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Sediment Characteristics of Gbalegbe River, Delta State, Nigeria

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ABSTRACT

The clarity of a river ecosystem and its ability to support and sustain aquatic life greatly depends on the quality and types of sediment it carries. The variation in the distribution of different categories of sediment could result in the changes in river channel formation and habitat. However, the paucity of information on the sediment quality of Gbalegbe River necessitated the investigation of its sediments characteristics dynamics. Gbalegbe River (12.5 km) was spatially stratified into eight sampling stations (S1, S2, S3, S4, S5, S6, S7, and S8) with reference to key anthropogenic activities. At each station, three sampling points were randomly chosen. Temporal stratification covered wet (March - October) and dry (November - February) seasons. Sediment samples were collected from each station forth - nightly for 24 months following standard methods. Sediment samples were analysed for Clay - %, Clay + Silt (CS - %), Organic Carbon (OC - mg.kg⁻¹), pH, Cation Exchange Capacity (CEC - Cmol⁺.kg⁻¹) and Average Phosphorus (AP - mg.kg⁻¹) following standard procedures. Data were subjected to descriptive statistic and ANOVA at $\alpha_{0.05}$. The highest (45.0) and least (20.3) Clay, CS (66.2, 35.3) were obtained in S2 and S1; OC ranged from 2.20±1.77 to 7.88±1.66 in S3 and S2; pH (4.30±0.93, 6.79±0.61) in S2 and S1; CEC (39.06±7.16, 108.59±34.43) in S1 and S6; AP (11.24±7.41, 41.83±22.78) in S3 and S8, respectively. Seasonally, Highest (45.8) and least (29.3) Clay; CS (75.0, 46.9) occurred in wet and dry seasons, respectively, while OC ranged 2.55±1.29 to 4.51±1.25; pH (5.61±0.89, 6.01±1.65); AP (14.49±1.79, 21.18±8.86) in wet and dry seasons, but highest (96.56±3.79) and least (91.04±3.67) concentrations of CEC were recorded in wet and dry seasons, respectively. The dynamics of sediments characteristics of Gbalegbe River are relatively unstable with Clay, CS, OC and pH. Therefore, its rich fisheries resources could be threatened.

Keywords: Gbalegbe River, Silt, Clay, Sediment Compositions and Colloid.

1. INTRODUCTION

Sediments are broken down materials naturally formed by the processes of weathering that are found at the bottom of aquatic environments (Baran and Guerin, 2012). They are made up of particulate matter of different sizes, forms and mineral constituents (Department of Irrigation and Drainage, DID, 2009). According to Olowu et al., (2012), sediments can also be classified into three categories, namely: Lithogenic sediment (obtained from disintegration of rocks); Biogenic sediment (originating from plant and animal sources) and Hydrogenic sediment (obtained from precipitation in river, sea and interstitial water).

Sediment Pollution and Sources

Sediments act as a reservoir for pollutants (Ewutanure and Olaifa, 2018a), because, anthropogenic effluents are constantly being discharged into water bodies (Japan International Corporation Agency, JICA, 2008). Total petroleum hydrocarbon, heavy metals and pesticides are potential threat to sediment and surface water (Ewutanure and Olaifa, 2018c). The Department of Irrigation and Drainage (DID, 2009) identified three major sediment supply which include: (i)

Erosion of upland and areas used for farming; (ii) Collapse of river banks and dam systems and (iii) Natural siltation and sediment storage along flood plains, channel migration, bank widening and avulsion.

Sediment transport

Sediment transport describes the mechanisms of river system, checkmates its flow rate and the channel boundary (Sarkula et al., 2010). While erosion explains the removal and transportation of sediment mainly from the boundary, deposition is concerned with the transportation and placement of sediment on the boundary (JICA, 2008). Erosion and deposition form the channel of any alluvial river as well as the floodplain through which it flows.

As observed by JICA, (2009) and DID, (2009), the volume and size of sediment moving through a river channel are controlled by three major factors which include: Competence; Capacity and Sediment supply. Competence is concerned with the largest size with respect to the sediment particle size which the flowing current can cause to migrate along the river bed. A river may not be able to mobilize and transport sediment of certain sizes even when such sediments are available for transportation if the current of such river is very slow (Oluwo et al., 2012). Therefore, a river can be termed competent or incompetent with respect to a given grain size.

