Research Journal of

Environmental Toxicology

ISSN 1819-3420

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Research Journal of Environmental Toxicology

ISSN 1819-3420
DOI: 10.3923/rjet.2016.135.143

Research Article

Water Quality and Phytoplankton Distribution in Nta-wogba Stream Receiving Municipal Discharges in Port Harcourt, Rivers State, Nigeria

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Abstract

Studies on the physicochemical and biological characteristics of a stream receiving municipal discharges located at Port Harcourt of Rivers State, Nigeria within latitude 4°50′′ and 5°00′′N and longitude 6°55′′and 7°00′′E were conducted for six months. The main aim was to investigate the effect of municipal discharges on the water quality of the stream. Samples were collected and analysed for physicochemical and biological characteristics. The results of the physicochemical parameters- showed limited variations for the stations except for the lower stretch of the stream where low concentrations of dissolved oxygen were observed reflecting high effluent waste particularly discharged at this limit. On the temporal basis, samples in the dry season had increased values of temperature (°C), pH, conductivity (us cm^{-1}) alkalinity, phosphate and ammonia (mg L^{-1}) indicating more pronounced effect of municipal discharges on the water quality. The results of the biological attribute showed relatively low species diversity, an increase in species abundance, an enhanced chlorophyll a biomass and primary production. Correlation coefficient analyses with all measured physicochemical parameters suggest a significant correlation between phytoplankton and most physicochemical parameters (temperature, alkalinity, ammonia and phosphate). Primary productivity was significantly correlated with conductivity and phosphate. The physicochemical studies indicate that despite the discharges, the water system does not appear to be polluted. However, the biological parameters described the state of the water more accurately in the preponderance of aquatic organism such as Cyanophyceae that are known to inhabit polluted water system.

Key words: Water quality, phytoplankton, streams, municipal discharges, BOD_5

Received: October 21, 2015 Accepted: January 29, 2016 Published: April 15, 2016

Citation: F.U. Obianefo, A.C. Chindah and E.B. Ochekwu, 2016. Water quality and phytoplankton distribution in Nta-wogba stream receiving municipal discharges in Port Harcourt, Rivers State, Nigeria. Res. J. Environ. Toxicol., 10: 135-143.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The problem of water pollution is of concern to all stakeholders, following the extent of degeneration of water bodies by human activities, arising from industrial and domestic sources. With the increasing population of Port Harcourt municipality, effluents and solid waste are generated which finally find their way into the natural water bodies. The natural water body of concern in this context is a perennial urban swamp forest stream that meanders through the city centre. Information on the water body and the level of impact of these discharges are limited.

Many studies have been carried out on streams and lakes. Such studies include, the effect of municipal drainage on the microflora of a black water stream in Port Harcourt (Amadi *et al*., 1997), the effect of industrial activities on the periphyton community at the upper reaches of New Calabar River (Chindah, 1998), phytoplankton diversity and succession in lagos lagoon (Nwankwo, 1996) and the response of periphyton community to salinity (Chindah, 2004). Studies carried out on similar waters has suggested that diversity decreases with colonisation due to dominance of some algal species (Ogamba *et al*., 2004). Chindah (2003) recorded a total of 46 species of phytoplankton in the Elele Alimini swamp forest stream located in the Niger delta.

However, major and critical water qualities were not considered in these studies. When such studies were conducted, they were for very short duration and hardly can the information be used to effectively characterize and determine the effect of the waste on the water quality and biota. It is on the basis of this, that critical physiochemical and biological attributes such as; chlorophyll a, primary productivity and species identification were used in order to characterize and identify indicator species for the water and to understand and monitor changes in watershed ecosystem.

MATERIALS AND METHODS

The Nta-Wogba stream is located in Port Harcourt city of the Rivers State of Nigeria (Fig. 1). The stream lies between latitude 4°5′′N and 5°00′′N and longitude 6°55′′ E and 7°00′′E. The climate of the area is basically that of tropical equatorial latitude with rainfall occurring almost all year round except for December, January and February and an annual rainfall is about 2.500 mm (Gobo, 1988).

