SEDIMENTOLOGICAL AND GEOCHEMICAL CHARACTERIZATION OF SURFICIAL SEDIMENT OF A MEANDER SECTION OF MBAA RIVER AT NNEISE–UGIRI COMMUNITY IN IMO STATE OF NIGERIA.

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ABSTRACT

Sediment deposition has increased at a meander section of Mbaa river resulting in a drastic reduction of water storage. It has necessitated calls for sand-mining or periodic dredging which could have a far-reaching impact on the aquatic ecosystem, depending on the texture and chemical compositions of the sediment. Therefore, surficial sediments samples were analyzed for textural characteristics, mineralogy and chemical compositions. Grain sizes and mineralogical analysis showed that the sediments were moderately sorted, mesokurtic, near symmetrical - slightly positive skewed, subangular – subrounded medium grained-sands, and consist of about 2.5% feldspar, 2.7% rock fragments, 5.4% hematite and 89% quartz. Mean TOC and pH were 0.39% and 6.48 respectively. Atomic Absorption Spectrophotometer (AAS) analysis results showed general low concentrations of metal elements: mean values of alkali/alkali earth metals ranged from 1.33 - 3.72ppm, transition metals ranged from 0.12 - 23.07ppm; while Pb (a poor metal) was not detected. General low concentrations of metals and TOC; and non-detection of Pb suggest lack of mineralization zone and minimal anthropogenic impacts in the upstream areas. Textural and chemical characteristics and moderate energy of river water flow suggest that human resuspension of the sediment deposit will result in minimal lateral dispersion of sediment in the water column, except during heavy rainfall. Therefore, periodic dredging or sand mining will cause minimal impact on the aquatic ecosystem, especially in the distant downstream areas, whereas within the meander section and nearby areas of the river, it is expected that there will be a significant change in water quality parameters due to the increase in the concentrations of suspended and dissolved compounds.

Keywords: Mbaa-River, meander-channel, surficial-sediment, sedimentology, geochemistry, Grain-sizes, mineralogy, metal elements.

1. INTRODUCTION

The Mbaa river in the Imo state of Nigeria has evolved over the years from an eroding river to a more depositional river especially at a meander section in Nnneise-Ugiri community. Consequently, the water storage of the river channel has reduced drastically, necessitating the calls for sand mining or periodic dredging. The deposition of sediment could be attributed to a decrease in the velocity of water flow due to a reduction in channel gradient, less rainfall and reduced rate of groundwater infiltration into the channel in the upstream areas. The increased in the rate of sediment supply to the section of the channel could be attributed to increasing in chemical and physical weathering of rocks in the source area and along the river channel; and increased in roads and gutters constructions that increase sediment-laden surface-runoffs to the river.

Dredging or sand-mining that could increase the water storage in the study meander section of Mbaa river will have far-reaching impacts on the aquatic environment. It is an activity that would result in sediment dispersion in the water column by the remobilization and the resuspension of already deposited sediment. Apart from the reduction of the quality of water which numerous riparian communities depend on for domestic use via increase of turbidity and the released of toxic metals stored in the sediment into the water column, the dispersed sediments will also have effects on the various components of the ecosystem. These include (1) influence on the productivity of the aquatic life by enriching the water column with nutrients; (2) the reduction of availability of sunlight necessary for photosynthesis; and (3) mortality of benthic organisms through burial during re-deposition of sediment in the downstream areas.

The lateral extent of sediment dispersion in water bodies depends principally on sediments' textural characteristics (grain size, shape and sorting), the density of sediment grains and speed of water current, while its temporal and permanent impacts on the aquatic environment and water quality depend on the sediments' mineralogy and chemical composition. The mineralogy of the sediment depends on the catchment petrology or regional geology [1]). The chemical composition of sediments depends on the elemental composition of the sediment matrix and the anthropogenic activities in the environment [2]. Before attempting sand mining or dredging, it is necessary to critically examine these aforementioned sedimentological and geochemical parameters. Therefore, the aim of this paper is to present the results of study for the determination of sediment grain size distribution and or textural characteristics, mineralogical and elemental/chemical composition of the sediment, relationship between mineralogy and elemental composition; and ascertaining the influence of anthropogenic activities on the quality or composition of the sediment in the study area.

1.1 Study Area

Nneise-Ugiri community is located in Ikeduru Local Government Area (LGA) of Imo State in Nigeria (Fig. 1). It lies between latitude 5°34'23.55" - 5°34'57.85"N and longitude 7°12'31.05" -7°13'56.08"E. The studied sediment deposit is situated precisely at 5°34'50.37"N and 7°13'44.04"E and is about 2.3km from Ugiri (Fig.1c) and about 18.5km from Owerri town, the capital of Imo State of Nigeria. The study area lies within a hydrological basin named "Mbaise/Mbano watershed" by [3] and "Otamiri river sub-Basin or watershed" by [4]. The sub-basin is drained by Rivers Mbaa, Otamiri, Oraminiukwa, Okitankwo, Nwaorie etc [4].

Mbaa river drains the northeastern part of Otamiri sub-basin. It originates from Amaraku and flows down south through Umu-Eze down to Nneise-Ugiri, and further flows in south-south western direction to join the Okitankwo river, from which it flows down-south as Oraminiukwa river, a tributary of Otamiri river (Fig. 1c). At Nneisi-Ugiri, the river trends a valley channel of a gentle gradient, with a thickly vegetated shallow and gently sloping overbank and width of about 223m. The river meanders in some locations (such as in the study location) with low to moderate sinuosity (Fig. 2). The depth of water in the river varies with season and time of the season. In the study location, the depth can be as low as 0.5m such that current ripples, wood debris and erosional structures are easily observed on the sediment deposition surface from the centre of the channel to the cut-bank side of the meander belt (Figs. 2 and 3). The point bar side is shallower with laterally accreting sand deposits and more thickly vegetated.

