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Benthic macroinvertebrate community and chlorophyll a (chl-a) concentration in sediment of three polluted sites in the Lagos Lagoon, Nigeria

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ABSTRACT: This paper reports the benthic macroinvertebrate community and chlorophyll a (chl-a) concentration in sediment of three polluted sites in the Lagos Lagoon, Nigeria. Values observed for DO ranged between 3.0 and 4.5 mg/L, while transparency varied from 3 cm to 32 cm. Turbidity ranged between 28 and 80 NTU and depth of the study stations fluctuated between 196.16 and 317.5 cm. Two major macroinvertebrate groups (Annelida and Mollusca) made up of eight species were identified from a total density of 7820 ind/m^2. Mollusca were the most abundant group with a density of 7800 ind/m^2 and accounted for 99.7 % of the total macroinvertebrate density. Density of benthic macroinvertebrate varied among the study stations, while the variations observed in the values ofchl-a in sediment were mainly in relation to sampling periods. Transparency of water correlated positively and significantly with chl-a in sediment (r_s= 1; p< 0.01) while turbidity and depth of water related negatively and significantly with chl-a in sediment. Results obtained in this study suggest that pollution in the three study sites impacted negatively on the benthic community. © JASEM

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***Key Words*:** Chl-a, benthic macroinvertebrate, pollution, estuarine ecosystem

Ecological consequences of damage to the aquatic environment are becoming increasingly evident (Nybakken, 1988; Ajao, 1996; Scot, 2005; Steigerwalt, 2005). Unless the aquatic systems are carefully protected, their function and economic potential cannot be sustainable. The aquatic ecosystem is one of humanity's most precious assets and it constitutes more than 71% of the earth's surface and are the greatest sources of biodiversity, containing 90% of the biosphere (Scot, 2005) and they play key role in climate and weather patterns. They also contribute to economic prosperity, social wellbeing and quality of life and are literally a source of survival for coastal communities. However, aquatic systems are under intense pressure, the pace of degradation of biodiversity and habitats; the level of contamination by dangerous substances and the emerging consequences of climate change are some of the most visible warning signals (Nybakken, 1988; Scot, 2005).

Numerous industrial and domestic wastes find their way into the Nigerian Coastal aquatic systems. According to Portmann *et al.* (1995), an estimated 10,000m^3 of industrial effluents are discharged into the Lagos Lagoon system per day. In addition, owing to seasonal distribution of rainfall, the lagoon system and creeks experience seasonal flooding which introduces a lot of detritus, nutrients as well as pollutants from land. Such pollutants arising from land based activities include domestic and industrial effluents, urban storm run-off, agricultural land run-off, sediment and contaminants from garbage and waste dump (Portmann *et al.,* 1995). The most notable point source arises from the dumping of untreated or partially treated sewage, and discharge of bio-degradable wood wastes from sawmill located along the stretch of the lagoons ((Nwankwo and Akinsoji, 1989). Wood shavings and leachates are sources of inert solids as well as toxic pollutants that directly clog gills of aquatic animals and indirectly reduce light penetration which limits productivity.

Contamination of the aquatic environment, makes aquatic organisms vulnerable ((Nybakken, 1988; Scot, 2005). Aquatic organisms especially the benthic community, are impacted by pollutants primarily as a result of changes in primary production and in the chemistry of water column and sediment. These changes potentially lead to reduced diversity and abundance, shifts in community composition, physiological changes and mass mortality. The sensitivity of benthic organisms to conditions of pollution varies with individual organisms due to differences in feeding habits, mobility, and life cycle (Rosenberg and Resh, 1993). As a result, measures of the structure of the communities can be used to assess the impacts of pollution on aquatic ecosystems (Rosenberg and Resh, 1993).

