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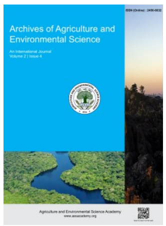

ORIGINAL RESEARCH ARTICLE

CrossMark

Impacts of sediment mining on the hydrochemistry and macrozoobenthos community in a coastal lagoon, Lagos, Nigeria

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ABSTRACT

The water chemistry and macrozoobenthos assemblage of ten study stations in the Lagos lagoon were studied from December 2016 to May 2017 to assess the impacts of sediment mining on the water quality and the biological indices of the macrozoobenthos. Water and composite benthic samples were collected monthly at each study station and analysed in the laboratory following standard procedures. Except temperature, pH, TSS, salinity and conductivity showed no significant ($P>0.05$) difference, while the other parameters were not significantly ($P<0.05$) different among the stations. The sediment grain size analysis of the study area indicated the dominance of sand in sediment. This could be as a result of the dredging of the study area as Lagos lagoon is originally known to have muddy substratum. A total of 1,237 organisms belonging to 3 phyla, 4 classes, 10 families and 10 Species were recorded during the study period. Analysis of benthic community structure of the study area reveals a community dominated by mollusks, with the Bivalve, *Aloides trigona* contributing 54% and the gastropod, *Pachymelania aurita* contributing 33% of the total benthic fauna assemblage during the period of study. The fluctuations in the physicochemical parameters, sediments, and the composition, abundance and diversity of the macrobenthic fauna of the study area were largely influenced by the anthropogenic activities. In particular, stations with pronounced sediment mining activities recorded highly turbid water, changed substratum type and defaunisation.

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INTRODUCTION

The act of sediment mining has serious environmental implications on the estuarine ecosystem. In the Lagos lagoon, the incessant sediment mining with its associated contaminant upload threatens the ecosystem services that the benthic fauna provide (Sogbamu *et al*., 2016). The survival of the benthic organisms is hampered owing to sediment plume, and the change in the chemical characteristics of the water column will impact negatively on the activities of the photosynthetic microphytes. As a result of the increase in suspended sediments produced by mining activity, planktotrophic and lecithotrophic larvae of benthic organisms would be buried by the settling sediment particles from overlying water (Nuttall and Bielby, 1973). Habitat distortion and removal of sediment top would lead to erosion of the epifauna and ultimately, to loss of biodiversity. Sediment mining, in addition to the direct physical disturbance of the habitat, often produces long range impacts on communities downstream which are not in the immediate sphere of activity. The impact of suspended solids on benthic fauna has long been studied. High levels of turbidity as well as siltation as a result of sand mining are known to have negative effects on species diversity (Chutter, 1969).

Benthic fauna perform a variety of roles that are essential for the proper functioning and health of the aquatic ecosystem (Wallace and Webser, 1996). The benthic secondary production serves as natural food source to pelagic and bentho-pelagic community. They accelerate detrital decomposition (Van de

Bund *et al*., 1994, Wallace and Webster, 1996) thereby making food available for the detrital and deposit feeders. The benthic fauna also release bound nutrients into solution by feeding activities, excretion and burrowing into the sediment (Covich *et al*., 1999). Benthic fauna play key roles in the cycling of nutrients and controlling nutrient outflows from the ecosystems by transforming organic detritus from sedimentary storage into dissolved nutrients (Barnes and Hughes, 1988; Covich, 1999).

