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The Sediment Physical and Chemical Characteristics in Sombreiro River, Niger Delta, Nigeria

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Abstract: The sediment characteristics in Sombreiro River of the Niger Delta region of Nigeria was studied for a period of two years (January, 2007 - December, 2009) using an Eckman grab of 10 cm diameter and 12 cm long. The sand contents of the sediment were high across the stations. The percentage sand content ranged from 81.96 to 94.52%. Station 4 (Odiemudie) had the highest value (94.52%) while station 1 (Degema) had the lowest value (81.96%). The percentage silt content ranged from 1.53 to 7.72%. The highest percentage silt content was recorded from station 1 (Degema) while the lowest value (1.53%) was obtained in station 4 (Odiemudie). The percentage clay content ranged from 3.95 to 10.32%. Clay content was highest in station 1 (Degema) (10.32%), while the lowest value (3.95%) was obtained in station 4 (Odiemudie). The result of the sediment analysis showed that sand was dominant across the stations, except station 1 (Degema) which revealed loam sand textual class. The pH values of the sediments were acidic across the stations. Station 2 (Ogbele) (5.06) was the most acidic while station 1 (Degema)(5.85) was the least. Conductivity of the sediments values ranged from 40 to 1,940 μS/cm. Station 1 (Degema) had the highest value (1,940 μS/cm) while the lowest value (40 μS/cm) was obtained from station 2 (Ogbele). The great difference arose from the fact that station 1 (Degema) is brackish sediment while station 2-4 are fresh sediments. The organic carbon percentage ranged from 2.020 to 4.134%. Station 1 (Degema) had the highest value of 4.134% while station 4 (Odiemudie) had the lowest value of (2.020%). The nitrate content of the sediments values ranged from 2.6 to 4.1 mg/kg. Station 3 (Ihuaba) had the highest value (4.1 mg/kg); while the lowest value (2.6 mg/kg) was obtained from station 2 (Ogbele). The phosphate content of the sediments ranged from 8.90 and 15.7 mg/kg with a mean value of 13.43 mg/kg. The highest value of 15.7 mg/kg was obtained from station 3 (Ihuaba) while the lowest value (8.90 mg/kg) was obtained from station 2 (Ogbele). The sulphate content of the sediments ranged from 21.0 to 30.0 mg/kg. Station 1 (Degema) had the highest value (30.0 mg/kg) while the lowest value (21.0 mg/kg) was obtained from station 2 (Ogbele). Total Hydrocarbon Content (THC) of the sediments ranged from 21.6 and 52.7 mg/kg. Station 3 (Ihuaba) had the highest value (52.7 mg/kg) while the lowest value (21.6 mg/kg) was obtained from station 1 (Degema).

Key words: Niger Delta, Nigeria, physical and chemical characteristics, Sediment, Sombreiro River

INTRODUCTION

Sediment is the loose sand, silt and other soil particles that settle at the bottom of a body of water (USEPA, 2002). It can come from soil erosion or from the decomposition of plants and animals. Wind, water and ice help to carry these particles to rivers, lakes and streams. Sediment strata serve as an important habitat for the benthic macro invertebrates whose metabolic activities contribute to aquatic productivity (Abowei and Sikoki, 2005). Sediment is also the major site for organic matter decomposition which is largely carried out by bacteria. Important macro-nutrients such as nitrogen and phosphorous are continuously being interchanged between sediment and overlying water (Abowei and Sikoki, 2005).

The type and intensity of agricultural land use determine sediment load which play a role in determining the insects which survive in a stream (Dance and Hynes, 1980). Intensive agricultural land use produces modifications which reduce the variety of macro-invertebrate taxa. Agricultural land drainage includes channelization of water courses and Hill (1976) points out that such drainage schemes can have a considerable impact on hydrology, sediment load, water temperature, chemistry and aquatic biology. Welch *et al.* (1977) found that fish and benthos were less abundant in streams near farms than in those flowing through natural and clear-out

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forests and they stated that chemical contamination and sedimentation had caused the reduction. Dance and Hynes (1980) stated that a comparison of historical and present day conditions indicates that modifications of the drainage basin have produced drastic effects on the stream which flows through the most intensively farmed basin.

