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THE IMPACT OF ENVIRONMENTAL CONDITIONS ON MICRO-PHYTOBENTHIC COMMUNITY IN A TROPICAL ESTUARINE ECOSYSTEM

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ABSTRACT

The micro-phytobenthic community structure in the estuarine Lagos Lagoon, South-west, Nigeria was investigated on a monthly basis for six months between May and October, 2016. A range of 7.0 - 300 mg/L, 31.0- 70.0 cm, 6.1 – 8.4, 0.00 – 0.84 mg/L and 0.21 – 5.4 mg/L were recorded for TSS, transparency, pH, nitrate and phosphate respectively. Whereas values obtained for DO ranged from 2.2 to 16.1 mg/L, those of BOD varied between 7.2 and 36.1 mg/L. Four major micro-phytobenthos divisions; Bacillariophyta, Cyanophyta, Chlorophyta and Chrysophyta made up of eight classes, 20 orders, 19 families and 21 genera were recorded in the study area. Bacillariophyta accounted for the highest number of taxa collected and constituted 72% of the total micro-phytobenthos population. The group Cyanophyta accounted for 14% while Chlorophyta constituted 9% of the micro-phytobenthos population. The division Chrysophyta was poorly represented in the study area. Generally, the number of cells of micro-phytobenthos was low and this may have arisen due to the degraded nature of the study area.

Keywords*:* Community structure, coastal lagoon, benthic microalgae.

INTRODUCTION

Estuaries perform several important ecological and economic functions (Rizzo and Wetzel, 1985; Sousa *et al*., 1998; Santos *et al*., 1997). They are well known for their biodiversity and the important nursery functions that they perform, such as providing nursery areas for marine fish as well as staging and feeding sites for important migratory birds (Tait and Dipper, 1998). However, estuaries constitute one of the most threatened habitats in the world (Shaffer and Onuf, 1983). Despite existing laws that govern activities in and around estuaries, the overall protection of these valuable assets remains low. Many estuaries are in poor condition as they suffer from major ecological degradation (Kelly *et al*., 1998) and they are under serious anthropogenic perturbations

The Lagos Lagoon, receives discharges from a variety of point and nonpoint sources, including urban storm water runoff, industrial and municipal wastewater discharges, atmospheric deposition of automotive and industrial emissions, accidental spills, illegal dumping, and drift of pesticides applied to residential, commercial, and agricultural lands (Akpata *et al*., 1993; Ajao, 1996). These discharges have occurred at varying rates for many years and contain a number of chemical compounds, which, if present in sufficiently high concentrations can be toxic to aquatic organisms. In the aquatic system some parts of these wastes, adhere to particulate matter and is deposited in bottom sediments. When present at elevated concentrations, sediment contaminants, such as metals and synthetic organic compounds can have a number of adverse environmental impacts, including acute or chronic toxicity, sublethal mutagenic changes, or changes in the density or taxonomic composition of bottom-dwelling (benthic) microalgae (Valiela, 1995). Freshwater inflows, which are vital to the maintenance of salinity profiles, nutrient supply and sediment scouring have been polluted or siphoned off. As a result of all these pressures, many Nigerian estuaries have become functionally degraded, and have led to the loss of certain species (Akpata and Ekundayo, 1978; Ajao, 1990; 1996).

The successful colonization of estuarine sediments by micro-phytobenthos is affected by numerous variables, such as grain size distribution, light, organic matter availability, grazer abundance, water chemistry, current velocity, and the amount of pollutants (Holmes and Mahall, 1982), and most of these factors depend strongly on the climate, geology, land-use and other landscape characteristics, and therefore are similar within ecological regions defined by these characteristics (Rizzo and Wetzel, 1985). Hence, the community structure prevalent at any particular time relate to a series of environmental variables (Sullivan and Montcreiff, 1988) that are often interrelated (Lin *et al*., 2004). Growth pattern of micro-phytobenthos is influenced by the degree of changes in environmental conditions. Diversity of the micro-phytobenthos increases when the prevailing environmental conditions allow for optimal exploitation of resources. Community structure remains relatively stable when available resources reduce the effect of adverse conditions. In the face of increasing unfavourable conditions, sensitive species

will disappear and the community will shift to a more opportunistic species composition. Further deterioration in environmental conditions will lead to further losses of the stress-intolerant species and the diversity of the micro-phytobenthic community will decrease and be dominated by a few pollution-tolerant, species.