The distribution of benthic communities is not continuous but patchy and influenced by several factors such as food distribution, environmental impacts, water flow and quality, dissolved oxygen and sediment stability. Biogeochemical processes that take place in the sediment create significant horizontal and vertical heterogeneities in the substrata that provide a physical template for distinct niches (Covich *et al*., 1999). According to Teixeira *et al*. (2012), sediment characteristics have great influence on the spatial structure of benthic assemblages. Recently, sediment mining has become more intense in the Lagos lagoon and its adjourning water bodies. The construction industry has created huge opportunities in the area of sediment mining for both skilled and unskilled labour in Lagos. Sand dredging in some places has been largely responsible for the loss of breeding habitats for sea turtles, which depend on sandy beaches for their nesting. Sediment mining could also permanently alter and destroy marine habitats, breeding, spawning and feeding areas of fish stock both within the mined area and surrounding area, raised turbidity impacting on many species, increased organic fallout causing oxygen depletion and die off, burial and smothering of seabed organisms in the mining and surrounding areas. This study seeks to investigate the effects of sediment mining on the hydrochemistry and the benthic macrofauna community of the coastal lagoon of Lagos, Nigeria.

MATERIALS AND METHODS

Study area

The study area (Figure 1) is located between latitude 6° 26' N and 6°38' N longitude 3° 23' E and 3° 43'E and is a major part of the barrier-lagoon complex of the Nigerian coastal zone. The barrier-lagoon complex extends eastwards for about 200km from the Nigerian-Benin Republic border to the western limit of the Transgressive Mud Coast and covers an area of about 208 km^2 (FAO, 1981). The Lagos lagoon empties into the Atlantic Ocean at the Lagos Harbour. The Lagos lagoon is a great expanse of shallow waters and is generally between 0.5 – 2 m deep in most parts but more is more than 5 m in some dredged parts of the lagoon. The interconnecting creeks are also very shallow and are sites of active silting and deposition of mud. The lagoon sediments range between mud, sandy mud, muddy sand, and sand (Ajao and Fagada, 1991). Ten sampling stations were selected for this study along the north-western axis of the lagoon taking into consideration, the extent of sediment mining and dredging and its ecological impacts on the coastal lagoon. The exact locations of the stations were determined with the aid of the global positioning system (GPS).

Collection and analysis of samples

Water temperatures, dissolved oxygen (DO) and total dissolved solids (TDS) were measured *in-situ* at every sampling station with mercury in glass thermometer, hand held LaMotte DO Meter (DO 6 PLUS) and LaMotte TDS Meter (TDS 6 PLUS) respectively. Water samples were collected at stations at subsurface level in ldm^3 sterile capped containers following the methods described by APHA (2005). Sampling bottles were kept in large, airtight plastic ice-cold cooler at 4°C and were transported to standard laboratory for analysis. The pH, conductivity, turbidity and salinity were measured in the laboratory with water quality checker (Horiba-U10). Separate water samples were collected in 250 ml dissolved oxygen bottles at each station and incubated in a dark cupboard for five days for completion of 5day biochemical oxygen demand determination as determined by APHA (2005).

Monthly composite benthic samples were collected with the use of Van-Veen grab (0.25 m^2) at each study area. Part of the sample for each study station was preserved in an aluminium foil paper for sediment grain size analysis in the laboratory. The remaining samples were sieved through 0.5 mm sieve. The materials retained on the sieve were stored in plastic container and preserved in 5% formalin for further analysis. The fixed samples were transported to the Benthic Ecology Laboratory in the Department of Marine Sciences, University of Lagos for analysis. Sorting of the samples was done with the aid of a handheld magnifying lens to get the clean samples of the macrozoobenthos. The sorted macrozoobenthos were counted and identified to species level where possible, and the numbers recorded. Identification of the benthic macrozoobenthos was done after Edmunds (1978), Barnes (1980), Fischer *et al*. (1981), Hayward and Ryland (1995) and Yankson and Kendall (2001).

Analysis of data

The statistical package for social sciences (SPSS11.0) Windows application and Microsoft Excel were adopted for the data analyses. Analysis of variance was calculated for the physicochemistry across study stations while PAST statistical program was used to compute the biological indices such as Margalef's index for species richness, Shannon–Wiener and Simpson's indices for species diversity, and the Equitability index for evenness of the community. The diversity indices were computed following description by Ogbeibu (2005) as follows.

