Nutrients and Phytoplankton Production Dynamics of a Tropical Harbor in Relation to Water Quality Indices

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Abstract: Six months (June ï November, 2009) study was carried out to investigate the Phytoplankton spectrum, nutrients status and associated Water Chemistry of three selected stations in the Lagos Harbour, Nigeria. The results revealed a generally low species composition and diversity. A total of 39 species of Phytoplankton spectrums were recorded from three taxonomic groups namely *Bacillariophyta*, *Cyanophyta* and *Dinophyta*. The dominant taxonomic groups were *Bacillariophyta* (Diatoms) with 31 taxa and 86.35% of the total Phytoplankton. The concentrations of Nutrients (NO_3^-, PO_4^{3-}, and SiO_4^{4-}) determined were relatively lower to FEPA limit. Some physical-chemical parameters were measured in the water column to assess the water quality such as Temperature, pH, Electrical Conductivity, Turbidity, Salinity, Dissolved Oxygen, Biochemical Oxygen Demand(BOD), Chemical Oxygen Demand(COD), Total Alkalinity and Total Dissolved Solids(TDS). The surface water of the harbor were characterized by alkaline pH (> 8.0mg/l), low BOD_{20}^5(< 2.16), total dissolved solids(<15.20) and moderate dissolved oxygen(<5.12) which fell below FEPA limit of 10mg/l. Salinity values in all the stations typify a brackish condition (<15.06ă). With the exception of pH, dissolved oxygen and Nitrate, all other parameters measured differed significantly (P< 0.05) among the study stations. The correlation between phytoplankton abundance and parameters measured except Air and Water temperature, Dissolved Oxygen, BOD, and Nutrients determined in this study were positive. The information and observation of this research will be very useful in formulating policies and regulatory framework for sustainable management of Lagos Harbour. [Journal of American Science 2010; 6(9):261-275]. (ISSN: 1545-1003).

Keywords: Harbour, Nutrients, Pollution, Phytoplankton, Water quality.

1. Introduction

Phytoplankton is the most important producer of organic substances in the aquatic environment and the rate at which energy is stored up by these tiny organisms determine the basic primary productivity of the ecosystem. All other living forms at higher trophic levels are directly or indirectly dependant on phytoplankton for energy supply and therefore, performing vital functions. Phytoplankton satisfy conditions to qualify as suitable pollution 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). The species composition of planktonic microalgae in seawater can be monitored as an indicator of water quality. 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).

Phytoplankton and microbial growth are promoted by the presence of nutrients such as nitrates, phosphates, silicates etc. in the seawater. Effluents from industrial and sewage sources are rich in these nutrients and eutrophication serves as indicator sewage pollution. Availability of bio-limiting elements such as nitrogen, phosphorous and silica is an important factor affecting primary production. Active growth of phytoplankton reduces the levels of micronutrients (nitrates, phosphates and silicates) in the surface layers thus restricting the primary production. The essential nutrients are replenished mainly by way of degeneration of dead ones and mixing of nutrient rich bottom water by upwelling and turbulence. This again is governed to a great extent by local climatic conditions and geography.

There exist current reports on the composition and distribution of phytoplankton community on the Lagos, Epe and Iyagbe lagoons, Estuarine Creeks and other coastal waters of Nigeria (Nwankwo, 1990, 1996, 2004, Kadiri, 2000, Onyeama, 2007, 2009, Chindah and Braide, 2001). There is presently a dearth of current information on

phytoplankton community and nutrient status in the Harbour in south-western Nigeria.

This study investigates the composition and distribution of phytoplankton as well as nutrients concentration in relation to water quality in a tidal Harbour in south-western Nigeria.

2. Materials and methods

2.1. Description of Study Area

Lagos Harbour, Nigeria's most important seaport is the first inlet from the Atlantic Ocean beyond the Republic of Benin. The Harbour is one of the three main segments of Lagos Lagoon Complex; other segments are: Metropolitan and the Epe Division Segments. The Lagos harbor (Figure 1) is located in Lagos state, Nigeria. The 2 km wide harbour receives inland waters from the Lagos Lagoon in the east, and from Badagry Creek in the west. It provides the only opening to the sea for the nine lagoons of South Western Nigeria. Lagos Harbour is a naturally protected basin equipped with docking and other facilities for the loading and unloading of cargo and usually with installations for the refueling and repair of ships. Apart from oil depots sited along the shore of western parts of the Harbour coupled with the proliferation of urban and industrial establishments on the shore of eastern part of the Harbour, the Harbour is used as a route to transport goods but subsistence fishing takes place at some locations by local fishermen.

Three sampling stations were chosen along the eastern parts of Lagos harbour. They were:

Station 1: East Mole

Station 2: NIOMR Jetty

Station 3: Defence Jetty (Opposite Apapa seaport)

