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THE PHYSICO-CHEMICAL CHARACTERISTICS, CHLOROPHYLL *a* LEVELS AND PHYTOPLANKTON DYNAMICS OF THE EAST MOLE AREA OF THE LAGOS HARBOUR, LAGOS

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ABSTRACT

The physico-chemical characteristics, phytoplankton composition and distribution at the East mole area of the Lagos harbour were investigated between January and June, 2012. The physico-chemical conditions varied between high brackish and sea water chemistry. Records were Air (26 - 33^{0}C) and Water temperatures (28 - 31^{0}C), Salinity (19.40 - 30.72$^0/_{00}$), Nutrients (Nitrate ≥ 3.11 mg/L; Phosphate ≥ 0.65 mg/L, Sulphate ≥ 878.6mg/L), alkaline pH (7.75 – 8.48), Transparency (141.2 - 236.5cm), Alkalinity (33 - 85.2mg/L), Conductivity (32700 – 49,600 µS/cm), Dissolved Oxygen (4.8 - 5.4mg/L) and Chlorophyll a concentrations (8.5 - 10.1mg/L). Chlorophyll a concentration was positively correlated with Salinity (r = 0.81), Total Dissolved Solids (r = 0.80), Conductivity (r = 0.81), Rainfall (r = 0.13), Phosphate (r = 0.87), Sulphate (r = 0.65), Silica (r = -0.62), Nitrate (r = 0.10), Dissolved Oxygen (r = -0.38) and Air temperature (r = -0.61). The phytoplankton diversity consisted of three main algal groups namely - Diatoms, Blue-green algae and Dinoflagellates. A total of 32 species belonging to 18 genera were observed. Diatoms formed the more abundant group making up 22 species from 13 genera. The Blue-green algae recorded five species from three genera and Dinoflagellates with five species from two genera. In terms of diversity, the dry season (Jan. – Apr. 2012) recorded a relatively higher phytoplankton diversity (S) and abundance (N) than the wet season. In terms of diversity, the Diatoms, reported 68.75% (Centric - 50% and Pennate diatoms –18.75%), while the Blue-green algae and the Dinoflagellates recorded 15.63% respectively. In terms of phytoplankton abundance, the month of February recorded the highest outcome. The biological indices reflected a similar trend of occurrence as the species composition and distribution. Notable species were Coscinodiscus centralis, Coscinodiscus radiatus, Synedra crystallina, Trichodesmium thiebatii, Ceratium bicephalum and Oscillatoria trichodes.

Keywords: Lagos habour, Diatoms, Blue-green algae, Dinoflagellates, Algae.

1. INTRODUCTION

Habours are sheltered parts of sea areas where ships, boats, and even barges can berth to offload and take on goods and services. The Lagos habour is part of the Lagos lagoon. The Lagos habour in Lagos Nigeria serves as the only exist for the outflow of lagoonal waters to the sea and inflow of sea waters resulting from tidal rise (Onyema *et al.*, 2008). According to Egborge (1994) the Lagos habour is Nigeria's most important sea-port and the first inlet from the Atlantic Ocean beyond the Republic of Benin. It is composed of three stone moles in the form of habour break waters. According to Nwankwo *et al.* (2004) the construction of the East, Training and West moles along the Lagos coastline (harbour) was more of an economic than ecological consideration. It achieved the protection of ships from waves in the habour and created Tarkwa bay. However, it changed the hydrodynamics and sediment regime that resulted in the accretion of sand at the light house beach and retrogation at the Victoria beach which is located to the east of the east mole of the harbour (Ibe, 1988; Nwankwo *et al.*, 2004; Onyema, 2007a).

The plankton provide a crucial source of food to a diverse range of larger and more familiar aquatic organisms such as invertebrates, fin and shell fish, whales etc. (Onyema *et al.*, 2007). The phytoplankton are the foundation of the aquatic food chain and its diversity and distribution varies from one aquatic ecosystem to the other. Phytoplankton species are key in aquatic primary production and provide food for organisms that are higher in the trophic levels. Changing hydro-environmental characteristics are the determinants of the phytoplankton standing crop at anytime (Onyema, 2013). Chlorophyll *a* levels are also a reflection of the biomass of phytoplankton in an aquatic system (Onyema, 2008).

There exist reports on the composition and distribution of phytoplankton community on the Lagos, Epe, Iyagbe lagoons, estuarine creeks and other coastal waters of Nigeria (Nwankwo, 1990; 1996a; 2004b; Kadiri, 2000; Chindah and Braide, 2001; Onyema, 2007a; 2009). There is presently a dearth of information on the phytoplankton community and nutrient status in the Harbour in south-western Nigeria especially at the east mole area. It is important to note that the East mole is the western boundary of the renowned Eko Atlantic City project. The level of sophistication of this project has not been previously recorded in Nigeria nay Africa.