Studies investigating micro-phytobenthos communities in Nigeria are scarce. In this present study the impact of environmental conditions on micro-phytobenthos community in the western urbanized area of the Lagos Lagoon was investigated. The main objectives are to; determine the community structure of micro-phytobenthos, and the environmental factors that may be responsible for observed pattern.

Study area and sampling stations

Six study stations located in the western urbanized area of the Lagos Lagoon (Fig. 1) were used for this study. Station 1 was located at Makoko (MK) with Latitude 6° 29' 51.4"N and Longitude 3° 23' 46.39"E. Colour of water was brownish green and sediment colour was black. The texture of the sediment collected in this station was fine mud. Station 2 was located at Iddo (ID) with Latitude 6° 28' 3.20"N and Longitude3° 23' 2.4"E. Station 3 with coordinates of Latitude6° 28' 9.01"N and Longitude 3° 23' 5.20"E was located at the Carter Bridge (CB). The water was cloudy for a larger part of the sampling period and the sediment colour was dark brown. Station 4 was situated at the discharge point of the Abule Agege Creek (ABG) with Latitude 6° 30' 19.70"N and Longitude 3° 23' 55.80"E as coordinates. The Sediment in this station was coarse sand in texture and water flow rate was high. The human activity in this station was relatively low and there was no physical evidence of perturbation. Station 5 was at Okobaba (OKB) with Latitude 6° 29' 25.20"N and Longitude 3° 23' 49.2"E. Colour of water was brownish green and sediment colour was black. Station 6 was located at Ogudu (OGD) area of the lagoon. The sampling point had Latitude 6° 33' 49.9"N and Longitude 3° 24' 11.3"E as coordinates and lay exactly at the discharge point of Ogudu Creek. This station was characterized by dark water colour with an offensive odor, probably resulting from degradation of domestic wastes discharged into Ogudu Creek which end up in the Lagos Lagoon.