The climate of the study area is that of Imo state which is humid and characterized by two seasons: the dry season and rainy (wet) seasons. The rainy season is between the month of March and November, while the dry season is between the month of December and February. The dry season in the month of January and early February is normally associated with cold and dusty harmattan wind. Generally, the State experiences heavy rainfall, with an average annual rainfall of 2000-2400 mm/year [4]. The highest amount of rainfall is usually recorded between the month of July and September, while the minimum rainfall is recorded between the month of January and December.

The pattern of rivers and the speed of surface runoffs depends on the geomorphology of the study areas. The state consists of two topographic regions, viz: (1) the highland region in the north with steep slopes, undulating topography, and elevation of about 344m above sea level; (2) lowland region in the south with an elevation of about 70m above sea level. The study area is midway between the two zones with elevations of 174 and 106metres above mean sea level at overbank areas and base of the river channel respectively.

***Geology**:* The study area is underlain by Benin Formation of Niger Delta basin, which is located at the southern end of the Anambra basin of the Benue Trough of Nigeria (Fig .4). The geology of Niger Delta has been discussed extensively by [5]. It consists of three lithostratigraphic units: Benin, Agbada and Akata Formations. The Benin Formation which is the topmost unit is Oligocene in age and consist of very porous and unconsolidated continental or coastal plain sands that is coarse to pebbly, poorly sorted and characterized by detrital clays and some impermeable clay layers. The Agbada Formation underlying the Benin Formation consists of alternating sand and shale. It has an age that ranges from Eocene to Pleistocene. The Akata Formation, which is the bottommost unit consists of overpressure shales with some streaks of sands taken as deposits of a turbidity current. Its age range from Paleocene to Holocene. The Akata Formation is taken to be an equivalent of the Imo shale of the Anambra basin

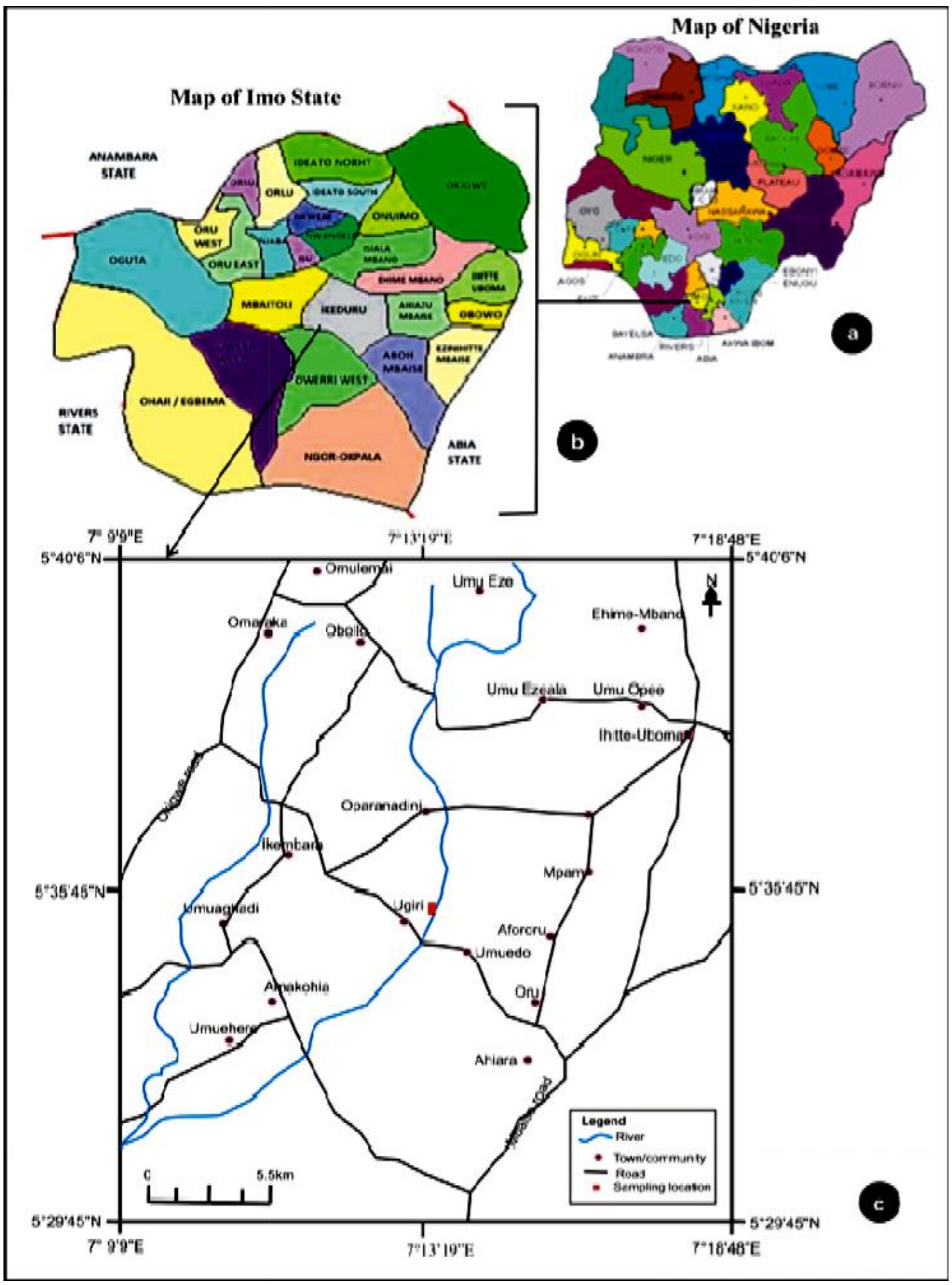


Fig.1: Shows map of Nigeria, Imo state and sediment sampling location in the study area

Fig. 2: Showing the meandering and shallowness of the study section of Mbaa river. The cut-bank on the left while the point-bar on the right.