Around the vicinity of the Lagos habour and East mole, there exist reports by Onyema *et al.* (2006), Edokpayi and Nkwoji (2007), (Onyema, 2007a; 2007b) and Onyema *et al.* (2007), Onyema *et al.* (2010), Nkwoji *et al.* (2010). Also, there exist previous reports by Sandison (1966), Sandison and Hill (1966) and (Oyewo *et al.*, 1982) on the Lagos habour. Additionally is a recent report on the nutrients and phytoplankton production dynamics of a tropical harbor in relation to water quality indices (James and I., 2010). Presently there is a report on a checklist of phytoplankton species offshore Lagos (Nwankwo and Onyema, 2007a) and the Light house beach (Nwankwo *et al.*, 2004) but there are no previous in-depth biological investigations of the East mole area of the Lagos Harbour.

Therefore, the aim of this work was to investigate the phytoplankton diversity, determine the water quality characteristics, Chlorophyll *a* concentrations and relate these to observed changes in phytoplankton bio-distribution at the East mole area of the Lagos Harbour.

2. DESCRIPTION OF STUDY SITE

The 2km wide Lagos harbour located in Lagos state, Nigeria, is Nigeria's most important seaport. It receives inland waters from the Lagos Lagoon and from Badagry Creek in the west and provides the only opening to the sea for nine lagoons of South-Western Nigeria (Onyema, 2009). It 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. Additionally subsistence fishing takes place at some locations by local fisher folks.

The East mole of the harbour break waters of the Lagos harbour entrance lies at the mouth of the Lagos lagoon to the sea. This area is located within the coastal water of south-western Nigeria and lies in the rainforest belt and experiences a marked bimodal rainfall pattern concentrated into one season (May – October) and a dry season that spans between November and April (Nwankwo, 1996b). The rainy season has two peak periods; usually in June and September or October, with rainfall being heavier in June (Olomukoro and Oronsaye, 2009). The tidal regime in this area is semi-diurnal with tidal heights that decrease inland from the Lagos Harbour into the Lagos lagoon system.

The sampling station chosen for this project lies along the eastern parts of the Lagos Harbour around the East Mole (Fig. 1) which is at the mouth to the Atlantic Ocean, and the area is continually dredged to allow for heavy water traffic as well as the attendant obstruction of the West-East shoreline sediment movement which continues to expand the Light house beach. The East mole area is therefore environmentally sensitive and is also the west-ward boundary of the Eko Atlantic City, which is currently undergoing construction. A massive coastal development project.

Species of drifting water hyacinth (*Eichhonia crassipes*), Sea weed (*Sargassum vulgare*) and other marine debris are common sights on the surface of the water in this area at different seasons. The presence of visible oil sheen probably reflecting refined oil contamination related to inputs from shore-based oil depots, commercial boating spills and the naval vessel discharges are also commonly sighted. The activities of large sea vessels (importing and exporting), fishing trawlers, dredgers, private boats and commercial out-board engine boats operating are frequently encountered realities in the area. Large scale dredging, Training and west moles renovations are also significant habitat modification projects in the immediate environment.

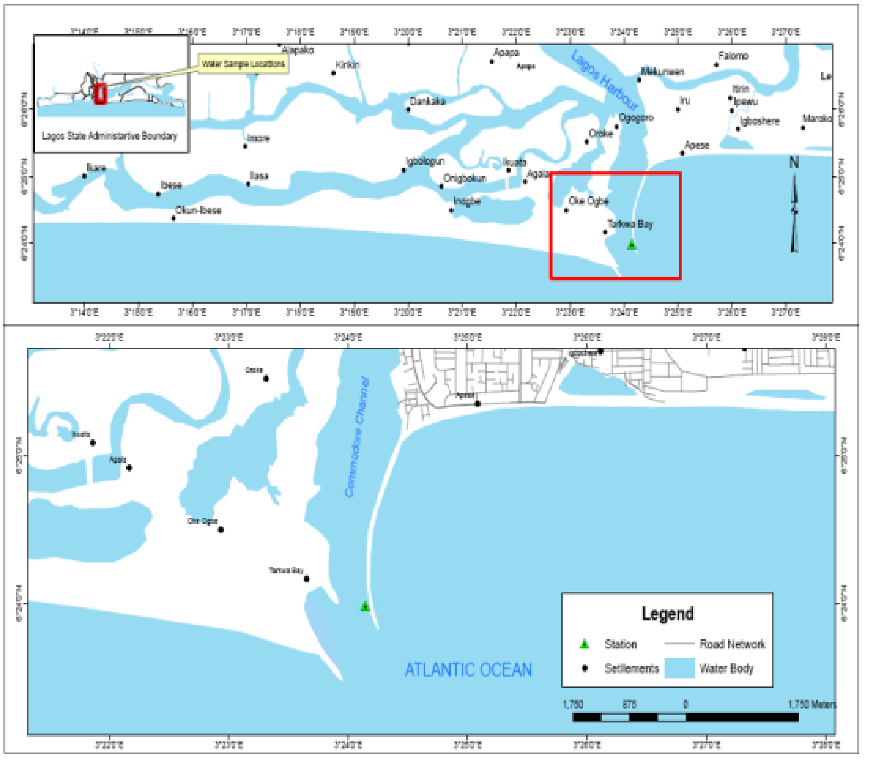
2.1. Collection of Water and Plankton Samples