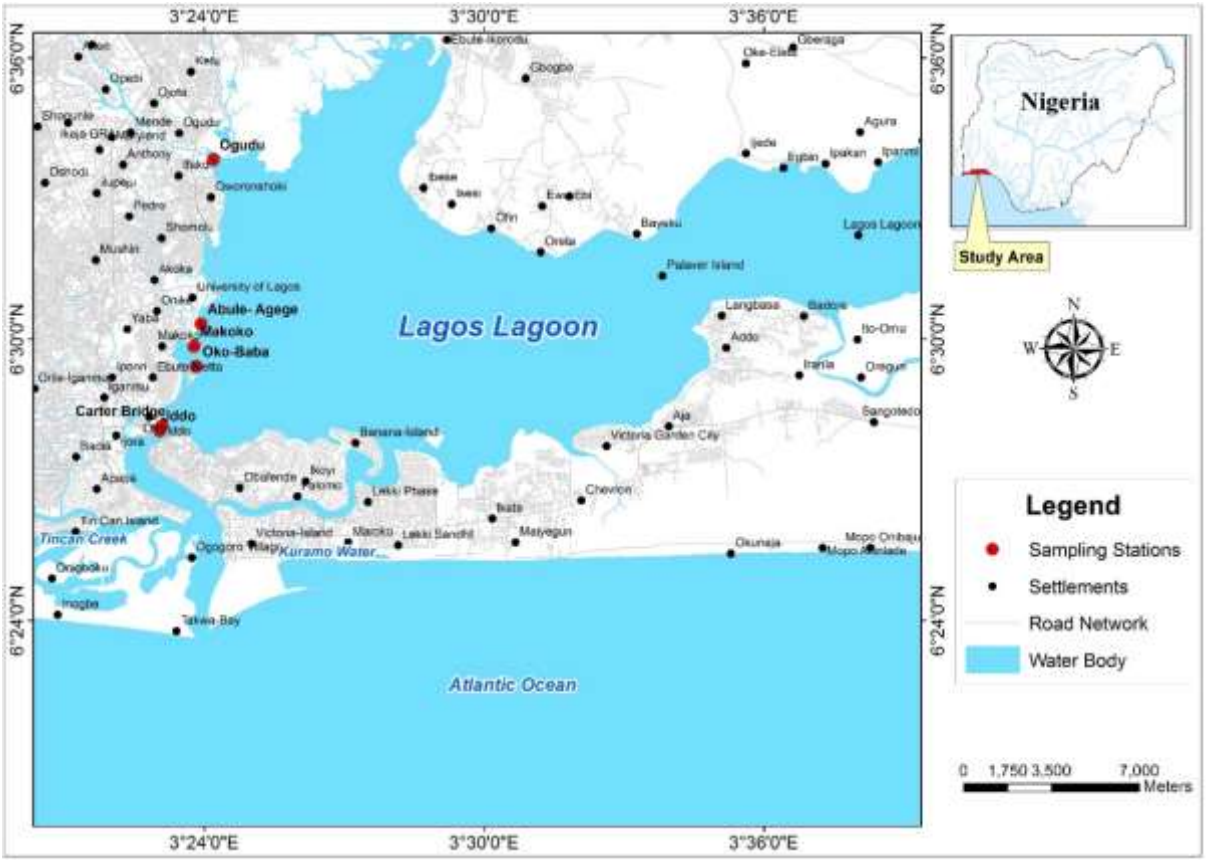

Fig. 1. Map of study area showing sampling points

MATERIALS AND METHODS

Field Investigation

In situ measurements of surface water temperature (^{0}C), pH and electrical conductivity (µS/cm) were carried out using battery operated Horiba U10 Water Quality Checker Model. Transparency was determined using a 20 cm diameter Secchi Disk painted black and white. Water samples for the determination of dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected in transparent and amber coloured 250 ml reagent bottles. The samples for DO were fixed on the field with 1 ml each of Winkler's solutions A (Manganese sulphate) and B (Sodium hydroxide and Potassium hydroxide). The water sample in the transparent bottle was fixed with 1 ml each of Winkler's solutions A and B, while the water samples in the amber coloured bottle were taken to the laboratory and incubated for 5 days at 20 ^{0}C (APHA, 1998). Samples for the analysis of other physico-chemical properties of water were taken from each sampling sites before organisms were sampled in order to avoid sampling disturbance of water quality.

Micro-phytobenthos samples were collected from the surface layer of the sediment-water interface by scooping the upper few centimetres of the sediment after successful deployment and retrieval of van Veen grab used for the sediment collection. The collected samples were then put into washed transparent plastic containers and pre-filtered water from the sampling station added and the sample gently stirred to allow the water to properly mix with the collected sediment. The samples were then transported to the laboratory for further processing.

Laboratory investigation

In the Laboratory, DO, BOD and other parameters were determined according to the methods described in (APHA, 1998). Micro-phytobenthos samples were exposed to light for an approximate period of 24 hrs to enhance the migration of the micro-phytobenthos to the surface water above the sediment. The water was then decanted into a clean container and fixed with 4% formaldehyde. The decanted subsamples were then examined under the microscope and micro-phytobenthic organisms identified, counted and recorded for each sampling station throughout the sampling month with the aid of different identification guides (Newell and Newell, 1977; Maosen, 1978) and confirmation made using an internet based global authoritative taxonomic information "the Integrated Taxonomic Information System (ITIS) of North America and the world" (Encyclopedia of Life, 2017). The number of cells and species belonging to the different taxonomic groups were recorded.

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

RESULTS

Physico-chemical variables

Summary of values of physico-chemical parameters of surface water at the study sites is presented in Table 1. Overall trends in water quality were relatively consistent for study sites, and all the parameters investigated did not exhibit significant variation ($p>0.05$) among study locations and ANOVA showed that mean values were not statistically different. A range of 7.0 - 300 mg/L, 31.0- 70.0cm, 6.1 – 8.4, 0.00–0.84 mg/L and 0.21 – 5.4 mg/L were recorded for TSS, transparency, pH, nitrate and phosphate respectively. In general, mean values of TSS were higher in Makoko (79.50 mg/L) and OKobaba (67.50 mg/L) sampling sites. Lowest mean value of transparency was recorded in Ogudu (45.4 cm) and Makoko (46.6 cm). Whereas values obtained for DO ranged from 2.2 to 16.1 mg/L, those of BOD varied between 7.2 and 36.1 mg/L