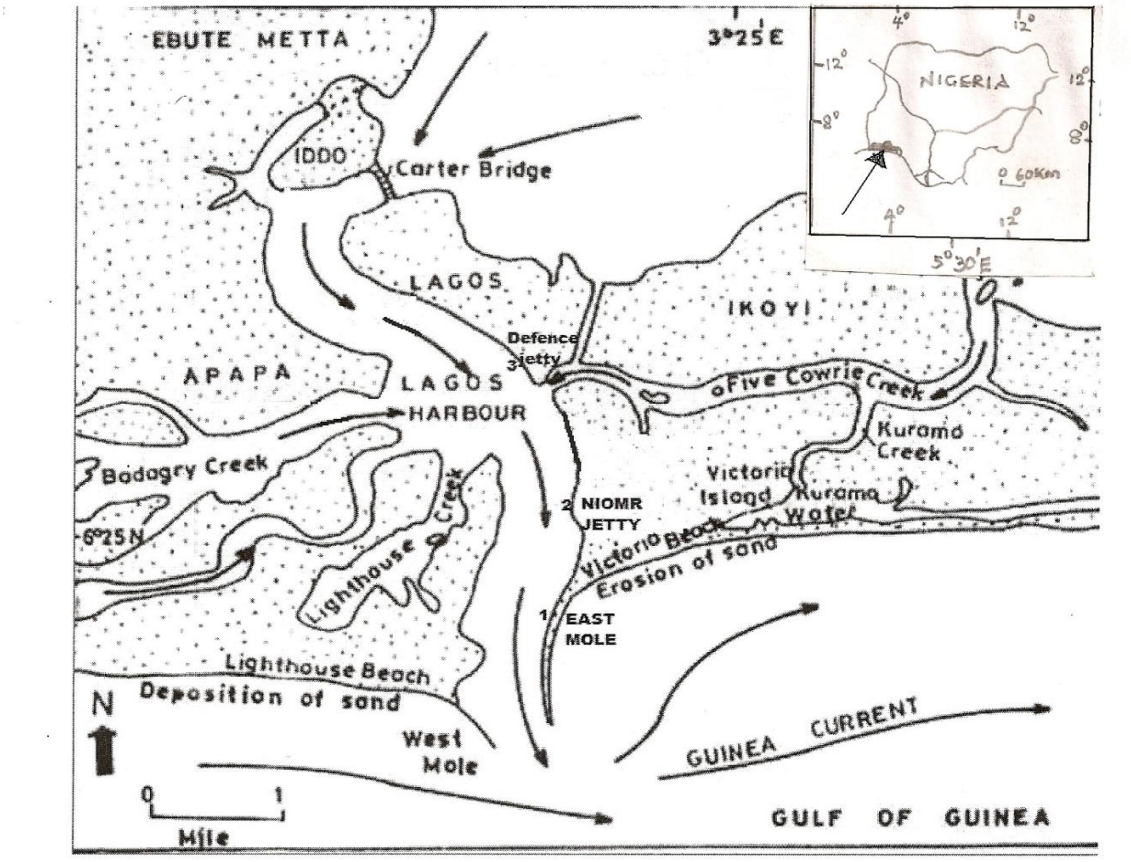


Figure 1: Map of Lagos Harbour Showing Sampling Stations denoted by **1, 2, and 3**.

2.2. Collection of Water Samples

Water samples for physical and chemical parameters determination were collected from the three sampling stations located in the harbor at monthly intervals from June 2009 to November 2009.

Water samples were collected from the surface with a $1dm^3$ water sampler and stored in 1 litre screw- capped plastic containers and stored in a refrigerator at $4^0C \pm 1^0C$ prior to analyses. Separate water samples were collected in amber glass bottle (300ml) with glass stoppers for BOD determination and in 250ml dissolved oxygen bottles at each station and fixed according to Winklerôs method using Manganous Sulphate and Alkaline Potassium iodide reagents for dissolved oxygen determination. Air and surface water temperature were measured using mercury-in-glass thermometers *in situ*. The samples were preserved as recommended in APHA (1989) for the different parameters measured. The time lapse between sample collection, preservation and analysis was a week for each set of samples.

2.3. Physical – chemical parameters analysis

Monthly rainfall data measured in mm were obtained from the NIMET marine office at the Nigerian Institute for Oceanography and Marine Research, Victoria- Island Lagos. pH, conductivity, salinity and turbidity were analysed *in situ* using a multi-meter water checker (Horiba U-12). Separate water samples collected in 250ml dissolved oxygen bottles at each station for dissolved oxygen determination were estimated using iodometric Winklerôs method (Stirling, 1999). Alkalinity of the water samples was determined by titrating dilute HCl against 50ml of the water sample using methyl orange as an indicator. Total Dissolved Solids (TDS) were determined by filtering a well ï mixed water sample through a fibre filter paper into a weighted dish. The filtrate (in the dish) was evaporated to dryness to a constant weight. TDS was calculated with the following formula (APHA, 1989).

$$\text{TDS (mg/l)} = \frac{(a \text{ ï } b) \times 1000}{\text{Sample Vol. (ml)}}$$

Where; a = Weight of dish (mg) + dried residue

b = Weight of dish (mg)

Biological Oxygen Demand (BOD_5^{20}) was carried out by measuring the amount of dissolved oxygen present in the samples before and after incubation in the dark at 20^oC for five days. The Biological Oxygen Demand in mg/litre is the difference in the dissolved oxygen values before and after incubation. Chemical Oxygen Demand (COD) was determined by adding mercury sulphate, 5 ml concentrated sulphuric acid (H_2SO_4) to 5 ml of samples and 25 ml of potassium permanganate was added. The mixture was refluxed for 2hr and allowed to cool: the solution was titrated against ammonium sulphate solution using the ferroin as indicator (APHA, 1989).

$$\text{COD (ppm)} = \frac{(a - b)\ N \times 800}{S}$$

Where; N = Normality of ferrous ammonium sulphate

a - b = Volume (ml) of Ferrous ammonium sulphate used in titration of Blank (a) and of

Sample efficient (b)

S = Volume (ml) of sample water

COD = Chemical Oxygen Demand.

2.4. Nutrients Analysis

Nitrate ï Nitrogen (No_3-N), Phosphate ï Phosphorus (Po_4-P) and Silicate ï Silicon (SiO_4-S) in the water sampled for each set of samples were measured in the laboratory with a portable datalogging spectrophotometer HACH DR/2010 after reduction with appropriate solutions.

All reagents used for the analyses were of analytical grade and double distilled water was used in the preparation of all the solutions.

