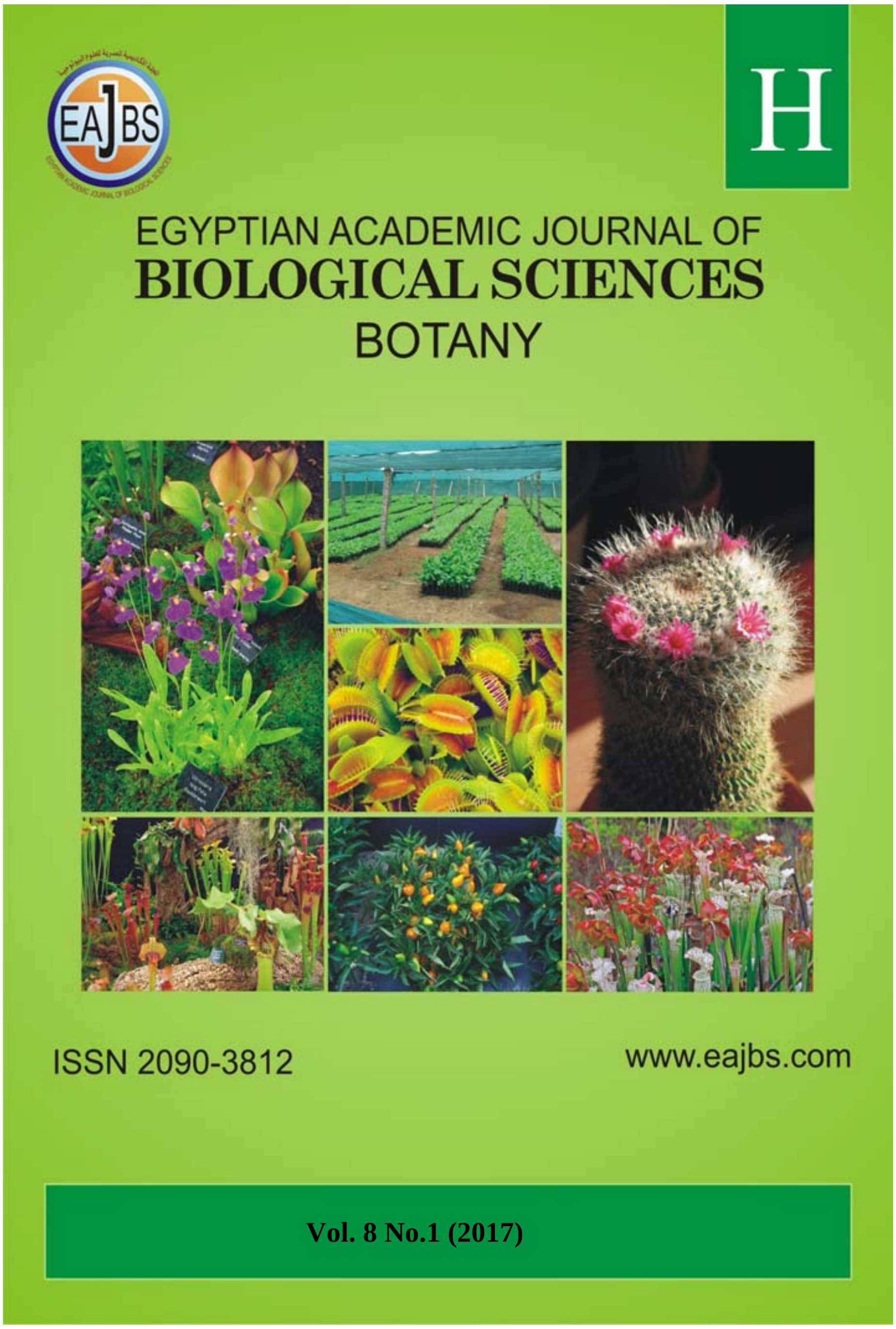

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www.eajbs.eg.net

Egypt. Acad. J. Biolog. Sci., 8(1): 13-23 (2017)

Egyptian Academic Journal Biological Sciences
H. Botany
ISSN 2090-3812
www.eajbs.eg.net

Water Quality Characteristics and Phytoplankton Diversity Around a Domestic Waste Polluted Site in Lagos lagoon

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ARTICLE INFO
Article History
Received:15/2/2017
Accepted:25/3/2017