Composition and Community Structure of micro-phytobenthos

Four major micro-phytobenthos divisions (Bacillariophyta, Cyanophyta, Chlorophyta and Chrysophyta) made up of eight classes, 20 orders, 19 families and 21 genera were recorded in the study area. Fig. 2 shows the relative contribution of the major MPB divisions. Bacillariophyta accounted for the highest number of taxa recorded and constituted 72% of the total micro-phytobenthos population. This group was represented by 3 classes (Bacillariophyceae, Coscinodiscophyceae, Fragilariophyceae), 10 orders (Surirellales, Cymballeles, Naviculales, Baciriallales, Aulacoseirales, Chaetocerotales, Coscinodiscales, Thalassiosirales, Triceratiales, Melosirales), 13 families (Surirellaceae, Cymbellaceae, Naviculaceae, Bacillariaceae, Pinnulariaceae, Aulacoseiraceae, Chaetocerotaceae, Coscinodiscaceae, Stephanodiscaceae, Triceratiaceae, Melosiraceae, Paraliaceae, Fragilariaceae) and 14 genera (*Campylodiscus, Cymbella, Nitzchia, Coscinodiscus, Suriralles, Paralia, Navicula, Pinnularia, Synedra, Aulacoseira, Chaetoceros, Cyclotella, Odontella, Melosira, Anabaena, Lyngbya* and *Oscillatoria*).

The group Cyanophyta was represented by a class (Cyanophyceae), two orders (Chroococcales,

Nostocales), 2 families (Chroococcaceae, Nostocaceae) and 4 genera (*Microcystis, Anabaena, Lyngbya, Oscillatoria*) and accounted for14% of the micro-phytobenthos population. Chlorophyta was represented by two classes (*Ulvophyceae, Conjugatophyceae*), two orders (*Cladophorales, Desmidiales*), two families (*Cladophoraceae, Closteriaceae*) and two genera (*Cladophora, Closterium*). This group constituted 9% of the microphytobenthos population. The division Chrysophyta contributed one class (*Dinophyceae),* two orders (*Dinophysiales, Noctilucales*), two families (Dinophysiaceae, Noctilucaceae) and two genera (*Dinophysis, Noctiluca*) to the microphytobenthos community observed in the study area.

Abundance and species richness of micro-phytobenthos

Table 2 shows the micro-phytobenthos taxa abundance and distribution in the study area, while variations in the total number of cells contributed by the different taxa are depicted in Figure 3. A total of 260 cells of MPB were recorded in this study. Of this number, Bacillariophyta contributed 176 cells, Cyanophyta contributed 53, Chlorophyta, 12 cells while Chrysophyta contributed 19 cells. Among the Bacillariophyta observed, *Melosera* sp. was the most abundant taxa, with a total of 20 individual cells, the organism accounted for 11.5% of diatom population. Also significantly represented in the group is *Cyclotella* sp which accounted for 10.9% (19 individual cells) of diatom population. *Anabaena spiroides* with 18 cells, *Lyngbya limnetica* with 16 cells, *Microcystis aeruginosa* with 13 cells and *Oscillatoria limnosa* with six cells were the representatives in the Cyanophyta group. Cyanophyta accounted 30%. The 12 cells recorded for Chlorophyta was contributed by the two genera (Cladophora, Closterium) represented in the group with each contributing seven and five cells respectively. *Dinophysis caudata* with 10 cells and *Noctiluca scintillans* with nine cells isolated from the study area were the representatives of Chrysophyta. The diatom, *Melosira undulata* with 20 cells enumerated ranked highest in abundance and was the dominant taxa recorded in this study. The highest number (7) of cells recorded per station of the organism occurred in Makoko.

The distribution of the micro-phytobenthos species did not demonstrate any particular trend in the study stretch although, there was remarkable variations in the occurrences of the various taxa recorded (Fig. 4). Of the total 22 genera collected from the area, four (*Nitzschia, Aulacoseira, Anabaena, Dinophysis*) approximately 18% occurred in all the study locations and therefore, were the most widely distributed, eight (*Campylodiscus, Surirella, Chaetoceros, Coscinodiscus, Paralia, Cladophora, Noctiluca*) approximately 36% occurred in five study location, seven (*Pinnularia, Cyclotella, Odontella, Melosira, Lyngbya, Microcystis, Oscillatoria*) approximately 32% recorded occurrences in four locations, two genera (*Synedra, Closterium*) approximately 9% recorded occurrences in three stations while one genus (*Navicula*) occurred only in two stations.