2.5. Collection and Preservation of Phytoplankton Samples

Phytoplankton sample was collected on each occasion and station by towing a 55 εm 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 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 taken to the laboratory for storage prior to microscopic analysis in the laboratory.

2.6. Phytoplankton Analysis

In the laboratory, five drops (using a dropper) of the concentrated sample (10ml) was investigated at different magnifications (50X, 100X and 400X) using a Wild II binocular microscope with calibrated eye piece and the average recorded. A suitable plankton sample mount was then created. The drop count microscope analysis method described by Onyema (2007) was used to estimate the plankton flora. Since each sample drop from the dropper accounts to 0.1ml, the results on abundance /

occurrence were multiplied accordingly to give the values as numbers of organisms per ml which is the standard unit of measurement. Appropriate texts were used to aid identification of the species (Patrick and Reimer 1975; Vanlandingham 1982; Nwankwo 1990, 2004; Siver 2003).

2.7. Data Analysis

Mean and standard error values were obtained for each of the physical-chemical parameters. Data collected for the environmental parameters were subjected to statistical analysis using analysis of variance (ANOVA) to determine their variations at stations. The linear correlation analysis was carried out on the water parameters and Phytoplankton to verify if there is any significant relationship.

Community Structure Analysis

Species Richness Index (d)

The Species richness index (d) according to Margalef (1951) was used to evaluate the community structure.

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

Where:

d = Species richness index

S = Number of species in a population

N = Total number of individuals in S species.

Menhinickôs Index (D) as presented by (Ogbeibu, 2005)

The Menhinickôs Index (D)

$$D = S / \sqrt{N}$$

S = Number of species in a population

N = Total number of individuals in S species.

Shannon and Wiener diversity index (Hs) (Shannon and Weiner, 1949) which Ogbeibu, (2005) presented as:

The Shannon and Wiener diversity index (Hs)

$$Hs = \frac{N \log N - \sum P_i \log P_i}{N}$$

Where Hs = Shannon and Wiener diversity Index

i = Counts denoting the *i*th species ranging from 1 ï n

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

N = Total abundance.

Shannon Index (H^1) which Ogbeibu, (2005) presented as

The Shannon index (H^1)

$$H^1 = - \sum_{i=1}^{\infty} pi \ln pi$$

Where *pi* is the proportion of individuals found in the *i*th species

(*pi* = *ni* /*N*, *N* being the total abundance).

Species Equitability or Evenness index (j) (Lloyd and Ghellardi, 1964) as presented by (Ogbeibu, 2005).

The Species Equitability /Evenness index (j)

$$j = \frac{Hs}{\log_2 S}$$

Where

J = Equitability index

Hs = Shannon and Weiner index

S = Number of species in a population.

Simpsons dominance index (C) as presented by (Ogbeibu, 2005).

$$C = \sum \left(\frac{n_i}{N}\right)^2$$

Where ni = number of individuals of the ith species
N = the total number of individuals for all species

Simpsonôs Index (D) which Ogbeibu, (2005) presented as

$$D = \sum_{i=1}^{s} ni\,(ni - 1)/N(N - 1)$$

Where ni = the total number of individuals in the ith species
N = the total number of individuals.

Simpsonôs Index (D^1)

The reciprocal form $D^1 = 1/D$
(Defined as the number of very abundant species)

3. Results

3.1. Phytoplankton composition, abundance and distribution

The composition, abundance and distribution of the phytoplankton in the study area are presented in Tables 1 and 2 respectively.

A total of 39 species of Phytoplankton were recorded from 3 taxonomic groups. *Asterionella spp* and *Aulacoseira granulata* had the highest number recorded (100 counts/ml, 5.94%) while species with the least abundance (5 counts/ml, 0.30%) were *Nitzschia angularis* and *Ceratium tripos var indicum*.

Bacillariophyceae (Diatoms) accounted for (1455 counts/ml, 86.35%) of the total phytoplankton taxa, mainly Centrales (1130 counts/ml, 67.06%) and the Pennales (325 counts/ml, 19.29%). Consequently, for diatoms, centric forms recorded 21 species while pinnate forms were represented by 10 species. Cyanophyceae made up of (180 counts/ml, 10.68%) of the total phytoplankton taxa and next in proportion to Bacillariophyceae. The Blue- green Algae were represented by 4 species among these included the genus *Oscillatoria* made up of 3 species and *Lynbgya martensiana.* The family Dinophyceae accounted for (50 counts/ml, 2.97%) of the total phytoplankton taxa. The dinoflagellates were represented by 4 species with the genus *Ceratium* made up of 3 species and *Dinophysis caudata*.

Considering Phytoplankton distributions among the stations, Station 1 recorded the highest number of species (30) while station 3 had the least species diversity (20). Of all the individuals (1685) collected, station 1 also recorded the highest number of 615(36.5%), while station 3 with 525(31.2%) had the lowest abundance.

Figure 2 show the Monthly number of phytoplankton from Lagos Harbour for the study period. The highest number (450 org. ml^{-1}, representing 26.7%) was observed in June, while the least number (95 org. ml^{-1}, representing 5.6%) was recorded in October.

Analysis of variance for the 3 sampling stations for diversity of Phytoplankton observed showed significant differences ($P < 0.001$) among the stations. The diversity of Phytoplankton in station 1 is significantly higher ($P< 0.001$) than that of station 2 and 3. Likewise, the diversity of Phytoplankton in station 2 is significantly higher ($P< 0.001$) than that of station 3.