Fig. 1: Map of river state showing the sampling points

The Nta-Wogba stream is a black water stream with its head water draining the Oro-Azi forest and meanders through the densely populated Port Harcourt city into Bonny estuary (Amadi *et al*., 1997). It is exposed to increasing amount of urban waste as it flows seaward, which are mainly from garages and domestic discharges. The upper limits (stations 1 and 2) of the stream represent fairly unpolluted area with low human population and were used as the reference for comparative purposes though there is no observable standard pollution free area of this stream. The lower limits represented by stations 3, 4 and 5 lie within the densely populated area of the city and receive large quantity of municipal discharges. Economic activities exert considerable pollution effect on the entire study area. About 4500 L of waste containing petroleum product are discharged into this water body daily. Over 250,000 L, of domestic waste are discharged, while human waste constitute about 100 and 50 L crankcase oil are discharged daily into the stream.

Field sampling: Five stations were established which include, stations1 (Graceland road) and 2 (Abacha road) represent upstream sectors that are fairly un-impacted areas, with low population density and less industrial activities. Stations 3 (Olu-Obasanjo road), 4 (Okija road) and 5 (Afam road) represent the lower limit of the stream which is exposed to high quantity of urban and industrial discharges. Samples were collected at intercept of these roads where the stream crosses the road. Samples were collected monthly for six months. On each sampling period, samples for physicochemistry and phytoplankton analyses were collected from the five established stations. The temperature of the water was measured *in situ* using mercury in bulb thermometer to the nearest 0.1°C. Surface water samples for physicochemistry were collected with a 2 L polyethylene jerry can at subsurface level and store in an ice chest before it was taken to the laboratory.

Biological Oxygen Demand/Dissolved Oxygen (BOD_5/DO) were determined using Winkler1 (Manganese sulphate solution) and Winkler11 (Iodine acid reagents) method. Phytoplankton samples were collected in polyethylene bottle by submerging the bottle below subsurface level. Immediately after collection, 5.00 mL of 10% formalin was used to fix 100 mL of the sample.

In the laboratory water samples were analysed for the following pH was determined using the Hann Instrument Model HI 8314, the Horiba water checker Model U10 was used to take the conductivity, for alkalinity the titrimetric method was adopted, for nitrate the Brucine method was used and values read off at 410 nm using 21D Model spectrophotometer (APHA., 1995), for phosphate, stannous chloride method was used (APHA., 1995), sulphate (Turbidimetric method), ammonia (Phenate method) dissolved oxygen, biochemical oxygen demand, primary productivity the light and dark bottle oxygen evolution technique was employed, phytoplankton chlorophyll a the trichromatic method was adopted.

Phytoplankton species identification: The preserved samples were allowed to stand for 48 h to allow the settlement of organisms. The supernatant was pipette off leaving 5.00 mL of concentrated sample from which sub samples were taken for identification and enumeration counting was done at 200x magnification and the technique followed APHA (1995). The pipette content was transferred into sedge wick-Rafter counting chamber for enumeration using the reports of Sieminska (1964), Starmach (1966), Patrick and Reimer (1966), Durand and Leveque (1980) and Chindah and Pudo (1991).

The light and dark bottle evolution technique was employed for primary productivity studies.

Statistical analysis: From the data collected the mean and standard deviation were calculated and were also subjected to analysis of variance and student's t-test.

The phytoplankton counts were expressed as units per mili liter (filament, colonies or single cells). Two indices used to obtain the estimate of species diversity and richness were Shannon and Weaver (1963) and Margalef (1958), respectively.

RESULTS

The detailed results of the mean and standard deviation of some of the physicochemical parameters are presented in Fig. 2-8.