An incompetent river will not transport sediment of a given size, while a competent river will move sediment of that size if available (FCDMC, 2004). Sediment capacity explains the highest quantity of sediment of a given size that a river can transport along its bed (Ogaga et al., 2015), 2008). The supply of sediments depends on the capacity of the channel gradient, discharge and the weight of the load because the presence of fines grains may increase fluid density and increase capacity, while the presence of large particles can obstruct the flow and reduce its capacity. Capacity transport occurs when sediment supply is in abundant and not limiting (Arimoro et al., 2007a).

Sediment supply refers to the quantity and size of sediment available for sediment transport (Gollenman 1978). Due to potential constraints of hydraulics and sediment supply, distinction is made between supply – limited and capacity – limited transport. Major rivers operate as sediment – supply limited system. The WHO, (2008) reported that, most of the materials supplied to a river are silt and clay which are carried in suspension. For the capacity of the river to transport silt and clay, the upper limit must be achieved. This is seldom achieved because natural channels and the quantity of silt and clay conveyed are limited in supply (WHO, 2006).

Sediment deposition

The compositions of the sediment at its point of deposition can be determined by the original constituents of its source, size of the source material, sorting in the process of migration and the physical characteristics at the location of disposal (Arimoro et al., 2007b). The patterns of sediment transport in rivers are relatively similar in relation to water velocity.

Particle size fractions of sediments

The size differences among sand, silt and clay are essential in the establishment of the infilling of a river and in sediment quality determination. Sand settles at the bottom immediately sediment migrates into rivers and the velocity increased, but silt and clay stay in suspension for a longer period and migrates more within the river (Ziv et al., 2012). The particle size of $\leq 62 \mu\text{m}$ of suspended sediment is responsible for the transportation of adsorbed particles.

The size of transported sediment particles ranged from clay – sized material notationally defined as (<0.004 mm). This fraction consists mostly of clay minerals such as, montmorillonite and kaolinite but may also include some other fine minerals and organic debris. The silt size range from 0.004 – 0.062, sand (0.062 – 2mm) while gravel is >2 mm.

Grain-size influence

The adsorptive ability of sediment is determined by the surface area. Therefore, the finest particles sizes are majorly the richest in heavy metals. This is essentially visible when separate chemical analyses are made on different size fractions.

Sediment quality

Increased migration of fine sediment grains of silt and clay are the major yearly carrier of heavy metals, nutrients and other related aquatic pollutants (Ewutanure and Olaifa, 2018). Among the 128 major pollutants enumerated by the USEPA, 65% of them are mainly found in sediment. The yearly 95% of phosphorus load in surface water migrates in – conjunction with sediment in suspension. JICA, (2009), reported that, nutrient enrichment in the aquatic environment are increasingly becoming more useful as a result of sediment quality determination.

Unfortunately, institutions vested with the responsibility of ensuring the that water quality criteria are strictly followed are failing in discharging their responsibilities in the study of suspended sediment because of: Paucity of information on current analytical procedures in sediment study; Inconsistent objectives applied in the monitoring of sediment research programmes; Undue attention on already established fact such as, faecal contamination and final and Inadequate finance, expertise and equipment.

Exchangeable cations and cation exchange capacity

Sediment possess electrostatic charges because of atomic replacement in the lattices of sediment minerals (Baran and Guerin, 2012). Ibeto and Okoye, 2010) reported that these charges attract ions and form exchange complex. Cations held by sediments can be replaced by exchangeable cations (Ca⁺⁺ can be exchanged for H⁺ or K⁺ and vice versa).

Cation exchange capacity (CEC)

The Department of Irrigation and Drainage, (2009) reported that the total number of exchangeable cations a sediment can hold is called its cation exchange capacity. Higher sediment CEC attracts and retains more cations. The CEC of sediment depends on the quantity, clay type and the levels of the organic matter within the aquatic ecosystem. High concentration of clay particles results in higher exchangeable cations present in it. The CEC contents of sediment increases as its organic matter increases (CCME, 2008).

The CEC of sediment is expressed in terms milliequivalents per 100 gram of sediment (me/100g) or in centimoles of positive charge per kilogram of sediment (C mol⁺/kg) which numerically translates to me/100g. While the CEC values of clay minerals are in the ranges of 10 to 150 C mol⁺/kg, the CEC of organic material ranges from 199.99 to 400.01 C mol⁺/kg (JICA, 2009).