Keywords:
Water quality
Diatoms
Oworonsoki
Phytoplankton pollution indicators

ABSTRACT

The water quality characteristics and phytoplankton at a domestic waste polluted site at Oworonsoki, Lagos Lagoon in relation to environmental factors were investigated for six months (October, 2012 – March, 2013). Plankton samples were collected horizontally with plankton hauls on each trip using standard plankton net of 55µm mesh size tied unto a motorized boat and towed slowly (≤4m/s) for 10 mins. The water quality characteristics showed monthly variation linked to hydrological flow conditions, namely the rainfall pattern and tidal seawater inflow. Air temperature (28.3 – 32˚C), Water temperature (29 - 31˚C), Transparency (12.95 – 101.5cm), Total suspended solid (8 – 35mg/L), Total dissolved solid (553.0 – 20712.66mg/L), Conductivity (1069.0 – 31100.0µS/cm), Salinity (0.50 – 17.11 %), Acidity (4.9 – 6.3mg/L), Total hardness (102.0 – 3811.0 mg/L), Dissolved oxygen (4.8 – 5.2 mg/L), Chemical oxygen demand (14 – 23 mg/L) recorded higher values in the dry than in the wet season. High nutrients, especially nitrates and heavy metal levels between December and February points to the inflow of domestic wastes. The water quality characteristics reflected freshwaters situation in October and November (0.52 – 0.82 ‰) while December through March were increasingly brackish (9.42 – 17.11 %). The phytoplankton diversity (S) and abundance (N) were notably higher in the dry than the wet season. The phytoplankton spectrum (Bacillariophyta, Cyanophyta and Chlorophyta) were dominated by the Bacillariophyta (Diatoms) (93.47% - Centrales – 69.77 % and Pennales – 30.23%). Notable species of were *Aulacoseira granulata* var. *angustissima, Odontella laevis, Coscinodiscus radiatus, Skeletonema coastasum, Chaetoceros convolutes, Bacillaria paxillifer, Gyrosigma balticum, Nitzschia sigmoidea, Synedra crystallina, Thalasiothrix fraunfeldii, Synedra ulna, Microcystis aeruginosa* and *Oscillatoria limnosa*. The phytoplankton diversity at each time was reflective of the water chemistry situation. Comparatively, low phytoplankton diversity, and the occurrence of indicators of organic waste pollution are noteworthy.

INTRODUCTION

The plankton has been reported by investigators to be a reflection of the hydro-environmental conditions per time, hence acting as bio-diagnostic components that point to the health of aquatic ecosystems (Onyema *et al.*, 2007). There are obvious relationships between water environmental factors and changes in phytoplankton communities (Wu *et. al.,* 2014). Phytoplankton therefore serve as bio-indicators to monitor an array of water chemistry conditions (Nwankwo, 2004; Onyema, 2007).

The growth and development of phytoplankton populations is dependent on light levels and nutrient availability as they are the foundation of the aquatic food web, especially in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell and finfish (Lawal-Are *et al*., 2009; Wu *et. al.,* 2014).

The ecological significance played by these biological systems in coastal aquatic ecosystems cannot be over emphasized. Moreso microalgal 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). Among the more important groups are the diatoms, cyanobacteria, dinoflagellates and coccolithophores.

Phytoplankton and microbial growth are promoted by the presence of nutrients such as nitrates, phosphates, silicates and so on in the aquatic ecosystem. Effluents from households and sewage sources are rich in nutrients (Odiete, 1999). Availability of bio-limiting elements such as Nitrogen, Phosphorous and Silica is an important factor affecting primary production.

Over the years, ecological studies have shown a good relationship between water quality or environmental characteristics and plankton community structure (Palmer, 1969; Odiete, 1999; Onyema and Nwankwo, 2006, Onyema, 2016). Similarly a number of literature (Nwankwo, 2004; Dakshini and Soni, 1982; Nwankwo and Akinsoji, 1988; Nwankwo and Onitiri, 1992; Chindah *et al.,* 1993, Nwankwo *et al.,* 1994; Onyema, 2008, 2013) have indicated that the phytoplankton have been diagnostic in assessing water quality and hydrological status.

Lagoons especially in Nigeria, serve as feeding, nursery and breeding grounds for finfish, shellfish and even migratory and shore birds (Nwankwo, 2004; Onyema *et al*., 2007 and Onyema, 2009, 2012). Furthermore, the Lagos lagoon, serves as a sink for the disposal of an increasing array of waste types and quantities (Ajao, 1996; Odiete, 1999; Onyema, 2007; Chukwu, 2011; Onyema, 2012; Onyema and Akingbulugbe, 2017).

Chukwu (2002) and Nwankwo (2004) are of the view that lagoons of south-western Nigeria, apart from their more ecological and economic significance, serve for waste disposal such as sewage, wood waste, refine oil, waste heat, municipal and industrial effluents among others which find their way into immediate coastal waters through conduits such as storm water channels, rivers, creeks and lagoon (Akpata *et. al*., 1993; Chukwu and Nwankwo 2004). Domestic / household wastes also constitutes a major category of water type especially in highly populated areas and slums, areas with poor waste disposal systems and poor sewerage. High volumes of Domestic/ household wastes impact the Lagos lagoon from this environ. These wastes find their way via indiscriminate dumping, creeks and storm water drains and channels, which all flow into the Lagos lagoon (Ajao., 1996; Onyema, 2009).

An attempt is made here to study the water quality characteristics in relation to the phytoplankton at Oworonsoki area of the Lagos lagoon with high attendant domestic wastes inputs.