Land activities may introduce large amounts of sediment into nearby streams and rivers (David *et al*., 1981). Sediment input may impact stream communities through a variety of direct and indirect processes (Oschwald, 1972), including reduced light penetration, smothering, habitat reduction and introduction of absorbed pollutants (pesticides, metals, nutrients). Sediment addition has been found to affect benthos (Rosenberg and Snor, 1975). The effect of sediment addition is simply to reduce available habitat area (David *et al*., 1981). The structure of the sediments in the intertribal zone plays a major role in the distribution of the organisms that live in or on them (Barnes and Hughes, 1988; Ajao and Fagade, 1991; Khan *et al*., 2003; Atabatele *et al*., 2005; Ikomi *et al*., 2005). Benthic organisms show habitat preference for specific types of sediment (Atabatele *et al*., 2005). The Physico-chemical parameters of the sediments such as salinity, dissolved oxygen, pH, and organic carbon could also influence the occurrence and abundance of species distributed in them (Mclusky and Elliot, 1981).

Mineral soils are often composed of inorganic particles of varying sizes called soil separates. The relative proportions of the various separate or size groups of individual soil grains in a mass of soil is referred to as soil texture. The soil texture specifically refers to the proportions of sand, silt and clay below 2000 μm (2 mm) in diameter in a mass of soil (Esu, 1999). Sand is generally coarse and gritty, silt is smooth like flour and clay is sticky and plastic when wet. The texture class determines the microbiological population of a soil and hence the biological and biochemical reactions taking place in such a soil, (Esu, 1999).

Excess nutrients especially phosphates, sulphates and nitrates are classified as pollutants in waste water. Large tonnage of phosphate enters rivers and lakes through super phosphate fertilizer washed from soil and from chemicals used to improve the performance of detergents (Abowei and Sikoki, 2005). Phosphate is considered a pollutant principally because of Lake eutrophication resulting in algal bloom (Odiete, 1999; Abowei and Sikoki, 2005). Braide *et al*. (2004) reported range values of pH (6.9 ± 0.07 - 7.8 ± 0.14), Sulphate (36.7 ± 9.23 - 92.9 ± 5.62 mg/kg), Nitrate (0.62 ± 0.28 - 2.83 ± 0.13 mg/kg,), Total phosphorus (0.29 ± 0.05 - 244 ± 10.8 mg/kg), total hydrocarbon content (49.04 ± 8.20 - 412.64 ± 29.05 mg//kg) and mean conductivity level ranged between 79.0 ± 1.07 - 225.0 ± 4 μS/cm. Down stream stations recorded higher conductivity in the dry season than wet season. Powell (1984), Pudo (1985) and Conides and Papoura (1997) attributed increase or decrease in hydrocarbon concentration to oil spillage rather than climatic conditions. The presence of hydrocarbon has been shown to have adverse effect on phytoplankton community structure and abundance Chinda and Braide (2003).

The granulometric and mass properties of lake and marine muds are similar, although lacustrine sediments at a given depth are typically finer grained than marine sediments because of lack of tidal currents and higher sedimentation rates. Problems linked to the toxicity of freshwater sediments are the subject of increasing attention on the part of water managers (Literathy and Csanyi, 1994; Seymore *et al*., 1994; Johansson and Anderson, 1995; Lim and Kiu, 1995). Prygiel *et al*. (2000) reported that management of contaminated sediments becomes a crucial problem due to past and present industrial activities. Physically complex substrate types (leaves, gravel or cobble, macrophytes, moss, wood) generally support more taxa than structurally simple substrates (sand and bedrock; Hawkins, 1984; Hubert *et al*., 1996) RPI (1985), Chinda *et al*. (1999) and Chinda and Braide (2003) have reported low nutrient level for the Niger Delta river system. Exception of sulphates, the bedrock of the Niger Delta drainage basin is not essentially rich phosphate and nitrate. Sombreiro River is one of the numerous water bodies in the Niger Delta of Nigeria providing nursery and breeding grounds for a variety of fish species and other aquatic fauna. The large wetlands and coastal waters of Nigeria, in particular the Niger Delta have great potentials for commercially important fishery (Powell *et al*., 1985).