Phytoplankton: A total of 87 species of phytoplankton were recorded during the study. Of these, Bacillariophyceae had 39 species representing 44.8%, Chlorophyceae was represented by 18 species amounting to 20.7%, while

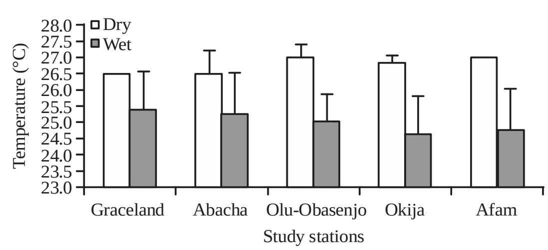

Fig. 2: Mean temperature values at the study stations for wet and dry periods

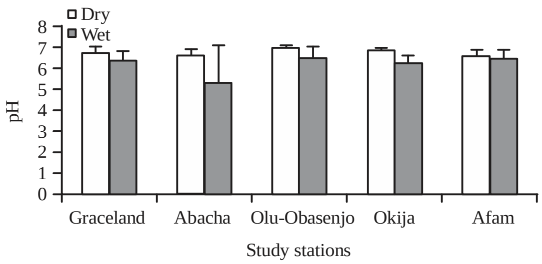

Fig. 3: Mean pH values at the study stations for wet and dry periods

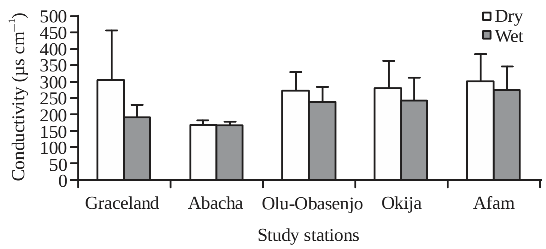

Fig. 4: Mean conductivity values at the study stations for wet and dry periods

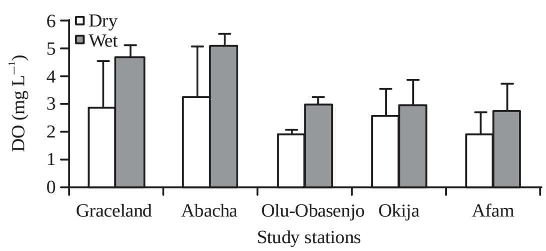

Fig. 5: Mean dissolved oxygen concentrations at the study stations for wet and dry periods

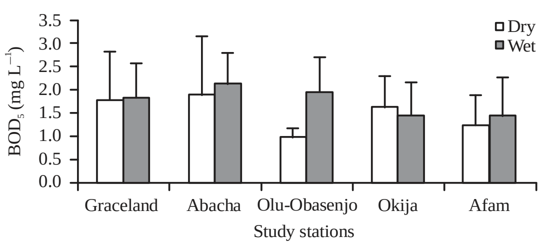

Fig. 6: Mean biochemical oxygen demand values at the study stations for wet and dry periods

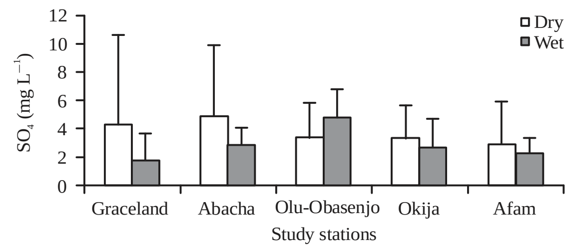

Fig. 7: Mean sulphate concentrations at the study stations for wet and dry periods

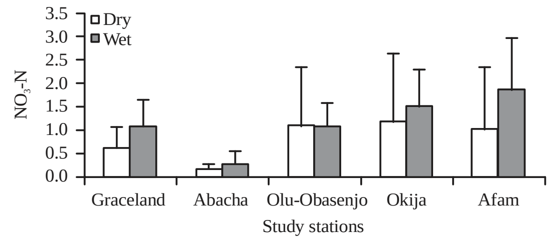

Fig. 8: Mean nitrate concentrations at the study stations for wet and dry periods