MATERIALS AND METHODS

DESCRIPTION OF STUDY SITE

The sampling site was located at Oworonsoki within the Lagos lagoon (Fig. 1). The GPS coordinate was 6º32'49"N and 3º24'8"E. The lagoon is an open, shallow and tidal lagoon, with a surface area of 208km^2 (FAO, 1969) and an average depth of less than two meters. The Oworonsoki area of the Lagos lagoon is exposed to high levels of domestic waste from densely populated areas of Akoka, Bariga, Somolu and Oworonsoki. The smell and colour of the water at this point is usually offensive and reflects poor water quality. The area is also very shallow and largely silty sand with regards to sediment type. The Lagos lagoon as a whole provides an opening to the Atlantic ocean for nine lagoons out of the ten lagoons in South Western Nigeria. Owing to the dynamics of river inflow and seawater incursion, the Lagos lagoon experiences brackish water conditions, more discernable in the dry season. In the wet season, the increased river inflow creates freshwater and low brackish conditions in various parts of the lagoon, especially northwards. These conditions are also prevalent at the Oworonsoki axis. The harmattan, a short season of dry, dusty North-East Trade winds experienced sometimes between November and January in the region reduces visibility and lowers temperatures (Onyema *et. al.,* 2003).

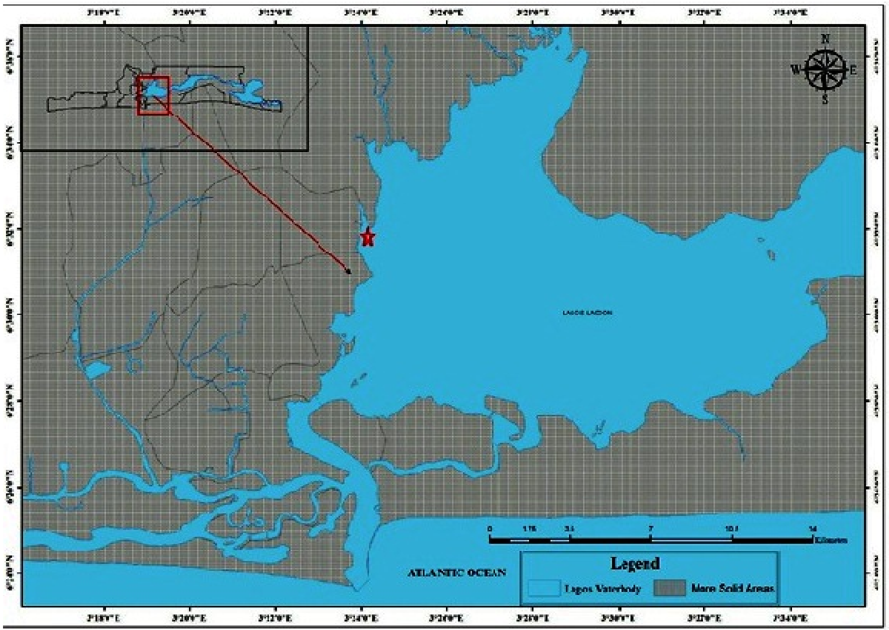

Fig. 1: The Lagos Lagoon showing the study area at Oworonsoki.

In the Lagos lagoon, there is a direct relation between the seasonal bimodal rainfall pattern, the environmental gradient and the biotal gradient. South-western Nigeria is endowed with an intricate network of rivers, creeks and lagoons, which serve as conduits transferring highly nutrified waters from hinterland to coastal areas (Webb, 1958; Nwankwo, 2004; Onyema, 2009).

Flood waters associated with rainfall are known to enrich the coastal environment, dilute its ionic concentration and break down existing environmental gradients (Olaniyan, 1969; Nwankwo, 1996). Conversely in the dry season, freshwater inflow is greatly reduced and seawater enters the lagoon through the harbour giving rise to marine conditions near the harbour and brackish water extending far inland (Hill and Webb, 1958; Nwankwo, 1996; Onyema *et al*., 2003). Hence, areas located in close proximity to the Lagos harbour are exposed to greater marine influence than places further inland.

Collection of Water, Chlorophyll *a* and Plankton Samples

The station was sampled for six months (October, 2012 - March, 2013). Water samples were collected each month between 9.00h and 12.00h from the station using 75cl plastic containers with each indicating the month of collection at the study site.

The plastic bottles were used to collect samples just below the water surface. This was then taken to the laboratory for physical and chemical analysis.

Water samples were also collected for Chlorophyll *a* analysis. These samples were collected in 1.5 liters plastic bottles with screw cap and stored in an ice chest prior to transportation to the chemical laboratory for analysis. One sample was collected per month at the study site. Plankton samples were collected horizontally with plankton hauls on each trip using standard plankton net of 55µm mesh size tied unto a motorized boat and towed slowly (≤4m/s) for 10 minutes. The plankton samples were then transferred immediately to a 60cl screw capped plastic containers and preserved with 4% unbuffered formalin before transfer to the laboratory for analyses.

