PHYSICOCHEMICAL DETERMINANTS OF PHYTOPLANKTON ABUNDANCE DURING THE WET SEASON IN A TROPICAL FRESHWATER SYSTEM IN NIGERIA

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ABSTRACT

The survey of wet season phytoplankton profile and its relation to the physicochemical properties of a tropical freshwaster system, the Udo Nwankwo River in Akwa Ibom State, Nigeria was carried out between the months of March, 2017 and August, 2017. Phytoplankton composition and water quality parameters were determined using standard methods in three selected Stations. The physicochemical attributes of the Udo Anwankwo River varied spatially between sample stations Although variations in temperature, pH and electrical conductivity were not significant between sampling stations, the difference in DO levels between stations was significant ($p<0.05$) and higher downstream (Station 3) than in upstream (Station 1) and midstream (Station 2). Monthly mean values of BOD_5 (7.50 ± 1.26 mg/L) and PO_4^{2-}(8.82 ± 0.05 mg/L) were slightly above the WHO standards. Three major classes of phytoplankton; Bacillariophyceae (70.8%), followed by Chlorophyceae (16.2%) and Cyanophyceae (13%) were encountered. Some pollution tolerant species such as *Osillatoria tenius* and *Microcystis aeruginosa* were also found. Pearson Product Moment Correlation analysis of the relation between physicochemical attributes and phytoplankton densities has revealed variable influence of the freshwater physicochemistry. Though the effect of pH changes was observed to be species specific, the elevated surface water temperature was strongly associated with low abundance of phytoplankton species, while the decrease in DO and increase in TDS levels negatively influenced plankton abundance. This forms the basis of concern because Udo Nwankwo River is under the influence of pollution in the near future. Hence constant monitoring of this water is recommended to ensure that life forms in the freshwater body are protected.

INTRODUCTION

The physicochemical characteristics of river ecosystem are temporally and spatially affected by the prevailing season especially in view of the increasing human population and activities. Phytoplankton is the base of the food chain and one of the most important links as the primary producer of aquatic ecosystem. The species and quantity variation of phytoplankton communities could directly or indirectly affect other aquatic organism distribution and density. Many studies have shown that there many closed relationships between the phytoplankton community and water quality, the different taxa of phytoplankton has variable sensitivities and adaptabilities to the aquatic environment (Descy, 1993). Monitoring the proliferation of plankton becomes very necessary since some groups of phytoplankton particularly blue green algae can enhance de-oxygenation, when they bloom, and this may lead to fish death.

Algal bloom can be a cause of some important environmental impacts worldwide and may result in a number of problems such as toxin production, trash and possibly unsafe drinking water. The presence of certain plankton species in water bodies explains the condition of the environment, and is therefore used to assess the water quality as reported by Esenowo *et al.* (2017). Miller (1999) has revealed that plankton production, growth and distribution may be higher within certain range of ambient environmental condition; and as such, they can be used as bio-indicators of water quality. A change in an individual species or population, known as bio indication, can gradually lead to a long term alteration in the biological or ecological community of the aquatic ecosystem (Oyema, 2007). Changes in an aquatic environment over time may be attributed to anthropogenic activities such as air, land or water pollution (Esenowo *et al.,* 2019). In Udo Nwankwo River, anthropogenic activities along the course of the river are on the increase and there is paucity of information on the phytoplankton profile of the river as influenced by its physico-chemical properties during the wet season, hence, need for the present study.

MATERIALS AND METHODS

Study Area/ Sampling Stations

Udo Nwankwo River is located at the boundary between Ikot Ekpene and Essien Udim Local Government of Akwa Ibom State, Nigeria. The River lies within latitude 5.15545'N and longitude 7.68246'E. It is a tributary of the Qua Iboe River (King and Ekeh, 1990). The adjourning lands around this River support a lot of agricultural activities such as cultivation of root and tuber crops, vegetables such as fluted pumpkin and water leaves, supports aquaculture and fishing. The river bed has been so exploited through sand and gravel dredging carried out in the River. The climate of the study area is seasonal tropical characterized by rainy months from March to October and dry months from November to March.