Fig. 3: Shows current ripples, erosional structures and wood debris on the deposition surface of the study section of Mbaa river (compass used as scale)

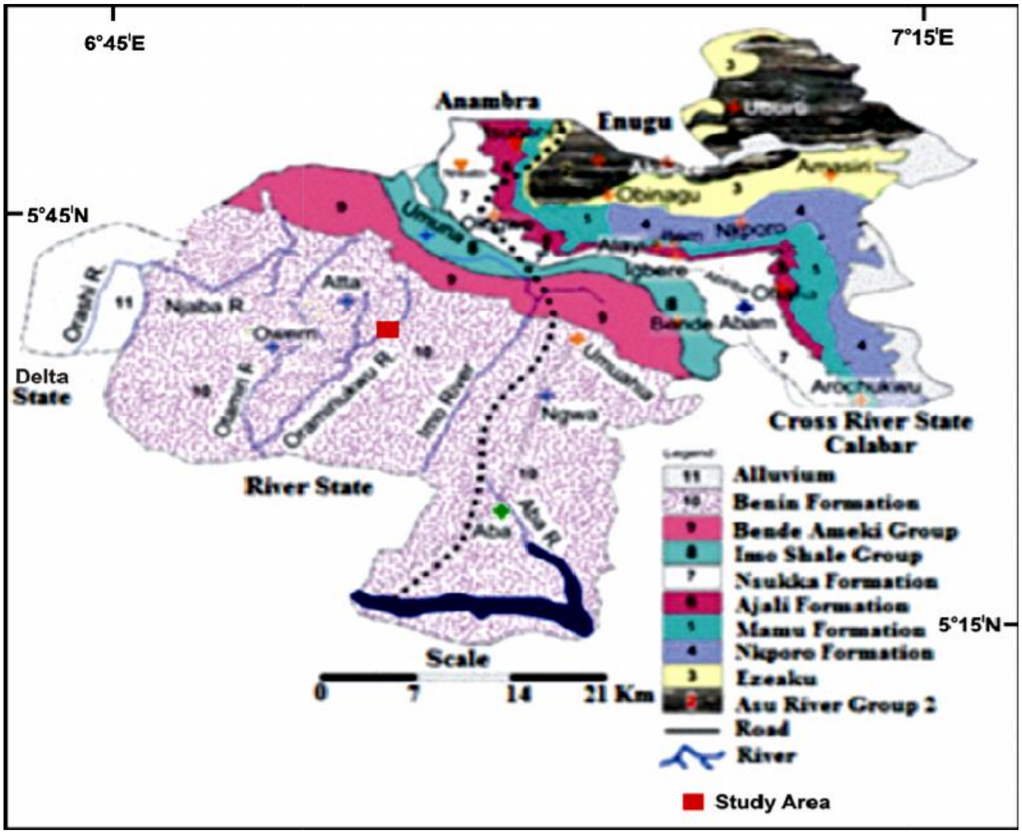


Fig. 4: Geological map of Imo State showing the study area, Benin Formation of the Niger Delta Basin and some formations of the adjacent Anambra Basin (modified after [6])

2.0 METHOD OF STUDY

Sediment samples were collected at locations about 5m apart in the longitudinal directions along the river channel's centre and the margin toward the cut-bank side of the meander section. Samples from the river channel centre were labelled A1 and A2, while that of the channel margin were labelled B1 and B2. Samples were bagged in an appropriately labelled polyethene bag. Duplicate samples were collected at each sampling locations. Physical descriptions and pH determination with portable pH meter were done immediately after samples collections. The coordinates and elevations of sampling locations were determined with a portable Global Positioning System (GPS) receiver, while the direction of river flow was determined with a compass. The coordinates were latter plotted in google earth pro software to view the satellite pictures of the area, from which the river trend, gradient or downward change in elevation, riparian and distant communities/towns and network of roads were determined.

To determine the grain size distribution, 100g were collected from each sample, dried in an ovum and screen through a stacked set of sieves using the methodology of [7]. The sieve sizes in millimetres (mm) were converted to phi (ϕ) scale using the [8] equation:

$\phi = -\log_2 (d)$.   d = grain diameter (mm)

Udden–Wentworth scale [9] was used for the grain sizes classification.

Histogram and cumulative curve for the samples were constructed with Microsoft Excel software by plotting the percentage weight retained and cumulative weight retained against the grain phi (ϕ) sizes respectively. From the cumulative curves, phi values at 5%, 25%, 16%, 50%, 75%, 84% and 95% were determined. The values obtained were inputted into the formulas of [7] for the determination of mean, inclusive graphic standard deviation (sorting), inclusive graphic skewness and kurtosis of the grain sizes distribution. The graphic median corresponds to the 50 percentile (ϕ50) on the cumulative curve.

To determine the shape of grains and minerals types in the sediment, a spoon-full of each sample was washed separately with distilled water. A little quantity was mounted on a slide with water and viewed with both reflected (incident) and transmitted light microscope. Roundness scale of [10] was used to determine the shape of grains, while the principles of using a microscope to determine minerals in [11] were applied for the determination of mineral types in the sediment.

