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The Phytoplankton Composition, Abundance and Temporal Variation of a Polluted Estuarine Creek in Lagos, Nigeria

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Abstract

The phytoplankton composition, abundance and temporal variation of a polluted estuarine creek in Lagos was investigated for 6 months (February – July, 2003). Strong positive correlation (≥7.3) recorded between physico-chemical characteristics at two stations within the creek likely point to their control by similar factors, chiefly hydro-meteorological forcings and the creeks pollution status. A total of 48 taxa from 26 genera and 3 classes namely bacillariophyceae (37 taxa), cyanophyceae (10 taxa), and shizomycetes (1 taxon) were recorded for the study. Higher phytoplankton diversity recorded during the rains was probably due to the additional recruitment from the phytobenthic community as a result of scouring of the creek by floodwaters. The bacterium - *Beggiatoa alba* was the most abundant and frequent taxon particularly in the wet months and strongly indicates high levels of bio-degradable waste contamination. The physico-chemical characteristics and phytoplankton indicator species reflect a polluted and rapidly deteriorating estuarine environment.

Key words: Phytoplankton, estuarine, pollution, tide, floodwaters, creek.

Introduction

Creeks are common hydrological features in south-western Nigeria and are essentially of two types. The tidal freshwater/brackish creeks surrounded partly by mangrove swamps and partly by freshwater swamps from points beyond the reach of tidal influence and the non- tidal freshwater creeks, surrounded by freshwater swamps and usually infested with aquatic macrophytes all through the year (Nwankwo and Amuda, 1993). Creeks in this region gravitate to coastal lagoons in their immediate area enroute to the sea via the Lagos harbour. The existence of environmental gradients keyed to rainfall distributive pattern and more discernable in the dry season has been reported by researchers for the Lagos lagoon and adjoining creeks extending east and westward from the harbour (Sandison and Hill, 1966; Olaniyan, 1969; Onyema *et al.,* 2003; Nwankwo *et al*., 2003).

The creeks and lagoons of south-western Nigeria, apart from their more ecological and economic significance, serve as sink for the disposal of an increasing array of waste types. Sewage, wood waste, refine oil, waste heat, municipal and industrial effluents among others find their way unabated into immediate coastal waters through conduits such as storm water channels, rivers, creeks and lagoons (Akpata *et al*., 1993; Chukwu and Nwankwo, 2004).

Environmental disturbances from such wastes are known to induce changes to the structure and function of biological systems (Odiete, 1999). As a result, ecologists over the years have attempted to judge the degree and severity of pollution by analyzing changes in biological systems (Nwankwo, 2004).

Phytoplankton satisfy conditions to qualify as suitable indicators in that they are simple, capable of quantifying changes in water quality, applicable over large geographic areas and can also furnish data on background conditions and natural variability (Lee, 1999). More so micro algal components respond rapidly to perturbations and are suitable bio-indicators of water condition which are beyond the tolerance of many other biota used for monitoring (Nwankwo and Akinsoji, 1992).

There is a dearth of information on phytoplankton community of creeks in south-western Nigeria. There exist reports on the composition and distribution of phytoplankton community on the Lagos and Epe lagoons and other coastal waters of Nigeria (Nwankwo, 1988, 1996, 1998a, Kadiri, 2000; Chindah and Braide, 2001; Nwankwo *et al*., 2003).

There is no previous ecological study on the Ijora creek. This study investigates the phytoplankton composition and distribution in an estuarine polluted tidal creek in south-western Nigeria in relation to the environmental characteristics.

Materials and Methods

Description of Study Site

The Ijora creek (Figure 1) is located about the upper part of the Lagos harbour, which is open all year round to the sea. It is shallow, sheltered and experiences semi-diurnal tidal oscillations (Olaniyan, 1975). Water enters the creek at high tide from the