Cation exchange

As reported by Baran and Guerin, (2012), cations are the positively charged nutrient ions and molecules. The dominant residual charge on most sediment colloids is negative. These negatively charged sites attract positively charged ions in the sediment water (Yi et al., 2008). Sediment acts as cations exchanger. Negatively charged colloids, attract cations and hold them tight. This characteristic explains why nitrate – nitrogen is more easily leached from the sediment than ammonium – nitrogen. Nitrate possess' a negative charge and as such, it is not held but remains as a free ion in sediment. The amount of cations in the sediment solution are closely related to the exchangeable ions, while any change in the concentration of a cation in the solution forces a change in the magnitude of all exchangeable ions.

Importance of cation exchange

Gupta, (2001) reported that, cation exchange is an essential feature in sediment nutrient enrichment and plays significant roles such as: it causes and corrects sediment acidity and basicity; it alters sediment physico-chemical properties; acts as a purifier of percolating water; it supplies calcium, magnesium and potassium to aquatic macrophytes from exchangeable forms; Cation exchange locations keep the ions of Ca, Mg, K, Na and NH₄ so as to avoid being leached away; Cation exchange sites adsorb metals such as Cd, Zn, Ni and Pb that are present in wastewaters and the cations exchange locations immobilized cations, but keep the exchangeable thereby making them available to the roots of aquatic macrophytes.

2. MATERIALS AND METHODS

Description of the study area

According to Ewutanure and Olaifa, (2021) Gbalegbe River traverse up to 12.5 km and it is situated on 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 1). It has its source from Asaba - Ase River, Delta State. Its highest and mean depths were 10.45m and 4.31m respectively, (Ewutanure and Olaifa, 2018).

Climate and vegetation of the study area

In the study area, wet season occurs from March to October with a shorter dry season occurring from November to February. The climate is regulated by South – West monsoon wind from the Atlantic Ocean (wind causes wet season) and the North – East trade wind from the Sahara Desert (causes dry season) (Aweto, 2002). The study area has mean yearly rainfall of 2700mm. Rainfall peaks in June/July and September, with a short break period in August, while the mean annual temperature was 27 °C (Ewutanure and Olaifa, 2021). The study area has rain forest vegetation with adjoining low-lying land that are seasonally or permanently waterlogged (Ogaga et al., 2015).

Experimental procedure

With respect to closeness to predominant anthropogenic activities (ISO, 2006; Mohammed et al., 2008), Gbalegbe River was spatially stratified into eight stations (S1, S2, S3, S4, S5, S6, S7 and S8). At each station, three sub – sampling points were randomly selected. According to Ewutanure and Olaifa, (2021), temporal stratification ranged from wet (March – October) and dry (November – February) seasons. The study was carried out for 24 months.

The percentage particle sizes were calculated by using the formula stated below:

$$\% \text{ Particle size} = \frac{\text{weight of sediment retained in sieve}}{\text{Total weight of sediment filtered}} \times 100 \quad (1)$$

APHA, (1998)

Determination of organic carbon, total nitrogen, phosphorus and cation exchange capacity in sediment of Gbalegbe River, Delta State

Determination of organic carbon in sediment of Gbalegbe River

The organic carbon content in the sediment of Gbalegbe River was determined using Walkley and Black rapid titration method (Gupta, 2001). About 1g of the sediment sample was introduced into a dry 500 mL conical flask and 10 mL of 1N K₂Cr₂O₇ was pipetted into it and the mixture was properly swirled for 1 minute. Thereafter, 20 mL of H₂SO₄ (containing AgSO₄) was added and swirled again for 2 minutes. The flask was then allowed to stand for 30 minutes before 200 mL of distilled water was added followed by the addition of 10 mL of phosphoric acid and 1 mL of diphenylamine as indicator. The content was then titrated with 0.5N ferrous ammonium sulphate solution until the colour changed from blue – violet to green. The experiment was repeated using a blank. The organic carbon content in the sediment sample was then calculated using:

$$\% \text{ Organic carbon in sediment} = N \frac{B-C}{\text{Weight of sediment sample (g)}} \times 0.003 \times 100 \quad (2)$$

AOAC, (1990)

Where: N = normality of ferrous ammonium sulphate, B (mL) = volume of 0.5N ferrous ammonium sulphate required to neutralized 10 mL of 1N K₂Cr₂O₇, C = volume of 0.5N ferrous ammonium sulphate needed for titration of soil sample.