Water samples were collected each month using 75cl plastic containers with screw caps and phytoplankton samples were collected by hauling horizontally standard plankton net of 55µm mesh size with a sample bottle attached to an anchored motorized boat for 10 minutes. Plankton samples were then transferred to a screw capped properly labeled plastic container. Sampling was carried out between 09.00 and 11.00 hours on each sampling day. Samples were preserved in diluted 10% formalin and transported to the laboratory for physical and chemical analysis.

2.2. Physico-chemical Analysis

Air and Water temperatures were measured using a Mercury – in – glass thermometer. Transparency was estimated with a Secchi disc, whereas Rainfall data was supplied by NIMET, Oshodi, Lagos. Methods as described by APHA (1998) were employed in estimating Salinity, Conductivity, pH, Total Suspended Solids, Total Dissolved Solids, Dissolved oxygen, Chemical Oxygen Demand, Biological Oxygen Demand, Nitrate, Phosphate, Sulphate, Silica, Calcium, Magnesium and Chlorophyll *a*. Heavy metal species such as Copper, Lead and Iron were measured using an Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS.

Fig-1. The Lagos habour area showing the sampling site at the East mole.



2.3. Phytoplankton Analysis

Plankton samples were allowed to settle in the laboratory for at least 24hrs and concentrated to 20ml. Five drops (using a dropper) of the concentrated sample (20ml) was investigated at different magnifications (50X, 100X and 400X) under a Carl Zeiss standard IV monocular microscope using the Drop Count Method described by Lackey (1938). Appropriate texts (Newell and Newell, 1966; Wimpenny, 1966; Olaniyan, 1975; Vanlandingham, 1982; Waife and Frid, 2001);(Nwankwo, 1990; 1995; 2004a) were used to aid identification of the Phytoplankton species.

2.4. Community Structure Analysis

Species richness (d), Species diversity index (Hs), Menhenicks (D), Evenness or equitability indices (j) and Simpson's Dominance index (C) (Ogbeibu, 2005) were used to estimate the phytoplankton biodiversity. Correlation coefficient between water quality parameters and rainfall were also investigated.

3. RESULT

3.1. Physical and Chemical Characteristics

Monthly variation in some physical and chemical characteristics at the East mole area of the Lagos harbour between January and June, 2012 are presented in Table 1. Air temperature ranged from 26^{0}C in June to 33^{0}C in March while Water temperature ranged from 28^{o}C in June to 32.5^{0}C in May. Transparency values ranged between 141.2 and 236.5cm, highest was recorded in January at 236.5cm and the lowest in March at 141.2cm. Rainfall value was highest in June (476.7mm) and lowest in January (1.1mm) (Fig. 2). Measurable differences were recorded for the Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). TDS varied from 32242.0 in January and 21909.0 mg/L in May while TSS varied between 3 and 13 mg/L. The pH throughout the study was alkaline (7.75 – 8.48). Dissolved oxygen levels were between 4.8 in June and 5.4mg/L in April whereas Conductivity values fluctuated between 32700 (May) and 49600µS/cm (January), Chemical oxygen demand ranged between 7.0 and 11.0mg/L, Biochemical oxygen demand had values ranging between 1.0 and 3.0mg/L. Furthermore, Alkalinity was between 33mg/L recorded in January and 85.20mg/L recorded in April while Salinity varied between 19.40 (May) and 30.72‰ (June). There were rise and fall in the values of all the Nutrients status throughout the sampling period. Nitrate levels was highest in April (22.11mg/L) and lowest (3.11mg/L) in May. Levels for Phosphate ranged between 0.65mg/L in May and 2.68mg/L in June with estimates for Sulphate concentration ranging between 878.6 and 1802.5mg/L with the minimum concentration (878.6mg/L) recorded. Silica values ranged between a minimum of 1.49mg/L in June and a maximum of 3.31mg/L in April. The cation contents, Calcium and Magnesium varied during the sampling period with Calcium recording a minimum value of 200.00mg/L in January to a maximum of 380.00mg/L in March. Magnesium had a minimum value of 643.7mg/L recorded in March and a maximum value of 1463.69mg/L recorded in April. Higher Copper value (0.005mg/L) was recorded in January and June while the lowest value (0.002mg/L) was recorded in March. The highest value (0.392mg/L) for Iron was recorded in May while the lowest value (0.004mg/L) was recorded in February. The lowest value for Zinc (0.006mg/L) was recorded in May while the highest value (0.013mg/L) was recorded in April.

Table-1. Monthly Variation in Water Quality Parameters at the East mole Area.