The Niger Delta is the richest part of Nigeria in terms of natural resources with large deposits of petroleum products (Moffat and Linden, 1995; Braide *et al*, 2004). Similarly, the vast coastal features which include forest swamps, mangrove, marsh, beach ridges, rivers, streams and creeks serve as natural habitats for various species of flora and fauna (Alalibo, 1988; Jamabo, 2008). The stretch of the Sombreiro River is one of the most important river systems in the Niger Delta providing nursery and breeding grounds for a large variety of fish species (Ezekiel *et al*., 2002). Results from studying the sediment physical and chemical characteristics from Sombreiro River in the Niger Delta area of Nigeria will facilitate the management of the water and similar water bodies. It also provides base line data for further studies.

MATERIALS AND METHODS

Study area: The study was carried out for a period of two years (January, 2007 - December, 2009) in Sombreiro River, in the Niger Delta of Nigeria. It is one of the rivers that drains the western part of Rivers State. The river provides nursery and breeding grounds for a large variety of fish species (Ezekiel *et al*., 2002). Four sampling stations were established along the length of the Sombreiro River whenever, it was accessible by road. Sombreiro River is located in three local government areas of Rivers stale - Ogba/Egbema/Ndoni and Degema between Latitude 6º30′ and 7º0′ E and Longitude 4º12′ and 6º17′ N. It is a distributary of the River Niger which arises from northern boundary of Rivers State with Imo State. It is one of the series of the Niger Delta rivers which drain into the Atlantic Ocean and is connected to other rivers via creeks in the coastal area of the Niger Delta (Ezekiel, 1986, 2001).

The river is narrow and steep as it flows southwards, it widens and the steep sidedness gradually disappears starting from the middle reaches. The system is lotic throughout the year; the lotic period reaches its peak in January to February (dry season) when the water level has fallen to the maximum. In August - September (wet season), the lotic nature of the river is reduced due to flooding (Ezekiel, 1986). The river is contained within the tropical rainforest although the lower reach is within the brackish mangrove zone.

From upstream the river bed consists of stones and gravels, the middle zone tending to be sandy with the sand bed giving way to a muddy one at the lower reach of the river (Ezekiel, 1986). A part from areas of human disturbance, the river is fringed by riverside forest. Numerous human activities such as fishing, sand nuning, dredging, mangrove cutting, logging of timber and transportation. These may be potential sources of pollution to the environment. Public toilets were observed at each of the sampling stations. Also observed were refuse dumps and run-offs into the river from the rivernie communities. The wastes from the comities may constitute source of pollution to the river.

Four sampling stations were established along the length of Sombreiro River. Stations were chosen in a manner to provide for even spread for effective sampling. Each of the stations was visited once a month, usually between the 15th and 22nd . Photographs were taken of each station to illustrate the habitat. Only qualitative description of stations were made in order to classify the stations according to general habitat types. The four stations investigated in this study are described below on the basis of personal visual observations.

Station 1 (Degema): This is the largest of all the sampling stations. The vegetation fringing the river at the left and right banks consists of mangrove plants such as *Rhizophora*, *Avicennia* and *Nypha Fruticans* (Nypa palm), arising from a characteristic muddy substrate that produces a foul odor. The water is highly turbid in the rainy months and clear in the dry months. This station is a brackish and tidal environment. There is no observable unidirectional flow of the water at this station due to the very wide nature of the river; thus the surface current is not very distinct to be determined. The bed of the river at this station is a mosaic mud and sand. No farmland was observed at this station but there were public toilets which discharge human wastes directly into the river.

Station 2 (Ogbele): At station 2, mangrove vegetation is replaced by riverine forest consisting mainly of *Raphia*, *Pandanus*, *Sanderiana*, *Calamas* sp. (swamp cane), *Khaya* sp. (Mahogany), *Vapaca* sp., *Ficus Vogeliana* and *Triculia african*. Aquatic marcophytes include *Nymphace* sp., *Eichornia crassipes*, *Sagittana* sp., *Pistia stratictes*. The station was flooded in the rainy season when the current velocity is slow. The station has a little tidal influence from the immediate tidal mangrove zone. The bed of the river at this station consists of sand and small gravel. No farmland was noticed but there were public toilets which discharge human wastes directly into the river.

Station 3 (Ihuaba): The vegetation fringing the river at this station is a mixture of riverine and terrestrial vegetation although no farmland was seen. The common plants noticed here are the *Raphia* and *Elaeis guineensis* (palm trees.). The aquatic macrophytes include *Typha lotifolia* (cat tail) and *Potamogetom* sp. (pond weed). The station was flooded from August to October with the flood receding from November to February. The speed of the current is slow in the rainy season. The bottom of the river at this station consists of sand and gravel of various sizes. No farmland was observed but there were public toilets which discharge human waste into the river.