Determination of sediment available nitrogen

The available nitrogen in the sediment of Gbalegbe River was determined using the Alkaline permanganate method described by Subbiah and Asija, (1956). About 20g of sediment samples were introduced into 800 mL dry Kjeldahl flask, 20 mL of distilled water was added and then swirled. About 1 mL of liquid paraffin and 5 glass beads were added to prevent frothing and bumping, respectively during distillation. Thereafter, 100 mL of 0.32% KMnO₄ solution was added followed by the addition of 20 mL of boric acid and mixed indicator solution in a conical flask with the end of the delivery tube dipped into it. About 100 mL of 2.5% NaOH solution was added into the Kjeldahl flask which was immediately fitted up in the distillation apparatus. The mixture was distilled steadily, while released ammonia was collected in a conical flask containing boric acid solution with mixed indicator. It was observed that, due to the absorption of ammonia, the original pink colour of the solution turned to green. The 100 mL of the distillate was collected in 30 minutes. The collected distillate was then titrated with 0.02N H₂O₄ to the original pink colour previously observed. A blank titration without sediment sample was also done for the final calculation.

$$\% \text{ Nitrogen in sediment} = N \frac{R-b}{\text{Weight of sediment sample (g)}} \times 0.02 \quad (3)$$

AOAC, (1990).

Where N = atomic weight of nitrogen, R = volume of 0.02N of H₂O₄ used for sediment titration and b = volume of 0.02N of H₂O₄ required for blank titration (without sediment sample).

Determination of sediment available phosphorus in sediment of Gbalegbe River

Available phosphorus in the sediment of Gbalegbe River was determined using the Bray's method as described by Gupta, (2001). About 5g of sediment was introduced into a 150 mL Erlenmeyer flask and 50 mL of Bray extraction solution (1:1 sediment to solution ratio), stoppered and shaken for 5 minutes on a mechanical shaker. Thereafter, the mixture was filtered through a Whatmann No 42 filter paper. About 5 mL of the aliquot of the extract was introduced into a volumetric flask and 7.5 mL of boric acid (50g of H₃BO₃ in 1 Litre of distilled water) was added to the aliquot to avoid interference of fluoride. Later, 20 mL distilled water and 4 mL of Murphy Riley solution was added. After 15 minutes, the intensity of a blue colour was measured using a Spectrophotometer at a wave length of 730 nm. The experiment was repeated using a blank (without sediment sample). Calculation:

$$\text{Bray's Phosphorus in sediment} = c \times \frac{v}{V \times \text{Weight of sample (g)}} \times 2.24 \quad (4)$$

APHA, (1998).

Where v = volume of the extractant, V = volume of aliquot, mg of phosphorus in the aliquot obtained from standard curve.

Determination of cation exchange capacity (CEC) in sediment of Gbalegbe River

The cation exchange capacity of the Gbalegbe River sediment was determined using 1N Ammonium acetate method (APHA, 1998). In a centrifuge tube, 5g of the sediment sample was placed, while 25 mL of 1.0N of sodium acetate was added, stoppered and vigorously shaken for 5 minutes. Thereafter, the tube was unstoppered and centrifuged at a speed of 2000 rpm for 10 minutes. The supernatant liquid was then decanted. This procedure was repeated four times. Later, 25 mL of 95% ethanol was added to the tube, stoppered, shaken for 5 minutes, unstoppered and centrifuged for 5 minutes. The supernatant liquid was decanted and discarded. The sample was then washed with 25 mL of ethanol three times.

25 mL of 1.0N ammonium acetate was then added into the tube, stoppered and shaken for 5 minutes, unstoppered and centrifuged at 2000 rpm until the supernatant liquid is clear. The supernatant liquid was then decanted into a 100 mL volumetric flask. This extraction was repeated three times to ensure that ammonium ions are replaced by sodium ions which were contained in the supernatant liquid. The content of the volumetric flask was then diluted and made to make. Sodium concentration was then determined using flame photometer, while CEC was calculated using:

$$\text{CEC} = \frac{\text{Na Conc.of extract (meq per Litre)} \times 100 \times \text{volume of extract (mL)}}{\text{Weight of sediment sample (g)} \times 1000} \times 0.02 \quad (5)$$

APHA, (1998).

Statistical analyses

Data from this study were subjected to descriptive and inferential statistics analysis using SPSS (version, 20). Data were pooled and presented as spatial and temporal mean variances and compared by means of one – way ANOVA in order to evaluate if their differences were significant at $p < 0.05$.