The Phytoplankton community structure analysis of the study areas for the period of study are presented in Table 2. Station 1 recorded highest values in Species Richness index(d)(4.515), Menhinick index(D)(1.210), Shannon-Wiener index(H)(1.408), Shannonôs index(H^1)(3.243) Equitability/Evenness index(E)(0.953) and Simpsonôs index(D^1)(26.316) while Station 3 had the lowest values of 3.033, 0.873, 1.214, 2.795, 0.933 and 15.875 in Species Richness index(d), Menhinick index(D), Shannon-Wiener index(H), Shannonôs index(H^1), Equitability/Evenness index(E) and Simpsonôs index(D^1) respectively. Conversely, station 3 had the highest values (0.067 and 0.063) in Simpsonôs dominance index(C) and Simpsonôs index (D) while station 1 had the lowest values of 0.038 each.

Table 1: Phytoplankton abundance Composition in Lagos Harbor (June ï November, 2009).
(1, East Mole; 2, NIOMR Jetty; 3, Defence Jetty [Opposite Apapa Seaport])

	Station 1	Station 2	Station 3	Counts/ml	Percentage Number
DIVISION ï BACILLARIOPHYTA					
CLASS-BACILLARIOPHYCEAE				1455	86.35%
ORDER I ï CENTRALES				1130	67.06%
Actinoptychus splendens Ehrenberg	-	10	35	45	2.67
Asterionella sp.	-	25	75	100	5.94
Aulacoseira granulata Ehrenberg (Ralfs)	15	35	50	100	5.94
Meloseira moniliformis Agardh	35	20	5	60	3.56
Odontella aurita (Lyngbe) Brebisson	25	10	-	35	2.08
Odontella sinensis Greville	20	35	15	70	4.15
Chaetoceros curvisetum	25	5	-	30	1.78
Chaetoceros decipens Cleve	-	25	20	45	2.67
Coscinodiscus centralis Ehrenberg	10	30	45	85	5.04
Coscinodiscus jonesiaanus Ehrenberg	10	-	-	10	0.59
Coscinodiscus marginatus Ehrenberg	-	25	15	40	2.38
Coscinodiscus radiates Ehrenberg	35	30	15	80	4.75
Coscinodiscus gigas Ehrenberg	40	45	5	90	5.34
Cyclotella menighiniana Kutzing	25	10	-	35	2.08
Cyclotella striata (Kutzing)	35	20	-	55	3.26
Ditylum brightwelli (T.west) Grunow	30	-	-	30	1.78
Hemidiscus cuneiformis Wallich	-	-	35	35	2.08
Leptocylindricus danicus Cleve	30	35	20	85	5.04
Rhizosolenia alata Brightwell	15	-	-	15	0.89
Terpsinoe musica (Ehr.) Hustedt	-	-	30	30	1.78
Thalasiosira subtilis (Ostenfeld) Gran	25	15	15	55	3.26
Order II ï PENNALES				325	19.29%
Gyrosigma balticum	-	-	30	30	1.78

Navicula cryptocephala (Kutz) Hustedt	30	5	-	35	2.08
Navicula cuspida Kutzing	10	20	-	30	1.78
Pinnularia major (Kutzing) Rabenh	25	10	-	35	2.08
Synedra sp.	5	15	15	35	2.08
Synedra crystalline (Ag) Kutzing	20	15	50	85	5.04
Synedra ulna (Nitzsch)	10	5	-	15	0.89
Pleurosigma angulatum (Quekett) Wm Smith	5	15	20	40	2.38
Fragillaria islandica Gunner	15	-	-	15	0.89
Nitzschia angularis	5	-	-	5	0.30
DIVISION ï CYANOPHYTA					
CLASS ï CYANOPHYCEAE				180	10.68%
Order ï HORMOGONALES					
Lynbgya martensiana Meneghini	45	-	-	45	2.67
Oscillatoria curviceps C.A. Agardh	-	-	10	10	0.59
Oscillatoria limnosa Agardh	30	35	20	85	5.04
Oscillatoria tenius Agardh	-	40	-	40	2.38
DIVISION ï DINOPHYTA					
CLASS ï DINOPHYCEAE				50	2.97%
Order - PERIDINALES					
Ceratium fusus Ehrenberg	15	5	-	20	1.19
Ceratium lineatum Ehrenberg	10	-	-	10	0.59
Ceratium tripos var indicum	5	-	-	5	0.30
Dinophysis caudata Kent	10	5	-	15	0.89
Total species diversity (S)	30	27	20	77	100
Total abundance (N)	615	545	525	1685	100
Percentage Number	36.5%	32.3%	31.2%	100	100

Table 2: Phytoplankton community structure Analysis. (1, East Mole; 2, NIOMR Jetty; 3, Defence Jetty [Opposite Apapa Seaport])

	Station 1	Station 2	Station 3
Log of Species diversity (Log S)	1.477	1.431	1.301
Log of abundance (Log N)	2.789	2.736	2.720
Species Richness/Margalef Index (d)	4.515	4.126	3.033
Menhinick Index (D)	1.210	1.157	0.873
Shannon-Wiener Index (H)	1.408	1.353	1.214
Shannonõs Index (H^1)	3.243	3.112	2.795
Equitability/Evenness Index (j)	0.953	0.945	0.933
Simpson's Dominance Index (C)	0.038	0.043	0.067
Simpsonõs Index (D)	0.038	0.043	0.063
Simpsonõs Index (D^1)	26.316	23.256	15.875