PARAMETERS	Jan.	Feb.	Mar.	Apr.	May	Jun.	Mean	Std Dev	Std Err.	Variance
Air temperature (^{0}C)	31.0	32.5	33.0	32.5	32.5	26.0	31.25	2.66	1.09	7.08
Water temperature (^{0}C)	29.5	28.5	31	29.5	32.5	28	29.83	1.66	0.68	2.77
Transparency (cm)	236.5	160.9	141.2	176.5	160.5	199.5	179.18	34.15	13.94	1166.25
Rainfall (mm)	1.1	61.2	28.7	161.0	221.1	476.7	158.30	176.79	72.17	31253.2
Total Suspended Solids (mg/L)	3	4	5	13	10	5	6.67	3.93	1.61	15.47
Total Dissolved Solids (mg/L)	32242.0	27912.0	30736.0	31813.0	21909.0	31166.0	29296.33	3926.01	160279	3926.01
pH @ 25°C	8.26	8.03	8.18	8.25	7.75	8.48	8.16	0.25	0.10	0.06
Conductivity (úS/cm)	49600.0	42100.0	45200.0	48200.0	32700.0	48700.0	44416.67	6368.49	2599.93	4.06
Salinity ($^{0}/_{00}$)	30.10	24.90	26.40	29.20	19.40	30.72	26.79	4.26	1.74	18.11
Acidity (mg/L)	<1	<1	<1	<1	1.00	< 0.1	1.00	0.0	0.15	0.14
Alkalinity (mg/L)	33.0	48.0	61.4	85.20	47.6	62.90	56.35	17.85	7.29	318.45
Total Hardness (mg/L)	5910.0	3426.2	3654.1	6750.0	5640.1	5220.0	5100.07	1309.73	534.69	1.72
Dissolved Oxygen (mg/L)	5.3	5.1	5.3	5.4	5.2	4.8	5.18	0.21	0.09	0.05
Biological Oxygen demand$_5$ (mg/L)	1	2	1	2	1	3	1.67	0.82	0.33	0.67
Chemical Oxygen Demand (mg/L)	8	8	7	9	8	11	8.50	1.38	0.56	1.9
Chloride (mg/L)	15438.0	13833.0	14620.0	16282.0	10779.0	17066.8	14669.80	2226.03	908.77	4.96
Nitrate (mg/L)	21.1	11.00	8.65	22.1	3.11	4.84	11.80	8.09	3.30	65.46
Sulphate (mg/L)	1011.0	900.0	970.0	999.4	878.6	1802.5	1093.58	351.35	143.43	123444
Phosphate (mg/L)	1.29	1.20	1.96	0.78	0.65	2.68	1.43	0.77	0.31	0.59
Silica (mg/L)	3.0	2.82	2.99	3.31	3.12	1.49	2.79	0.66	0.27	0.43
Calcium (mg/L)	200.00	225.04	380.00	241.20	299.4	288.1	272.29	64.82	26.46	4202.27
Magnesium (mg/L)	1288.10	681.20	643.70	1463.69	1164.9	1071.6	1052.20	329.41	134.48	108513
Zinc (mg/L)	0.007	0.009	0.007	0.013	0.006	0.011	0.01	0.00	0.00	7.37
Iron (mg/L)	0.090	0.004	0.250	0.092	0.392	0.102	0.16	0.14	0.06	0.02
Copper (mg/L)	0.005	0.003	0.002	0.004	0.004	0.005	0.00	0.00	0.00	0.37
Chlorophyll *a* (µg/L)	9.8	9.2	9.8	9.1	8.5	10.1	9.42	0.59	0.24	0.35

3.2. Biological Characteristics

3.2.1. Chlorophyll *a* (µg/L)

The values of chlorophyll *a* recorded during the sampling period with highest (10.1µg/L) in June and lowest (8.5µg/L) in May was relatively constant. Chlorophyll *a* was positively correlated with some parameter and negatively correlated with others (Table 2).

Table-2. Pearson correlation co-efficient between Chlorophyll a and physic-chemical characteristics at the East mole.

PARAMETERS	r	PARAMETERS	r	PARAMETERS	r
Air temperature (^{0}C)	-0.61	Acidity (mg/L)	-0.56	Phosphate (mg/L)	0.87
Water temperature (^{0}C)	-0.61	Alkalinity (mg/L)	-0.03	Silica (mg/L)	-0.62
Transparency (cm)	0.43	Total Hardness (mg/L)	-0.21	Calcium (mg/L)	0.10
Rainfall (mm)	0.13	Dissolved Oxygen (mg/L)	-0.38	Magnesium (mg/L)	-0.21
Total Suspended Solids (mg/L)	-0.66	Biological Oxygen demand$_5$ (mg/L)	0.35	Zinc (mg/L)	0.16
Total Dissolved Solids (mg/L)	0.80	Chemical Oxygen Demand (mg/L)	0.33	Iron (mg/L)	-0.46
pH @ 25°C	0.86	Chloride (mg/L)	0.78	Copper (mg/L)	0.15
Conductivity (úS/cm)	0.81	Nitrate (mg/L)	0.10	Chlorophyll *a* (µg/L)	1.00
Salinity ($^0/_{00}$)	0.81	Sulphate (mg/L)	0.65		