To determine the metallic composition of the sediment, 1g of the sample was digested with combined mineral acids and turned to a clean solution on heating with an electro-thermal hot plate. The combined mineral acids are 10ml of concentrated nitric acid, 5ml of 52% perchloric acid and 0.5ml of concentrated sulphuric acid. The digest was cooled to room temperature and diluted to 50ml volume with distilled water. The solution was then filtered through Whatman filter paper number 541. The filtrate was analyzed for metal ions with Atomic Absorption Spectrophotometer (AAS) based on a standard method of analysis for the individual metal element. The metals analyzed include some alkali metals [sodium (Na) and potassium (K)], alkali earth metals [calcium (Ca) and magnesium (Mg)) and heavy metals comprising some transition metals [chromium (Cr), manganese (Mn), iron (Fe), nickel (Ni) copper (Cu) and zinc (Zn)] and a poor metal [lead (Pb)].

The total organic carbon (TOC) of the sediment was determined with a rapid oxidation method as described by [12] and [13].

3. RESULTS AND DISCUSSION

3.1 Physical and Textural Characteristics

Physical and textural characteristics (grain sizes, shapes and sorting) of sediments are related to provenance, sedimentary process, and sedimentary dynamics [14]. Therefore, they can be used to determine the source of the sediment, current energy or velocity, oxidation condition/depth of water and the type of depositional process/depositional system.

Colour: The colour of the sediments ranged from light brown in channel centre (under subaqueous condition) to brown/reddish brown in the channel margin (under periodic subaerial condition). The colour suggests the presence of ferric ion (Fe^{3+}) derived from the oxidation of ferrous ion (Fe^{2+}) by the exposure to oxygen. The increased in the brownish colouration in channel margin sample as compared to that of channel centre is as a result of an increase in the degree of exposure to oxygen as the depth of water decreases.

***Grain size distribution**:* Grain size analysis results and cumulative distribution charts (Tables 1 and 2; and Fig. 5) show that grain sizes of sediment in the two sampling locations ranged from pebbles (>-2ϕ) to silt /clay (< 3.8 ϕ) and that there is no too much difference between the two samples. The histogram of sample "A1" shows unimodal distribution, while that of sample "B1" shows a slightly bimodal distribution (Fig. 6). The percentage of granules/pebbles, very coarse sand (0 to -1ϕ) and silt/clay grains ranged from 0.7 - 0.82%, 2.9 – 3.96 % and 8.09 – 13.20% respectively, increasing from channel centre to the margin. But the coarse (1 to 0ϕ), medium sand (2 to 1ϕ) and fine/very fine sand (3.75 to 2ϕ) grains ranged from 10.53 - 12.79%, 46.29 - 47.9% and 27.21 – 29,2% respectively, increasing from channel margin to the centre. However, the calculated median and mean grain size are both medium grained-sand (Table 3).

The mean grain size of sediment is a function of the size range of available materials and the amount of energy imparted to the sediment which depends on the current velocity of the transporting medium [15]. The dominance of medium-sand grains indicates the dominance of saltation population over suspension and rolling or surface creeping population in the subaqueous transportation of sediment [14]; and steady moderate current energy with periodic fluctuations. The increase of pebbles and coarse/very coarse grains towards the channel margin is typical of meander river channel deposition in which the energy of water flow increases from the point-bar side towards the cut-bank. The increase in the percentage of silt/clay towards the channel margin could be attributed to the fluctuation in the volume of water and energy of flow in the channel caused by the variations in volumes and rate of flow of sediment laden surface runoffs into the channel during rainfall. During a flash flood, silt and clays are deposited in the overbank and channel margin that is periodically subaerial, while in the centre that is constantly under water flow, they are continuously winnowed downstream.

Table 1: Sieve analysis data

Grain diameter (mm)	ϕ size	Sample A1			Sample B1		
		Weight retained (g)	% weight retained	Cumulative weight %	Weight retained (g)	% weight retained	Cumulative. % Wight
4.75	-2.2	0.2	0.20	0.2	0.2	0.20	0.20
2.36	-1.2	0.5	0.50	0.7	0.6	0.61	0.81
2	-1.0	0.1	0.10	0.8	0.1	0.10	0.91
1.18	-0.2	1.2	1.20	2	1.8	1.83	2.74
1	0.0	1.6	1.60	3.6	2	2.03	4.77
0.6	0.7	11.2	11.19	14.79	8.4	8.53	13.30
0.425	1.2	22.7	22.68	37.47	23.2	23.55	36.85
0.3	1.7	25.2	25.17	62.64	22.4	22.74	59.59
0.15	2.7	29.3	29.27	91.91	26.8	27.21	86.80
<0.074	<3.8	8.1	8.09	100	13	13.20	100.00
TOTAL		100.1	100		98.5	100	