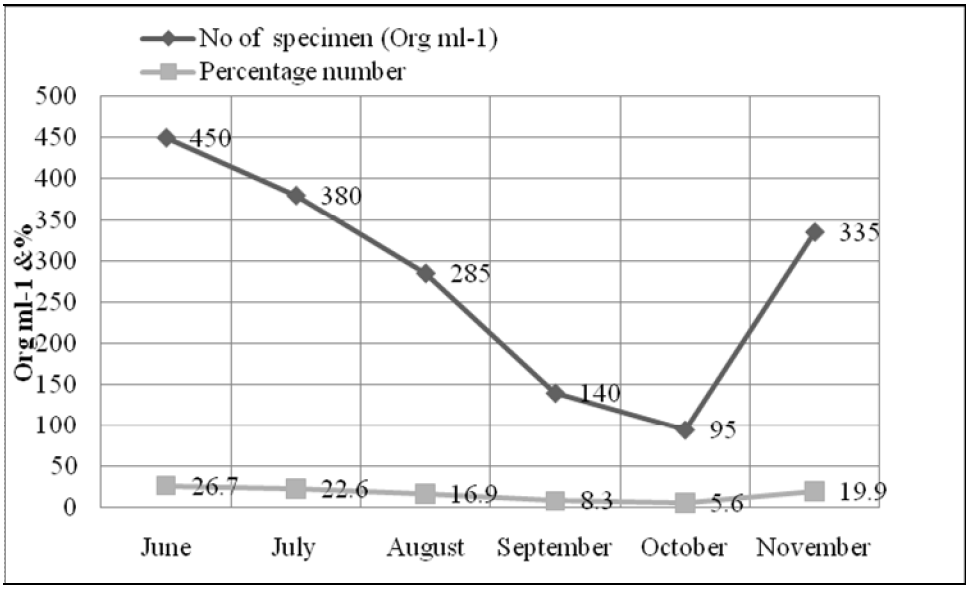


Figure 2: Monthly Phytoplankton Number and Percentage in Lagos Harbor (June ï November, 2009).

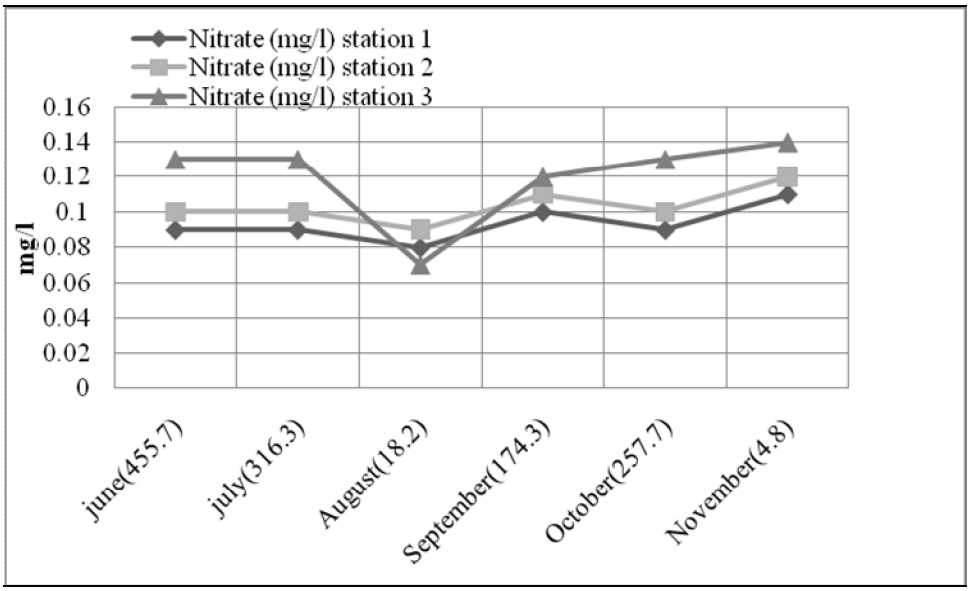
3.2. Nutrients Dynamics

The values of the Nutrients measured in the study areas of Lagos Harbour during the period June to November are presented in Table 3. The maximum mean concentration of Nitrate of 0.11mg/l was recorded in Station 3, although there was no significant different (P< 0.05) in the 3 stations sampled. The mean values of Phosphate ranged from 0.65 to 1.66mg/l. Silicates showed variations in the 3 stations sampled and was significantly different (P< 0.05). The variations in these Nutrients in the three stations are compared in Figure 3.The lowest and highest level (0.07mg/l and 0.14mg/l) of Nitrate was recorded in station 3 in the month of August and November respectively. The lowest phosphate level of 0.07mg/l occurred at station 1 in August while the highest phosphate level of 2.20mg/l was recorded in station 2 of same month. Silicates had the highest values with station 3 recording the least level of 0.60mg/l in August while the highest level of 11.30mg/l was observed in October at station 2.

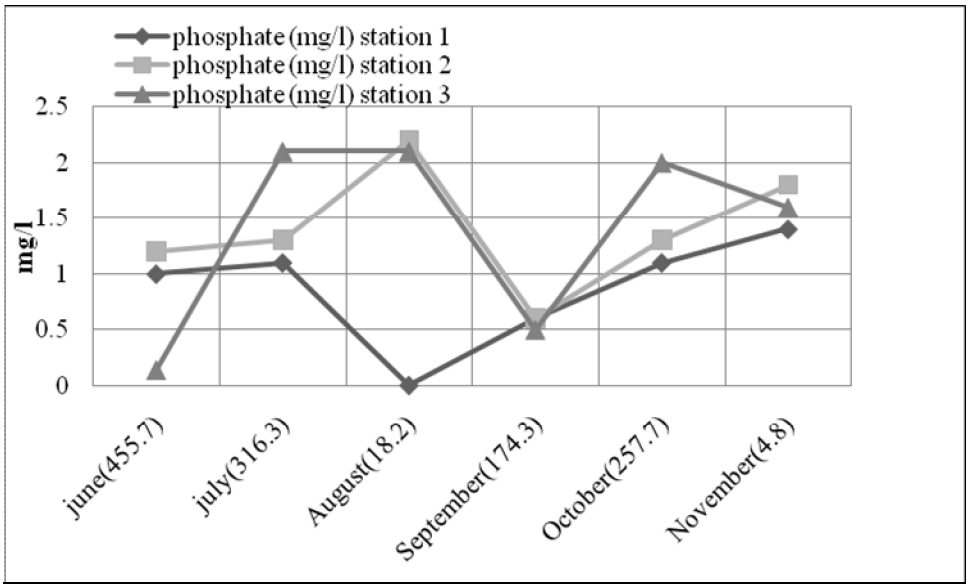
Table 3: The Result of Nutrient analysis of the study stations of Lagos Harbour from June to November 2009 (Range values in parentheses) values is; Mean ± SE. (1, East Mole; 2, NIOMR Jetty; 3, Defence Jetty [Opposite Apapa Seaport]). NS = Not specified; Means with the same superscript in each row are not significantly different (p<0.05).