4. RESULTS

Sediment compositions of Gbalegbe River

Sediment particle sizes among stations and between seasons

The percentage (%) mean particle sizes of sediment among stations and between seasons are presented in Tables 1 and 2. Spatially, the highest and least clay particle size of sediment in Gbalegbe River were 45.0% and 20.3%, Silt (21.2%, 15.0%), Clay + Silt (Colloid) (66.2%, 35.3%) in Stations 2 and 1, but Fine Sand (39.4%, 17.7%) occurred in Stations 8 and 2, while Coarse Sand (45.9%, 15.81%) were recorded in Stations 1 and 2, respectively.

Seasonally, Clay particle size of sediment ranged from 29.3% to 45.8%, Silt (17.6%, 29.2%) and Silt + Clay (46.9%, 75.0%) during the dry and wet seasons, while highest and least Fine Sand were 15.4% and 28.3%, Coarse Sand (9.7%, 24.9%) occurred during the wet and dry seasons, respectively.

Table 1. Percentage (%) sediment particle sizes among stations

Sediment particle size	S1	S2	S3	S4	S5	S6	S7	S8
Clay	20.3	45.0	33.8	24.2	22.5	31.0	23.6	23.0
Silt	15.0	21.2	17.9	21.2	16.8	14.1	19.1	17.0
Clay + Silt	35.3	66.2	51.7	45.5	39.2	45.1	42.7	40.1
Fine Sand	19.1	17.7	20.4	20.3	22.1	30.5	35.3	39.4
Coarse Sand	45.9	15.8	28.0	34.0	38.9	24.7	22.9	20.9

Note: S1 to S8 = stations 1 to 8.

Table 2. Seasonal mean variation of sediment particle sizes (%)

Sediment particle sizes	Wet season	Dry season
Clay	45.8	29.3
Silt	29.2	17.6
Clay+Silt	75.0	46.9
Fine Sand	15.4	28.3
Coarse Sand	9.7	24.9

The mean of sediment compositions among stations and between seasons are presented in Tables 3 and 4. Least (18.43±10.49) and highest (53.79±10.06) mean of exchangeable cation were recorded in Stations 1 and 2, it ranged from 5.06±4.67 to 41.93±9.01 in wet and dry seasons.

The least and highest mean values of organic carbon recorded were $2.33 \pm 1.97 \text{ mg.kg}^{-1}$ and $7.88 \pm 1.66 \text{ mg.kg}^{-1}$ in Stations 1 and 2, respectively. Seasonally means of organic carbon ranged from $2.55 \pm 1.29 \text{ mg.kg}^{-1}$ to $4.51 \pm 1.25 \text{ mg.kg}^{-1}$ in wet and dry seasons.

The means Total Nitrogen ranged from $43.25 \pm 37.01 \text{ mg.kg}^{-1}$ to $51.06 \pm 4.41 \text{ mg.kg}^{-1}$ in Stations 2 and 4, but varied from $46.25 \pm 3.47 \text{ mg.kg}^{-1}$ to $51.13 \pm 3.45 \text{ mg.kg}^{-1}$ in wet and dry seasons. Highest ($41.83 \pm 22.78 \text{ mg.kg}^{-1}$) and least ($10.67 \pm 7.93 \text{ mg.kg}^{-1}$) mean phosphorus in sediment occurred in Stations 8 and 1, respectively. The seasonal mean values varied from $14.49 \pm 1.78 \text{ mg.kg}^{-1}$ to $21.18 \pm 8.86 \text{ mg.kg}^{-1}$ during wet and dry seasons, respectively.

The Mean magnesium ranged $10.34 \pm 5.95 \text{ mg.kg}^{-1}$ to $23.08 \pm 4.21 \text{ mg.kg}^{-1}$ in Stations 1 and 2. The least ($12.58 \pm 6.50 \text{ mg.kg}^{-1}$) and highest ($13.12 \pm 6.50 \text{ mg.kg}^{-1}$) seasonal means occurred in dry and wet seasons. The least and highest sodium concentrations were $11.94 \pm 4.95 \text{ mg.kg}^{-1}$ and $21.97 \pm 5.76 \text{ mg.kg}^{-1}$ in Stations 2 and 6, respectively.

Seasonally, it ranged from $16.58 \pm 7.12 \text{ mg.kg}^{-1}$ to $18.44 \pm 3.50 \text{ mg.kg}^{-1}$ in dry and wet season respectively. Least and highest mean values of calcium in sediment were $14.18 \pm 7.44 \text{ mg.kg}^{-1}$ and $40.83 \pm 6.37 \text{ mg.kg}^{-1}$ in Stations 2 and 8, while the values ranged from $30.25 \pm 13.56 \text{ mg.kg}^{-1}$ to $35.51 \pm 3.73 \text{ mg.kg}^{-1}$ in dry and wet seasons, respectively. There were significant differences ($P < 0.05$) in the means of Ca among stations and between seasons.