3.3. Phytoplankton Spectrum

The diversity and abundance of phytoplankton in the East mole area of the Lagos Harbour between January and June, 2012 are presented in Table 2. Phytoplankton population was more in the dry season than the wet season. A total of 32 species belonging to 18 genera were observed (Fig. 3 and 4). The phytoplankton diversity was represented by three Divisions namely; Bacillariophyta, Cyanophyta and Dinophyta. The Bacillariophyta was represented by 22 (twenty-two) species from two orders (16 Centrales and 6 Pennales), the Cyanophyta was represented by five (5) species from One Order (Homogonales) and the Dinophyta was represented by five (5) species from One Order (Peridinales). Among the phytoplankton divisions, the Bacillariophyta had the largest percentage (75.43%), followed by the Cyanophyta (16.38%) and the Dinophyta (8.19%) in terms of abundance. The centric diatoms were more important in abundance and in terms of numbers. The notable genera include *Asterionella*, *Coscinodiscus*, *Ditylum*, *Hemisdiscus*, *Odontella*, *Rhizosolenia* and *Triceratium*. For the pennales, they were *Bacillaria*, *Nitzschia*, *Pleurosigma*, *Synedra* and *Thalassionema*. Representing the Cyanophyta were *Lyngbya*, *Oscillatoria* and *Trichodesmium*, while the Dinophyta were represented by *Ceratium* and *Protoperidium*. In terms of phytoplankton abundance, the month of February recorded more individual phytoplankton cells (Fig. 5).

Table-2. The Composition and Abundance of Phytoplankton at the East Mole.

PHYTOPLANKTON TAXA	JAN.	FEB.	MAR.	APR.	MAY	JUN.	TOTAL
DIVISION: BACILLARIOPHYTA							
CLASS: BACILLARIOPHYCEAE							
ORDER 1: CENTRALES							
Asterionella glacialis Cleve	-	-	-	4	-	-	20
Asterionella japonica Cleve	-	-	-	-	-	8	40
Chaetoceros convolutus Castracane	-	-	-	1	-	1	10
Chaetoceros didymus Cleve	-	-	7	-	-	-	35
Coscinodiscus centralis Ehrenberg	1	5	8	10	-	2	120
Coscinodiscus eccentricus Ehrenberg	-	8	3	1	-	-	60
Coscinodiscus gigas Ehrenberg	-	2	-	-	-	-	10
Coscinodiscus lineatus Ehrenberg	-	9	-	-	-	-	45
Coscinodiscus radiatus Ehrenberg	3	86	11	1	-	4	525
Coscinodiscus sub-bulliens Jorg	-	4	-	-	-	-	20
Ditylum brightwelli (T.West) Grunow	-	-	-	-	-	1	5
Hemisdiscus cuneiformis Wallich	-	3	-	-	-	-	15
Odontella aurita (Lyngbe) Brebisson	-	-	-	-	-	1	5
Odontella ragia (Schultze) Ostenfeld	-	-	-	-	-	1	5
Rhizosolenia hebatata Brightwell	-	-	-	2	-	-	10
Triceratium favus Ehrenberg	-	-	-	1	-	-	5
ORDER II: PENNALES							
Bacillaria paxillifer (O.F.Muller) Hendey	-	-	-	-	5	-	25
Nitzschia sigmoidea (Witesch) W. Smith	-	-	1	-	-	-	5
Pleurosigma angulatum Wm Smith	-	-	-	6	1	-	35
Synedra crystallina (Ag) Kutzing	-	1	-	3	-	6	50
Thalassionema longissima Cleve and Grunow	-	-	1	-	-	2	15
Thalassionema nitzschioides Cleve and Grunow	-	-	7	-	-	-	35
DIVISION: CYANOPHYTA							
CLASS: CYANOPHYCEAE							
ORDER: HOMOGONALES							
Lynbgya martensiana Meneghini	-	-	-	5	-	-	25
Oscillatoria limnosa Agardh	-	-	1	-	-	-	5
Oscillatoriatrichodes Szafer	-	-	3	-	-	-	15
Oscillatoria sp. I	2	2	-	-	-	4	40
Trichodesmium thiebatii Gomont	-	-	30	1	-	-	150
DIVISION: DINOPHYTA							
CLASS: DINOPHYCEAE							
ORDER: PERIDINALES							
Ceratium bicephalum Ehrenberg	-	-	-	1	-	-	5
Ceratium furca Ehrenberg	-	-	1	-	-	-	5
Ceratium macroceros (Ehr.) Cleve	2	-	8	1	-	-	55
Ceratium tripos (O. F. M.) Nitzsch	-	-	3	-	-	4	35
Protoperidinium depressum Bailey (Balech)	-	-	4	-	-	-	20
Species Diversity (S)	4	9	14	13	2	11	32
Species Abundance (N)	8	120	88	37	6	34	1465