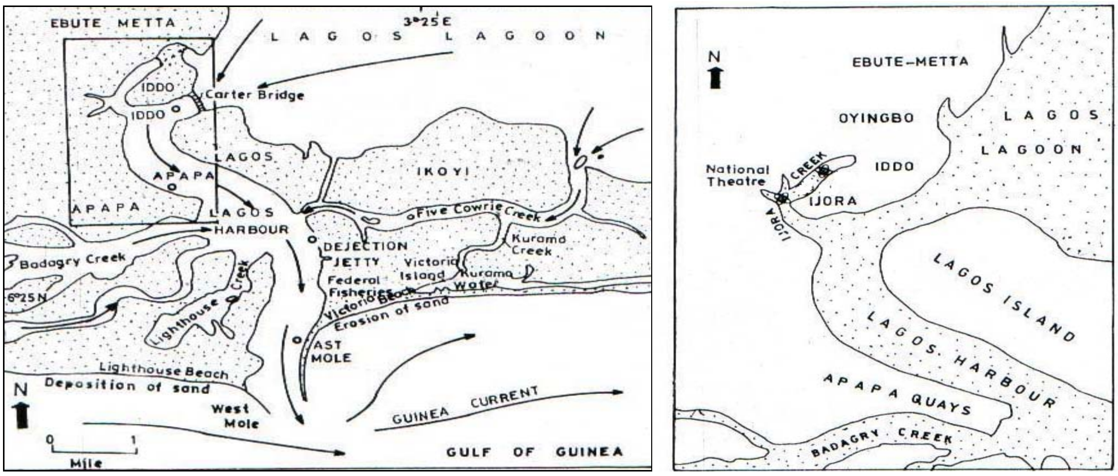

Figure 1. Part of Lagos Lagoon showing Ijora creek and sampling sites.

Lagos harbour and as the tide ebbs, water drains from the surrounding region back into the harbour. The wet (May – October) and dry season (November – April) are the two distinct seasons experienced in the area. An extensive expanse of mudflat is usually exposed at low tide. The creeks substratum, exposed at low tide is usually covered by a thick greenish slimy layer particularly in the dry season with characteristic Hydrogen Sulphide and Ammonia perceived in the area. Notable riparian flora of the creek includes *Paspalum orbiquilare, Typha* sp, *Mariscus alteriforlus, Rhynchospora* sp and few white (*Avecennia nitida*) and red mangroves (*Rhizophora racemosa*). Notable fauna include *Periopthalmus, Balanus pallidus, Chthamalus, Gryphea gasar, Tympanotonus fuscatus* var *radula* and birds that feed on exposed inertial biota. Refined oils related discharges, industrial effluents, sewage materials and municipal waste from the highly populated environ constantly find their way to the creek on daily basis.

Collection of Phytoplankton and Water Samples

The site was assessed at Low Low Water (LLW) with a dugout canoe from its connection to the Lagos harbour. The canoe was anchored and phytoplankton sample was collected on each occasion with a 55 µm mesh size standard plankton net held against the current of the ebbing tide for 10mins. The net was then hauled in and the sample transferred to a 250 ml well labeled plastic container with screw cap each time. Samples were preserved with 4% unbuffered formalin to disallow possible dissolution of diatom cell walls (Nwankwo, 1996) and stored in the laboratory prior to microscopic analysis in the laboratory.

Monthly surface water samples were also collected for six months (February – July, 2003) for physical and chemical analysis using 500 ml plastic containers with screw caps at two stations (Stations A and B). Collection was at ebbing tide between 10h and 14h each time. Samples for dissolved oxygen were collected just a few centimeters below the water surface and fixed with white and black ampoules for more accurate Dissolved oxygen estimation (APHA, 1981). The plastic containers were then labeled appropriately and transported to the laboratory within 1h and then stored in the refrigerator (t < 5°C) prior to further analysis.

Physical and Chemical Analysis

Air and surface water temperatures were measured using a mercury thermometer. Depth was estimated using a pre-calibrated pole. Transparency was estimated using a 20 cm diameter Secchi disc. Total dissolved solids were evaluated by evaporating 100ml aliquot at 105ºC while total suspended solids were determined by filtering 100ml sample though a pre-weighed filter paper which was subsequently dried to constant weight and reweigh. Conductivity was measured using the HANNA instrument, a wide range conductivity meter, while salinity was determined using the silver nitrate chromate method. Whereas pH was determined with a Griffin pH meter (model 80), dissolved oxygen was estimated using a Griffin oxygen meter (Model 40) and biochemical oxygen demand was measured using methods according to APHA (1981) for water analysis. Calorimetric methods using a lovibond Nesslerier were adopted for the direct determination of phosphate-phosphorus and nitrate-nitrogen values while sulphate levels were measured using the gravimetric method. Oil and grease was calculated using the carbon tetra chloride method and the filtrate was viewed at 450 nm with a DR 2000 spectrophotometer. Data on rainfall distributive pattern were obtained from the Federal Meteorological Department Oshodi, Lagos.