The least mean concentration of potassium ions was $14.92 \pm 1.63 \text{ mg.kg}^{-1}$ in Station 7, while the highest was $26.49 \pm 13.72 \text{ mg.kg}^{-1}$ in Station 2. The highest seasonal mean value of K^+ recorded was $22.71 \pm 1.52 \text{ mg.kg}^{-1}$ during the dry season, while the least was $21.56 \pm 0.51 \text{ mg.kg}^{-1}$ in wet season. There were significant differences ($P < 0.05$) in the means of K^+ among stations. Spatially, the highest and least mean values of pH in sediment were 6.79 ± 0.61 and 4.30 ± 0.93 in Stations 1 and 2, respectively. The highest (6.01 ± 1.65) and least (5.61 ± 0.89) seasonal mean value of pH in sediment occurred in dry and wet seasons.

The least (0.86 ± 0.50) and highest (3.48 ± 1.59) mean exchangeable acidity recorded in sediment occurred in Station 2 and 8, while seasonal variation ranged from 2.31 ± 1.55 to 2.58 ± 0.34 in wet and dry seasons. Significant differences ($P < 0.05$) existed in the means of exchangeable acidity among stations. The highest and least mean values of cation exchange capacity in sediment were $39.06 \pm 7.16 \text{ Cmol}^+/\text{Kg}$ and $108.59 \pm 34.43 \text{ Cmol}^+/\text{Kg}$ in Stations 1 and 6, while $91.04 \pm 3.67 \text{ Cmol}^+/\text{Kg}$ and $96.56 \pm 3.79 \text{ Cmol}^+/\text{Kg}$ were recorded in dry and wet seasons, respectively.