3.4. Community Structure Indices

The diversity and distribution of phytoplankton per ml per station is shown in Table 2 whereas Table 3 tabulates the phytoplankton community's eco-mathematical indices (biological indices). In all a total of Thirty-two (32) species were recorded for the six months studied. Total number of species recorded per month ranged between 2 and 14. March, 2012 recorded the highest number of species (14 species) while May, 2012 recorded 2 species only. Furthermore, February recorded the highest number of individuals (120 individuals per ml) while May 2012 recorded 6 individuals per ml. Log of Species diversity recorded ranged from 0.30 to 1.15. Log of phytoplankton abundance ranged between 0.78 and 2.08. Whereas Shannon-Wiener Index (Hs) was between 0.20 and 0.96, Menhinick Index (D) was between 0.82 and 2.14. Margalef Index (d) values were from 0.56 to 3.32, Equitability was between 0.51 and 0.95 and Simpson's Dominance Index was between 0.14 and 0.72.

Fig-2. Monthly Variation in Air Temperature, Water Temperature, Transparency and Rainfall at the East mole Area.

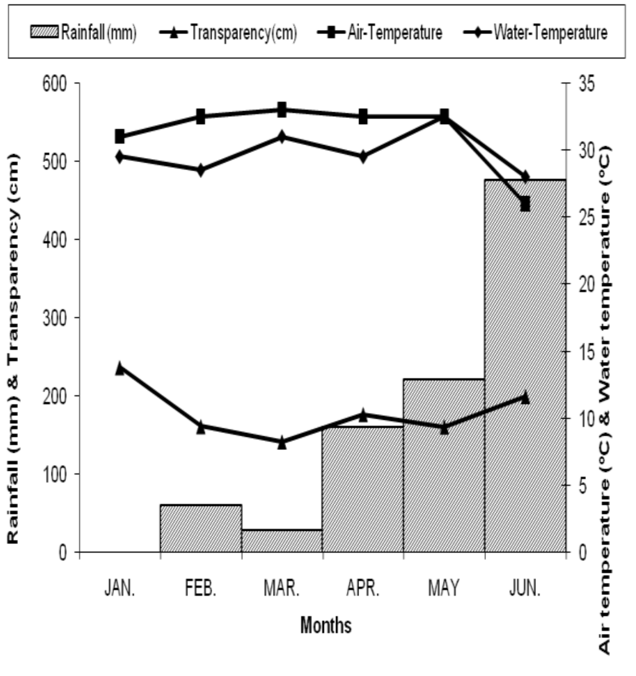


Fig-3. Monthly Variation in Phytoplankton Abundance and Rainfall at the East mole.

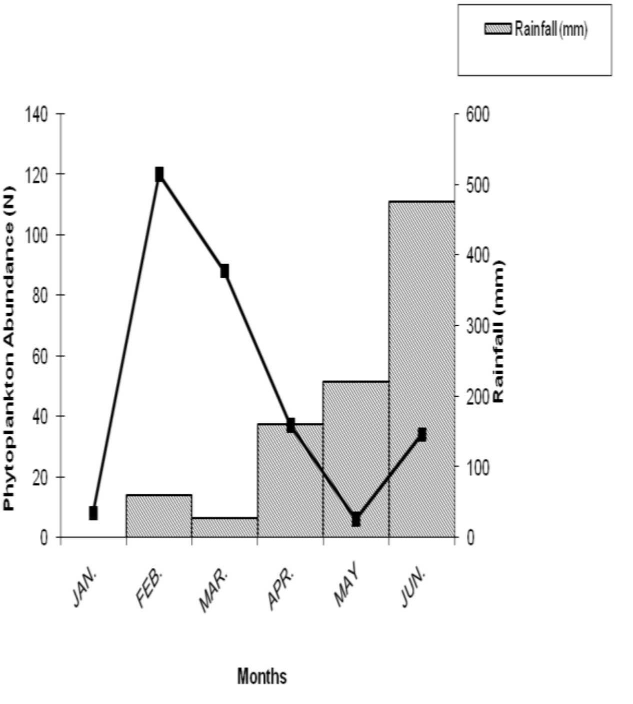


Fig-4. Monthly Variation in Phytoplankton Abundance, Nitrate and Chlorophyll *a* at the East mole.