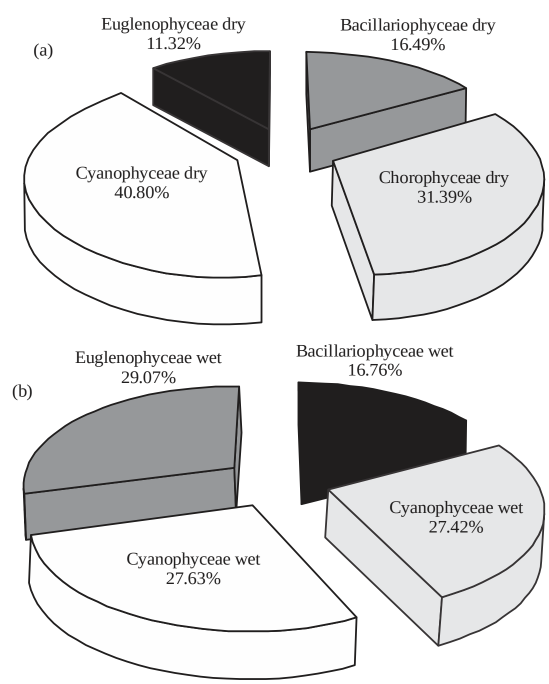

Fig. 9(a-b): Relative composition of taxonomic groups for the (a) Dry and (b) Wet period

Cyanophyceae and Euglenophyceae had 17 and 14 species representing 19.6 and 6.1%, respectively. The dominant species among the diatoms were *Achanthes gibberala, Cymbella* sp., *Diatoma hiemale*, *Eunotia monodon*, *Nitzschia accicularis.* Amongst the Chlorophyceae was *Closterium closteriodes.* The Cyanophyceae had *Oscillatoria limosa, Gleocapsa rupestris* and *Anacytis pleuronectus*. While, Euglenophceae had *Phacus onyx* and *P. pleuronectus*.

The majority of the phytoplankton was diatoms comprising 18 genera and 39 species. The Chlorophyceae were made up of 9 genera and 18 species while the Cyanophyceae and Euglenophyceae were made of 10 and 4 genera, representing 17 and 14, respectively (Table 1).

The distribution of Margalef (1958) species richness showed variation between stations and seasons. In all, species richness ranged from 0.47-3.12. The stations at the upper stretched of the stream had higher values for all the taxonomic groups, a decline was observed downstream of the study area exception of Okija station which showed slightly higher value than other stations for Cyanophyceae and Euglenophyceae families (Table 2).

The Shannon weaver diversity index for the entire study period ranged from 0.04-0.26. The wet season values ranged from 0.06-0.23, while the values for dry season were 0.04-0.26. The taxonomic group Euglenophyceae had higher diversity index for the dry season while the taxonomic group Chlorophyceae had the highest for the wet season. Bacillariophyceae had the least value for all the stations for both seasons. Okija station recorded the highest diversity value for amongst the taxonomic groups (Table 3).

The relative composition of the phytoplankton taxonomic group showed that the Cyanophyceae constituted the bulk of the phytoplankton population for all the stations. In dry season, the value ranged from 8.17-43.16 and 13.89-35.52% in wet season.

There was irregular pattern in the distribution of the different taxonomic group for all the stations. The highest value was obtained in Afam station (43.16%) and the lowest (Table 4) at Abacha station (19.97%).

The community structure for the phytoplankton showed a consistent pattern of Cyanophyceae (39.98%) >Chlorophyceae (30.14%)>Bacillariophyceae (16.87%) >Euglenophyceae (13.02%) (Fig. 9a) in that decreasing order of importance for all the stations in the dry season and wet season (Fig. 9b) had a sequence of the order was Euglenophyceae (29.07%)>Cyanophyceae (27.63%) >Chlorophyceae (27.42%)>Bacillariophyceae (16.76%).