Margalef's species richness index

The Species richness index (d) was used to evaluate the community structure. The equation below was applied and results were recorded to two decimal places.

$$d = \frac{S-1}{\ln N}$$

Where:

d = Species richness index;

S = Number of species in a community;

N = Total number of individuals in species.

Shannon and Wiener diversity index (H)

Shannon and Wiener diversity index (H) is given by the equation:

$$Hs = \frac{NlogN - \sum PilogPi}{N}$$

Where:

Hs = Shannon and Wiener Diversity Index

i = Counts denoting the *ith* species ranging from *i* –*n*

Pi = Proportion that the *ith* species represents in terms of numbers of individuals with respect to the total number of individuals in the sampling space as whole.

Species equitability or evenness index

Species Equitability or Evenness index (j) (Ogbeibu, 2005) was used to calculate how evenly the species are distributed in a community. It is determined by an equation.

$$J \frac{Hs}{log_2 S}$$

Where:

J = Equitability index;

Hs = Shannon and Wiener index;

S = Number of species in a community;

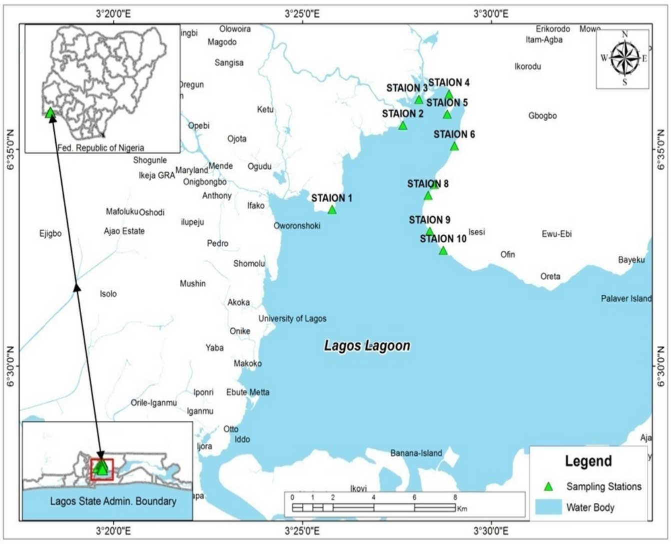

Figure 1. *Map of the Lagos Lagoon showing study sites.*

Table 1. Sampling locations and their coordinates.

Station no.	Location	Average depth (m)	Coordinates
1	Agboyi	2.2	Latitude N 06° 33' 37.0'', Longitude E 003° 25' 47.4''
2	Magidun entrance	11.1	Latitude N 06° 35' 33.8'', Longitude E 003° 27' 40.4''
3	Magidun II	4.0	LatitudeN 06° 36' 09.4'', Longitude E 003° 28' 05.3''
4	Ogolonto	2.7	LatitudeN 06° 36' 16.9'',Longitude E 003° 28' 53.4''
5	NPA	1.6	LatitudeN 06° 35' 49.0'', Longitude E 003° 28' 50.4''
6	Ibeshe	10.2	LatitudeN 06° 35' 05.1'', Longitude E 003° 29' 02.0''
7	Owode Ilaje	3.3	LatitudeN 06° 34' 11.6'',Longitude E 003° 28' 30.1''
8	Ofin I	3.1	LatitudeN 06° 33' 56.6'',Longitude E 003° 28' 20.3''
9	Ofin II	3.7	LatitudeN 06° 33' 06.8'', Longitude E 003° 28' 22.7''
10	Oreta	14.0	LatitudeN 06° 32' 40.6'',Longitude E 003° 28' 44.2''

Simpson's dominance index

Simpson's dominance index (C) (Ogbeibu, 2005).

$$C = \sum(\frac{ni}{N})^2$$

Where:

C = dominance index;

n = the total number of organisms of a species;

N= the total number of organisms of all species.