Benthic organisms are widely accepted as useful indicators for assessing impacts of pollution in aquatic ecosystems. The major advantages of using benthos in biological assessment have been summarized by a number of authors (Hellawell, 1989; Rosenberg and Resh, 1993).Benthic community consists of many representatives from a wide range of orders. It is

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assumed that such a range of species provides sufficient probability of sensitive species being present; spatial and temporal mobility of species is quite restricted, hence they can be considered as inhabitants of the aquatic system under investigation; organisms integrate environmental conditions over longs periods of time. In addition, benthic community forms very important links in the aquatic food chain. Benthic microalgae (as represented by chlorophyll *a*) are of great ecological importance contributing considerably to primary productivity. Chlorophyll *a* (chl-a) has been used as a parameter for the measurement of algal standing crops in productivity studies of aquatic systems (Schubert *et al*, 2005). The pigment content of living algal populations is influenced by environmental factors (Coljin and Dijkema, 1981; Sun *et al*., 1994; Murphy *et al*., 2008), and over a period of time, succession of species or changesin nutrient status may result in changes in the ratio of pigment to organic matter in sediment material.

The Lagos Lagoon has received a lot of research attention, however, most of the studies carried out, are mainly on the determination of the pollutant load in water and sediment. Studies focusing on biota of the polluted sediment are scarce, where they exist interest has mainly being on fauna. In this study, both fauna and flora of the polluted sediment were investigated to determine the biotic composition especially with respect to macroinvertebrates and chl-a in three selected sites, with a view to ascertaining the level of impact on the benthic community

MATERIALS AND METHODS

Description of study area: Lagos Lagoon (Fig. 1) is located in the heart of Lagos, occupying the southern part of the metropolis. It is bounded by the Atlantic Ocean in the west and south through the Lagos Harbour, and connecting with Lekki and Epe Lagoons in the east. It is about 6,354.788sq km in area and 285 km in perimeter. It is generally between 0.5 - 2 m deep in most parts with a maximum of about 5 m in the main lagoon and 25 m in some dredged parts of the Lagos Harbour. The lagoon serves as means of recreation, transport, and a major disposal channel for residential and industrial discharges.

A large percentage of the industries in Nigeria are located in Lagos State and they all discharge their effluents directly or indirectly into the Lagos Lagoon. Most of the effluents discharged are untreated as many of the industries do not have treatment plants. In addition to wastewater from industries, domestic sewage, garbage and wood shavings from sawmill depots are also discharged into the lagoon. The proliferation of urban and industrial establishments along the shores of the lagoon has resulted in a complex mix of both domestic and industrial wastes which eventually find their way into the lagoon (Ajao, 1996).

Apart from waste discharged into the lagoon, Lagos Lagoon is also faced with a lot of pressure resulting from human activities such as; sand filling, dredging, sand mining, general habitat destruction and unregulated fishery exploitation. These have resulted in the reduction of biodiversity in the lagoon as reported in previous studies (Nwankwo and Akinsoji, 1989).

Three study stations (Figure 1; Table 1) located at major polluted sites were selected for this study. Station 1 was at Okobaba ($6^{o}34'24''$N and $3^{o}31'52''$E), this part of the lagoon is known for the deposition of wood waste which is indiscriminately released into the lagoon. Station 2 was located at the Iddo ($6^{o}47'36''$N and $3^{o}27'29''$E) area of the lagoon, which is a sewage dump site. Station 3 was at the Tin Can Island Port slightly adjacent the Lagos Harbour ($6^{o}52'19''$N and $3^{o}43'41''$E), pollutants here include; oil and related products from shipping and associated human activities.

Fig.1. Lagos Lagoon showing the study stations.

Sample collection: Transparent and amber coloured reagent bottles (250 ml) were used for the collection of water samples used for the analysis of Dissolved oxygen (DO). Depth of study stations was measured using a graduated wooden pole while water transparency was determined using a 20 cm diameter Secchi Disk painted black and white. Turbidity of water samples was determined according to the methods described in APHA (1998). From each station, samples of benthic macrofauna were taken in three replicates with a van Veen grab of 0.1 m^2 in area. Samples were washed through a sieve of 0.5 mm mesh size and organisms retained by the sieved were collected in sample containers and preserved with 10 % formaldehyde solution *in situ*. Samples of sediment for chl-a analysis were collected in BOD bottle and resuspended with water from the site.