The community structure pattern for Abacha, Okija and Afam stations were in the sequence of as, Chlorophyceae (35.52%)>Euglenophyceae (24.95%)>Cyanophyceae (19.97%)>Bacillariophyceae (19.83%) while Oluo-basanjo exhibited a different pattern in the sequence of Euglenophyceae>Cyanophyceae (26.21%)>Bacillariophyceae (16.62%)>Chlorophyceae (15.42%) (Table 4).

Table 1: Number of species (Abundance) phytoplankton

	Taxa/group				
Seasons	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Euglenophyceae	Total phytoplankton
Dry	39	17	17	12	85
Wet	38	18	17	14	87

Table 2: Species richness obtained for the different taxonomic group for both seasons

		Sample location				
Taxa/group	Season	GL	AB	OL	OK	AF
Bacillariophyceae	Dry	3.12	3.12	3.00	2.60	1.69
	Wet	2.83	2.34	2.83	2.46	2.22
Chlorophyceae	Dry	1.57	0.61	0.61	0.73	0.61
	Wet	1.40	0.82	0.093	1.05	0.82
Cyanophyceae	Dry	1.52	0.44	0.94	1.68	1.28
	Wet	1.64	0.74	1.17	1.09	0.82
Euglenophyceae	Dry	1.21	0.81	0.67	1.08	0.81
	Wet	0.81	0.81	0.70	1.05	0.81

GL: Graceland road, AB: Abacha road, OL: Olu-Obasanjo road, OK: Okija road, AF: Afam road

Table 3: Species diversity obtained for the different taxonomic group for both seasons

		Sample location				
Taxa/group	Season	GL	AB	OL	OK	AF
Bacillariophyceae	Dry	0.46	0.49	0.42	0.50	0.42
	Wet	0.46	0.47	0.49	0.46	0.43
Chlorophyceae	Dry	0.46	0.46	0.42	0.51	0.45
	Wet	0.46	0.49	0.38	0.51	0.43
Cyanophyceae	Dry	0.48	0.45	0.41	0.51	0.45
	Wet	0.47	0.40	0.49	0.51	0.41
Euglenophyceae	Dry	0.47	0.51	0.40	0.51	0.33
	Wet	0.47	0.42	0.49	0.50	0.42

GL: Graceland road, AB: Abacha road, OL: Olu-Obasanjo road, OK: Okija road, AF: Afam road

Table 4: Phytoplankton abundance and relative composition

		Sample location				
Taxa/group	Season	GL	AB	OL	OK	AF
Bacillariophyceae	Dry	15.85	19.19	17.19	16.12	16.17
	Wet	16.76	19.83	16.62	13.89	17.93
Chlorophyceae	Dry	28.67	28.85	31.71	29.94	32.52
	Wet	27.42	35.52	15.42	29.65	29.15
Cyanophyceae	Dry	42.68	35.14	38.99	40.27	43.16
	Wet	27.63	24.95	26.69	28.51	24.64
Euglenophyceae	Dry	12.85	16.84	12.13	13.68	8.170
	Wet	29.07	24.96	26.89	28.51	28.10
Total phytoplankton	Dry	2699	2672	1977	3399	2115
	Wet	3890	3494	4673	4734	3149

GL: Graceland road, AB: Abacha road, OL: Olu-Obasanjo road, OK: Okija road, AF: Afam road

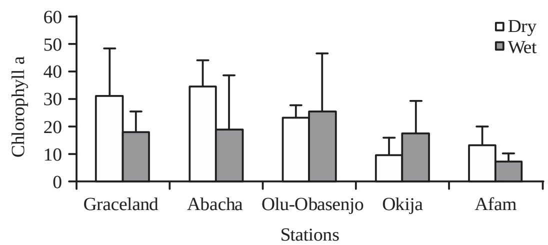

Fig. 10: Mean chlorophyll a concentrations at the study stations for wet and dry periods