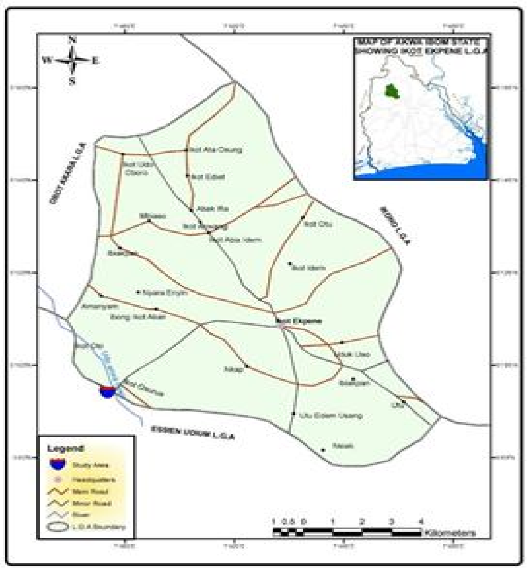

Figure 1: Map showing the course of Udo Nwankwo River

The sampling stations were selected based on the ecological settings and human activities within the study area.Station 1 is popularly called "Abia-Okpo", located upstream where human activities are limited to only local transportation and occasionally fishing and agriculture at the adjourning farmlands. Station 2, also called "Esa-Ibok" is located midway at the bank of the river, and is a major site for sand dredging activities using local boat. The third Station also called "Iso-Inyang", is located downstream where human activities such as bathing, washing, laundry and domestic waste disposal is very common. The water is shallow at this station and the water velocity is low.

Physicochemical Analysis of Water Samples

Highly unstable parameters of surface water samples such as Temperature, Hydrogen ion concentration (pH), Total Dissolved Solid (TDS), and Electrical Conductivity (EC) were measured *in-situ* with the multi-parameter monitoring instrument (model- EXTECH, EC, 500). Dissolved Oxygen (DO) was measured with DO meter-model-EXTECH 11, DO 600 while

Biochemical Oxygen Demand (BOD_5) was determined with DO-meter after five (5) days incubation at 20^0C.Other parameters such as nitrates, phosphates, and sulphates were determined *ex-situ* using standard procedures (APHA, 1998).

Phytoplankton Analysis

The methods used in assessing the plankton included collection, fixation, identification and counting using standard plankton identification key (Han, 1978 and Carmichael, 1981). Conical shaped plankton net of mesh number $30cm^2$ and size 60 mm was used for collecting plankton samples. This was done by hauling horizontally the net anchored on a moving local boat for 10 minutes. The plankton samples were transferred from a 250 ml collection bottle attached to the net into a screw capped plastic container. Sample were preserved in 4 % formalin and transported to the laboratory for analysis.

In the laboratory, the plankton samples were allowed to settle down for 48 hours before decanting the supernatant leaving an aliquot of known volume and cells of phytoplankton were counted using Sedgewick Rafter counting chamber.

Data Analysis

All data was analyzed using Statistical Package for Social Sciences (SPSS) software, version 21. Descriptive statistics was used to compute the means and standard deviations of physicochemical parameters. ANOVA and Fisher's exact tests were used to compare the means and establish significant differences while Pearson Product Moment Correlation analysis was employed to evaluate the relations between plankton abundance and physicochemical attributes

RESULTS

Variations in Physicochemical Parameters of Water

The physicochemical attributes of the Udo Anwankwo River varied spatially between sample stations (Table 1). Although variations in temperature, pH and electrical conductivity were not significant between sampling stations, the differences in DO level between stations was significant. The lowest DO values was recorded in Station 3 (3.83±1.12mg/L) whereas values in Station 1 (5.70±1.37mg/L) and Station 2 (5.40±1.67mg/L)were significant ($p<0.05$). Total Dissolved Solids showed its highest value (200 ± 63.05 mg/L) in Station 3 but was within the standard value of 500mg/L as recommended by WHO (2005). Highest value of BOD_5 (3.97 ± 1.66 mg/L) in Station 3 was significantly different ($p<0.05$) from that of Stations 1 and 2 nutrients (Sulphate, Nitrate and Phosphate) showed little spatial variations. However, in all the Stations, the values of these physicochemical parameters were seen to be within the acceptable range set out by WHO (2005) except for BOD5 which was seen to be slightly above the WHO standard for unpolluted water.