Nutrients	Station 1	Station 2	Station 3	FEPA, 1991 LIMIT
Nitrate (mg/l)	0.09 ± 0.01^{a} (0.08 ï 0.11)	0.10 ± 0.01^{a} (0.09 ï 0.12)	0.11 ± 0.02^{a} (0.07 ï 0.14)	20
Phosphate (mg/l)	0.65 ± 0.27^{a} (0.07 ï 1.40)	1.62 ± 0.30^{b} (0.60 ï 2.20)	1.66 ± 0.30^{b} (0.50 -2.10)	5
Silicate (mg/l)	4.74 ± 1.44^{b} (1.40 ï 8.70)	5.90 ± 1.82^{c} (1.80 ï 11.30)	3.84 ± 1.40^{a} (0.60 ï 7.70)	NS

A



B



C

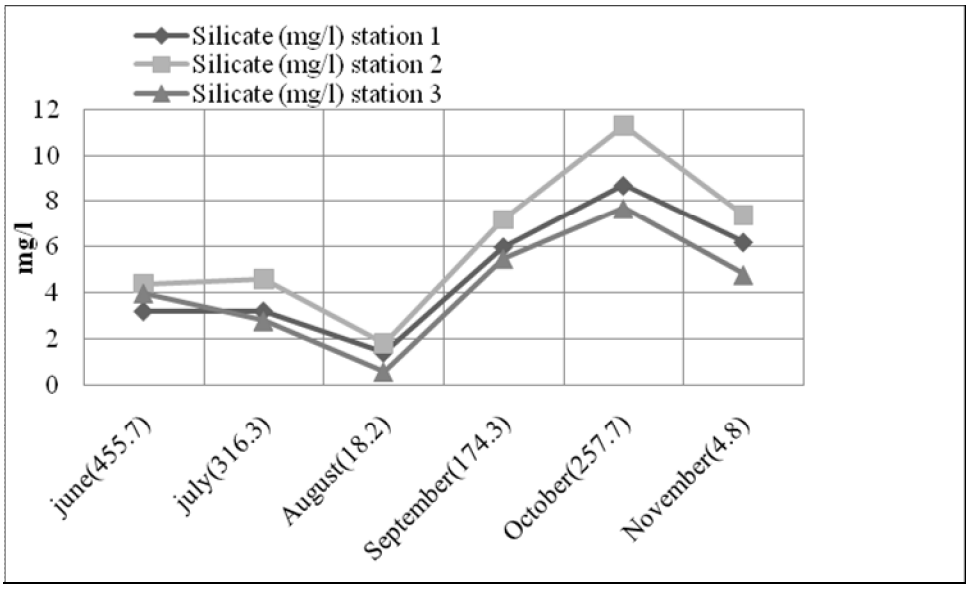


Figure 3: Variation of Nutrients; Nitrate (**A**), Phosphate (**B**), and Silicate (**C**) with months (rainfall).

3.3. Water Chemistry

Rainfall data of the study area during sampling periods are shown on Figure 4. Rainfall reduced slightly from June to July, dropped in August and then increased steadily until sharp fall in November. The mean of the physical and chemical parameters measured during the period June to November in the study areas of Lagos Harbour are presented in Table 4.

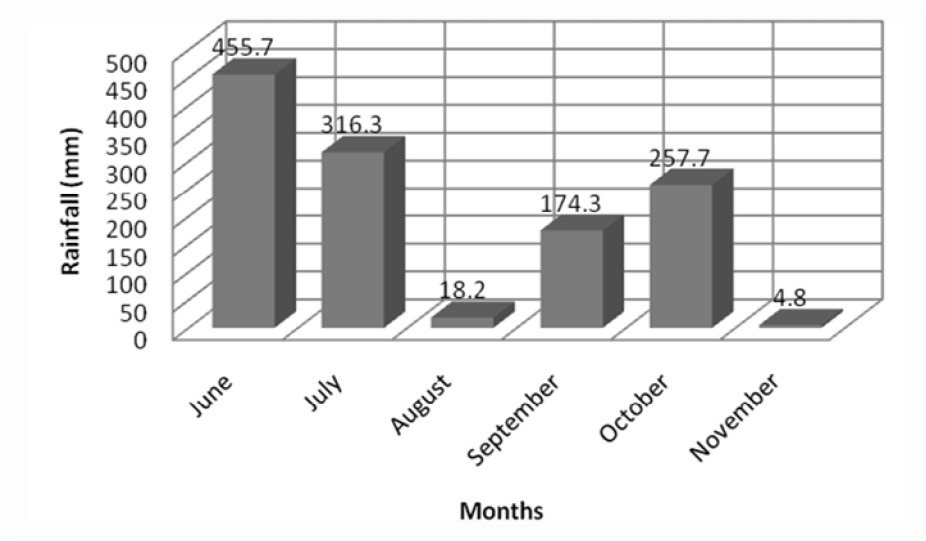


Figure 4: Monthly variations in rainfall in the study area (June ï November, 2009) (Source: NIMET marine office at the Nigerian Institute for Oceanography and Marine Research, Victoria- Island, Lagos, Nigeria.)