Analysis of physico-chemical features, Chlorophyll *a* and Plankton Samples

Air and water temperatures were determined using a mercury-in-glass bulb thermometer. Rainfall data was supplied by Nigerian Meteorological Agency, Oshodi Lagos (NIMET). Other physico-chemical parameters were estimated as stated in APHA (1998).

For the extraction of chlorophyll *a*, 200 ml of water sample was filtered through 0.45µm glass fibre membrane filter. The residue on the filter was transferred to a tissue blender and covered with 3ml 90% aqueous acetone and then macerated for 1min. the sample was transferred quantitatively with 90% acetone to a centrifuge tube. It was capped and allowed to stand for 2hours in the dark at 4ºC (in a refrigerator). Thereafter, it was centrifuged at 500 g, for 20 min. The supernatant was decanted, and the volume noted. The fluorometer was then calibrated with standard chlorophyll solutions (2, 5, 10 and 20µg chlorophyll a/L). The readings for each solution at ×1; ×3; ×10; ×30 sensitivity settings were noted. This is in accordance with APHA (1998).

Phytoplankton samples were allowed to settle in the laboratory for a period of at least 48hrs and then decanted until a concentration of about 20ml was achieved. 5 mounts for each sample of 0.2ml (2 drops) were investigated under an Olympus binocular microscope. Relevant identification texts were used to confirm the taxa. The Total number of species (S), abundance of species (N), Log of Species diversity (Log S), Log of species abundance (Log N), Shannon-Wiener Index (Hs), Menhinick Index (D), Margalef Index (d), Equitability (j) and Simpson's Dominance Index (C) were employed to analyse biological data (Ogbeibu, 2005).

RESULTS

Monthly variations in the physico-chemical parameters at the Oworonsoki area of the Lagos lagoon are presented in Table 1. From October till February, some parameters showed generally increasing values, whereas others show reducing values. The range of values for the hydro-environmental factors were - Air temperature (28.3 – 32 ^{0}C), Water temperature (29 – 31 ^{0}C), Transparency (39.5 – 101.5cm), Rainfall (17.4 - 148.9mm), TSS (8 – 35 mg/L), TDS (553.0 – 20712.66 mg/L), pH (7.21 - 7.69), Conductivity (1069.0 – 31100.0 µS/cm), Salinity (0.50 – 17.11%),Acidity (4.9 – 6.3 mg/L), Alkalinity (30.6 – 62.1mg/L), Total Hardness (102.0 – 3811.0 mg/L), Dissolved Oxygen (4.6 – 5.2 mg/L), Biological Oxygen Demand$_5$ (2 – 4 mg/L), Chemical Oxygen Demand (14 – 23 mg/L), Chloride (258.3 – 9277.8 mg/L), Nitrate (3.36 – 19.93 mg/L), Sulphate (2.0 – 3982.8 mg/L), Phosphate (1.12 - 15.77 mg/L), Silica (3.8 – 6.1 mg/L), Calcium (24.04 – 308.80 mg/L), Magnesium (9.34 - 667.71 mg/L), Zinc (0.021 - 0.040 mg/L), Iron (0.10 – 0.28 mg/L), Copper (0.003 - 0.008

mg/L), Cadmium (0.0006 - 0.0009 mg/L), Lead (<0.001 mg/L), Chromium (<0.001mg/L), Manganese (0.016 - 0.067 mg/L), Nickel (<0.001 mg/L).

Chlorophyll *a* concentration showed monthly variation. The highest recorded value (18.2 µg/L) was in December while the lowest value (10.2 µg/L) was recorded in March, 2013. The mean and standard deviation values for Chlorophyll *a* were 14.20 µg/L and ±3.20 respectively.

Table 1: Monthly Variation in Water Quality Parameters at Oworonshoki area of the Lagos Lagoon (October, 2012 – March, 2013).