Sampleanalysis: In the laboratory fixed benthic samples were washed with tap water to remove the fixative and any remaining sediment and other debris for easy sorting. The animals were sorted into different taxonomic groups using suitable identification manuals including Edmunds (1978) and Barnes *et al*., (1988). The numbers of taxa and individuals for each station were counted and recorded for all the sampling months. Chlorophyll samples were filtered through Whatman GF/F filters and extracted in acetone in the dark and under refrigeration (Holm-Hansen, 1978; Daemen, 1986). Chlorophyll *a* was determined fluorometrically.

Statistical analysis: One-Way analysis of variance (ANOVA) was used to determine variations in environmental conditions at the study stations. When significant variations are detected, a *post hoc test* using Duncan New Multiple Range Test (DMRT) in the case of physico-chemical variables and Turkey's Test in the case of biotic variables were performed to determine the locations of significant differences. The following ecological parameters were assessed to describe the structure and composition of benthic macroinvertebrates; density = number of individuals per 0.1 m^2 (ind/m^2), diversity = number of species of benthic macroinvertebrates.

Table1: GPS coordinates of polluted sites in the Lagos lagoon

Stations	N-coordinates	E-coordinates	Major pollutant
Okobaba	$6^0 34'24''$	$3^0 31'52''$	Wood waste
Iddo	$6^0 47'36''$	$3^0 27'29''$	Faeces
Tin can	$6^0 52'19''$	$3^0 43'41''$	Oil, grease

RESULTS AND DISCUSSION

Environmental factors: Summary of environmental conditions in the polluted sites is presented in Table 2. Values observed for DO was highest in station 1 (4.5 mg/L) and lowest in station 2 (3.0 mg/L). Mean values of DO recorded for three stations were; 3.8 mg/L for station 1, 3.42 mg/L in station 2, and 3.4 mg/L in station 3. Water transparency was highest in station 1 where a range of 3 – 6 cm and a mean value of 88.8 cm were recorded. In station 2, the value of transparency varied between 9.3 and 32 cm and a mean of 23.46 cm was observed. Transparency in station 3 was lowest, ranging between 8 and 23 cm with a mean value of 14 .0 cm.

In contrast to the pattern displayed by transparency, turbidity values were lowest in station 1 and highest in station 3. In station 1, a range of 28 – 80 NTU and a mean value of 50.85 NTU were recorded, while values observed for stations 2 and 3 ranged from 10 to 70 NTU (mean = 54.5 NTU) and between 3 and 180 NTU (mean = 69.67 NTU) respectively were recorded. The depth of the study stations varied directly with the turbidity. While a mean depth value of 173.16 cm was measured in station 1, higher values of 196.16 cm for station 2 and 317.5 cm for station 3 were recorded.

The values of water quality parameters reported in this study are obvious reflection of the degraded state of the polluted sites. Lagos Lagoon sediment is dominated by an increasing accumulation of organic materials. This can be associated with the high organic matter discharge from diffuse sources. Several studies (Nwankwo and Akinsoji, 1989; Ajao and Fagade, 1991; Ajao, 1996; Oyewo, 1998; Brown, 2000) have shown that the sediment of the lagoon is laden with different degrees of pollutants which alter the original composition and render it unfit for habitation by benthic organisms. The study sites were charactrised by low water transparency, high turbidity and low DO (range 3.0 – 4.5 mg/L) as shown in the results. These conditions largely accounted for the low species richness and diversity as well as the poor chl-a composition recorded in the sediment at the polluted sites as observed in subsequent sections of this study.