Table 4: Physical-Chemical parameters of the study stations of Lagos Harbour from June to November 2009 (Range values in parentheses) values are; Mean ± SE. (1, East Mole; 2, NIOMR Jetty; 3, Defense Jetty [Opposite Apapa Seaport]). NS = Not specified; Means with the same superscript in each row are not significantly different ($p<0.05$).

Parameters	Station 1	Station 2	Station 3	FEPA,1991 LIMIT
Air Temp (^oC)	26.40 ± 0.68^b (25.0 ï 28.0)	25.90 ± 0.76^a (24.50 ï 28.00)	26.80 ± 0.20^b (26.00 ï 27.00)	NS
Water Temp (^oC)	26.80 ± 0.41^a (26.00 ï 28.00)	27.10 ± 0.68^b (26.00 ï 29.00)	26.50 ± 0.67^a (25.00 ï 28.00)	<40
pH	8.10 ± 0.12^a (7.90 ï 8.56)	8.10 ± 0.12^a (7.70 ï 8.40)	8.04 ± 0.14^a (7.50 ï 8.30)	6-9
Conductivity (mS/cm)	22.44 ± 4.14^c (14.00 ï 38.20)	20.40 ± 3.95^b (12.00 ï 35.00)	17.92 ± 2.11^a (11.00 -23.00)	NS
Turbidity (NTU)	57.26 ± 28.08^c (8.00 ï 126.00)	27.60 ± 8.48^b (8.00 ï 48.00)	17.60 ± 3.48^a (8.00 ï 28.00)	NS
Salinity (ă)	15.06 ± 4.36^c (8.00 ï 32.30)	12.40 ± 2.58^b (7.00 ï 22.00)	10.62 ± 1.41^a (6.00 -14.00)	600
Dissolved Oxygen (mg/l)	5.12 ± 0.56^a (4.00 ï 6.80)	5.28 ± 0.29^a (4.80 ï 6.00)	5.12 ± 0.67^a (3.60 ï 6.80)	10
BOD_5 (mg/l)	2.16 ± 0.37^b (1.20 ï 3.20)	1.48 ± 0.84^a (0.20 ï 4.80)	1.52 ± 0.63^a (0.40 ï 3.60)	30
COD (mg/l)	6.50 ± 0.55^a (5.00 ï 8.00)	6.38 ± 0.76^a (5.30 ï 9.40)	7.62 ± 0.42^b (6.70 ï 8.90)	NS
Alkalinity (mg/l)	13.20 ± 1.49^c (10.00 ï 18.00)	12.00 ± 0.89^a (10.00 ï 14.00)	12.80 ± 1.20^b (8.00 ï 14.00)	NS
TDS (mg/l)	15.20 ± 0.41^c (7.00 ï 24.00)	13.17 ± 2.67^b (6.00 ï 20.00)	10.05 ± 1.27^a (5.00 ï 13.00)	2000

Maximum mean air temperature (26.80^0C) was recorded in station 3. Minimum mean water temperature of 26.50^0C was also recorded in station 3. pH values of all the stations were alkaline and remained relatively stable throughout the sampling period. pH values recorded exhibited no significant difference among the stations. Station 1 recorded the highest Conductivity, Turbidity and Salinity mean value of 22.44, 57.26 and 15.06 while station 3 recorded the least value of 17.92, 17.60 and 10.62 respectively. These parameters show significant difference (P< 0.05) among the stations. Dissolved Oxygen was more in station 2 (5.28mg/l) when compared with other stations. No significant difference (P< 0.05) among the stations. The BOD mean value at station 1 (2.16mg/l) were significantly higher than those at other stations. Station 3 had the highest COD mean value of 7.62mg/l and significantly higher than other stations (P< 0.05). The highest alkalinity mean value (13.20mg/l) was recorded in station 1 while the lowest value of 12.00mg/l was recorded in station 2. Minimum TDS mean value of 95.60mg/l was recorded in station 3. TDS exhibited significant difference (P< 0.05) among the stations.

Table 5a: Pearson Correlation Co-efficient Matrix of Phytoplankton and Nutrients measured in Lagos Harbor (June ï November, 2009).

	Phytoplankton	Nitrate	Phosphate	Silica	Rainfall
Phytoplankton	1.0				
Nitrate	-0.29	1.0			
Phosphate	-0.07	-0.03	1.0		
Silicate	-0.7	0.74	0.16	1.0	
Rainfall	0.3	-0.11	-0.53	0.01	1.0

Table 5b: Pearson Correlation Co-efficient Matrix of Phytoplankton and Physical-Chemical parameters measured in Lagos Harbor (June – November, 2009).