The temperature, pH and dissolved oxygen also varied between the sampling months having their peak values in the month of March with mean values of 28.77± 0.06ºC, 8.13 ± 1.27mg/L and 8.04 ± 1.85mg/L respectively (Table 2). TDS and Nitrate had their peak values in the month of August with mean values of 230.00 ± 1.73mg/L and 3.30 ± 0.52mg/L respectively. Highest BOD_5value of 7.5 ± 1.26mg/L was recorded in June. Levels of Sulphate 7.93 ± 0.07mg/L and phosphate 8.82 ± 0.08mg/L were highest in August and June respectively. However, apart from DO and BOD_5, the values of all other parameters were within the allowable range for unpolluted water as prescribed by WHO (2005).

Phytoplankton Profile of the Freshwater Body

The three classes of phytoplankton found were Bacillariophyceae, Chlorophyceae and Cyanophyceae. The dominant class of phytoplankton present was Bacillariophyceae having a total of 520 cell/ litre (70.8 %), followed by Chlorophyceae with 119 cell/litre (16.2 %) and Cyanophyceae was the least dominant 95 (13 %) (Figure 2). As observed in this study, the most abundant phytoplankton species was *Navicula* sp. (125 individuals) followed by *Synedra* sp and the least abundant phytoplankton species was *Asterionella* sp (11 individuals). The highest population of this phytoplankton was observed in the month of August. Presence of some pollution tolerant species such as *Osillatoria tenius* and *Microcystis aerugenosa* was observed in this study. Their presence poses a threat to the aquatic ecosystem.

Relation between Phytoplankton and the Physicochemical Parameters of Water.
Result revealed that high water temperature was strongly associated with low abundance of phytoplankton species. This strong negative associations were significant with *Coscinodiscus eccentricus* (r = -0.862, p = 0.027), *Coscinodiscus radiates* (r = -0.938, p = 0.006) and *Navicula sp.* (r = -0.861, p = 0.027). pH had a significantly strong negative association with *Microcystic aeruginosa* (r = -0.845, p = 0.034), *Cosmarium* (r = -0.845, p = 0.034), *Coscinodiscus radiates* (p = -0.872, p = 0.023) and *Coscinodicus concinnus* (p = -0.845, p = 0.034). Dissolved oxygen and TDS were oberved to be negatively associated negatively with phytoplankton abundance. . . Strong and significant associations between TDS and *Closterium ehrenbergii* (r = -0.910, p = 0.012), *Gonatozygon monotaenium* (r = -0.900, p = 0.014) and *Asterionella sp.* (r = -0.900, r = 0.014) were also observed. Relation between electrical conductivity, BOD_5 and phosphate of the water and the abundance of phytoplankton in the water was weak, negative and not significant. Relation between sulphate and *Coscinodiscus radiates* (r = -0.828, p = 0.042). High nitrate content was strongly associated with low abundance of phytoplankton species. This strong negative associations were significant with *Coscinodiscus radiates* (r = -0.881, p = 0.020), *Gonatozygon monotaenium* (r = -0.914, p = 0.011), and *Asterionella* sp. (r = -0.914, p = 0.011).