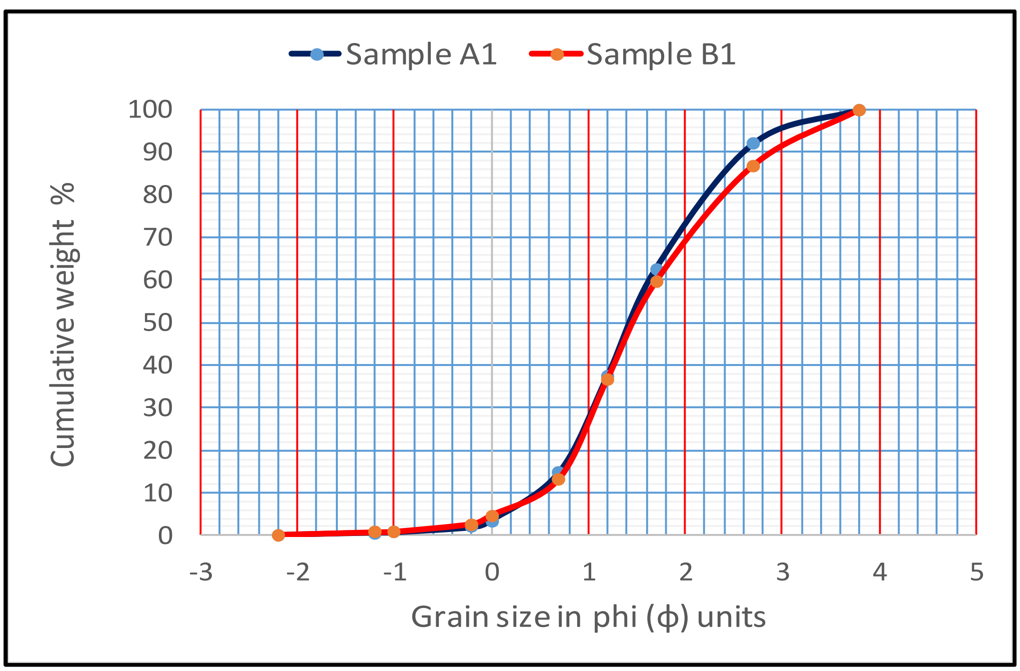
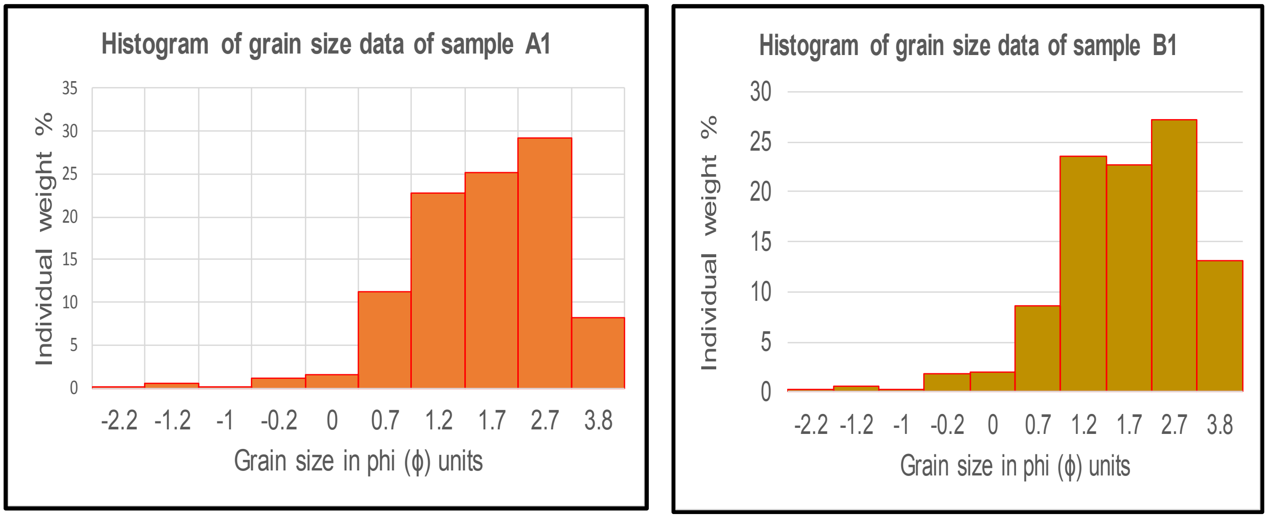


Fig. 5: Grain-size cumulative distribution curves for samples A1 and B1 showing grain sizes ranging from clay/silt to pebbles but with the dominance of fine and medium grains.



(a) (b)

Fig. 6: Histogram of grain sizes showing a unimodal distribution in sample "A1" and a slightly bimodal distribution in sample "B1"

Table 2: Measures for statistical calculations from cumulative distribution curves

	Sample A1	**Sample B1**
%	ϕ size	ϕ size
95	2.9	3.3
84	2.35	2.55
75	2.05	2.2
50	1.42	1.45
25	0.95	0.95
16	0.75	0.8
5	0.1	0

Table 3: Statistical parameters of grain sizes in samples A and B

Samples/ Parameters	**Sample A1 (in phi unit)**	**Sample B1 (in phi unit)**
Median grain size	1.42 (medium sand)	1.45 (medium sand)
Graphic mean grain size	1.51 (medium sand)	1.6 (medium sand)
Inclusive graphic standard deviation (sorting)	0.82 (moderately sorted)	0.94 (moderately sorted)
Inclusive graphic Skewness	0.11 (near symmetrical)	0.19 (fine skewed)

Kurtosis	1.043(mesokurtic)	1.08 (mesokurtic)

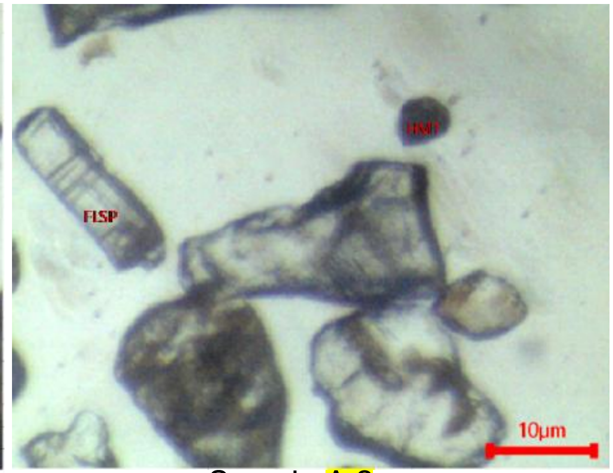
Sorting, skewness and Kurtosis and grain shapes: Inclusive graphic standard deviation and kurtosis calculations indicate that the sediments in channel centre and margin are both moderately sorted and mesokurtic (Table 3). But the channel centre sediments are near symmetrical while that of margin is slightly positively skewed. The kurtosis values corroborated the unimodal and slightly bimodal histogram distributions of the grain sizes of the channel centre (A1) and margin (B1) samples respectively (Fig. 6). Microscopic observation showed that the shape of grains ranged from subangular to subrounded (Fig. 7). All these characteristics showed that the sediment deposit in the study area is texturally sub-matured and a second cycle reworked sediments, sourced possibly from Benin Formation sands or the adjacent Bende Ameki Group of the Anambra basin (Fig. 4). According to [16], the Benin Formation sand is very fine to coarse-grained, sub-angular to subrounded, Poor to fairly well sorted and mostly lithic arenite.