PARAMETERS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	MEAN	±STD
Air temperature (^{0}C)	28.3	32	29	29	30	30.1	29.73	1.30
Water temperature (^{0}C)	29	30.5	29	29	31	30	29.75	0.88
Transparency (cm)	39.5	12.95	101.5	60	31	50	49.16	30.30
Rainfall (mm)	148.9	123.2	17.4	133.7	34.7	121.8	96.62	55.78
TSS (mg/L)	22	9	8	35	14	11	16.50	10.37
TDS (mg/L)	553.0	836.0	10802.8	16832.0	20305.0	20712.66	11673.58	9216.23
pH @ 25°C	7.40	7.47	7.42	7.21	7.55	7.69	7.46	0.16
Conductivity (µS/cm)	1069.0	1660.0	17440.0	26300.0	30400.1	31100.0	17994.85	13771.20
Salinity ($^0/_{00}$)	0.50	0.82	9.42	14.71	16.71	17.11	9.88	7.65
Acidity (mg/L)	5.3	4.9	5.1	6.0	6.3	5.8	5.57	0.55
Alkalinity (mg/L)	37.4	30.6	44.2	38.2	62.1	59.3	45.30	12.72
Total Hardness (mg/L)	102.0	240.0	1830.0	2250.0	3577.2	3811.0	1968.37	1584.47
DO (mg/L)	4.6	4.9	4.8	5.2	4.8	5.1	4.90	0.22
BOD_5 (mg/L)	3	3	2	3	4	2	2.83	0.75
COD (mg/L)	14	19	15	19	23	14	17.33	3.61
Chloride (mg/L)	258.3	450.1	5218.8	8165.0	9277.8	9501.2	5478.53	4252.92
Nitrate (mg/L)	3.36	5.21	19.93	14.91	16.39	9.75	11.59	6.56
Sulphate (mg/L)	2.1	2.0	1040.0	2001.0	3890.2	3982.8	1819.68	1800.80
Phosphate (mg/L)	1.95	15.77	1.12	8.02	4.12	9.18	6.69	5.49
Silica (mg/L)	3.8	4.9	4.9	6.1	5.8	4.4	4.98	0.86
Calcium (mg/L)	24.04	24.07	108.01	310.80	308.90	319.3	182.52	146.23
Magnesium (mg/L)	9.34	42.86	371.43	351.19	667.71	474.71	319.54	253.68
Zinc (mg/L)	0.021	0.024	0.033	0.021	0.033	0.040	0.03	0.01
Iron (mg/L)	0.28	0.19	0.09	0.10	0.080	0.160	0.15	0.08
Copper (mg/L)	0.008	0.007	0.006	0.003	0.004	0.003	0.01	0.00
Cadmium (mg/L)	0.0009	0.0006	0.0009	0.0008	0.0007	0.0006	0.00	0.00
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00
Manganese (mg/L)	0.016	0.017	0.031	0.029	0.018	0.067	0.03	0.02
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00
Chlorophyll *a* (µg/L)	10.9	13.9	18.2	16.9	15.1	10.2	14.20	3.20

PHYTOPLANKTON SPECTRUM

The diversity and abundance of phytoplankton at Oworonsoki area of Lagos Lagoon are presented in Table 2. Phytoplankton population was more in the dry season than the wet season. The Phytoplankton diversity was represented by three Divisions namely; Bacillariophyta, Cyanophyta and Chlorophyta.

Table 2: Inventorial of recorded species at Oworonshoki area of Lagos Lagoon (October, 2012 – March, 2013).

DIVISION	CLASS	ORDER	SPECIES
BACILLARIOPHYTA	**BACILLARIOPHYCEAE**	**CENTRALES**	*Aulacoseira granulata* var. *angustissima* Muller
			Chaetoceros convolutus Castracane
			Coscinodiscus radiatus Ehrenberg
			Odontella laevis Ehrenberg
			Skeletonema coastasum Cleve
		PENNALES	*Bacillaria paxillifer* (O.F. Muller) Hendey
			Gyrosigma balticum (Ehr) Rabenhorst
			Nitzschia sigmoidea (Witesch) W.Smith
			Synedra crystallina (Ag) Kutzing
			Synedra ulna (Nitzsch) Ehrenberg
			Thalasiothrix fraunfeldii Cleve & Grunow
CYANOPHYTA	**CYANOPHYCEAE**	**CHROCOCCOCALES**	*Microcystis aeruginosa* Kutzing
		HORMOGONALES	*Oscillatoria limnosa* Agardh
CHLOROPHYTA	**CHLOROPHYCEAE**	**ZYGNEMATALES**	*Closterium ehrenbergii* Meneghini

The Bacillariophyta was represented by eleven species from two orders (5 Centrales and 6 Pennales), the Cyanophyta was represented by two species from two orders (1 Chrococcocales and 1 Hormogonales), and the Chlorophyta was represented by one species from one order (Zygnematales). Among the Phytoplankton Divisions, the Bacillariophyta had the largest percentage (93.47%), the Cyanophyta (4.34 %), and the Chlorophyta (2.17 %) in terms of abundance. The Centric diatoms were more important in abundance and in terms of number and the notable genera include *Aulacoseira granulata* var. *angustissima*, *Odontella laevis*, *Coscinodiscus radiatus*, *Skeletonema coastasum* and *Chaetoceros convolutes*. For the Pennales, they were *Bacillaria paxillifer, Gyrosigma balticum*, *Nitzschia sigmoidea*, *Synedra crystallina, Synedra ulna* and *Thalasiothrix fraunfeldii*. For the Chrococcocales, they were *Microcystis aeruginosa* and for Hormogonales they were *Oscillatoria limnosa*. Representing the Zygnematales is *Closterium ehrenbergii*.

In all a total of fourteen (14) species were recorded. Total number of species recorded per month ranged between 2 and 7. January recorded the highest number of species (7 species) while November recorded 2 species only. Furthermore, January recorded the highest number of individuals (62 individuals per ml) while, November recorded 2 individuals per ml.Log of Species diversity recorded ranged from 0.30to 0.85. Log of phytoplankton abundance were between 0.30 and 1.79. Whereas Shannon-Wiener Index (Hs) was between 0.30and 0.70, Menhinick Index (D) was between 0.89 and 1.89. Margalef Index (d) values were from 1.03 to 2.06, Equitability on the other hand was between 0.83 and 1.00 and Simpson's Dominance Index ranged between 0.22 and 0.50, for the stations studied. Pearson correlation co-efficient (r) matrix of water quality indices, Chlorophyll *a* and Phytoplankton are shown in Table 4.