Station 4 (Odiemudie): The vegetation consists of a terrestrial vegetation in which can be seen farmland, and riverine vegetation extending into a large area of swamps. Some include *Raphia*, *Pandanus Sanderiana*, *Elaeis guineensis* (palm trees) Aquatic macrophytes include/ *Pomea aquatica*, *Lemna* sp. (duck weed), *Utricularia* sp., *Nympaea* sp. and *Pistia stratiotes* (water lettuce). Current is moderate in the rainy months, becoming fast in the dry months when the flood recedes. The water is clear and the bottom consists of small stones, gravel of various sizes and sand.

Sample collection: The benthic samples for the analysis of benthic organism, sediment particle size and sediment Physico-chemical parameters were collected using an Eckman grab of 10cm diameter and 12 cm long. Three hauls were made at each sampling station by sending the grab down into the bottom and using the messenger to close and grab some quantity of sediment. The benthic samples were collected monthly from each station. Composite samples were composed from each station and put into labeled polythene bags for the determination of the sediment particle sizes. The remaining benthic samples were washed through a seize of 1 mm × 1 mm mesh size to collect the benthic organisms. The washed sediment with macro-invertebrates were poured into a wide mouth labeled plastic container and preserved with 10% formalin solution to which Rose Bengal (dye) had been added. The Rose Bengal dye strength was 0.1% selectivity colored all the living organisms in the sample (Claudiu *et al*., 1979; Zabbey, 2002; Idowu and Ugwumba, 2005). The preserved samples were taken to the laboratory for further analysis.

The washed and preserved sediment with the benthic macro-invertebrates were poured into a white enamel tray and sorted in the laboratory. For effective sorting, moderate volume of water was added into the container to improve visibility. Forceps were used to pick large benthos while smaller ones were pipetted out. The benthos were sorted into their different groups and preserved in 5% formalin. The preserved benthos were later identified to their lowest taxonomic group under light and stereo dissecting microscope and counted. The identification was done using the keys by Day (1967), Pennak (1978) and Hart (1994). The monthly percentage occurrence and relative numerical abundance of macro-invertebrates were estimated. The densities of abundant species were analyzed for each of the sampling stations using the formula:

$$\text{Density} = \frac{\text{Total Number of Organisms}}{\text{Area of sampling unit}} \tag{1}$$

Sediment texture or sediment particle size was analysed by the Bouyoucos (1961) hydrometer method modified by Day (1967). The sediment was dispersed with a solution of sodium hexametaphosphate (calgon 44 g/L) and sodium carbonate (8 g/L). The pH of the solution was maintained at about 8.3. The textual class was determined using the triangular diagram.

The pH and conductivity of the sediment were determined by the method of Bates (1954) 50 gr at sediment was diluted with 50 mL of distilled water in a 100 mL beaker to produce a ratio of 1:1 mixture. This was stirred with a stirring rod to homogenize the mixture and then left for 30 min to settle. After 30 min, pH and conductivity readings were taken by inserting their respective electrodes in the soil solution.

Nitrates, sulphates and phosphates in the sediment were analyzed using APHA 4500-NO3B, APHA 4500-SO_4B and APHA 4500 - P of APHA (1995). 10 mL of sediment solution was transferred into sample curette. To this was added the contents of one reagent powder pillow; whether for the nitrates, sulphates and phosphates to complex the colors, if any of the nutrients were present in the sample. The readings (mg/L) were taken on the HACH DR 2400 spectrophotometer.