Table 3: Mean sediment compositions among stations

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
EC	18.43±10.49 ^d (6.32-20.54)	53.79±10.06 ^c (10.90-65.67)	33.32±10.55 ^b (11.17-55.46)	36.12±11.33 ^{ab} (13.03-59.21)	36.53±11.51 ^{ab} (14.41-58.65)	41.63±5.14 ^{ab} (17.58-65.69)	41.12±10.28 ^{ab} (19.13-63.12)	46.78±12.15 ^a (31.12-62.43)
OC (mg.kg ⁻¹)	2.33±1.97 ^c (1.27-3.37)	7.88±1.66 ^c (0.99-8.77)	2.20±1.77 ^c (1.26-3.14)	4.01±3.03 ^b (2.39-5.62)	2.72±2.00 ^{bc} (1.66-3.79)	2.83±2.00 ^{bc} (1.76-3.89)	3.09±2.26 ^{bc} (1.89-4.30)	6.15±2.02 ^a (5.07-7.22)
TN (mg.kg ⁻¹)	47.54±39.32 ^a (26.59-68.49)	43.25±37.01 ^a (23.52-62.97)	45.49±3.98 ^a (25.25-65.73)	51.06±4.41 ^a (28.99-73.12)	43.52±3.53 ^a (24.59-62.45)	44.25±3.30 ^a (25.44-63.06)	48.70±3.76 ^a (30.17-67.22)	44.15±25.36 ^a (30.64-57.67)
AP (mg.kg ⁻¹)	12.67±7.93 ^b (8.44-16.90)	11.40±7.69 ^b (7.31-15.50)	11.24±7.41 ^b (7.30-15.19)	15.75±8.34 ^b (11.31-20.20)	13.11±8.24 ^b (8.72-17.50)	14.06±8.13 ^b (9.73-18.40)	17.19±12.05 ^b (10.77-23.62)	41.83±22.78 ^a (29.69-53.97)
Mg (mg.kg ⁻¹)	3.78±0.63 ^a (2.25-17.31)	7.65±6.31 ^b (4.29-11.02)	11.46±6.53 ^{ab} (7.99-14.94)	13.37±7.37 ^a (9.44-17.30)	13.29±5.25 ^a (10.49-16.08)	16.33±5.21 ^a (13.55-19.11)	15.60±6.57 ^a (12.10-19.10)	14.24±7.38 ^a (10.32-18.18)
Na (mg.kg ⁻¹)	18.27±4.40 ^{ab} (15.93-20.62)	11.94±4.95 ^{ab} (9.30-14.57)	15.86±4.37 ^b (13.53-18.19)	17.01±4.53 ^b (14.59-19.42)	18.15±5.00 ^{ab} (15.49-20.82)	21.97±5.76 ^a (18.90-25.04)	21.55±5.81 ^a (18.45-24.65)	17.86±6.93 ^{ab} (14.17-21.56)
Ca (mg.kg ⁻¹)	34.37±8.125 ^c (30.05-38.70)	14.18±7.44 ^d (10.21-18.14)	31.37±8.70 ^c (26.73-36.00)	32.58±8.93 ^{bc} (27.83-37.34)	34.52±9.01 ^{bc} (29.72-39.32)	35.64±8.10 ^{ab} ^c (31.33-39.96)	38.60±7.38 ^{ab} (34.66-42.53)	40.83±6.37 ^a (37.44-44.22)
K (mg.kg ⁻¹)	24.58±2.37 ^a (12.12-37.03)	17.2±18.42 ^a (7.43-27.06)	22.97±2.94 ^a (11.28-34.66)	23.86±2.10 ^a (2.08-35.64)	25.54±2.33 ^a (13.11-37.98)	26.49±23.72 ^a (13.86-39.13)	14.92±1.63 ^b (9.26-20.58)	18.20±6.63 ^a (14.66-21.73)
pH	6.79±0.61 ^a (4.96-5.61)	4.30±0.93 ^{bc} (2.81-7.80)	6.18±0.56 ^b (5.89-6.48)	6.52±0.44 ^a (6.28-6.75)	5.57±0.77 ^{bc} (5.16-5.98)	5.57±0.77 ^{bc} (5.16-5.98)	5.86±0.71 ^{bc} (5.48-6.24)	6.66±1.00 ^a (6.13-7.19)
EA	2.78±2.12 ^a (1.65-3.90)	0.86±0.50 ^a (0.59-1.12)	2.45±2.04 ^a (1.36-3.54)	2.55±2.04 ^a (1.46-3.64)	2.15±2.07 ^a (1.04-3.25)	2.59±2.15 ^a (1.44-3.73)	2.44±1.47 ^a (1.66-3.22)	3.48±1.59 ^a (2.63-4.32)
CEC (Cmol+.kg ⁻¹)	39.06±7.16 ^c (29.26-58.86)	55.16±27.49 ^b (40.52-69.81)	90.29±35.46 ^a (71.40-109.19)	95.87±36.33 ^a (76.51-115.22)	99.22±37.20 ^a (79.40-119.04)	108.59±34.4 ^{3a} (90.25-126.94)	98.58±23.83 ^a (85.88-111.28)	105.15±26.17 ^a (91.20-119.10)

Means with the same superscripts along column were not significantly different at p>0.05.

Note: exchangeable cation, OC=organic carbon, TN=total nitrogen, AP=average phosphorus, Mg=magnesium, Na=sodium, Ca=calcium, K=potassium, EA=exchangeable acidity and CEC=cation exchange capacity.

Table 4: Mean sediment compositions between seasons

	Range	Wet season	Range	Dry season	P - value
EC	21.51-40.11	35.06±4.67	30.35-51.73	41.93±9.01	0.80**
OC (mg.kg ⁻¹)	0.51-3.00	2.55±1.29	2.89-6.93	4.51±1.25	0.20*
TN (mg.kg ⁻¹)	35.22-50.12	36.25±3.47	45.14-61.23	51.13±3.45	0.04*
AP (mg.kg ⁻¹)	10.81-23.52	14.49±1.78	14.61-30.37	21.18±8.86	0.04*
Mg (mg.kg ⁻¹)	9.86-15.44	13.12±6.50	9.55-15.99	12.58±6.58	0.07**
Na (mg.kg ⁻¹)	10.58-22.19	18.44±3.50	11.12-20.82	16.58±7.12	0.08**
Ca (mg.kg ⁻¹)	23.79-40.91	35.51±3.73	22.51-32.98	30.25±13.56	0.65**
K (mg.kg ⁻¹)	15.32-25.33	21.56±0.51	15.20-30.00	22.71±1.52	0.43**
pH	3.55-7.16	5.61±0.89	3.74-10.71	6.01±1.65	0.12**
EA	0.91-3.27	2.58±0.34	1.09-3.58	2.31±1.55	0.09**
CEC(Cmol+.kg ⁻¹)	63.88-105.11	96.56±3.79	59.48-120.18	91.04±3.67	0.23**

Note: * = There were significant differences at p<0.05

** There were no significant differences at p>0.05

Cu=copper, Pb= lead, Ni=nickel, Cd=cadmium, Fe=iron, Zn=zinc, Mn=manganese and Cr=chromium.