3.2 Mineralogical Composition

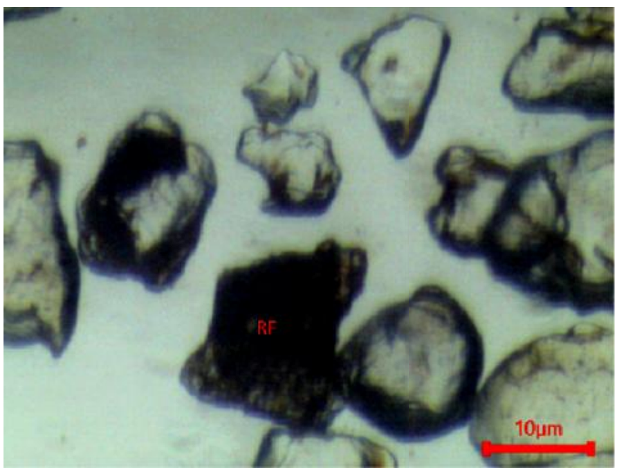
Microscopic examination of the sediment grains showed that most of the grains in the two samples were vitreous (glassy) with scanty occurrences of rock (lithic) fragments and opaque or ore minerals, and complete absence of pleochroic or coloured minerals. The dominant vitreous mineral grains in the two samples were characterized by conchoidal fractures, percussion marks and lack of any form of cleavages indicating quartz (Fig. 7). The other scanty vitreous mineral identified was prismatic in form and characterized by pinacoidal or parallel cleavage lines indicating orthoclase feldspar (Fig). Scanty reniform or kidney-shaped opaque mineral grains were identified in the four samples and were interpreted as haematite mineral grains (Fig. 7). The presence of haematite mineral is what is responsible for the light brown and reddish brown colours of samples A and B respectively. Compositely, the sand in the study area, which ranged from 86.8 to 91.91% per cent of the sediments (Table 1) contains about 2.7% rock fragments, 5.4 haematite and 2.5% feldspar and 89% quartz.

The percentage concentrations of minerals reflect the mineralogical composition of the parent rock and the degrees of stability of minerals in both chemical and physical/mechanical weathering conditions. Quartz (SiO_2) and orthoclase feldspar ($KAlSi_3O_8$) are rock-forming minerals in felsic rocks such as granite and rhyolite, while haematite (Fe_2O_3) suggests sourcing from mafic rock such as amphibolite. The melanocratic texture of the rock fragments also suggests mafic parent rock such as diorite and gabbro or biotite granite parent rock. Quartz, the most dominant mineral, is mechanically and chemically stable, followed by haematite, and then feldspar that is mechanically stable but chemically unstable, while rock fragments, the least in percentage concentrations, is mechanically and chemically unstable [17].

Sample A 1



Sample A 2



Sample B 1

Sample B 2

Fig. 7: Photomicrograph of grains in sample A1, A2, B1 and B2 showing types of shapes, the dominance of quartz grains, and rare presence of rock fragments (RF), reniform or kidney-shaped hematite (HM) and prismatic form feldspar (FLSP) grains.

3.3 pH and Total Organic Carbon (TOC)

The Mean pH value of sediments was 6.48, with values increasing from channel centre to the margin (Table 4). The pH is the measure of acidity and the measured values indicate that the sediments were deposited in a slightly acidic environment. High acidity or low pH value promotes the dissolution of rock minerals and inhibits decomposition of vegetal organic matter [18]; [19].

The TOC concentrations of the sediments were low with a mean concentration of 0.39% (Table 4) and values increasing slightly from channel centre towards the margin. Total organic carbon (TOC) in sediment reflects the amount of organic matter from dead plants and animals, and the level of contamination from industrial effluent and sewage. TOC is a carrier of inorganic pollutants such as heavy metals from sewage and petroleum products [20]. It also indicates the oxygen level and depth of water of the depositional environment. TOC increased with depth reflecting the change from oxic to suboxic or dysoxic depositing conditions that inhibit degrading microbial activities and promotes the preservation of organic matter. In shallow water depth, characterized by high oxidation rate and concomitant organic matter biodegradation, the percentage of TOC in sediments could be used to estimate the level of anthropogenic influence on the chemical composition of the sediment. Therefore, the low percentage concentrations of TOC in the sediments can be attributed to a high level of oxidation and minimal anthropogenic impacts.

3.4 Metal Elemental Composition

The concentrations of metal elements in the sediments from all the sampling locations were generally low (Tables 4 and 5). The mean concentrations of alkali and alkali earth metals, K, Na, Mg and Ca were 1.33, 2.50, 1.33 and 3.72ppm respectively. The alkali metals, K and Na, increased slightly toward the channel margin reflecting concentrations more in finer grains than coarse grains, while the alkali earth metals, Mg and Ca, increased considerably (especially the latter) from channel margin to the centre.

Out of the heavy metals analyzed, only Pb (a poor metal) that was not detected. The mean concentrations of the transition metals, Ni, Cr, Cu, Zn, Mn and Fe were 0.26, 0.39, 0.37, 0.58, 0.12 and 23.07ppm respectively. Apart from Zn, the metal concentrations increased toward the channel margin suggesting their sensitivity to redox. The concentrations of Fe correlate with the presence of hematite mineral and the colour of sediments that changed from light brown in the channel centre to reddish brown in the channel margin.