Total organic carbon content of the sediment was determined using the Walkey - black method of ASTM and APHA (1995). This method is based on the theory that the color of a soil sample determines the organic carbon content of that soil. 0.5 g of sediment samples was sieved through a 2 mm mesh-size sieve and weighed into 250 mL conical flask. 10ml of potassium dichromate ($K_2Cr_2O_7$) and 20 mL H_2SO_4 were added and left to stand for 30 min on asbestos after intermittent swirls. 100ml of distilled water (spectator ion) was added. To this was added 3-4 drops of ferrous indicator and titrated with 0.5N $FeSO_4$. $7H_2O$. If the soil sample is rich in organic carbon it will assume a greenish cast on adding all reagents and indicators but if it is not rich in organic carbon it will assume an orange color. Upon titration, an organic carbon rich soil goes from green to light green and finally to maroon red or brown; that is the end point. Total organic carbon was then calculated thus:

$$\text{Organic Carbon (\%)} = \frac{\text{Titre value} - \text{Titre Value} \times 0.195 \text{ (factor) of blank of sample}}{\text{Weight of soil sample (g)}} \tag{2}$$

Total hydrocarbon content of the sediment was determined using American Standard tests and method (ASTM D 3921) 1995.5 g of sediment sample after air - drying was sieved through a 2 mm mesh-size sieve. The essence of sieving was to obtain particle sizes of almost uniform diameter, increase surface area so as to enhance the contact/spreading of organic solvent within the soil matrix. 25 mL of chloroform was added to soil sample in a beaker, stirred carefully to allow for proper extraction of organic materials or extract. The organic extract was used to dehydrate the sample of any excessive moisture so as to avoid interference of moisture within the organic extract. Chloroform ($CHCL_3$) was used as blank and the organic extract as sample. The blank was inserted into the cell holder of the spectrophotometer. The blank was zeroed and removed from the cell holder. In turn the sample was inserted; the concentration was obtained on the digital read-out of the spectrophotometer when it was stable. Total hydrocarbon content was calculated thus:

$$\text{THC (g/kg)} = \frac{\text{Dilution x Spectrophotometer reading x vol. of solvent}}{\text{Weight of soil (g)}} \tag{3}$$

RESULTS

Sediment particle size: The results of the percentage composition of sand, silt and clay of the stations of Sombreiro River are presented in Table 1. The sand contents of the sediment were high across the stations. The percentage sand content ranged from 81.96 and 94.52% with a mean of 88.6%. Station 4 (Odiemudie) had the highest value of 94.52% while station 1 (Degema) had the lowest value of 81.96%

The percentage silt content ranged from 1.53 and 7.72% with a mean of 4.31%. The highest percentage silt

Table 1: Sediment particle size in Sombreiro River, Niger Delta, Nigeria

	Station				
Parameters	1	2	3	4	Mean Value
Sand (%)	81.96	85.96	91.96	94.52	88.6
Silt (%)	7.72	6.28	1.72	1.53	4.31
Clay (%)	10.32	7.76	6.32	3.95	7.09
Textural class	Loam sand	Sand	Sand	Sand	Sand

Table 2: Physical and chemical parameters of sediment in Sombreiro River, Niger Delta, Nigeria

Parameters	Station				
	1	2	3	4	Mean value
pH	5.85	5.06	5.74	5.70	5.59
Conductivity (μS/cm)	1,940	40	70	65	528.75
Organic Carbon (%)	4.134	2.535	2.28	2.020	2.68
Nitrate (mg/Kg)	3.9	2.6	4.1	4.0	3.65
Phosphate (mg/Kg)	14.6	8.90	15.7	14.5	13.43
Sulphate (mg/kg)	30.0	21.0	26.9	25.3	25.8
Total hydrocarbon Content (THC) (mg/kg)	21.6	24.3	52.7	50.4	37.25

content was recorded from station 1 (Degema) while the lowest value 1.53% was obtained for station 4 (Odiemudie). The percentage clay content ranged from 3.95 and 10.32% with a mean value of 7.09%. Clay content was highest in station 1 (Degema) with a value of 10.32%, while the lowest value of 3.95% was obtained in station 4 (Odiemudie). The result of the sediment analysis showed that sand was dominant across the stations, except station 1 (Degema) which revealed loam sand textual class.

Sediment physico-chemical parameters: The results of the Physical and chemical parameters of Sombreiro River sediments are presented in Table 2. The pH of the sediment ranged from 5.06 and 5.85 with a mean value of 5.59. The pH values of the sediments were acidic across the stations. Station 2 (Ogbele) 5.06 was the most acidic while station 1 (Degema) 5.85 was the least. Conductivity of the sediments ranged from 40 and 1,940 μS/cm with a mean value of 528.75 μS/cm. Station 1 (Degema) had the highest value of 1,940 μS/cm while the lowest value of 40 μS/cm was obtained from station 2 (Ogbele). The great difference arose from the fact that station 1 (Degema) is brackish sediment while station 2-4 are fresh sediments.