Table 3: Community Structure Indices at Oworonshoki area of Lagos Lagoon (October, 2012 – March, 2013).

PARAMETERS	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Total species diversity (S)	5	2	5	7	3	3
Total abundance (N)	7	2	11	62	3	7
Log of Species diversity (Log S)	0.70	0.30	0.70	0.85	0.48	0.48
Log of abundance (Log N)	0.85	0.30	1.04	1.79	0.48	0.85
Shannon-Wiener Index (Hs)	0.64	0.30	0.64	0.70	0.48	0.42
Menhinick Index (D)	1.89	1.41	1.51	0.89	1.73	1.13
Margalef Index (d)	2.06	1.44	1.67	1.45	1.82	1.03
Equitability Index (j)	0.92	1.00	0.91	0.83	1.00	0.87
Simpson's Dominance Index (C)	0.27	0.50	0.26	0.22	0.33	0.43

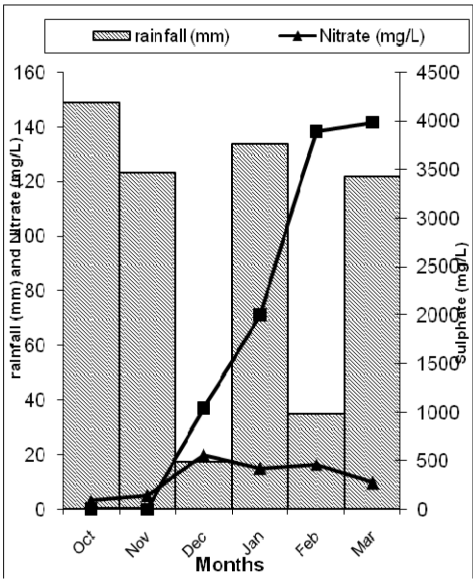

Fig. 2: Monthly Variation in Rainfall, Nitrate and Sulphate at Oworonsoki area of Lagos Lagoon (October, 2012 - March, 2013).

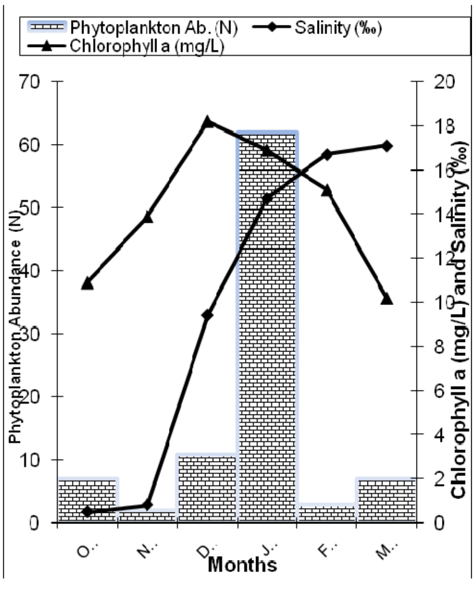

Fig. 3: Monthly Variation in phytoplankton Abundance, Chlorophyll *a* and Salinity at Oworonsoki area of Lagos Lagoon (October, 2012 – March, 2013).