Phytoplankton Analysis

In the laboratory at least five drops of each concentrated sample (10ml) were investigated at different magnifications (X100 and X400) after mounting on a glass slide and covering with a cover slip each time. Thorough investigation was then carried out, observing all fields within the cover slip border using a Wild II binocular microscope with calibrated eye piece. The average of 5 mounts was then taken (Lackey, 1938). Since each drop amounts to 0.1ml the results on density of species (i.e. averages) were multiplied by 10 to give values as numbers of organisms (cell, filament and colony) per ml. Appropriate texts were used in order to aid identifications (Hendey, 1958; 1964; Wimpenny, 1966; Patrick and Reimer, 1966; 1975; Whitford and Schumacher, 1973; Nwankwo, 1990; 2004).

Community Structure Analysis

Species Richness Index (d)

The Species richness index (d) according to Margalef (1951) was used to evaluate the community structure. The equation below was applied and results were recorded to two decimal places.

$$d = (S - 1)/ \mathrm{Log}_e N$$

Where:
d = Species richness index
S = Number of species in a population
N = Total number of individuals in S species.

Shannon and Weiner diversity index (H)

Shannon and Weiner (1949) diversity index (H) given by the equation:

$$Hs = \sum Pi \, 1n \, Pi$$

Where
Hs = Diversity Index
i = Counts denoting the ith species ranging from 1 – n
P_I= 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 (j)

Species Equitability or evenness (Pielou, 1969) was determined by the equation:

$$j = Hs / \mathrm{Log}_2 S$$

Where
J = Equitability index
Hs = Shannon and weaver index
S = Number of species in a population

Correlation Coefficient Values (r)

The Pearson's coefficient of correlation (r) for the relationship between some physico-chemical parameters and biotic structure in the different stations were obtained using the formula:

$$r=[n(\sum XY)–(\sum X)(\sum Y)]/[\sqrt{}(n(\sum X^2-(\sum X)^2][n\sum Y^2– (\sum Y)^2]$$

Where
r = Coefficient of correlation
X and Y = Variables under consideration

Results

Physical and Chemical Properties

Air temperature ranged from 28.5ºC to 32.8ºC at both stations during the study. The highest air temperature was recorded in March and lowest in June. Surface water temperature ranged from 27ºC to 31ºC. There was no significant difference between air and surface water temperatures at both stations ($P<0.05$). Depth estimates were higher in the dry season than in the wet season for both stations. Transparency was also relatively higher in the dry months. Total dissolved solids values were highest in February and reduced afterwards with the lowest value recorded in July for both stations. Conversely total suspended solids were highest in July and least in April. Rainfall was highest in June (383.0 mm) with lower values recorded in February and March (< 17.0mm). Alkaline pH was estimated throughout this investigation (8.0 – 9.0).

Dissolved oxygen values ranged between 3.8 and 4.2 mgl^{-1} and biological oxygen demand were high throughout the period of investigation with higher estimates (>18 mgl^{-1}) recorded in February, March and April.

Salinity values were high in March (between 17.57 and 22.85 ‰ in Stations A and B) and subsequently dropped to 1. ‰ in July at both stations. Conductivity values were low in March. Nitrate-nitrogen values declined from February till July. Nitrate-nitrogen levels ranged between 3.05 and 6.82 mgl^{-1}. Levels for Phosphate-phosphorus ranged between 0.48 and 0.97 mgl^{-1} with estimates for sulphate lower in the wet months. Values for oil and grease were higher in the wet months at both stations than in the dry months. Table 1 shows the monthly variation in physico-chemical characteristics in stations A and B in the Ijora creek.

Biological Characteristics

A total of 48 taxa from 26 genera and 3 classes namely bacillariophyceae (37 taxa), cyanophyceae (10 taxa), and shizomycetes (1 taxon) were recorded for the study. The bacterium - *Beggiatoa alba* was evidently the most abundant and frequent taxon particularly in the wet months (April and May) (Table 2).