RESULTS AND DISCUSSION

Hydrochemistry

The mean values of the physico-chemical parameters in water measured at the study stations during the period of study are shown in Table 2. The spatiotemporal variations in the values of major parameters measured during the study are represented in Figures 2-9. The relatively high salinity and conductivity values recorded in all the study stations are indicative of the season of study. Nwankwo (1994) has classified the hydrological season in Nigeria into two; the dry season (November to April) and the rainy season (May to October). The period of the current study falls into the category of the dry season. The high evaporation of the surface water and the reduction in the introduction of fresh water through precipitation or run-off, could have contributed to the high values in salinity, conductivity and total dissolved solids in the study area (Nkwoji *et al*., 2010).

The mean values of the water temperatures and pH across the study stations showed very little or no variations (Table 2). This agrees with Nkwoji (2016) that surface water temperature in the Tropics is conservative and could only vary significantly with seasons. The pH range of the water (6.48 to 7.00) was also conservative (Nkwoji *et al*., 2010). There was no significant ($P<0.05$) difference in the pH values at the study stations (Table 2). Such study stations as Majidun Entrance (Station 2), Ibeshe (Station 6) and Oreta (Station 10) recorded higher turbidity and total suspended solids (TSS). These stations are areas of high level of dredging and sediment mining. Stations 2 and 6 also recorded lower dissolved oxygen values. This could be attributed to the reduction in photosynthetic activities as a result of increase in the concentration of suspended particulate matters in the water (Edokpayi and Nkwoji, 2007). In general, the dissolved oxygen concentrations across the stations are not below of 5.0 mg/L

Table 2. The Mean±SD of the physico-chemical parameters of water sample in the study area.

Parameters	Agboyi	Magidun Entrance	Magidun II	Ogolonto	NPA	Ibeshe	Owode Ilaje	Ofin I	Ofin II	Oreta	
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	P. stat
Water temp. (°C)	30.67±1.37	30.83±0.98	30.67±0.82	30.67±0.82	30.50±1.22	30.67±1,86	30.33±1.37	30.67±1.37	30.83±1.17	30.67±0.82	*P>0.05*
pH	6.77±0.33	6.48±0.17	6.95±0.28	6.75±0.19	6.88±0.20	6.60±0.24	6.92±0.17	6.75±0.08	6.73±0.12	7.00±0.22	*P>0.05*
Salinity (ppt)	12.48±3.90	12.70±3.34	13.13±4.52	12.58±3.65	12.82±4.99	13.35±4.29	12.47±5.68	13.85±3.94	15.62±5.28	15.30±6.79	*P>0.05*
Conductivity (µS/cm)	14.17±3.33	9.42±1.02	13.20±3.94	9.77±2.27	14.03±2.58	11.30±2.00	13.53±2.48	11.37±2.02	10.33±2.25	13.33±3.08	*P>0.05*
Turbidity (mg/L)	9.50±1.05	11.33±0.82	7.50±2.07	8.00±0.89	8.50±1.76	11.17±1.60	7.00±1.79	8.00±1.67	6.62±2.25	10.98±0.96	*P<0.05*
TSS (mg/L)	9.17±1.17	10.00±2.76	9.83±4.75	10.17±5.27	7.00±2.97	10.83±3.82	9.42±2.15	12.17±2.93	12.10±5.36	11.25±4.26	*P>0.05*
TDS (mg/L)	12.23±1.72	10.05±0.76	11.13±1.55	11.92±0.59	11.83±1.20	9.78±1.00	11.28±0.62	9.90±0.57	12.53±1.56	11.65±1.25	*P<0.05*
DO (mg/L)	5.85±0.52	5.43±0.20	5.98±0.21	6.42±0.08	6.60±0.06	5.82±0.15	6.57±0.19	6.35±0.12	6.53±0.27	6.63±0.33	*P<0.05*
BOD (mg/L)	7.72±0.56	7.70±0.63	8.58±1.93	6.48±1.22	7.42±0.45	6.02±0.78	6.55±0.67	5.07±0.47	5.23±0.59	7.27±0.63	*P<0.05*

Table 3. Spatial variation in ecological indices of samples collected at the study stations.