The organic carbon percentage ranged from 2.020 and 4.134% with a mean value of 2.68%. Station 1 (Degema) had the highest value of 4.134% while station 4 (Odiemudie) had the lowest value of lowest value of 2.020%). The nitrate content of the sediments ranged from 2.6 mg/kg and 4.1 mg/kg with a mean value of 3.65 mg/kg. Station 3 (Ihuaba) had the highest value of 4.1 mg/kg while the lowest value of 2.6 mg/kg was obtained from station 2 (Ogbele).

The phosphate content of the sediments ranged from 8.90 and 15.7 mg/kg with a mean value of 13.43 mg/kg. The highest value of 15.7 mg/kg was obtained from station 3 (Ihuaba) while the lowest value of 8.90 mg/kg was obtained from station 2 (Ogbele). The sulphate content of the sediments ranged from 21.0 and 30.0 mg/kg with a mean value of 25.8 mg/kg. Station 1 (Degema) had the highest value of 30.0 mg/kg while the lowest value of 21.0 mg/kg was obtained from station 2 (Ogbele). Total Hydrocarbon Content (THC) of the sediments ranged from 21.6 and 52.7 mg/kg with a mean value of 37.25 mg/kg. Station 3 (Ihuaba) had the highest value of 52.7 mg/kg while the lowest value of 21.6 mg/kg was obtained from station 1 (Degema).

DISCUSSION

In terms of texture the particle size of sediments in Sombreiro River ranged from sand to silt. The result indicated that the sediment is sandy in three stations (Station two, three, and four) and loam sand in station one. This finding compared favorably with the observation of George *et at*. (2010) who reported the sediment particle size of Okpoka Creek, Niger Delta to consist of sand, clay and silt. The sediment particle size of this study is also similar to the report of Ajao and Fagade (1991) who observed a wide variety of sediments ranging from fine, medium and coarse sands to admixture of silt and clay which provide wide selection of habitats. The result of this study also agrees with the report of Darlington (1977) that the mud types of Lake George in Uganda does occur in other tropical African Lakes and is associated with similar benthic fauna. The percentage particle size obtained from this study also compare favourably with that reported by Mclachlan and Mclachla (1971) from Lake Kariba. This study therefore reveals that African aquatic sediments are of similar inorganic particles of varying sizes which Esu (1999) described as soil texture.

The mean percentage values of sand (88.6), clay (7.09) and silt (4.31) obtained in this study compared favorably with the observation of George *et al*. (2010) who recorded mean values of 73.97, 22 and 27% for sand, clay and silt respectively. However, it may be noted that the percentage sand content of Sombreiro River is higher than that of Okpoka Creek while the clay and silt contents of Okpoka Creek are higher than those of Sombreiro River. These variations may be attributed to the fact that Sombreiro River is a freshwater lotic environment while Okpoka creek is brackish and tidal. Their sediment loads may vary. Allan (1995) reported that sediments depend on the parent material available and deposits of materials.

The ecology of *Neritina* in the Lagos Lagoon was studied by Ajao and Fagade (1991) who reported that their distribution and abundance were dependent on the silt content, total organic matter and contamination of sediment. They also reported a wide variety of sediments ranging from fine, medium and coarse sands to admixture of silt and clay which provide wide selection of habitats. They further reported abundance of *Capitella capitala*, *Nereis* sp. and *Polydora* sp. in polluted areas of Lagos Laggon. They concluded that diversity indices indicated that the communities exhibited high dominance with a small number of species. Cummins and Lauf (1969) reviewed the relationship between benthic organisms and the substrate and reported associations between chironomid laiva and organic matter. Mclachlan and Mclachlan (1971) reported that correlations between chironomid biomass and percentage sand, silt and clay were not significant. Coarse sand value of 69% and above are limiting to chironmids.