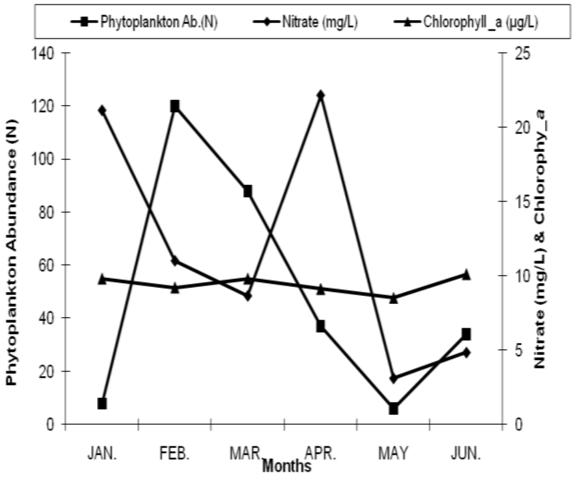


Fig-5. Percentage Composition of Phytoplankton Abundance of each month at the East mole.

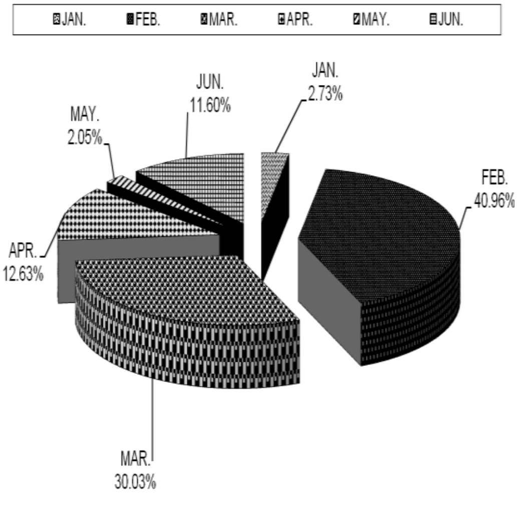


Table-3. Community Structure Indices at the East mole.

Parameters	Jan.	Feb.	Mar.	Apr.	May	Jun.
Total species diversity (S)	4	9	14	13	2	11
Total abundance (N)	8	120	88	37	6	34
Log of Species diversity (Log S)	0.60	0.95	1.15	1.11	0.30	1.04
Log of abundance (Log N)	0.90	2.08	1.94	1.57	0.78	1.53
Shannon-Wiener Index (Hs)	0.57	0.49	0.94	0.96	0.20	0.93
Menhinick Index (D)	1.41	0.82	1.49	2.14	0.82	1.89
Margalef Index (d)	1.44	1.67	2.90	3.32	0.56	2.84
Equitability Index (j)	0.95	0.51	0.82	0.86	0.65	0.90
Simpson's Dominance Index (C)	0.28	0.53	0.17	0.14	0.72	0.14

4. DISCUSSION

The range of characteristics for the physico-chemical parameters shows clearly that the East mole study area reflects tidal sea conditions influenced by brackish water from the Lagos lagoon system. According to reports on the area, the quality and distribution of rainfall is significant in determining the condition of the Lagos lagoon environment (Hill and Webb, 1958; Sandison, 1966; Olaniyan, 1969; Nwankwo, 1984; Nwankwo and Akinsoji, 1992). These seasonal differences in rainfall pattern determine salinity in coastal waters and the distribution of aquatic biota (Hill and Webb, 1958; Akpata *et al.*, 1993; Brown and Oyenekan, 1998).

There were fluctuation in the air temperature, surface water temperature and transparency values. This is related to the characteristics of the tropics, increased cloud cover conditions and reduction in solar insolation. Similar observations in temperature and transparency have been reported in the Lagos and Iyagbe Lagoons by Nwankwo and Akinsoji (1989) and Onyema (2008). Total Suspended Solid and Total Dissolved Solid values recorded varied throughout the study period and followed a similar trend with the nutrients. Transparency was higher in the dry than the wet season. This may be linked to the effect of rainfall. (Ezra and Nwankwo, 2001) are of the view that a low transparency in the Gubi Reservoir is as a result of silt particles brought in by floodwaters.

Conditions including salinity were higher in dry season (January – April, 2012) than in the wet season. Similar conditions and regimes have been reported by Onyema *et al.* (2010) at the Bar beach for physico-chemical characteristics. This is before the sand filling of the Eko Atlantic City Project commenced.

The extensive buffering capacity of seawater may be the cause of change in pH within the narrow limit and its alkaline status. Dissolved Oxygen level was high comparatively, throughout the study period except in June. This may be as a result of heavy influx of fresh water from adjourning creeks and Lagoons. Also oxygenation in aquatic ecosystems is as a result of an imbalance between the process of photosynthesis, degradation of organic matter, re-aeration and oceanographic properties of water (Muller, 1988). According to Ibe (1988) as compared with other coastal inlets along the Gulf of Guinea, tidal actions have a tremendous influence on the coastal waters of the Lagos harbour. The alkaline pH may be due to the buffering effect of the sea and it is an indicator of environmental condition in agreement with Olaniyan (1969). According to Erondu and Chindah (1991) and Kadiri (1999), alkalinity is regarded as a measure of productivity of natural waters. Alkalinity according to Kadiri (1999) citing Talling and Talling (1965) is a crucial factor determining diatom communities in the aquatic environment. Tidal creeks in south-western Nigeria are known to be alkaline (Nwankwo and Akinsoji, 1992).