	Agboyi	Magidun Entrance	Magidun 2	Ogolonto	NPA	Ibeshe	Owode Ilaje	Ofin 1	Ofin 2	Oreta
Total species diversity (S)	4	4	4	3	5	5	4	3	5	3
Total abundance (N)	189	205	90	48	323	62	61	74	75	110
Shannon-Wiener index (Hs)	0.46	0.38	0.42	0.22	0.41	0.51	0.48	0.14	0.42	0.28
Margalef index (d)	0.57	0.75	0.67	0.52	0.69	0.97	0.73	0.46	0.93	0.43
Equitability index (j)	0.76	0.55	0.70	0.47	0.59	0.73	0.79	0.30	0.60	0.58
Simpson's dominance index (C)	0.40	0.56	0.43	0.74	0.53	0.37	0.39	0.85	0.46	0.65

stipulated as minimum level for normal aquatic life by Federal Ministry of Environment of Nigeria (Odiete, 1999). The analysis of variance showed significant (*P<0.05*) differences in the values of turbidity and dissolved oxygen in the study stations. Although the analysis of variance indicated no significant (*P<0.05*) difference in total suspended solids values among the study stations, the Post Hoc Tests of Multiple Comparison showed significant (*P<0.05*) difference in TSS values between Stations 2, 6 and 10 on one side, and the other stations on the other side.

Sediment grain size analysis

The mean spatial variation in sediment grain size of the study area is presented in the Figure 9. The sediment particle is dominated by sand grains. This is at variance with previous studies on the sediment type of the Lagos lagoon. Ajao and Fagade (1991) and Nkwoji *et al.* (2011) worked on the sediments of Lagos lagoon and posit that the lagoon has predominantly muddy sediment. The dredging of the lagoon, and the indiscriminate mining of the muddy top substratum, and the consequent exposure of the sandy, subsurface substratum may be responsible for the change in sediment characteristics. The only study station that has higher percentage of its sediment composition as mud is Station 10. The station was highly dredged and relatively deeper that the other stations. Siltation from the surrounding shallower mud substrates may have resulted in muddy top sediment recorded. The most obvious effect of sediment mining on the water quality of any water body is the suspension of sediment particles in the water column and these results to increased turbidity.

Macrobenthic community structure

The community structure of the macrozoobenthos sampled during the period of study is presented in Table 3. Species abundance was highest in Station 5 (NPA), Station 1 (Agboyi) and Station 9 (Ofin2) study stations while number of individuals sampled was highest in Station 5 and least in Station 4 (Ogolonto). The general low abundance in macrozoobenthos assemblage could be attributed to habitat distortion and destruction occasioned by the dredging of the lagoon and indiscriminate sediment mining in the study area. The maximum species diversity and richness indices, 0.51 and 0.97 respectively, recorded in this study are very low compared to what have been reported previously from the Lagos lagoon and some other coastal waters in Nigeria (Yakub and Igbo, 2014; Nkwoji *et al.*, 2010; Edokpayi and Nkwoji, 2007).

The percentage contribution of taxa to the overall macrozoobenthos community is presented in Figure 10. The bivalve mollusc, *Aloides trigona* contributed the highest (54%), followed by the gastropod mollusc, *Pachymelania aurita* (35%). The polychaetous annelids, *Capitella capitata* and *Nereis* sp., the crustacean, *Clibanarius africanus* and *Sersama huzerdii*, and the bivalve *Crassostrea gazar*, contributed less than 1% each to the benthic macrofauna sampled during the period of study. The very low abundance of the crustaceans in this study could be indicator to the stressed nature of the study area. Nkwoji *et al.* (2016) have identified the crustacean species as sensitive to stressed environment.