Table 4: Pearson correlation co-efficient (r) matrix of water quality indices, Chlorophyll *a* and Phytoplankton at Oworonsoki, Lagos Lagoon (October, 2012 – March, 2013).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33		PARAMETERS
1	1.00																																	1	Air Temp (°C)
2	0.75	1.00																																2	Water Temp (C)
3	-0.60	-0.67	1.00																															3	Transparency (cm)
4	0.02	-0.24	-0.48	1.00																														4	Rainfall (mm)
5	-0.52	-0.48	0.01	0.51	1.00																													5	TSS (mg/L)
6	-0.10	0.25	0.26	-0.36	0.11	1.00																												6	TDS (mg/L)
7	0.41	0.62	-0.25	-0.20	-0.74	0.29	1.00																											7	pH @ 25°C
8	-0.12	0.22	0.29	-0.37	0.12	1.00	0.27	1.00																										8	Conductivity (µS/cm)
9	-0.12	0.22	0.28	-0.35	0.13	1.00	0.25	1.00	1.00																									9	Salinity (‰)
10	-0.23	0.29	-0.07	-0.12	0.43	0.84	0.09	0.83	0.83	1.00																								10	Acidity (mg/L)
11	-0.08	0.46	0.09	-0.47	-0.26	0.82	0.67	0.81	0.80	0.71	1.00																							11	Alkalinity (mg/L)
12	-0.02	0.35	0.20	-0.40	-0.06	0.98	0.47	0.97	0.97	0.79	0.90	1.00																						12	Total Hardness (mg/L)
13	0.23	0.00	0.09	0.24	0.34	0.59	-0.09	0.60	0.61	0.38	0.11	0.50	1.00																					13	DO (mg/L)
14	0.13	0.53	-0.63	-0.04	0.29	0.01	-0.17	0.00	0.00	0.47	0.08	-0.02	-0.24	1.00																				14	BOD_5 (mg/L)
15	0.40	0.66	-0.43	-0.32	0.13	0.29	-0.13	0.29	0.29	0.50	0.18	0.25	0.13	0.83	1.00																			15	COD (mg/L)
16	-0.12	0.22	0.28	-0.35	0.13	1.00	0.25	1.00	1.00	0.83	0.80	0.97	0.61	0.00	0.29	1.00																		16	Chloride (mg/L)
17	-0.25	-0.06	0.70	-0.81	-0.03	0.65	-0.14	0.67	0.66	0.39	0.43	0.59	0.25	-0.07	0.31	0.66	1.00																	17	Nitrate (mg/L)
18	0.02	0.45	0.03	-0.30	-0.04	0.95	0.53	0.94	0.94	0.84	0.92	0.98	0.46	0.10	0.30	0.94	0.45	1.00																18	Sulphate (mg/L)
19	0.86	0.45	-0.62	0.46	-0.10	-0.13	0.14	-0.14	-0.14	-0.19	-0.31	-0.12	0.52	0.02	0.23	-0.13	-0.43	-0.07	1.00															19	Phosphate (mg/L)
20	0.14	0.25	0.05	-0.34	0.37	0.55	-0.39	0.56	0.57	0.58	0.15	0.43	0.53	0.46	0.80	0.57	0.65	0.39	0.14	1.00														20	Silica (mg/L)
21	-0.09	0.24	0.12	-0.15	0.30	0.97	0.18	0.97	0.97	0.90	0.73	0.92	0.68	0.12	0.35	0.97	0.52	0.92	-0.02	0.60	1.00													21	Calcium (mg/L)
22	-0.06	0.39	0.26	-0.62	-0.09	0.94	0.36	0.94	0.93	0.79	0.88	0.95	0.34	0.15	0.43	0.93	0.75	0.91	-0.26	0.57	0.85	1.00												22	Magnesium (mg/L)
23	0.16	0.38	0.27	-0.52	-0.64	0.65	0.82	0.64	0.62	0.26	0.83	0.77	0.16	-0.39	-0.13	0.62	0.40	0.73	-0.11	-0.08	0.48	0.70	1.00											23	Zinc (mg/L)
24	-0.06	-0.21	-0.44	0.72	0.03	-0.73	0.06	-0.75	-0.75	-0.49	-0.46	-0.68	-0.46	-0.07	-0.53	-0.75	-0.93	-0.57	0.10	-0.82	-0.65	-0.81	-0.42	1.00										24	Iron (mg/L)
25	0.00	-0.19	-0.17	0.11	-0.28	-0.94	-0.14	-0.95	-0.95	-0.79	-0.62	-0.89	-0.81	0.02	-0.29	-0.95	-0.53	-0.86	-0.11	-0.62	-0.98	-0.79	-0.48	0.68	1.00									25	Copper (mg/L)
26	-0.86	-0.78	0.63	-0.18	0.36	-0.27	-0.61	-0.25	-0.25	-0.16	-0.28	-0.35	-0.46	-0.10	-0.32	-0.25	0.26	-0.43	-0.82	-0.13	-0.31	-0.21	-0.39	0.08	0.37	1.00								26	Cadmium (mg/L)
27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00							27	Lead (mg/L)
28	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00						28	Chromium (mg/L)
29	0.01	-0.06	0.31	0.09	-0.18	0.58	0.54	0.58	0.58	0.21	0.51	0.63	0.58	-0.69	-0.49	0.58	0.12	0.59	0.12	-0.18	0.54	0.39	0.72	-0.15	-0.61	-0.37	1.00	1.00	1.00					29	Manganese (mg/L)
30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00				30	Nickel (mg/L)
31	-0.10	-0.19	0.54	-0.62	0.12	0.15	-0.58	0.18	0.18	0.01	-0.17	0.04	0.15	0.07	0.42	0.18	0.79	-0.10	-0.21	0.71	0.08	0.27	-0.14	-0.75	-0.14	0.38	1.00	1.00	-0.35	1.00	1.00			31	Chlorophyll *a* (µg/L)
32	-0.80	-0.84	0.59	0.13	0.79	0.09	-0.81	0.12	0.12	0.18	-0.27	-0.08	0.20	-0.12	-0.19	0.12	0.33	-0.16	-0.48	0.26	0.15	-0.05	-0.46	-0.14	-0.16	0.75	1.00	1.00	-0.08	1.00	0.43	1.00		32	Phytoplankton (S)
33	-0.37	-0.52	0.30	0.29	0.86	0.28	-0.76	0.31	0.32	0.35	-0.26	0.09	0.65	0.00	0.12	0.32	0.30	0.04	0.02	0.59	0.42	0.07	-0.44	-0.33	-0.49	0.27	1.00	1.00	0.04	1.00	0.44	0.82	1.00	33	Phytoplankton (N)