Table 2: Summary of environmental conditions of study sites

	1			2			3		
Parameter	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
Dissolved oxygen (mg/L)	3.4	4.5	3.8±0.42	3.0	4.0	3.42±0.34	3.1	4.3	3.4±0.5
Transparency(cm)	3	60	88.8 ± 24.54	9.3	32	23.46 ±9.06	8	23	14.0 ± 5.78
Turbidity (NTU)	28	80	50.85 ± 18.98	10	70	54.5 ±75.42	3	180	69.67 ± 58.54
Depth (cm)	83	96	173.16± 147.07	96	365	196.16± 94.21	131	570	32.5±18.92

Community structure and spatio-temporal variations in density and diversity of macroinvertebrates: Two major macroinvertebrate groups (Annelida and Mollusca) were identified from a total density of 7,820 ind/m^{2}recorded in the study area. Mollusca was the most abundant group with density of 7800 ind/m^2 (comprising 65 % gastropoda and approximately 35 % of bivalves) and accounted for 99.7 % of the total macroinvertebrate density. It was represented by 2 classes, 4 families and 7 species. Among the molluscs observed, the estuarine gastropod *Pachymelania aurita* was the most abundant with a density of 2540 ind/m^2 and accounted for 33 % of molluscan population. Also significantly represented in the Molluscan group is another estuarine gastropod *Tympanotonus fuscatus* which accounted for 23.2 % (density 1810 ind/m^2) of mollusc population. Other gastropods recorded include *T. fuscatus* var *radula* (7 %; 540 ind/m^2) and *Neritina glabarata* (1 %; 80 ind/m^2). Among the bivalves *Tellina nymphalis* (13 %; 990 ind/m^2) dominated in abundance while *Aloides* sp (11 %; 840 ind/m^2) ranked second and *Macoma cumana* constituting 10.89 % with a population density of 820 ind/m^2 was the least contributor. Annelida was represented by 20 specimens (constituting 200 ind/m^2) of *Nereis lamellose* and accounted for 3% of the total benthic macroinvertebrate population.

Table 3: Variation in benthic macroinvertebrate taxa composition in the polluted sites

Taxa	Study stations					
	1		2		3	
	No. of taxa	No. of individuals	No. of taxa	No. of individuals	No. of taxa	No. of individuals
Neritidae	1	8	-	-	-	-
Melaniidae	1	143	1	32	1	87
Potamididae	2	150	2	35	2	53
Aloididae	1	39	1	11	1	32
Tellinidae	2	69	2	16	2	98
Capitellidae	-	-	1	8	-	-
Nereidae	1	1	1	19	-	-
Total number of taxa	8		7		6	
Total density (ind/m^2)	410		113		270	
Shannon-Wiener Index (Hs)	1.05		0.62		0.90	
Margalef Index (d)	2.07		1.13		1.45	
Equitability Index (j)	1.12		1.12		0.96	

Table 3 shows variations in macroinvertebrtae taxa composition, density and diversity at the study sites. High variability in fauna density and diversity at polluted sites was observed in this study (Fig. 2). Although there was no significant difference (ANOVA, F = 0.722, $P< 0.05$) in the monthly density of benthic macroinvertebrates recorded, significant difference (ANOVA, F = 8.282, $P> 0.05$) was observed in the density of benthic macroinvertebrate recorded at polluted sites. A *post-hoc* test using Duncan Multiple Range Test shows that density of benthic macroinvertebrates were significantly higher and similar in stations 1 and 3 than station 2. Of the three stations, station 1 recorded the highest density (410 ind/m^2) and number (8) of species, while stations 2 and 3 recorded 105 ind/m^2, seven spp and 270 ind/m^2, six spp respectively.

Analysis of the spatial occurrence of the species indicates that only six spp (*P. aurita, T. fuscatus, T. fuscatus var radula, Aloides* sp., *T. nymphalis, M.cumana*) occurred in all the study stations (Fig 2.). *Nereis lamellose* was restricted to stations 1 and 2, while *Neritina glabarata* occurred only in station 1. All the species recorded highest densities in station 1 (except *N. lamellose* which occurred in greatest number in station 2). Generally, individual species representation was lowest in station 2.