The spatial percentage contribution and to the overall benthic macrofauna assemblage in the study area is represented in Figure 11. The relatively high abundance of the benthic organisms recorded in Station 5 could be attributed to the fact that this station was restricted from the indiscriminate sediment mining prevalent in the study area. Although Station 9 recorded lower numeric abundance, the diversity and richness indices are relatively high. Stations 1 and 5 recorded relatively high species and numeric abundance. The stations also recorded high diversity and richness indices. There were no activities of dredging and sediment mining in these study stations as at the period of this research.

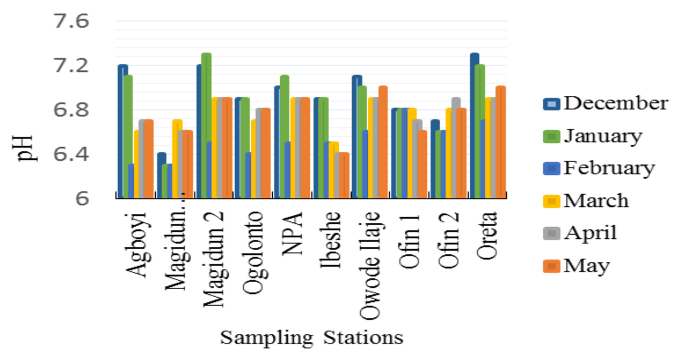

Figure 2. *Spatiotemporal variation in pH values.*

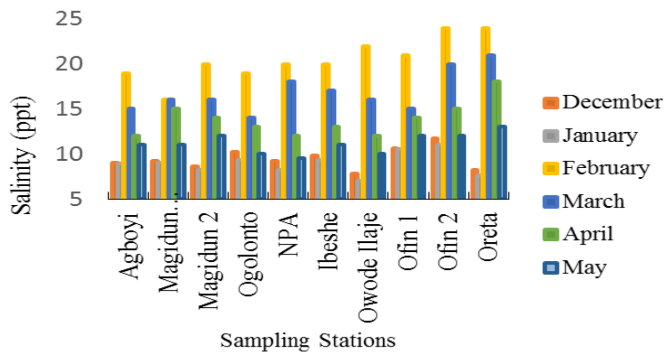

Figure 3. *Spatiotemporal variation of salinity.*

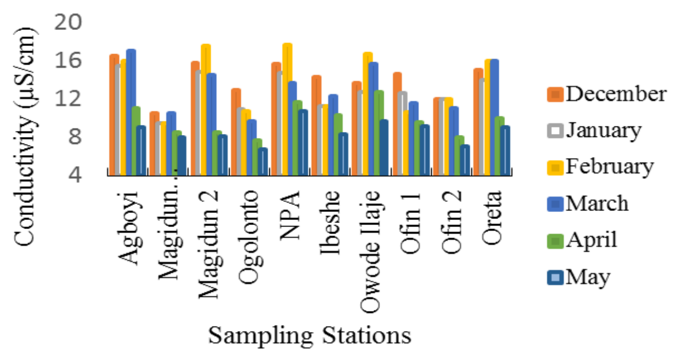

Figure 4. *Spatiotemporal variation in conductivity*

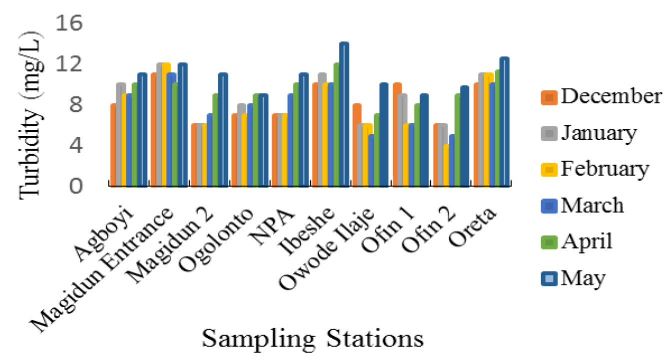