Table 1. Monthly variation in physico-chemical characteristics at two sampling stations (A and B) in the Ijora creek (February - July 2003)

Parameter	February		March		April		May		June		July	
	A	B	A	B	A	B	A	B	A	B	A	B
Air temperature (^{0}C)	31.5	31.5	32.8	32.8	30	30	31	32	29	29	28.5	28.5
Water temperature (^{o}C)	31	30	30	31	28	28	29	30	27	27	28	28
Depth (cm)	162.8	85.1	157.6	78.8	158	57.2	147	55.8	149.4	56.7	152.8	53.4
Transparency (cm)	28	60	21	20.5	16.3	15.5	14.8	8.8	9.5	10.8	8.4	7.2
pH	8.8	9	9	8.6	9	8.8	8.6	8.4	8.4	8.2	8	8.2
D.O. (mgl^{-1})	4	4.2	3.8	4	3.9	3.7	3.6	3.4	4	4.1	4.2	4.2
B.O.D. (mgl^{-1})	22	26	18	20	24	22	19	20	18	19	18	17
T.D.S. (mgl^{-1})	17862	23932	7152	7350	1538	1868	1954	1969	2115	2168	2110	2100
T.S.S. (mgl^{-1})	668	1022	316	264	70	50	469	512	946	1100	1115	1110
NO_3-N (mgl^{-1})	4.64	6.82	4.24	4.5	3.11	3.25	3.07	3.17	3.05	3.09	3.07	3.08
PO_4-P (mgl^{-1})	0.64	0.97	0.56	0.6	0.48	0.51	0.5	0.5	0.52	0.52	0.51	0.52
SO_4 (mgl^{-1})	2556	3572	2161	1747	1389	1492	1382	1350	1450	1482	1450	1485
Conductivity (scm x10^{-2}	3.6	4.8	1.4	1.5	3.1	3.7	4	4.1	4	4.2	3.8	4
Salinity (‰)	17.57	22.85	7.73	7.03	1.93	2.11	1.76	1.76	1.22	1.31	1.3	1.3
Oil and grease (mgl^{-1})	3.2	10.5	6.1	4.6	5.4	2.7	2.5	2.46	1.68	1.66	1.64	1.62
Rainfall (mm)	16.7		17.0		244.1		208.6		383.0		101.7	

Table 2. Temporal variation of 20 more important planktonic algae of a polluted tropical creek (February - July 2003)

Taxa	February	March	April	May	June	July
Class-Shizomycetes						
Order - Beggiatoales						
Beggiatoa alba	6	41	1,790	1,020	44	9
Class-Bacillariophyta						
Order I –Centrales						
Biddulphia regia Ostenfed	-	10	-	-	-	-
B. sinensis Graville	29,945	35	-	-	-	-
Coscinodiscus centralis Ehrenberg	-	-	5	-	-	-
Cyclotella menighiniana Kutzing	-	-	5	20	-	-
Order II: Pennales						
Cocconeis placentula Ehrenberg	30	-	35	-	-	-
Gyrosigma balticum (Her) Rabenhorst	-	-	5	-	-	-
Navicula carnifera Grunow	5		10	-	10	-
N. mutica Kutzing	5	5	5	5	40	-
Nitzchia palea (Kutzing) Wm Smith	-	-	-	-	5	-
Pleurosigma angulatum Wm Smith	5	-	-	35	5	-
Thallasionema nitzschoides Grunow	-	-	-	80	40	5
Trachyneis aspera var *aspera* Hendey	-	-	15	85	20	25
Class – Cyanophyceae						
Order I – Chroococcales						
Microcystis flos-aquae Kirchner	-	-	655	-	-	-
Order II – Hormogonales						
Anabaena constricta Geitler	30	415	25	95	5	-
Oscillatoria chalybea Gomont	-	-	-	-	110	110
O. trichodes Szafer	-	-	5	10	-	-
Spirulina jenneri Geitler	5	-	5	20	15	-
S. platensis Geitler	-	-	330	105	25	-
Phormidium uncinatum Gomont	-	-	7,600	-	-	-

The pennate diatoms were the more diverse group and their diversity and abundance increased with the onset of the rains. Notable of this group were *Navicula mutica*, *Pleurosigma angulatum, Trachyneis aspera* var. *aspera, Navicula carinifera, Cocconeis placentula, Thallasionema nitzschioides* and *Gyrosigma balticum.* Notable centric diatoms were *Coscinodiscus* and *Biddulphia* species.

The four blue-green algae species recorded were *Anabaena constricta Spirulina platensis, Spirulina jenneri* and *Oscillatoria trichodes* while *Microcystis flos-aquae* and *Phormidium uncinatum* occurred only in April.