Table 4: Alkali and alkali earth metals concentrations, pH and TOC

Samples	pH	TOC %	Alkali and alkali earth metals			
			K (ppm)	Na (ppm)	Mg (ppm)	Ca (ppm)
A1	6.7	0.29	1.303	2.282	1.555	6.225
A2	6.5	0.43	1.310	2.346	1.623	6.051
B1	6.4	0.31	1.359	2.748	1.037	1.326
B2	6.3	0.51	1.362	2.631	1.102	1.271
Mean	6.48	0.39	1.33	2.50	1.33	3.72

Table 5: Concentrations of heavy metals (poor and transition metal elements)

Samples	Ni (ppm)	Cr (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Mn (ppm)	Fe (ppm)
A1	0.185	0.383	0.137	0.613	ND	0.048	15.928
A2	0.208	0.375	0.152	0.633	ND	0.064	16.432
B1	0.324	0.392	0.629	0.514	ND	0.159	29.550
B2	0.322	0.397	0.561	0.546	ND	0.212	30.364
Mean	0.26	0.39	0.37	0.58	ND	0.12	23.07

ND= Not detected

Stream sediment composition is affected by lithology or mineralogy, geomorphology, climate, water chemistry and human/industrial activities [21]. Therefore, the metal elements extracted from the sediments with combined acids are either from the lattice structure of the minerals or grain coatings or colloidal particles of clay minerals and or organic matter. Trace elements such as Cr, Cu, Ni, Pb and Zn occur as trace constituents of primary rock-forming minerals. Also, major elements such as Al, Ca, Fe, K, Mg and Si (silicon) occur as major elements in trace minerals and in primary rock-forming minerals [21]. For example, in the basement rocks complex of Nigeria which is possibly the original source of these sediments, Cr is a constituent of Kyanite schist; and Fe, Mg, Mn, are constituents of mafic rocks (rich in ferromagnesian minerals) such as diorite, amphibolite and banded hornblende gneiss [22] and [23]. In the same vain, K, Na, Ca, Si and Al (aluminium) are major constituents of felsic rocks (rich in quartz and feldspar) such as pink granite, biotite granite, granite gneiss and rhyolite.

The metals in stream sediment/water can be from different sources which include: (1) dissolution of rock minerals and surrounding soils; (2) wet deposition from the atmosphere; (3) industrial effluent and sewage dumps; and (3) decomposing organic matter. Ni is associated with alkaline magmatic rock and silty sedimentary rock as well as agricultural waste and organic matter [18]; [24]. Cu and Cr are derived from sewage [25]; [26]. Different types of heavy metals are connected with crude oil and associated products that get into the sediment from direct dumping, surface runoffs and wet deposition from the atmosphere.

3.5 Environmental/Health Implications

The moderate energy of the flow of the river, low water volume and the mean percentage of silt/clay or mud of about 10.65% (Table 1) suggest quick re-deposition of re-suspended sediment [27]. Therefore, remobilization or resuspension of the sediment deposit via dredging or sand mining will result in minimal sediment dispersion in the water column as well as minimal impact on the aquatic ecosystem, except during heavy rainfall or storm.

The concentrations of heavy metals composition in the sediments were generally low and below Nigeria's Federal Ministry of Environment limits [28] and Department of Petroleum Resources (DPR) Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) intervention limits [29]. However, remobilization or resuspension of the sediment via dredging or mining will increase the concentration of the heavy metals in the stream water either as dissolved elements or as a constituent of suspended particles. Some of these heavy metals are injurious to human health when consumed through drinking water. According to the Nigerian Standard for drinking water quality [30], Cr^{5+} and Ni are carcinogenic, while the consumption of Cu^{+2} and Mn^{+2} can result in gastrointestinal and potential neuro-degenerative disorders respectively.

4. CONCLUSIONS

The sediments were moderately sorted, mesokurtic, near symmetrical-slightly positive skewed medium grained-sand and mineralogically composed of about 2.7% rock fragments, 5.4% hematite and 2.5% feldspar and 89% quartz. The shape of grains ranged from subangular to subrounded. These characteristics showed that the sediments were texturally and compositionally sub-matured sediments possibly sourced from Benin Formation sands of Niger Delta basin or the adjacent Bende Ameki Group of Anambra basin.

The concentration of metal elements in the sediments was generally low and can be attributed to the sediments being a second cycle reworked sediments and, lack of mineralized locations and low anthropogenic impact in the upstream areas.

The pH value indicates the sediments were deposited in an acidic environment. The recorded low Cu, Cr and TOC concentrations, as well as non-detection of Pb, suggest a low anthropogenic impact on the sediment.

Based on the fact that the maximum percentage of silt/clay or mud was about 13.2% and the energy of flow usually moderate except during heavy rainfall or storm, human remobilization or resuspension of sediment will result in minimal lateral dispersion of sediment in the water column. Therefore, dredging or mining of sand deposit in the meander section of the river will result in minimal impact on the aquatic ecosystem in the distant downstream areas, whereas in the closed areas it is expected that there will be an increase in the concentrations of suspended and dissolved compounds that affect water quality.