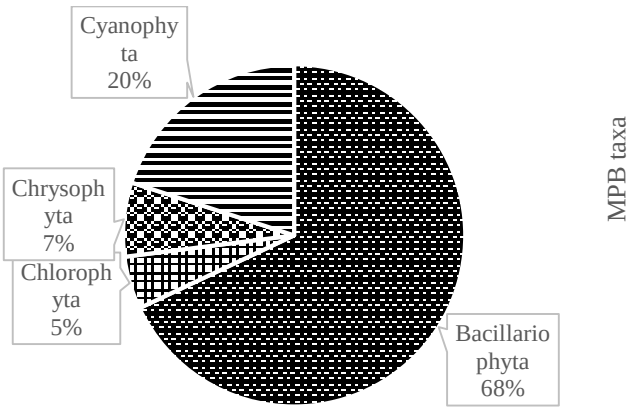

Fig. 2. Relative contribution of the major MPB divisions

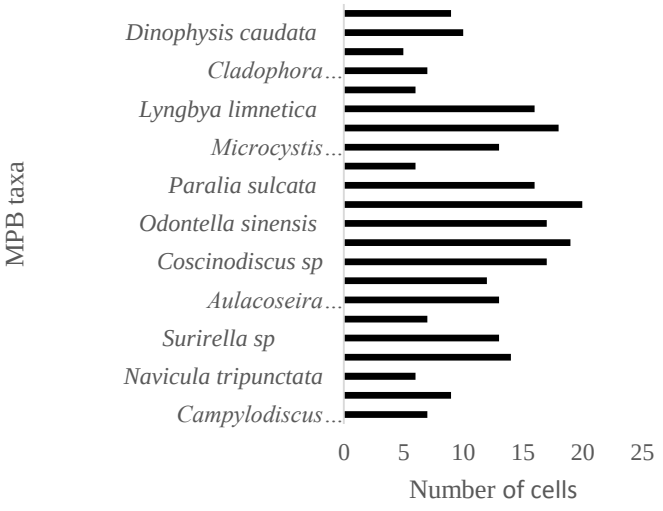

Fig. 3. Variations in the number of cells of MPB taxa collected in the study area.

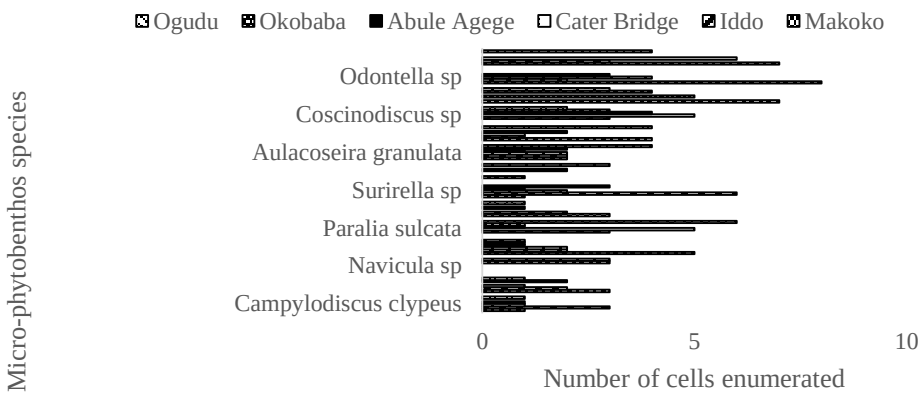

Fig. 4. Variations in spatial distribution and abundance of MPB taxa along the study stretch.

Table 2. Micro-phytobenthos taxa distribution and abundance in the Lagos Lagoon.