Textural class of sediment has been reported by Mclachlan and Mclachlan (1971) in Lake Kariba. They obtained mean values of sand (69%), silt (14%) and clay (17%). They also reported mean values of organic carbon (1.02%), total nitrogen (0.81%), phosphate (13 ppm) and pH (6.2) in the sediment of Lake Kariba. These mean values were presented in order to establish their relationship with other soil types. The sediment of Lake Kariba tended to be sandy with relatively small proportion of silt and clay. A sand habitat is generally considered to be an area of low benthic productivity, mainly due to its instability. Soft silt sediments are often unfriendly environment to which few invertebrate species have managed to adapt (Rhoads, 1974). Mclachlan and Mclachlan (1971) also reported low estimates for organic carbon, available phosphate and total nitrogen. Variation in horizontal distribution of benthos was attributed to the texture and stability of the substrate in Lake George in Uganda (Darlington, 1977). *Uca tangeri* densities were high in the dry season, declined during the rains and were generally influenced by substrate texture.

In the Niger Delta, Nigeria George *et al*. (2010) reported the percentage compositions of sand, silt and clay. The sand contents of the sediment were high across the study stations in Okpoka Creek. The percentage sand content ranged between 60.12 and 90.68% with a mean of 73.97%. The percentage silt content ranged between 13.46 and 38.35% with a mean value of 27.14%. The percentage clay content ranged between 18.6 and 30.98% with a mean value of 22%. They also concluded that sand dominates across the stations of Okpoka creek with the exception of one station which revealed loamy sand textural class. They also attributed the high silt content of sediment in station 2 to the high organic discharge from the abattoir. Allan (1995) reported that sediments depend on the parent material available and deposits of materials. George *et al*. (2010) further reported that the station with the highest percentage of clay also had the highest percentage of silt. The percentage particle size of Okpoka Creek showed that the Creek had sandy mud (73.97%) sediment. This was attributed to the regular sand mining going on in the creek.

The result of this study across the stations showed that station 4 (Odiemudie) had the highest percentage of sand (94.52) and least percentage of clay (3.95) and silt (1.53). This may account for the heavy sand mining activity going on at this station (personal observation). Station 4 (Degema) had the least percentage of sand (81.96) and highest percentage of clay (10.32) and silt (7.72). The variations in the sediment texture observed at the stations of Sombreiro may be due to the finding of Allan (1995) that sediments depend on the parent material available and deposits of materials. The study revealed that the particle size of the sediments of Sombreiro River is sandy mud (88.6%).

The hydrogen ion concentration (pH) of Sombreiro River sediments ranged between 5.06 and 5.85 with a mean value of 5.59. This indicates that pH of the river sediment is acidic across the stations and follows the pattern of the water pH. Comparatively, the sediment is more acidic (5.59) than the water (6.40). The mean value of the sediment pH obtained in this study does not compare favorably with the report of Braide *et al*. (2004) who reported alkaline range of 6.9-7.8 from the freshwater stream of Minichida stream, Niger Delta. Whereas Minichida stream sediment is alkaline that of Sombreiro River is acidic. This difference may be attributed to the fact that Minichida stream is in urban location characterized by land drainage pollution arising from the presence of automobile workshops photographic workshops and other commercial activities Braide *et al*. (2004).

Station 2 (Ogbele) was the most acidic (5.06) and Station 1 (Degema) least acidic (5.85). This may be attributed to the more commercial activities such as timber works and transportation by engine boats going on at station 1. Prygiel *et al*. (2000) reported that management of contaminated sediments becomes a crucial problem due to past and present industrial activities. Literathy and Csanyi (1994), Seymore *et al*. (1994), Johansson *et al*. (1995) and Lim and Kiu (1995) have earlier reported that problems linked to the toxicity of freshwater sediments are the subject of increasing attention on the part of water managers.

The conductivity of the study area ranged between 40 and 1,940 μS/cm with a mean of 528.75 μS/cm. This compares favorably with the range of 79.0 - 225.0 μS/cm reported by Braide *et al.* (2004) from Minichida stream, Niger Delta. The wide variation between the conductivity of the sediment at station one (1,940 μS/cm) and stations 2, 3 and 4 (40, 70 and 65 μS/cm) respectively are attributed to the fact that station 1 is brackish with more ionic content than the other freshwater stations of 2, 3 and 4.