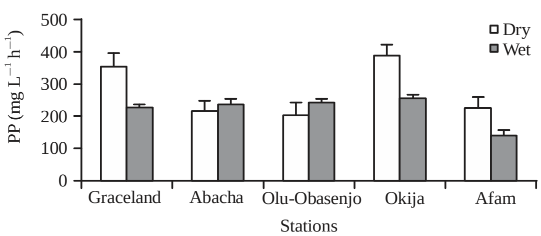

Fig. 11: Mean primary productivity values at the study stations for wet and dry periods

The phytoplankton abundance showed seasonal fluctuation with higher values in the wet season than the dry. Generally the total phytoplankton abundance ranges from 5264-8133$\times$10^3 individuals L^{-1}. The values for dry season varied from 2699-3399$\times$10^3 individuals L^{-1} and the values for the wet season ranges from 3149-4734$\times$10^3 individuals L^{-1}.

The taxonomic group Cyanophyceae constituted the bulk of the phytoplankton population for all the station 2690$\times$10^3 individuals L^{-1} the highest value was obtained from Okija station which is located at lower stretch of the stream within the densely populated area of the city. The least value was obtained from Abacha station located at the upper stretched of the stream.

Chlorophyll a: Chlorophyll a concentrations ranged from 7.38-34.65 mg m^{-3} for the entire study period. Wet season concentrations ranged from 7.38-25.50 mg m^{-3}, with Oluobasanjo station having the highest concentration and Afam station with the lowest. In dry season, concentrations ranged from 9.63-34.65 mg m^{-3}.

Generally the concentrations for dry season were higher than that recorded for wet season for the upper stretched of the stream but the reverse was observed for the lower sections of the stream except for Afam station that demonstrated similar trend for the upper stations (Fig. 10).

Comparatively, the differences in the chlorophyll a concentrations between seasons were not statistically significant (student t-test (0.39) <p(2.13) at 0.05).

Primary productivity values ranged from 138-385 mg L^{-1} h^{-1}. Primary productivity concentrations for dry season were higher than that of the wet season (Graceland, Okija and Afam stations) except for Abacha and Oluobasanjo stations, where wet season values were slightly higher than dry season.

Wet season values ranged from 138.75-250 mg L^{-1} h^{-1}, while the dry season values ranged from 201.25-385 mg L^{-1} h^{-1} (Fig. 11).

Statistically, there were no significant differences between seasons and stations (student t-test (0.60) <p(2.13) at 0.05).

DISCUSSION

The generally high value of temperatures with narrow variations between stations is expected as this had been reported by other studies in the Niger Delta (Braide *et al*., 2004), which is within the equatorial tropical areas where temperature variation between seasons are minimal (Gobo, 1988). The remarkable differences between wet and dry season can be attributed to the effect of hot climate on the stream since it is an open water body. The relative differences in temperature between the lower and upper limit of the stream may possibly be due to the absence of vegetation cover in the lower limit of the stream.

The acidic pH observed in the stream is expected in such stream system, where litter fall underlies the stream bed and through the processes of decay, produces humus substances that induces acidic condition. The almost uniform pH for all the stations between seasons implies that municipal input into the system do not remarkably alters the pH of the entire system. Obunwo *et al*. (2004) observed higher values in the wet season than in the dry season. This may be due to the fact that the water body natural processes had been altered following time series changes in the system. For example, between the period of study by Obunwo *et al*. (2004) and this, the stream has been dredged to enable free flow of water and thus reducing stational differences to a minimum.

Generally high values were observed along the stream stretch for both seasons, above what is expected of similar swamp forest stream. This implies that the amount of materials dissolved in the stream were high. This suggests that the dissolved components are from domestic and industrial discharges into the stream. Higher conductivity values recorded during the dry season as against the wet season is an evidence indicating the role of season in the water body as storm water during the wet season helps to flush the system more than in the dry season. The relatively higher values in the lower stretch suggest that it receives more municipal discharges than the upper stretch.

As it was observed for conductivity, alkalinity recorded high concentration, which is an indication of high buffering capacity of the stream following the presence of carbonate components or other buffering substances from waste water. Higher alkalinity values observed in the dry season than in the wet season suggest the ability of the stream to maintain the pH of the stream to near neutral level.