	Phytoplankton	Air Temperature	Water Temperature	pH	Conductivity	Turbidity	Salinity	Dissolved Oxygen	BOD	COD	Alkalinity	TDS	Rainfall
Phytoplankton	1.0												
Air Temperature	-0.88	1.0											
Water Temperature	-0.78	0.9	1.0										
pH	0.7	-0.73	-0.36	1.0									
Conductivity	0.6	-0.37	-0.23	0.59	1.0								
Turbidity	0.72	-0.73	-0.89	0.18	0.17	1.0							
Salinity	0.53	-0.42	-0.16	0.76	0.92	-0.03	1.0						
Dissolved Oxygen	-0.26	0.6	0.48	-0.38	0.45	-0.37	0.26	1.0					
BOD	-0.18	0.53	0.47	-0.41	-0.14	-0.07	-0.38	0.39	1.0				
COD	0.52	-0.13	-0.16	0.04	0.2	0.43	-0.05	0.14	0.73	1.0			
Alkalinity	0.65	-0.76	-0.65	0.58	0.18	0.76	0.13	-0.65	-0.13	0.25	1.0		
TDS	0.92	-0.65	-0.52	0.64	0.74	0.5	0.64	0.06	0.06	0.66	0.42	1.0	
Rainfall	0.3	0.06	-0.1	-0.29	-0.05	0.34	-0.31	0.21	0.73	0.92	-0.03	0.44	1.0

4. Discussions

Phytoplankton data from this investigation reveals reduction in abundance and diversity of species compared with earlier works (Olaniyan, 1957, 1969; Nwankwo, 1996, 2004; Onyema *et.al*., 2003). This variation could be attributed to human activities of sporadic dredging and sand mining of the harbor. Ajao, (1996) identified sand mining, sand filling, industrial effluents discharge, oil wastes, domestic water sewage discharges among others as human related activities capable and presently destroying the sensitive coastal environment of Nigeria species. Diatoms dominated the phytoplankton of this study. This finding is also similar to earlier reported by Olaniyan, 1969; Nwankwo, 1996, 2004; Onyema *et.al*, 2003. These previous workers are of opinion that the Lagos Lagoon which is linked to the Atlantic Ocean is dominated by diatoms with regard to its phytoplankton spectrum. However, the largest number of phytoplankton in this study was recorded when rainfall was highest. The low species richness (d) and shannonôs Diversity indices recorded in this study may be a pointer to the impact of perturbation stress on the phytoplankton communities.

The periods of low phytoplankton abundance coincided with relatively higher turbidity values, which may have reduced light penetration for photosynthesis. Temperature, Current velocity, nutrients availability and light among others were factors influencing phytoplankton abundance.

The correlation between phytoplankton abundance and parameters measured except Air and Water temperature, Dissolved Oxygen, BOD, and Nutrients determined in this study were positive (Table 5a &b).

Air and water temperatures were fairly constant throughout the study period. These temperatures were typical for the tropics and similar ranges have been reported by Ajibola et.al, 2005, Nkwonji *et.al,* 2010, etc. The relatively small range of variation in water temperature observed in this study area is in line with the observation of previous workers (Longhurts, 1958; Olaniyan, 1969; Onyema *et.al*, 2009; Nkwonji *et.al,* 2010)

The pH observed throughout the sampling period was alkaline in nature. This stable pH may be attributed to the buffer properties of sea water. Similar views have been reported by Oyewo, 1998; Nwankwo, 1996; Ajao, 1990; Nkwonji *et.al,* 2010 etc. Consequently, the biological activity of the coastal zone ensures stable pH, a notable feature of the marine environment; whereby conditions are remarkably constant over certain areas.

Conductivity values of the study sites increase with rise in salinity and TDS. Salinity regimes in Lagos Lagoon Complex have been linked to rainfall pattern. There is variation in the salinity values observed in the study area during the sampling periods. This could be attributed to the influx of water mainly due to rainfall as many workers (Olaniyan, 1969; Ajao, 1990; and Oyewo, 1998) reported this has been major factor controlling the seasonal distribution of salinity in Lagos Lagoon and environs. Conductivity and salinity have been reported as associated factors (Onyema, 2009b). In this study, there is positive correlation between conductivity and salinity (r= 0.92), consequently, conductivity and TDS showed a similar relationship (r = 0.74) Table 5b.

The specific concentration of nutrients in an environment may serve as bio-indicators of the presence of pollutants in such an environment (Baker, 1976). There was a variation on the nutrients level of the study area. This is in agreement with Ajao (1990) who observed that the nutrient levels obtained in Lagos lagoon were mainly governed by suspended sediments transportation with the fresh water influx into the study area and this usually occurs during the wet seasons. Nitrate is an essential nutrient but at high concentration, it becomes toxic and is capable of disturbing the aquatic environment but nitrate level less than 0.5 ml/l will not pollute the water. Nutrients concentrations recorded in the study sites during the sampling period were moderately high except nitrate. The nitrate values obtained are common to a fairly unpolluted coastal system. Under normal condition the nitrate generally occur in trace quantities in surface water but the value is enhanced by inputs from other sources (Bilger and Atkinson, 1997). The phosphate is also of great importance as an essential nutrient in aquatic system. Phosphates are generally the limiting nutrient for plant growth, and excesses can lead to eutrophication. The levels of the phosphate during the study period are attributed to inputs of domestic and industrial effluents. Silica in the form of dissolved Silicate is important only for the skeletons of diatoms which are usually an important component of the phytoplankton. The concentration of silica was found to be high and decrease as rainfall decreased but poorly correlated (r = 0.01) with rainfall (Table 5a).

Conclusion

The phytoplankton community abundance, composition and diversity have been greatly affected by perturbation stress from anthropogenic activities like sand mining and dredging as well as substrate instability. Although dredging is inevitable to maintain sufficient water depth in shipping channels and harbors, which are continually filled in by deposition, the clear dominance of diatoms in the harbour water, both in abundance and diversity observed during the present study suggests the presence of a fairly clean environment. Chemical analysis of the water also supports this conclusion and rules out significant level of pollution.

The information and observation of this research will be very useful in formulating policies and regulatory framework for sustainable management of Lagos Harbour especially multi-usage of transportation/shipping with other sector like fisheries.

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