The benthic community observed in this study was characterized by an abridged community structure, low density and diversity of benthic macroinvertebrates. In the description of the benthic macrofaunal communities of Lagos lagoon by Oyenekan (1988), five communities (Mangrove community, the *Pachymelania* community, Estuarine Amphiopleus community, the Venus community and Estuarine Rock community), based on the nature of deposits and the characteristic faunal element were described. In view of the sampling design the *Pachymelania* community was majorly covered in this study. Of all the species listed in the *Pachymelania* community by the author, only *P. aurita* and *Neritina glabarata* were observed in the study area while the mangrove community was represented by *T. fuscatus* var *radula* and *T. fuscatus.* Other members of the communities were absent due to defaunation caused by pollution.

The other macroinvertebrate species recorded (*T. nymphalis, M. cumana, Aloides* sp, *Nereis lamellose*) and the once earlier mentioned are known opportunistic mollusc species. Molluscs tolerant of pollution respond to polluted environment by increase in abundance (Barnes *et al.*, 1988). Their significantly higher overall abundance in this study could be attributed to opportunistic condition created by pollution. According to Mozley (1954), bivalve and gastropod molluscs are tolerant to physical and chemical variations in the aquatic ecosystem and they can inhabit a broad range of habitats. This may be attributed to their ability to adapt to stress conditions. For example, many bivalves have their mantle modified into restricted inhalant and exhalant openings (Nybakken, 1988). The siphon which allows them to live many centimeters buried in the bottom is extended to the bottom water surface.

In addition, molluscs that live in estuaries are adapted to relatively high turbidities with the closure of the shells and anaerobic respiration (Hart and Fuller, 1979). Hence, despite of the high organic load as represented by fragments of wood and other related materials observed at the study sites molluscs were able to survive. The polycheate species *N. lamellose* is known to be associated with polluted environments especially sites with high organic load. They respond to organic pollution by increase in abundance. Their restriction to station 1is an attestation to this fact. They can live in extremely polluted waters with very low oxygen levels (Barnes, 1988; Mason, 19996). Diversity indices also signified low density and diversity of macrobenthic fauna. The taxa richness (d), general diversity (H') and evenness (E) all revealed the unfavourable impact of pollution on benthic community. The generally low taxon recorded in the three sites is a typical response of benthic community to pollution.

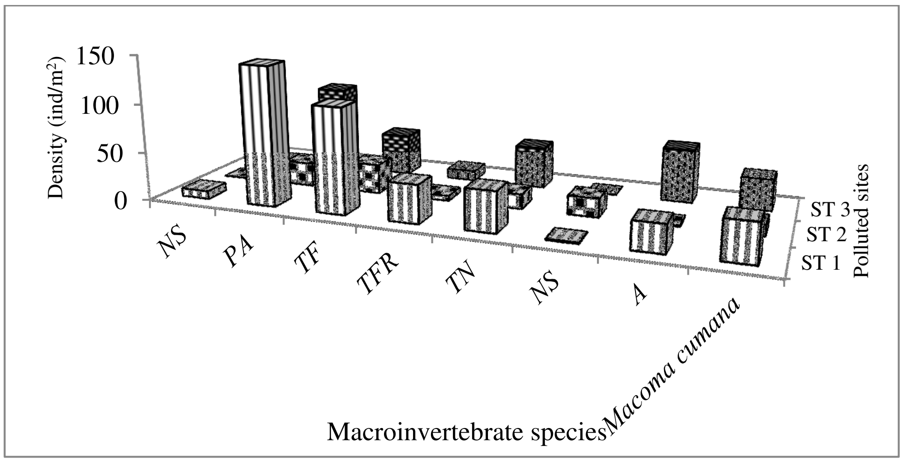

Fig.2: Spatial variations in density and distribution of benthic macroinvertebrate species. NS = *Neretinaglabarata*; PA = *Pachymelaniaaurita*; TF = *Tympanotonusfuscatus*; TFR = *Tympanotonusfuscatus*var*radula*; TN = *Tellinanymphalis*; NL = *Nereis lamellose*; A = *Aloides* sp.; MC = *Macomacumana*