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REFERENCES

1. Wu, W., Zheng, H., Xu, S., Yang, J. and Liu, W. Trace Element Geochemistry of Riverbed and Suspended Sediments in the Upper Yangtze River. *Journal of Geochemical Exploration*. 2013; 124: 67-78.
2. Hazermoshar, A., Lak, R., Espahbood, M.R., Ghadimvand, N.K. and Farajzadeh, R. Geochemical, Sedimentological and Mineralogical Characterization of Surficial Sediments in Eynak Marsh (North of Iran). *Open Journalof Geology*. 2016; 6: 640-659. http://dx.doi.org/10.4236/ojg.2016.67050
3. Okoro, B.C., Uzoukwu, R. A., Chemezie, N.M. River basins of Imo State for sustainable water resource management. Journal of Civil and Environmental Engineering. 2014; 4(1): 134. doi:10.4172/2165-784X.1000134.
4. Amangabara; G. T. Drainage Morphology of Imo Basin in the Anambra –Imo River Basin Area, of Imo State, Southern Nigeria. JGEESI. 2015; 3(1): 1-11, Article no. JGEESI.17114. DOI: 10.9734/JGEESI/2015/17114
5. Short, K.C. and A.J. Stauble. Outline of geology of Niger Delta: AAPG Bull. 1967; 51: 761-779.
6. Onyeagocha, A. C. Petrography and depositional environment of the Benin Formation, Nigeria. Journal of Mining and Geology.1980; 17: 147 – 151.
7. Folk, R. L. and Ward W. C. Brazos River bar: A study in the significance of grain-size parameters: J. Sediment. Petrol. 1957; 27:3–26.
8. Friedman G. M. and Sanders J. E. Principles of Sedimentology, John Wiley & Sons, New York. 1978; 792pp.
9. Wentworth, C. K. A scale of grade and class terms for clastic sediments: J. Geol. 1922; 30:377–392.
10. Powers, M. Roundness scale. J. Sed. Petr.1953; 23: 117-110.
11. Gribble, C.D. and Hall, A.J. A Practical Introduction to Optical Mineralogy. George Allen & Unwin. (Publishers) Ltd. 1985; 249 pp.
12. Anderson, J. M. and Ingram, J. S. Tropical Soil Biology and Fertility: A handbook of methods. CAB international. Welligford, U.K. 1993; pp38.
13. Nelson, D.W. and Sommers, L.E. A rapid method and accurate method for estimating organic carbon in soil. Proc. Of the Indiana Academy of Sciences. 1975; 84: 456-462.
14. Visher, G.S. Grain Size Distributions and Depositional processes. Journal of Sedimentarypetrology. 1969; 39(3):1074-11O6.
15. Folk, R. L. Petrology of Sedimentary Rocks. Hemphill Publishing Company, Austin Texas, 78703. 1974; 190pp.
16. Amajor, L. C. Aquifers in the Benin Formation (Miocene to Recent) Eastern Niger delta, Nigeria: Lithography, hydraulics, and water quality. Environ. Geol. Water sc. 1991; 17(2): 85-101.
17 Pettijohn F.J., Potter P.E. and Siever R. Sand and Sandstone. Springer-Verlag, New York.1987; 553 pp.
18. Barałkiewicz, D. and Siepak, J. Chromium, Nickel and Cobalt in Environmental Samples and Existing Legal Norms. Polish Journal of Environmental Studies. 1999; 8(4): 201-208.
19. Krachler, R. F., Krachler, R., Stojanovic, A., Wielander, B. and Herzig, A. 2009. Effects of pH on aquatic biodegradation processes. Biogeosciences Discuss. 2009; 6: 491–514. www.biogeosciences-discuss.net/6/491/2009/
20. Mei, F.F., Chuan, O. M. and Ling, L. C. Determination of Total Organic Carbon Concentration in Surficial Sediments of Sungai Juru and Sungai Tengah, Penang, Malaysia. Middle-East Journal of Scientific Research. 2016; 24 (4): 1470-1476. DOI: 10.5829/idosi.mejsr.2016.24.04.23468
21. Meyer, W.T., Theobald, P.K., Jr., Bloom, H., Stream Sediment Geochemistry; !!!: Geophysics and Geochemistry in the Search for Metallic Ores; Peter J. Hood, editor; Geological Survey of Canada, Economic Geology Report. 1979; 31: 411-434.
22. Rahaman, M. A. Recent Advances in the study of the Basement Complex of Nigeria. In: Oluyide, P. O., Mbonu, W. C., Ogezi, A. E., Egbuniwe, I. G., Ajibade, A. C. and Umeji, A.C., (eds). Precambrian Geology of Nigeria, G.S.N.1988; 11-41.
23. Rahaman, M.A. Review of the Basement Geology of South Western Nigeria. In: Kogbe, C. A. (ed) Geology of Nigeria. Elizabethan Pub. Co. Lagos.1976; 41-58.
24. ATSDR. Agency for Toxic Substances and Disease Registry (ATSDR). 2005.
25. Barceloux, D.G. Chromium. Journal of Toxicology. Clinical Toxicology.1999; 37:173-194.
26. Fernandes, H.M. Heavy Metal Distribution in Sediments and Ecological Risk Assessment: The Role of Diagenetic Processes in Reducing Metal Toxicity in Bottom Sediment.

Environmental Pollution, 1997;97:317-325. http://dx.doi.org/10.1016/S0269-7491(97)00004-3
27. Sahu, B.K. Depositional Mechanisms from the Size Analysis of Clastic Sediments. *Journal of Sedimentary Petrology*. 1964; 34:73-83.
28. FEPA. Federal Environmental Protection Agency. National Interim Guidelines and Standards for Industrial Effluent, Gaseous Emissions and Hazardous Waste Management in Nigeria. 1991.
29. DPR. Environmental Guidelines and Standards for The Petroleum Industry In Nigeria (EGASPIN), issued by the Department of Petroleum resources (DPR), Lagos. 2002; 415pp
30. NIS. Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard, NIS 554., Standard Organization of Nigeria (SON). 2007; 30pp.