Community Structure

Species diversity was highest in the phytoplankton with the onset of the rains. In April high species diversity (31 species) was recorded. Phytoplankton biomass in terms of numbers was higher in the drier months than during the wet months (Figure 2)

Higher species richness (d), Shannon and Weaver and Equitability index values were recorded in the phytoplankton community with the coming of the rains while in the dry months (Feburary and March) comparatively lower outcomes were recorded (Table 3).

Correlation coefficient for the same physico-chemical characteristics at stations A and B for the sampling period was ≥ 7.3 in all cases except for oil and grease (0.23) (Table 4). Strong positive correlation (≥0.75) was also estimated between total bacillariophyta and transparency, depth, total dissolved solids, biological oxygen demand, salinity, nitrate-nitrogen, phosphate-phosphorus and sulphate (Table 5).

Discussion

Information on the variation in physico-chemical factors and hydrology of the Ijora creek confirms earlier observations in the Lagos lagoon that two dominant factors, fresh water discharge and tidal sea water incursions governs the physical, chemical and biological characteristics of the area (Hill and Webb, 1958; Sandison and Hill, 1966; Nwankwo, 1988, 1998b; Brown, 1998).

High air and water temperatures were recorded throughout the study period with relatively higher values in the dry months (February and March) than in the wet months (April, May, June and July). This could be attributed to increase cloud cover and

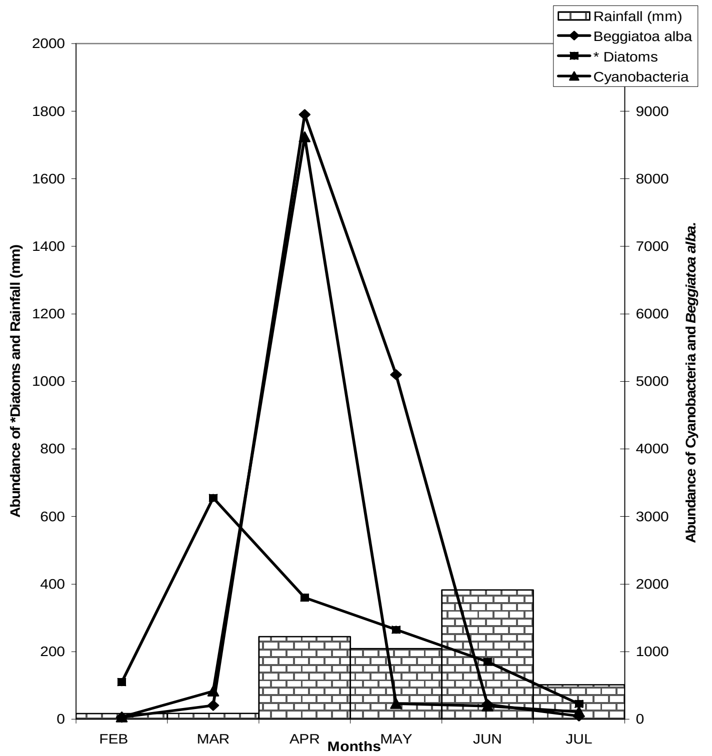

Figure 2. Monthly variation in abundance of Cyano bacteria, *Beggiatoa alba* and rainfall volume of Ijora creek.

*: Diatoms : (Diatom population minus *Biddulphia sinensis* bloom in February –29,945 individuals).

Table 3. Monthly variation in the abundance of the major classes and community structure of phytoplankton at the Ijora creek (February – July 2003)

	February	March	April	May	June	July
Shizomycetes (Bacteria)	6	41	1790	1020	44	9
Bacillariophyceae (Diatoms)	30,055	655	360	265	170	45
Cyanophyceae (Cyanobacteria)	35	415	8,620	230	195	110
Total biomass	30,901	1,106	10,780	1,520	404	169
Species diversity	12	5	31	16	20	8
Species richness index (d)	1.07	0.57	3.25	2.05	3.17	1.36
Shannon and Weaver index (Hs)	0.02	0.38	0.46	0.59	1.07	0.56
Equitability index (j)	0.14	0.24	0.13	0.21	0.36	0.27

Table 4. Correlation coefficient values (r) between physico-chemical characteristics at station B and the abundance of major phytoplankton classes

