changes in *Clarias gariepinus* juveniles exposed to sublethal concentrations of lead and zinc chloride in water with and without bracken fern (Pteridium aquilinum) *The 2nd SETAC Central/West Africa Regional Conference, Environmental sustainability and pollution control through science*. Book of Abstract, 4 Pp.

Ezemonye, L. I., Ikpesu, T. O. and Tongo, I. (2009): Distribution of endosulfan in water, sediment and fish from Warri River, Niger delta, Nigeria. *African Journal of Ecology* 48.1: 248–254.

Federal Environmental Protection Agency (FEPA), 1991. *Guidelines and Standards for Environmental Pollution Control in Nigeria.* National Environmental Standards-Parts 2 and 3, Government Press, Lagos. 1 – 238.

Galadima, A., Garba, Z. N., Leke, L., Almustapha, M. N. and Adam, I. K. 2011. Domestic water pollution among local communities in Nigeria - causes and consequences. *European Journal of Scientific Research* 52.4: 592 – 603.

Gollenman, H.L., Clymo, B. S. and Ohnstad, M. A. M. 1978. *Methods for physical and chemical analyses of freshwaters*. IBP – Handbook, No. 8. Black well Scientific Publications, Oxford, UK 213.

Gupta, P. K. 2001. *Methods in environmental analysis: Water, Soil and Air*. AGROBIOS (India) Publisher. 1 – 408.

International Standard Organisation (ISO), 2006. Environmental management – life cycle assessment – principle and framework. ISO 14040, second edition. ISO14040:2006(E).

Jaji, M. O., Bamgbose, O., Odukoya, O. O. and Arowolo, T. A. 2007. Water quality assessment of Ogun River, South West Nigeria. *Environmental Monitoring Assessment* 33.1 – 3: 473 – 482.

Japan International Corporation Agency (JICA). 2008. *Comprehensive Management Plan for Muda River Basin*, Final Report. 1 – 34.

Joseph, B. and Raj, S.J. 2011: Effect of curacron toxicity on ALT and AST in the serum of *Cyprinus carpio*. *International Journal of Biology and Chemistry* 5: 207 – 211.

Kaoud, H.A. and El-Dahshan, A.R. 2010. Bioaccumulation and histopathological alterations of the heavy metals in *Oreochromis niloticus* fish. *Nature and Science* 8.4: 147 – 156.

Kennedy, A. J., Cherry, D. S.,and Currie, R. J. 2004. Evaluation of ecologically relevant bioassays for a lotic system impacted by a coal-mine effluent, using Isonychia. *Environmental Monitoring and Assessment* 95: 37–55.

Kottek, A., Atua, W.P. and Philips, T.J. 2006. Methods of analysing primary productivity of fish ponds. *Journal of Agricultural Research* 4.1: 45 – 53.

Mohammed, G., Parinaz, P., Mohammad, Mehdi, A., Mohammad, Z., Hamid, G., Seyyed, A. M., and Amir, H. R., 2008. Environmental impact assessment of the industrial estate development plan with geographical system and matrix methods. *Journal of Environmental and Public Health* 12: 4 – 10.

Montaser, M., M.E. Mahfouz, S.A.M. El-Shazly, G.H. Abdel-Rahman and Bakry, S. 2010. Toxicity of Heavy Metals on Fish at Jeddah Coast KSA: Metallothionein Expression as a Biomarker and Histopathological Study on Liver and Gills. *World Journal of Fish and Marine Sciences* 2.3: 174 – 185.

Mustapha, M. K. 2008. Assessment of the water quality of Oyun Reservoir, Offa, Nigeria, using selected physico-chemical parameters. *Turkish Journal of Fisheries and Aquatic Sciences* 8: 309 – 319.

Nigeria Industrial Standards (NIS). 2007. Nigeria standard for drinking water quality ICS 12.060.20.www.unicef.org/Nigeria/ng_publication_nigeria_standard_for_drinkingwater

Ochuko, A.U., Wi, R. and Akpan, D.G. 2008. Liquid waste management Warri, Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences* 3.1: 132-153.

Ogaga, A.A., Oyelese, O.A. and Ohimain, E.L. 2015. Heavy metal levels in water and sediment of Warri River, Niger Delta, Nigeria. *International Journal of Geology, Agriculture and Environmental Sciences* 3.1: 20- 24

Ogbuagu D. H. 2013. In situ yields in primary productivity of sand mine ponds of the Otamiri River in a southeastern city of Nigeria. *Scientific Journal of Environmental Sciences* 2.4: 84 – 92.

Olaifa, F. E. 2004. Impact of oil spillage on the Fisheries resources of Cross River and Akwa Ibom states, *Nigeria. Journal of Environmental pollution* 4: 23 – 27.

Olatunji, M. K., Kolawole, T. A., Albert, B. O.and Anthony, I. 2011. Assessment of Water Quality, Asa River, Nigeria. *Journal of Fisheries Resources* 4:1 – 12.

Osibanjo, O., Daso, A. P. and Gbadebo, A.M. 2011. The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria. *African Journal of Biotechnology* 10.4: 696 – 702.

Ovie, S.O. and Ovie, S.I. 2014. *Aquaculture in focus.* 2nd ed. ESPATEK Limited. 22 – 31.

Statistical Package for Social Scientis (SPSS). 2015. IBM SPSS software for Windows version 20.0, SPSS Inc., Chicago, IL.

Taiwo, A.M., O.O., Olujimi, O., Bamgbose and T.A., Arowolo, T. A. 2012. Surface Water Quality Monitoring in Nigeria. WWW.water/management/strategy/Nigeria/water.

Town Planning Authority, Ughelli, Delta State, 2014. Metereological data and other related information unit. 45 – 67.

Trivedy, R. and Goel P. 1984. Chemical and biological methods for water pollution studies. Env. Pub. Karad, India. 1 – 104.

Udosen, E. D. and Benson, N. U. 2006. Spatio-temporal distribution of heavy metals sediments and surface water in Stubbs Creek, Nigeria. *Trends in Applied Sciences Research* 1.3: 292–300.

United Nations' Children's Fund (UNICEF). 2008. Handbook on Water Quality. 191.

USEPA (United States Environmental Protection Agency) 2003. What are Suspended and Bedded Sediments (SABS)? SABS. 6 – 12.

USEPA, 1978a: Methods for the chemical analysis of waste water (EPA/600/4-79/020).

USEPA, 1993. Methods for determination of Inorganic substances in environmental Samples. EPA-600/R/93/100 - Draft. Environmental monitoring systems Lab., Cincinnati, Ohio.

Vollenweider, R. A., 1969. A manual on methods for measuring primary production in aquatic environments. IBP HandbookNo. 12. Blackwell Scientific Publication, Oxford, 213.

WHO, 2001. Assessment of aquatic biota of temperate region. *Journal of Environmental Health, Rome* 3: 1238 - 12456

WHO. 2008. Guidelines for drinking water quality,3rd edition, health criteria and supporting information, Geneva. 1 – 10.

Wondie, A., Mengistu, S., Vijverberg, J. and Dejen, E. 2007. Seasonal variation in primary production. *Fisheries Resources* 4: 23 – 54.

Woodcock, T. S. and Huryn, A. 2007. The response of macroinvertebrate production to a pollution gradient in a headwater stream. *Freshwater Biology* 52.1: 77 – 196.

World Health Organization. (WHO), 2004. Communicable Disease Toolkit for Sierra Leone :Communicable Disease Profile WHO/CDS/2004.