DISCUSSION

The physical and chemical changes observed in Oworonshoki area of Lagos Lagoon reflect the influence of seasonal changes on the lagoon environment. The lowest salinity, temperature and transparency values were recorded in the wet months. The inverse relationship between rainfall and salinity was probably due to dilution (Hill and Webb; 1958, Olaniyan 1969; Nwankwo, 1990). Furthermore, Nwankwo (1996) highlighted the seasonal variation in transparency in the coastal waters of south-western Nigeria and linked it to the rainfall pattern and associated floods and mixing from rivers.

Air temperature value fluctuated with the highest value (32°C) recorded in November, 2012. Similarly, the same observation was revealed for water temperature with highest value (31°C) also recorded in February, 2013. According to Onyema (2008), meteorological conditions are key factor controlling air temperature in the tropics. Transparency was recorded to be relatively higher in the dry season than the wet season. This may be linked to the effect of rainfall and a corresponding introduction of waste materials from land.

The alkaline nature of the water was typical of that of a marine environment. According to Onyema and Akingbulugbe (2017), the high pH of the coastal waters may be due to the buffering effect of the sea. The nutrient level recorded was high especially for sulphate with the highest value (3982.8mg/L) recorded in March, 2013. The phosphate and nitrate concentrations were quite low throughout the study. According to Nwankwo and Akinsoji (1992), rainfall also introduces chelating agents as well as increasing the nutrient levels of the Lagos Lagoon. The silica concentration was observed to increase appreciably as the dry season became more pronounced with the highest value (6.1mg/L) recorded in January, 2013. Hence, confirming higher levels of pollution at the study site.

The stability and the gradual increase in salinity tending towards the dry season may be as a result of increases in evaporation, reduced flood water inflow, associated creeks and rivers. Barnes (1980) is of the view that during rainy seasons, lagoons and creeks are diluted considerably by freshwater from rain and river systems while in the dry season, evaporation becomes more prominent. Therefore salinity regime in the Oworonshoki area is related to rainfall distribution pattern and consequent inflows from adjoining areas (Olaniyan, 1969; Nwankwo and Amuda, 1993; Onyema *et al*., 2003, 2007).

The value of chlorophyll *a* which is a measure of photosynthetic productivity increased with an increase in phytoplankton biomass. According to Kadiri (1993), seasonal fluctuation in abundance of phytoplankton is influenced by changes in physical and chemical properties of water. The abundance and distribution of phytoplankton species at Oworonshoki recorded 14 species. This diversity was higher in the dry period than the wet period. The Bacillariophyta were the more abundant group followed by the Cyanophyta and the Chlorophyta.

The Bacillariophyta or Diatoms were the most abundant and diverse species observed during the study with *Coscinodiscus radiatus* being the most abundant. According to Onyema *et al.* (2003) diatoms and copepods were the most abundant groups in the Lagos Lagoon among the plankton. Notably encountered genera for the study were *Coscinodiscus radiatus, Aulacoseira granulata* var. *angustissima, Odontella laevis, Skeletonema coastatum* and *Chaetoceros convolutus* (Centrales), *Bacillaria paxillifer*, *Gyrosigma balticum*, *Nitzschia sigmoidea, Synedra* and *Thalasiothrix fraunfeldii* (Pennales), *Microcystis aeruginosa* (Chrococcocales), *Oscillatoria limnosa* (Hormogonales), *Closterium ehrenbergii* (Zygnematales).

According to Onyema (2013) the occurence of phytoplankton forms such as *Aulacoseira granulata* var. *angustissima* usaually indicates Fresh – low brackish / moderate – high organic pollution condition, whereas *Bacillaria paxillifer* and *Chaetoceros convolutus* in coastal waters indicates Low brackish – sea situations / alkaline pH and high cation levels. Nwankwo (2004) refered to *Microcystis aeruginosa* as indicative of moderate organic pollution while *Oscillatoria limnosa*was reflective of heavy organic pollution in fresh to low brackish water situations. Nwankwo and Akinsoji (1992) posited the occurence of *Bacillaria paxillifer* in the plankton in south-western Nigerian lagoons to indicate brackish water prevalent conditions.

It is hence evident from this study that the water quality characteristics and the abundance of phytoplankton species at Oworonshoki, Lagos Lagoon is largely controlled by the prevailing environmental condition. These environmental conditions are notably tidal seawater incursion which increases salinity and abundance of species in the dry season and rainfall distribution pattern which has more impact in the wet season and also reduces diversity through dilution and outflow to sea. Additionally, the effect of the domestic waste pollution was deleterious and noteworthy. It reduced phytoplankton diversity and encouraged the prevalence of known tolerant or hardy phytoplankton species that have been previously recorded for the region.

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