Parameters	Taxa		
	Total Shizomycetes	Total Bacillariophyceae	Total Cyanophyceae
Water temperature	-0.13	0.33	-0.30
Transparency	-0.28	0.97	-0.14
Depth	-0.42	0.75	-0.26
Total Dissolved Solids	-0.4	0.97	-0.28
Total Suspended Solids	0.73	0.35	-0.68
Salinity	-0.36	0.97	-0.24
Nitrate-nitrogen	-0.38	0.94	-0.25
Phosphate -phosphorus	-0.14	0.98	-0.25
Sulphate	-0.37	0.99	-0.23
Dissolved oxygen	-0.79	0.40	-0.37
Biological oxygen demand	0.14	0.85	0.20
Conductivity	-0.27	0.45	-0.04
Oil and grease	-0.29	0.95	-0.19
Rainfall	0.26	-0.5	0.28

Table 5. Pearson correlation coefficient matrix between physico-chemical characteristics in stations A and B at the Ijora creek

	Station B														
Station A	Air temperature	Water temperature	Depth	Transparency	pH	D.O.	B.O.D.	T.D.S.	T.S.S.	NO_3-N	PO_4-P	SO_4	Conductivity	Salinity	Oil and Grease
Air temperature	0.97	0.92	0.78	0.48	0.6	-0.2	0.51	0.49	-0.5	0.59	0.44	0.39	-0.55	0.52	0.58
Water temperature	0.78	0.88	0.89	0.79	0.72	0.1	0.69	0.83	0.11	0.88	0.8	0.77	-0.15	0.84	0.87
Depth	0.26	0.34	0.77	0.79	0.86	0.45	0.73	0.75	-0.16	0.79	0.75	0.75	-0.11	0.77	0.78
Transparency	0.55	0.58	0.9	0.89	0.93	0.26	0.87	0.86	-0.21	0.91	0.84	0.84	-0.11	0.88	0.91
pH	0.71	0.53	0.57	0.41	0.78	-0.33	0.65	0.32	-0.77	0.41	0.29	0.27	-0.42	0.36	0.44
D.O.	-0.76	-0.57	-0.05	0.12	-0.16	0.85	-0.15	0.14	0.63	0.08	0.19	0.21	0.3	0.11	0.03
B.O.D.	0.05	-0.05	0.17	0.46	0.8	-0.21	0.73	0.33	-0.43	0.32	0.34	0.38	0.31	0.36	0.03
T.D.S.	0.44	0.53	0.91	0.98	0.72	0.46	0.81	1	0.25	1	0.99	0.98	0.16	1	0.4
T.S.S.	-0.61	-0.43	-0.23	-0.09	-0.62	0.62	-0.42	0.01	0.95	-0.08	0.95	0.05	0.43	-0.03	0.99
NO_3-N	0.63	0.7	1	0.87	0.71	0.42	0.7	0.89	0.02	0.94	0.87	0.84	-0.22	0.9	-0.13
PO_4-P	0.42	0.51	0.91	0.92	0.57	0.56	0.69	0.96	0.36	0.96	0.95	0.93	0.1	0.95	0.91
SO_4	0.56	0.65	0.99	0.89	0.68	0.49	0.7	0.92	0.12	0.96	0.9	0.88	0.14	0.93	0.93
Conductivity	-0.58	-0.58	-0.54	-0.89	-0.33	-0.08	-0.06	-0.09	-0.61	-0.22	-0.04	0	0.93	-0.11	0.93
Salinity	0.5	0.57	0.94	0.98	0.77	0.43	0.83	0.99	0.16	1	0.98	0.97	0.09	0.99	0.99
Oil and Grease	0.59	0.51	0.46	0.17	0.61	-0.2	0.33	0.11	0.85	0.23	0.07	0.05	0.72	0.15	0.23

consequent reductions in solar radiation. The creek was alkaline throughout the study probably a reflection of the buffering effect of tidal seawater experienced in the area. The creek also recorded reduced transparency values for the rainy season probably an outcome of mixing of the creek by more turbid floodwater inputs and re-suspension of bottom materials.

Low dissolved oxygen and high biological oxygen demand values recorded are likely pointers to pollution stress to which the creek is exposed. Nutrient (nitrate – nitrogen, phosphate – phosphorus and sulphate) and salinity levels recorded high estimates in the dry season, possibly a reflection of the high amount of bio-degradable waste discharges in the region and reduced dilution effects from floodwaters.