Abacha station was observed to have very low alkalinity and conductivity for both seasons the reason can be from the location of this station which is very close to the headwater and away from dense economic activities. Hence this stretch receives less dissolved substance.

The concentrations of dissolved oxygen were generally high. The high concentrations suggest that the stream is sufficiently aerated by wind and effluent is rapidly dissipated. Comparatively, dissolved oxygen concentrations (Fig. 5) for wet season were higher than dry season. The higher wet season concentrations suggest that inflow of oxygen rich flood water which helps to dissipate the waste. The low concentration in the dry season can be attributed to the presence of carbon (iv) oxide in the stream which can lead to the depletion of dissolved oxygen. The relatively lower concentration of Dissolved Oxygen (DO) in the lower limit of the stream may indicate the high risk of waste generated by the surrounding domestic and economic activities at that stretched of the stream, which can affect the life of aquatic organisms.

Generally, high concentrations of BOD_5 (Fig. 6) were observed. As compared to DO, BOD_5 concentrations were lower than the DO concentration. The lower concentrations of BOD_5 suggest the ability of the water to carry out self purification. The BOD_5 concentration for wet season were higher than dry season and may be attributed partly to the effect of waste water and increase microbial activities and also from the diffusion of oxygen into the stream from surface runoff. The upper stretch of the stream was observed to have higher BOD_5 concentration than the lower limit, this might be due to re-suspension of organic matter and associated biological load resulting in the increase in biochemical oxygen demand.

Generally, sulphate concentrations were observed to be high (Fig. 7). The moderate level of sulphate can be attributed to the combined effect of effluents from industrial activities, municipal drainage which are characteristically rich in sulphate, since most fresh water are known to be poor in sulphate. It can also be attributed to the absence of thiosulphate bacteria which normally utilized sulphate by degrading it.

The pattern of sulphate concentration in the dry season shows decreased in trend downward and it can be suggested that the presence of thiosulphate bacteria in the lower limit of the stream might have being responsible for the low concentration.

In the upper (Graceland and Abacha) and lower (Afam and Okija) stations, dry season concentrations were higher than wet season while, the reverse pattern was observed in Olu-Obasanjo station. The higher values in the wet season noticed in this station can be due to the influence of flood water. The higher levels of sulphate gotten in this study were not in accordance with that gotten by Amadi *et al.* (1997) on similar water body, this can be attributed to increase population and hence more waste produced.

The concentrations of phosphate were low and it is a common factor in fresh water bodies found in the Niger delta. The reason for this low level has been associated with the nature of the drainage basin and the poor nutrient status of the stream. In spite of that, elevated level of phosphate were observed in the dry season at the lower limit of the stream and this may be another indication that the municipal waste discharged, contained more of these nutrient load and this might have been responsible for the preponderance of the blue green algae observed in the periphyton population in some stations (Olu-Obasanjo, Okija, Afam).

In the wet season the level of phosphate were uniformly low in all the stations, while in the dry season the upper stations have lower level of phosphate than the lower stations. The high level observed in the lower limit of stream in the dry season can be associated with detergent gotten from domestic sewage, which are the major causes of increased dissolved phosphorus loadings since the area host several economic and industrial activities. Braide *et al.* (2004) observed higher level of phosphate in the wet season than in the dry season in the miniweja stream well the difference might have come from the location and the type of activities in the area, where this stream is located.

The levels of NH_3 were uniformly very low for all the stations in the wet season. In the dry season, the pattern showed an increase in concentration downstream of the systems. The high ammonia observed here may have resulted from accumulation of municipal waste compared to the lower level in the wet season. It is also probably that at this time the increase water level might have caused dilution, which may be the reason for the low wet season concentration.