*Spatial and temporal variations in sediment*chl-a:

Fig. 3 shows the spatial and temporal variations in sediment chl-a at the polluted sites. Values were not significantly different at the polluted sites (ANOVA, F = 0.790, $p > 0.05$). In station 1, the values varied between 0.14 and 0.91 mg/kg, and a mean value of 0.55 mg/kg recorded. Stations 2 and 3 had concentrations ranging from 0.76 – 1.21mg/kg and 0.35 – 1.32 mg/kg respectively and mean values observed in the two stations were 0.92 mg/kg and 0.74 mg/kg respectively.

The concentration of chl-a in sediment was highest (3.44 mg/kg) in the month of March and lowest (1.99 mg/kg) in the month of April. Total chl-a values recorded for the other sampling months were; 2.14 mg/kg in February, 2.11 mg/kg in May, 2.57 mg/kg in June and 2.32 mg/g in July. Monthly concentrations of chl-a in sediment in the study area varied between 0.49 and 0.89 mg/g in February, 0.91 – 1.32 mg/kg in March, 0.35 – 0.89 mg/kg in April, 0.44 – 0.86 mg/kg May, 0.64 – 1.07 mg/kg in June, and 0.53 – 0.93 mg/kg in July. Chl-a in sediment was significantly different (ANOVA, F =1.927, $p > 0.05$) during the sampling months, with values significantly lower in the months of February, April, and May, but significantly higher in March, June and July.

The Concentration of chl-a observed in this study also depicts a stressed environment. The effects of increased turbidity and reduced transparency of water on chl-a in estuarine ecosystems have been widely studied (Pinckney and Zingmark, 1993; MacIntyre and Cullen, 1995; Brotas and Plante-Cuny, 1998; Moreno and Niell, 2004). Chlorophyll a is the main pigment involved in algal photosynthesis. The range of chl-a recorded in this study is low when compared to those (6.13 - 15.19 mg/kg) reported by Moreno and Niell (2004). Variations observed in chl-a values indicated that although there were significant differences in the total monthly values recorded, values measured at the study sites were not significantly different. This shows that the overall pattern displayed in the chl-a concentration was a general reflection of the conditions at the polluted sites.

The low transparency (a measure of the depth of light penetration into the water) and turbidity values observed in this study may have impacted negatively on the development of chl-a in sedimentof the polluted sites. According to Underwood and Kromkamp (1999), light conditions affect the growth and photosynthesis of microalgae directly. Microalgae needs a light/dark regime for productive photosynthesis, it needs light for a photochemical phase to produce Adenosine triphosphate (ATP), Nicotinamide adenine dinucleotide phosphate-oxidase (NADPH) and also needs dark for biochemical phase to synthesize essential molecules for growth (Marra, 1978; Scot, 2005). Experimental investigations have shown that, the duration and intensity of light directly affects the number of microalgae. Chlorophyll is the green molecule in plant cells essential for energy fixation in the process of photosynthesis. Chlorophyll-a is used to measure algal biomass that is relatively unaffected by non-algal substances and provides an estimate for measuring algal weight and volume, and acts as an empirical link between nutrient concentration and other biological phenomena in aquatic ecosystems (Murphy *et al*., 2008). Algal production, in turn, affects the entire biological structure of an ecosystem. Chlorophyll-a provides a measure of the amount of active algal biomass (as periphyton) present per area of aquatic sediment, or a measure of phytoplankton from a volume of water.