The organic carbon content of the stations of Sombreiro River ranged 2.02 and 4.134% with a mean of 2.68%. The mean value of 2.68% obtained in this study is below the mean value of 1.02% obtained from Lake Kariba by Mclachlan and Mclachla (1971). The level of organic matter decomposition may be attributed for the variation in organic carbon content. Sediment is a major site for organic matter decomposition which is largely carried out by bacteria (Abowei and Sikoki, 2005). Human activities in Lake Kariba and Sombreiro River may also vary in terms of agricultural practice. Agricultural land drainage includes chanelization of water courses and Hill (1976) pointed out that such drainage schemes can have a considerable impact on hydrology, sediment load, water temperature, chemistry and aquatic biology. Station 1 has the highest organic carbon content of 4.134% than stations 2, 3, and 4 with organic carbon content by 2.535, 2.28 and 2.020%, respectively. This difference may be attributed to difference in deposition of organic matter at the various stations.

Darlington (1977) compared the mud of Lake George, Uganda with other inter-tropical African Lakes and reported that mud of the types found in lake George does occur in other lakes, and is associated with somewhat similar benthic fauna. Mclachlan and Mclachlan, (1971) studied the benthic fauna and sediments in the newly created Lake Kariba (Central Africa) and reported that; sediment affected the distribution of bottom fauna, in which chironomid larva predominated. Ikomi *et al*. (2005) reported significantly high density of microbenthic invertebrates in the dry season months in their study and attributed this to the unstable nature of the substrate during the rainy season months arising from inputs of storm water thus accounting for the low density of organisms. Similar observations had been made by Victor and Ogbeibu (1991) in an urban stream in Nigeria, Edokpayi *et al.* (2000) in Ibekuna stream, Ekpoma, Delta State, Tumwesigye *et al*. (2000) in River Nyamweru, Western Uganda.

The mean nitrate content of sediments is 3.65 mg/kg. This value, although higher compares favorably with the range values of 0.62 - 2.83 mg/kg, reported by Powell (1984). These values are generally low and are attributed to the low nutrient level of the Niger Delta. The Niger Delta is not essentially rich in nitrate (Chinda and Braide 2003). Excess nitrate in water is considered as pollutant (Odiete, 1999). Nitrate concentration is uniformly distributed in stations 1, 3, and 4 but lower in station 2. This is attributed to differences in sediment nutrient input from the drainage systems of the various stations. Land-disturbing activities may cause introduction of large amounts of sediment into nearby streams and rivers (David *et al*. 1981).

The mean phosphate concentration recorded is 13.43 mg/kg. This compares favorably to the range value of 0.29-244 mg/kg obtained by Braide *et al*. (2004). The phosphate concentration distribution follows the same pattern as nitrates. The factors which affected nitrate concentration also affect phosphate distribution in the stations. Abowei and Sikoki (2005) reported that large tonnage of phosphate enters rivers and lakes through super-phosphate fertilizer from soil and from chemicals used to improve the performance of detergents. Excess phosphate in water is considered a pollutant (Odiete, 1999) and farm activities along this river need to be regulated to avoid algal bloom in this river. The mean sulphate concentration obtained in the sediments of Sombreiro River is 25.8 mg/kg. This value compares favorably with the range values of 36.7-92.9 mg/kg obtained by Braide *et al*. (2004). The sulphate level of Sombreiro is considered normal in the Niger Delta. Chinda and Braide (2003) reported that the Niger Delta is rich in sulphate. This assertion is observed in the uniform distribution of sulphates across the stations of Sombreiro River. Excess sulphate in water is however considered a pollutant (Odiete, 1999). The mean Total Hydrocarbon Concentration (THC) recorded in this study is 37.25. This compares favorably with the range values of 49.04-412.64 recorded by Powell (1984). The presence of commercial activities especially transportation and frequent oil spillage in the Niger Delta water ways may be attributed to the occurrence of hydrocarbon in the sediment of Sombreiro. Powell (1984), Pudo (1985) and Conides and Papoura (1997) have earlier attributed increase in or decrease in hydrocarbon concentration to oil spillage rather climatic conditions. Hydrocarbon in the sediment of Sombreiro River may produce adverse effect on the benthic communities. Chinda and Braide (2003) reported that the presence of hydrocarbon in water have adverse effect on phytoplankton community structure and abundance. Higher mean concentration of total hydrocarbon concentration was observed in stations 3 and 4 while lower values were observed in stations 1 and 2.

CONCLUSION

- The particle size of sediments in Sombreiro River ranged from sand to silt.
- The river sediment pH is acidic across the stations and follows the pattern of the water pH.

Comparatively, the sediment is more acidic (5.59) than the water (6.40).

- The mean value of the sediment pH obtained in this study varied from other reports

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