The assessment of nutrient levels showed variations. For instance temporal variation in sulphate can be attributed to several factors, more importantly the proportional physical mixing of seawater with freshwater (Ghosh, 1992), adsorption of reactive Sulphate into suspended sedimentary particles in overlay waters (Praus, 2005) and biological removal by phytoplankton especially by diatoms and silicoflagellates (Dutta, 2008). Nitrate levels were also high ($\geq$3.11 mg/L). On the other hand, Chlorophyl *a* values were positively strongly correlated with Salinity, Conductivity, pH, Chloride and Nutrients (Phosphate and Sulphate). It was however negatively correlated with Total Suspended Solids, Celica and Iron among others. This supports the fact that phytoplankton production is higher in the dry season within the brackish waters of the Lagos lagoon system. (Olaniyan, 1969; Nwankwo and Akinsoji, 1988; 1996a; Onyema *et al.*, 2007; 2008; 2010; Onyema, 2013).

The phytoplankton recorded a total of 32 species. This diversity was higher in the dry period than the wet period. Diatoms were the more abundance group among the phytoplankton categories followed by the blue-green and Dinoflagellate. Nwankwo and Akinsoji (1988; 1996a) has already reported that the phytoplankton production in the Lagos Lagoon was high and principally dominated by Diatoms. The qualitative and quantitative dominance of diatom in this study area is worthy of note because they have been known to be indicators of water quality and environmental conditions (Mossaer *et al.*, 1996; Wackstrom *et al.*, 1997; Kelly, 1998). The combination of the most abundant diatoms *Coscinodiscus radiatus* and *Coscinodiscus centralis* accounted for 59.27%. The dominant and wide occurrence of *Coscinodiscus* spp. has also been observed in other work in the Gulf of Guinea (Kadiri, 1999; Olomukoro and Oronsaye, 2009). A good number of species encountered for this study have been recorded before now in marine situations in the region (Nwankwo and Akinsoji, 1988; 1996a; 1998; Kadiri, 1999; Nwankwo *et al.*, 2003; 2007a; Nwankwo *et al.*, 2004). Notably encountered genera for the study were *Coscinodiscus* spp. (6 taxa), *Asterionella* spp. (2 taxa), *Chaetoceros* spp. (2 taxa), and *Odontella* spp. (2 taxa) (Centric diatoms), *Thalassionema* spp. (2 taxa) (Pennate diatom), *Oscillatoria* spp. (3 taxa), (Blue-green), *Ceratium* spp. (4 taxa) (Dinoflagellate).

The presence of *Chaetoceros, Thalassionema, Odontella, Skeletonema* and *Rhizosolennia* spp. probably points to their source of recruitment because they are known marine forms in the zone (Nwankwo and Onyema, 2007a). The presence of known marine species further confirms the incursion of seawater into the Lagos harbour (Nwankwo, 1996b; 2004; Kadiri, 2007; Onyema, 2010; 2011). These species are commonly found in sea conditions within the coastal waters of Nigeria and in the dry season. Seawater incursion is a prominent feature of the Lagos harbour. The effect of rainfall on total suspended solids is evident as it may bring along decomposed materials and flush in silt particles especially during erosion into the surrounding environment. (Nwankwo *et al.*, 2003; 2007a) and Onyema (2011) are of the view that the diluting and enriching effects of floodwater and inflow of sea water governs the biota distribution of the Lagos coastal area.

It is possible that the reduced phytoplankton diversity in the wet season may be linked to the flushing of planktonic algal forms towards the sea during rainy season by flood waters and to the low water clarity which reduced the amount of light available to the planktonic algal component for photosynthesis. This confirms to similar inferences for the Ijora creek according to Onyema and Nwankwo (2006). According to Nwankwo (1996b), lesser concentrations in some instance and diversity of phytoplankton are recorded especially during the wet season and could be attributed to the effects of rainfall pattern.

With reference to Onyema *et al.* (2003) frequently occurring pennate diatoms in the phytoplankton samples from the Lagos Lagoon were likely a reflection of the mixing of the shallow lagoon and phytobenthic community by tides and flood waters at different seasons. The pennate diatoms, *Navicula*, *Nitzschia* and *Synedra* were prominent genera observed during the study.

Generally, in the investigation of the water quality and phytoplankton at the east mole area, proximity to the sea and dilution from floodwaters associated to rain events from land were the two major controlling factors. There are reports of critical changes in the tidal flow dynamics around the east mole of the Lagos Habour as a result of the construction of the great wall of Lagos (Southern limit of the ongoing Eko Atlantic city project). There is need for more frequent (possibly weekly) study of the area. This will reveal more trends and regimes while contributing to the science and literature of the area.

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