	Sampling locations					
Taxa	Makoko	Iddo	Carter bridge	Abule Agege	Oko baba	Ogudu
Family: Surirellaceae						
Campylodiscus clypeus	1	3	1	1	-	1
Surirella sp	1	6	2	1	3	-
Family: Cymbellaceae						
Cymbella sp	3	2	1	-	2	1
Family: Naviculaceae						
Navicula tripunctata	-	-	-	-	3	3
Family: Bacillariaceae						
Nitzschia sp	5	2	2	1	1	3
Family: Pinnulariaceae						
Pinnularia sp	3	2	-	1	-	1
Family: Aulacoseiraceae						
Aulacoseira granulate	2	2	2	1	2	4
Family: Chaetocerotaceae						
Chaetoceros convolutes	4	1	1	2	-	4
Family: Coscinodiscaceae						
Coscinodiscus sp	-	3	5	4	3	2
Family: Stephanodiscaceae						
Cyclotella comta	7	-	5	-	4	3
Family: Triceratiaceae						
Odontella sinensis	8	2	4	3	-	-
Family: Melosiraceae						
Melosira undulata	7	3	6	-	-	4
Family: Paraliaceae						
Paralia sulcata	-	3	5	1	1	6
Family: Fragilariaceae						
Synedra sp	1	-	-	2	-	3
Family: Chroococcaceae						
Microcystis aeruginosa	6	-	3	3	1	-
Family: Nostocaceae						
Anabaena spiroides		5	1	3	5	3	1
Family: Oscillatoriaceae						
Lyngbya limnetica		3	4	-	-	3	6
Oscillatoria limnosa	-		1	1	-	2	2
Family: Cladophoraceae						
Cladophora glomerata		2	1	2	1	-	1
Family: Closteriaceae						
Closterium sp		1	-	1	-	3	-
Family: Dinophysiaceae						
Dinophysis caudata		1	1	1	3	3	1
Family: Noctilucaceae						
Noctiluca scintillans	-		3	1	2	2	1

Table 1. Summary of values of physico-chemical parameters of surface water at the sampling locations.

Parameter	Sampling locations											
	Makoko		Iddo		Carter bridge		Abule Agege		Oko baba		Ogudu	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
TSS(mg/L)	15 - 300	79.50 ± 11.2	17 - 98	58.83 ± 32.12	11 - 84	50.42 ± 26.14	10 - 132	56.83 ± 43.18	7 - 190	67.50±64.1	36 – 65	50.33±11.7
Transparency (cm)	32 - 58	46.6 ± 11.4	35 - 70	53.3 ±14.7	35.5 – 58	46.7 ± 8	31 - 68	47 ± 14.2	44 - 68	52.1 ± 10	34 – 62	45.4 ± 12
pH	6.1 - 8.1		6.2 - 7.4		6.2- 8.2		6.4 - 8.2		6.3 - 8.4		6.1 - 8.2	
Nitrate(mg/L)	0.03 - 0.78	0.28 ± 0.28	0.02 - 0.72	0.32 ± 0.25	0.04 - 0.62	0.33 ± 0.21	0.07 - 0.63	0.31 ± 0.20	0.00 - 0.84	0.43 ± 0.32	0.00 - 0.61	0.35 ± 0.34
Phosphate(mg/L)	0.56 - 5.4	2.51 ± 1.77	0.25 - 3.1	1.31 ± 1.22	0.21 - 2.2	0.86 ± 0.74	0.47 - 2.55	1.02 ± 0.81	0.41 - 4.3	1.6 ± 1.5	0.41 - 4.6	1.6 ± 1.7
DO(mg/L)	4.8 - 8.4	6.6 ± 1.43	2.3 - 12.3	5.51 ± 3.73	3.2 - 10.6	6.35 ± 2.92	5.8 - 16.1	8.76 ± 3.78	2.2 - 13.2	6.08 ± 3.99	3.9 - 16.1	7.5 ± 4.44
BOD(mg/L)	10.4 - 28.5	18.20 ± 6.65	12.6 - 19.2	16.03 ± 2.09	8.1 - 30.2	18.83 ± 8.16	8.8 - 36.1	18.13 ± 9.94	12.8 - 21.67	16.52± 3.52	7.2 - 22.8	18.43± 5.74