5. DISCUSSION

Sediment particle sizes of Gbalegbe River, Delta State

While a number of hydrological parameters of Gbalegbe River show wide variation, Ewutanure and Olaifa, (2021) reported that water quality is affected by sediment and the nature of the rocks of the area. The data reveal a considerable degree of erosion of the river banks. River bank erosion is mainly responsible for the increase of the concentration of suspended solids to a level as high as 328 mg/L (DID, 2009). Generally, Stations 1 and 8 recorded the lowest and highest particle sizes, respectively.

The low amount of particle size recorded at station 1 might be attributed to the low level of industrial and anthropogenic activities coupled with relative undisturbed nature of the water bed. The highest quantity of sediment particles sizes for all the particles at Station 8 could be attributed to the movement of these particles downstream during sand mining process and the industrial effluents discharged from the various industries located along Gbalegbe River.

Percentage clay and silt particle sizes were highest during the wet season. The reason being that, during the wet season, large quantities of suspended solids and organic materials were transported into Gbalegbe River due to increased rainfall, thereby giving room to high clay and silt content (Hynes, 2006). These particles were easily picked up by the water current and deposited downstream which act as threat to the entire aquatic organisms (Salman et al. 2011). The percentage coarse sand was highest during the dry and lowest during the wet seasons. This could be due to reduced inflow of water into Gbalegbe River as a result of lower amount of rainfall.

Persistent and uncontrolled sand mining, rubber and petroleum industrial activities are gradually could threatened the health status aquatic life of Gbalegbe River. The process of sand mining activity could cause great distortion to the natural build – up of sediment by making the water heavily turbid and reduction in primary production. This could reduce the amount of dissolved oxygen, increased water temperature, destruction of natural spawning ground for fish which will eventually result into the states of hypoxia and anoxic condition on fish, zooplankton and benthic invertebrates (Ewutanure and Olaifa, 2017).

Sediment nutrient composition of Gbalegbe River, Delta State

Gupta, (2001) reported that, cation exchange is an essential feature in sediment nutrient enrichment and plays the roles such as: causes, correction of sediment acidity and basicity; it alters sediment physico-chemical qualities; acts as a purifier of percolating water; supply of calcium, magnesium and potassium to aquatic macrophytes from exchangeable forms; cation exchange binds the ions of Ca, Mg, K, Na and NH_4 to avoid being leached away; cation exchange sites adsorb metals such as Cd, Zn, Ni and Pb that are present in wastewaters.

Cation exchange capacity (CEC) was lowest at Station 1 and highest at Station 6. Ogamba et al., (2015b) reported that grain size is an important factor in determining CEC, the smaller the sediment particle size, the higher the CEC it can carry. This was further buttressed by Olowu et al., (2010) that CEC is a function of grain size, amount of organic matter, coating on the grains and mineral contents of the sorbing material and that the higher the clay contents of sediment, the higher the CEC.

Majolagbe et al., (2011) reported that sediment with low CEC has little ability to store nutrients, unaffected by pH and the solubility of the mineral nutrients available to the aquatic plants. Adsorption removes ions from the percolating water, thereby cleaning the water that drains into the surface waters. Cations are tightly held together on adsorption sites to reduce their losses through leaching (Ogamba et al., 2015b).

Cations can migrate from site on colloids into the sediment water solution where they become available to phytoplankton and other aquatic macrophytes uptake (Doisy and Rabeni, 2001). The cations exchange locations immobilized cations but keep the exchangeable thereby making them available to the roots of aquatic macrophytes. Nutrient enrichment in aquatic environments are rapidly on the rise and becoming very useful in sediment quality determination (Wondie et al., 2007).

The pH concentration of the sediment determines its degree of acidity and alkalinity levels (Ewutanure and Olaifa, 2018b). The lowest mean value was during the wet season which might be due to dilution effects, while the highest was dry season which might be attributed to higher rate of evaporation. It had been reported that the level of sediment pH determines the types of organism found within a water body (Adewuyi et al., 2012).

Fine sediment grains (silt and clay) are the major carrier of nutrients, heavy metals and other related aquatic pollutants (Baran and Guerin, 2012). Among the 128 major pollutants enumerated by the USEPA, 65% of them are mainly found in sediment. About 95% of phosphorus annual load in surface water migrates in-conjunction with sediment in suspension.

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