Figure 5. *Spatiotemporal variation in Turbidity*

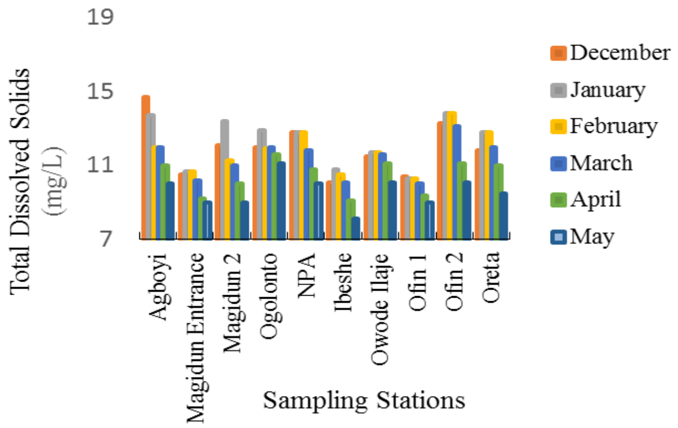

Figure 6. *Spatiotemporal variation of total dissolved solids.*

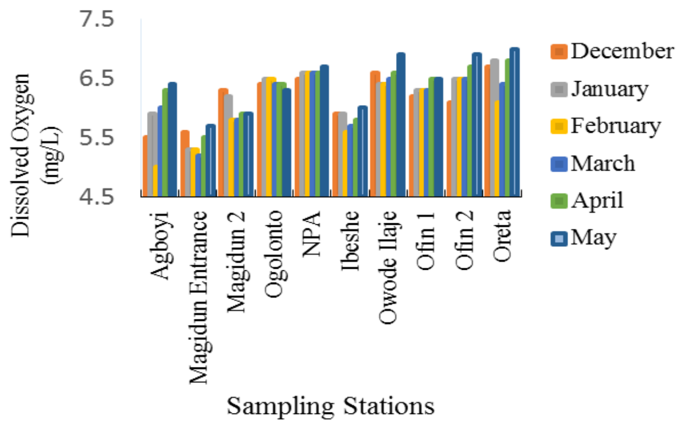

Figure 7. *Spatiotemporal variation of dissolved oxygen.*

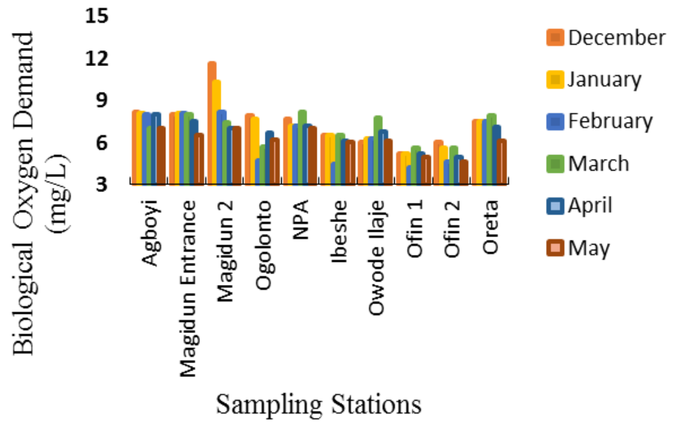

Figure 8. *Spatiotemporal variation of biological oxygen demand .*

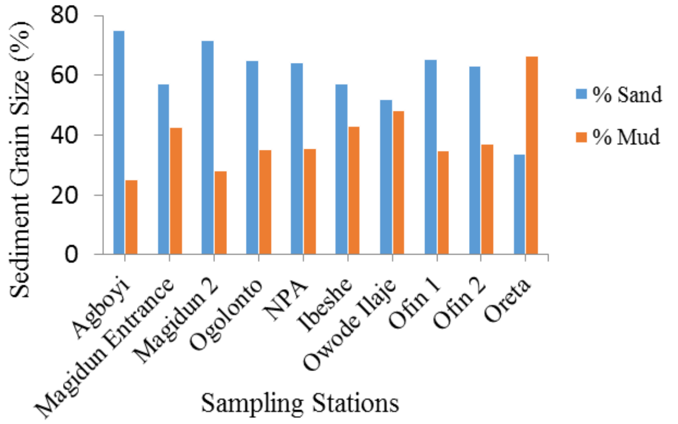

Figure 9. *Mean spatial variation of sediment grain size.*

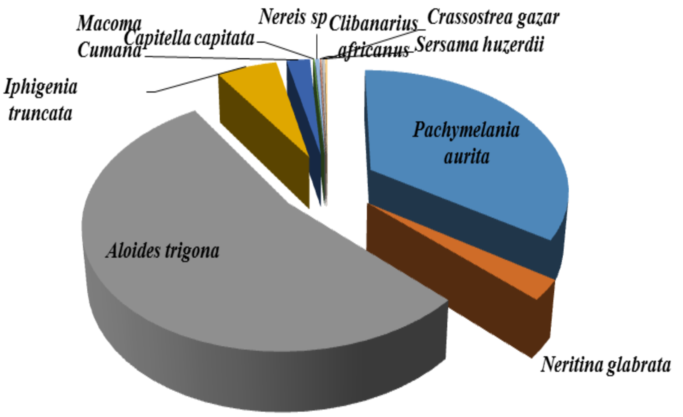

Figure 10. *Taxa contributions to the overal macrobenthic fauna.*

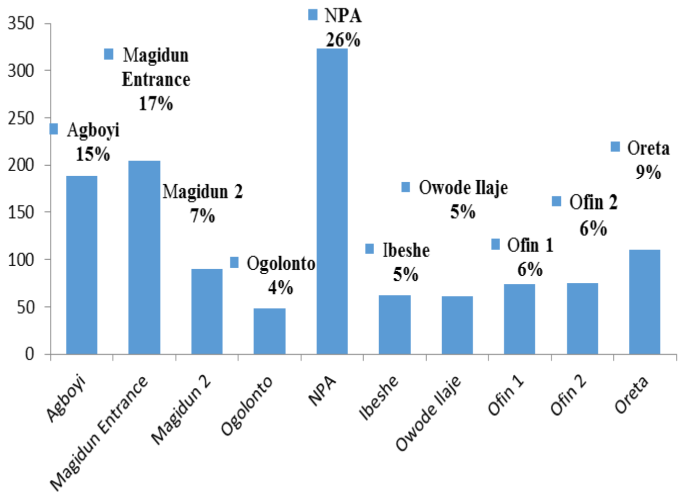

Figure 11. *Spatial percentage distribution of benthic macrofauna.*

Conclusion

The sediment mining increases the turbidity of the water and reduces the photosynthetic layer. Consequently, the dissolved oxygen of the water would reduce. Furthermore, the general physicochemical characteristics of the water would be altered and the health of the aquatic biota hampered. The benthic fauna are the worst hit. Their habitat is distorted and destroyed leading to defaunisation. Also, their pelagic larvae are buried by the settling sediment particles, leading to poor recruitment of the benthos. The role of the benthic fauna in the aquatic ecosystem cannot be over-emphasised. They are needed for a balanced energy transfer in the food web and their existence must be guaranteed by ensuring healthy water because their distribution and diversity correlate with the water quality. The benthic ecologists posit that the macrozoobenthos are reliable indices for assessing the stability and health of the aquatic ecosystem. The impact of sediment mining the water chemistry and the benthic fauna of Lagos lagoon is grave. There should be regulations backed with enforcements against this menace. Since the benthic fauna are the worst affected by this act, benthic studies should be intensified on the lagoon to buttress the negative impact and forestall the total collapse of this coastal body of water.

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