The most striking observation was the extreme degradation of the stream in Afam station, which can clearly be seen in the evolution of ammonia and phosphate which might have resulted from recent deposition of waste which form complex molecules that are utilized by various organisms and eventually converted in to simpler molecules which form ammonia. The dry season concentrations were higher than the wet season this can be associated to the excretory of both human and animal which attain maximum density during this period. Seasonal differences were statistically not significant student t-test $p<0.05$.

The concentration of nitrate were generally low for the entire study period this can be linked to the nature of the drainage basin which is not generally rich in nitrate (Fig. 8). It can also be attributed to the presence of primary producers such as algae which can strip the water of any added nitrogen. The concentrations of nitrate were lower in the upper limit of the stream than the lower limit in the dry season. The same pattern was also observed in the wet season. The reason for high level can be attributed to excess fertilizer in the land runoff, since streams are known to have low level of nitrate. This also point to the abundance of such algae as *Gomphonema* sp., *Nitzschia* sp., *Synedra* sp. and *Euglena* sp., known to be good indicators of organic pollutions may be a pointer that the Ntawogba stream is undergoing rapid deterioration.

Phytoplankton: The 83 species recorded for the entire study period were slightly lower than 91 species recorded by Amadi *et al.* (1997) on the same water body in Port Harcourt municipal but higher than other similar studies in water bodies of the Niger Delta, Egborge (1987) recorded less than 60 species in Warri river, Nwadiaro and Ezefili (1985) had a total of 56 species in the New Calabar, Chindah (2003) recorded a total of 46 species in the Elele Alimini swamp forest stream.

The paucity of phytoplankton species and the low densities observed for these waters is attributed to the acidic condition (low pH) and poor nutrient status. Therefore the relatively higher values observed for the Nta-wogba stream may be associated with the nutrient load and other discharges from the municipal sources. The species richness which showed higher values in the dry season than the wet season may in addition be associated with the increased retention time which gave the phytoplankton species to develop and populate as flow rate decreased considerably.

The lower diversity despite the high phytoplankton abundance and the relatively higher Margalef (1958) species richness of 0.44-3.34 indicate that a few opportunistic organisms are dominating the phytoplankton populations of the stream. This is in consonance with observations by Ogamba *et al.* (2004) that diversity decreased with colonization time due to an increased dominance of some algal species. The community structure demonstrated a more complex and diverse representation by the four family groups. The Cyanophyceae consisted over 39% of the entire phytoplankton population for all the station except Abacha station, where Chlorophyceae represented the greater proportion. This disparity can be as a result of the retention and exposure time of this organism.

The abundance of euglenophyceae over other groups in the wet season may be due to domestic and industrial sewage disposal which seem to favour the euglenoids which are important indicator of saprobic situations.

The primary productivity showed no clear pattern of variation between seasons, for the different stations show inconsistent trend. However, the values were generally high. The negative effect of nutrient loading from non-point source in Ntawogba stream is indicated by the high values of primary production. Despite this, primary productivity had strong positive association with alkalinity, conductivity and phosphate. This is in agreement with observation from earlier studies that phosphate is an important element in biological productivity (Chindah, 2003).

The chlorophyll a concentrations were higher in the upper stations than at the lower stations for both seasons. Statistically seasonal variations were not significant at ($p<0.05$). The high concentration of chlorophyll a may be due to eutrophication even though high algal biomass can also accumulate in less productive habitats after long period of stable flow (Stevenson, 1984). The low level can be attributed to toxic effect of the waste generated from the surrounding industries and urban discharges.

CONCLUSION

The physicochemical studies indicate that the water quality does not appear to be polluted despite the observation made visually. However, the biological parameters appear to describe the state of the water more accurately. This indicates that while physicochemical changes may not readily describe the quality of the water succession, aquatic organism appears to be more realistic as early indicators of pollution in such water systems.

The low abundance of diatoms and low level of phytoplankton chlorophyll a suggest the impact of the waste load on the biological life. The abundance of the families of Cyanophyceae and Euglenophyceae further confirms the deteriorating state of the stream since these families are known to strive in polluted streams.

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