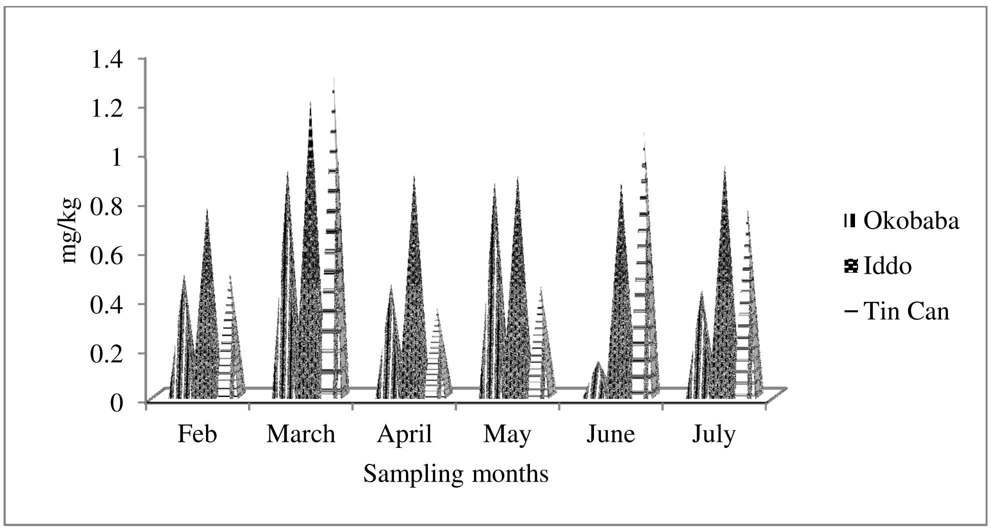

Fig. 3: Monthly fluctuations in the values of chl-a in sediment at the polluted sites

*Impact of environmental factors on benthic community***:** Spearman's correlations between the physical factors and chl-a shows that transparency of water correlated positively and significantly with chl-a in sediment (r_s=1; p< 0.01).Turbidity and depth of water related negatively but significantly with chl-a in sediment. Graphical relationship among the mean values of transparency, turbidity and chl-a in the polluted sites is shown in Fig. 4.

The depth of light penetration in water is regulated by the water itself and by various optically active substances, which absorb or scatter the light (Marra, 1978; Platt *et al*., 1980). While the scattering of light, depends on the amount of light in the aquatic environment, its incidence angle and the amount of optically active substances which cause a deeper light penetration, absorption completely attenuates the light radiation (Sun *et al*., 1994). Measurement of transparency permits the understanding of the optical features of water affecting visibility and composition of substances influencing the water transparency. The high turbidity of water at the sampling sites caused by a high organic load and other pollutants were the main factor restricting the light range.

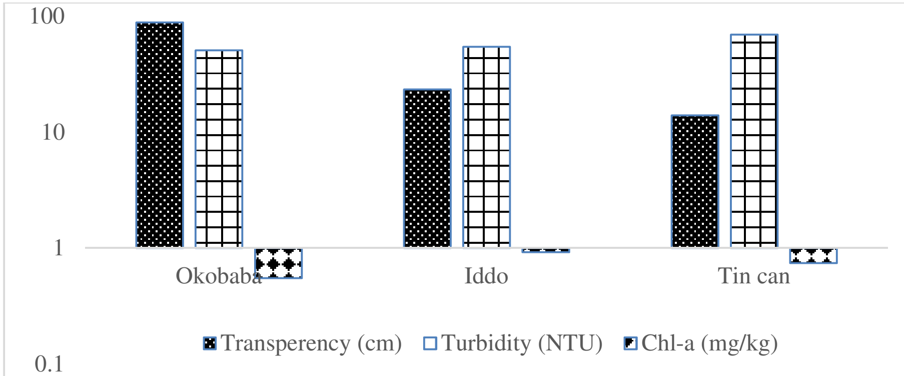

Fig. 4: Variations in mean values of transparency, turbidity and chl-a in the polluted sites

Conclusion: The overall pattern displayed in the community structure and concentration of chl-a is a demonstration of the response of a typical benthic community to environmental alteration. The apparent change in the composition of macrobenthic fauna in this ecosystem shows an unstable estuarine system with low diversity composed of a few opportunistic species.

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