DISCUSSION

A comparison of the abiotic data obtained during this study with data from other parts of the Lagos Lagoon system shows that values observed depict a stressed environment, particularly with respect to extent of light penetration in water (Transparency). Whereas the range observed in this study was 31.0-70.0 cm that recorded for Lekki Lagoon for example, was 40 – 119 cm (Uwadiae *et al*., 2011). The relatively lower mean values of transparency in stations (Ogudu and Makoko) with high rate of human activities also suggest that the study locations were environmentally degraded. In the same vain, higher mean values of TSS were recorded in Makoko and Okobaba which are also noted for intense human activities. The Lagos Lagoon estuary have suffered a lot of environmental impacts due to ever increasing human activities in and around the lagoon (Ajao, 1996; Valiela, 1995; Uwadiae *et al*., 2011). The discharge of wastes from diffuse sources into the water indiscriminately may be responsible for the low transparency and high TSS. Human activities such as fishing may result in the resuspension of sediment which may likely affect the physical and chemical characteristics of water. Contaminants that enter the aquatic environment through human activities concentrate on the surface of water before deposition on the sediment. The time taken for these contaminants to settle may be long, so these materials continue to shade-off light from the benthic community as they persist in the water column and when these substances finally settle, they form part of the sediment and depending on their nature, they may interfere with productivity of micro-phytobenthos, especially when they are resistant to chemical and/or biological degradation (Colijn and De Jonge, 1984). This study was conducted in the rainy months during which there was increase in the discharge rate of all the water bodies feeding the lagoon. According to Holmes and Mahall (1982),and Naicker (2006), rainfall in the vicinity of Mnweni estuary, which increased the rate of river discharge led to reduced transmission of light to the benthos. Micro-phytobenthic production was drastically reduced when turbidity increased coincident with freshwater intrusion in early April 2005 in the South African Estuary and storm events experienced during the rains interrupted what appeared to be an increasing trend of benthic community production from winter to early spring, reducing net production from 14.74 to -2.33 $mgCm^{-2}hr^{-1}$(Naicker, 2006).

Variability in physical and chemical factors has been emphasized as the primary organizational force controlling benthic community (Rosenberg and Resh, 1993; Uwadiae, 2009). Thus, the community structure of micro-phytobenthos can be related to abiotic factors. A total of 260 cells of micro-phytobenthos were collected from the study area, this population is low when compared with those of (Yang *et al*., 2009) who recorded a total of 18 genera and 94 species of diatomian upland loch, Scotland. This may be attributed largely to degraded environmental conditions in the study area. According to Yang *et al*. (2009), one of the factors limiting the growth of micro-phytobenthos is the availability of light. As light only penetrates the sediment to a depth of 0.2-2 mm, micro-phytobenthos could only photosynthesis to this depth (Colijn and Dijkema, 1981; Davis and McIntyre, 1983; Lehman, 1992), therefore, they are largely confined to the surface of the sediment within this depth. The distribution of benthic micro algae is restricted to this relatively thin surface layer (Welker *et al*., 2002), the layers in which light is sufficient enough for the micro-phytobenthos to photosynthesize is influenced by water quality.

Naicker, (2006) reports that, the diatom diversity and assemblage composition in the Mnweni River in South Africa was related to changes in the water chemistry as well as organic pollution, habitat characteristic relating to the water flow, river bank character and catchment land use. The report also noted that, the diatom assemblages that were found at the sites are typical of clean or mildly enriched water conditions. This is similar to an observation made in this study, micro-phytobenthic taxa recorded are those previously reported for locations with different degrees of organic pollution.

Micro-phytobenthos live, grow and are consumed in the top few millimetres of sediment and use light energy to fix $C0_2$ into organic matter. Potential impacts of human activities in coastal areas include direct smothering of benthic organisms and reduction of light from increased turbidity resulting in stress and/or mortality of photosynthetic organisms, and remobilization of heavy metals and pesticides/herbicides. Motile micro-phytobenthic organisms (mainly diatomic forms) are known to migrate upward during the day and downward at night in response to light. However, where penetration of light is impaired as observed in the study area, micro-phytobenthic primary production is hampered. At the beginning of the daytime emersion period the surface of the sediment reaches a saturation value, with micro-phytobenthos production, this is governed by the productivity of benthic micro algae and changes in light exposure. According to (Joergensen *et al*., 1983; Jong *et al*., 1994; David *et al*., 2003), possible causes for the patchy distribution in micro-phytobenthos are variations in the texture and relief of the sediment surface as well as light variability. The above assertion corroborates the observation established in this study.

CONCLUSION

Detailed comparison of the quality of the assemblage recorded in this study with those of other reports is difficult. As observed by Naicker (2006), comparability of micro-phytobenthos studies is severely restricted by differences in methodologies (sediment volume, sampling techniques and measurement techniques), habitats and geographical distance. The dominance of particular algal groups at different times of the year have been shown by several authors and it was found that despite a general dominance of diatoms, as observed in this study, green algae and Cyano bacteria are known to be important components of the moicro-phytobenthos community (Khondker and Dokulil, 1988; Krammer and Lange-Bertalot, 1991; Pinckney and Zingmark, 1991).

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