Similarly, total dissolved solids and total suspended solids were high in the dry months. According to Nwankwo and Akinsoji (1989) the Lagos lagoon is under intense pressure from pollution such as untreated sewage, sawdust, petrochemical materials, detergent and industrial effluents. A reduction in the pollution status of the creek during the rains could be linked to floodwater dilution and reduced resident time of the polluted water, which probably ameliorated situations.

Strong positive correlation (≥7.5) recorded for total bacillariophyta and transparency, depth, total dissolved solids, salinity, nitrate – nitrogen, phosphate

– phosphorus, sulphate, biological oxygen demand and oil and grease are likely clear responses of diatoms to changing hydroclimatic characteristics. Similar regimes have been recordd by Nwankwo (1998b). Conversely strong negative correlation (-0.5) was recorded between total bacillariophyta and rainfall (Nwankwo, 19996; Nwankwo and Onyema, 2003; Onyema *et al*., 2003). This further highlights rainfall and associated floodwater conditions as key determinants of hydrology hence the plankton spectrum of south-western Nigeria (Olaniyan, 1969, 1975).

Higher species diversity encountered during the rains was probably due to the recruitment of phytobenthic forms as a result of the scouring of the creek by floodwaters. It is likely that, in the dry season the more important source of recruitment of planktonic algae may have been the sea. On the other hand, the scouring effect of floodwaters could have dislodged attached forms into the plankton in the wet season and leading to the marked presence of *Beggiatoa alba*; an indicator of sewage pollution. Similar situations have been reported by Onyema and Nwankwo (2006).

Numerically, the bacterium – *Beggiatoa alba* was the most important species reported. Lee (1999) is of the opinion that the genera *Beggiatoa* is possibly a cyanobacterial form that has lost its essential pigmentation probably through evolution. According to Stanier (1963) *Beggiatoa* shows striking morphological resemblance to the blue-green algae and infact is unmistakably a morphological counter part of the blue-green alga, *Oscillatoria*. This may further explain the strong positive correlation (0.85) between trends in abundance of *Beggiatoa alba* and cyanobacteria populations Van Niel and Stainer, 1963).

The presence of *Beggiatoa alba* may confirm the pollutions status of the creeks. Abundance of this taxa increased during the rains probably resulting form perturbations of the creeks epipelic community to which the taxon would likely be a key member. According to APHA (1981), *Beggiotoa alba* is a good indicator of sewage pollution. Sewage disposal trucks on daily basis are seen at the Ijora creek discharging untreated sewage. This diagnosis is supported by the presence of *Oscillatoria chalybea* (Dakshini and Soni, 1982), *Oscillatoria trichodes* (Nwankwo, 2004) and *Spirulina* spp. (Vanlandingham, 1982) which may be indicators of high levels of biodegradable waste pollution.

It would seem also from the dynamics of phytoplankton occurrences that apart from gross amounts of biodegradable contaminant, signs of toxic chemical waste are also reflected in the phytoplankton diversity. *Biddulphia sinensis*, *Beggiotoa alba*, *Microcyctis flos – aquae*, *Spirulina platensis* and *Phormidium uncinatum* in high numbers at one time or the other are clear bio – indicators of the alkaline and brackish nature of the creek, its high nutrients status and the presence of toxic contaminants (Nwankwo 1998b, 2004; Vanlandingham, 1982; APHA, 1981; Nwankwo and Akinsoji, 1992). According to Patrick (1973), community affected by toxic pollutant has a low diversity and low number of species whereas a community affected by organic pollutant has a fairly high number of species but low diversity.

The presence of *Microcystis* only in April may be due to its inability to survive in high brackish and marine water conditions. Nwankwo *et al.,* (2003) has reported *Microcystis* in fresh and low brackish water conditions in south-western Nigeria. The absence of known low salinity and fresh water algal forms through out sampling could be indicative of a rapid changing regime and extent of salinity variations from one tidal cycle to the next, even during the rains. Additionally, the presence of raphed pennate diatoms confirms the shallow nature of the creek.

Semi-diurnal tidal oscillation resulting in dilution of the creeks polluted waters (at high tide) and eventual out flowing (at low tide) to the sea (Atlantic Ocean) may be the key factor preventing an epidemiological outbreak in the region. It is worthy of note that taxa belonging to the class dinophyceae were not recorded throughout the study. However this group has been reported in the region before now (Nwankwo, 1988; Nwankwo *et al* 2003; Onyema *et al*., 2003).

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