Table 1: Spatial Variation of Physicochemical Parameters in Udo Anwankwo River

Parameters / Stations	Water Temp. (^oC)	EC (S/cm)	pH	DO (mg/L)	TDS (mg/L)	BOD5 (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	PO_4^{2-} (mg/L)
Station 3	26.50 ± 1.96	1.99± 0.98	6.77± 1.87	3.83 ± 1.12	200.00± 63.05	3.97± 1.66	0.63 ± 0.35	2.90 ± 0.91	0.85 ± 0.32
Station 2	18.00± 2.72 ^{a}	1.66 ± 0.00^a	6.03± 1.08 ^{a}	5.40± 1.67 ^{a}	196 ± 63.29 ^{a}	2.42± 1.05 ^{a}	0.58± 0.66 ^{a}	2.43± 0.78 ^{a}	0.45± 0.22 ^{a}
Station 1	20.72± 0.00 ^{a}	1.76 ± 0.83^a	6.07± 1.04 ^{a}	5.70± 1.37 ^{a}	199 ± 60.29^a	2.52± 0.55 ^{a}	0.88 ± 0.36 ^{a}	2.73 ± 0.48 ^{a}	0.65 ± 0.02 ^{a}
WHO, (2005)	20-32	250	6.5-8.5	4-8	500	<3	500	10.00	5.00

Values are expressed as Mean ± S.D, n = 6, a = p<0.05, comparing with Station 1

DISCUSSION

Rivers and streams are highly heterogeneous at spatial as well as temporal scales, and several investigators have documented their heterogeneity focusing on the physicochemical dynamics of the water bodies. This study has shown that fluxes in physicochemical attributes especially changes in DO, TDS and surface water temperature may remarkably influence the distribution and abundance of phytoplankton in freshwater ecosystem. This finding is in agreement with previous reports by WHO (2005) that the temperatures in tropics vary between 20 - 32^0C.

The DO levels recorded were generally higher than the threshold value (4-8mg/L) both spatially and monthly. The slight increase of DO observed in this study indicates a good mixing in the water column. Similar observation has previously been reported by Essien-Ibok *et al*. (2010). . TDS was expectedly higher as the wet season progressed. This may have been due to the anthropogenic activities around the river; and the possible organic and inorganic matters that drained into the river as surface run-offs. The value of this parameter observed at station 3 of the River was not surprising. The Station is located downstream where human activities such as bathing, washing, laundry and domestic waste disposal is very common. The water body is shallow at this station and water velocity is very low. This result agrees with the report of Akpan (2004) on water bodies in Uyo, Akwa Ibom State.

Table 2: Monthly Variation in Physicochemical Parameters of Udo Anwankwo River

Parameters / Months	Water Temp (°C)	EC (S/cm)	pH	DO (Mg/L)	TDS (Mg/L)	BOD_5 (Mg/L)	SO_4^{2-} (Mg/L)	NO_3^- (Mg/L)	PO_4^{2-} (Mg/L)
March	28.77±0.06	0.15±0.01	8.13±1.27	8.04±1.85	71.00±3.46	4.47±2.02	2.67±0.12	1.30±0.17	3.22±0.01
April	28.30±0.17	2.37±0.40[a]	7.50±0.69	4.67±0.58[a]	209.00±1.73	3.43±1.27	3.13±0.02	2.57±0.23	3.73±0.19
May	28.10±0.17[a]	2.80±0.17[a]	6.43±0.40[a]	4.40±1.04[a]	227.33±2.87[a]	3.07±0.81	3.19±0.01	3.07±0.06[a]	5.89±0.09[a]
June	26.07±0.46[a,b,c]	1.00±1.29[a,b,c]	3.93±1.67[a,b]	5.07±0.06[a]	157.00±13.37[a]	7.50±1.26[a]	5.49±1.22[a]	2.56±1.45	8.82±0.05[a,b,c]
July	25.10±0.17[a,b,c,d]	1.87±0.12[a,b]	5.07±0.06[a]	4.67±0.58[a]	225.67±2.30[a]	2.20±0.35[d]	6.87±0.01[a,b,c,d]	2.97±0.06	8.12±0.14[a,b]
August	24.07±0.06[a,b,c,d,e]	1.97±0.06[a,b]	5.60±0.17[a]	4.30±1.21[a]	230.00±1.73[a]	2.13±0.40[d]	7.93±0.07[a,b,c,d,e]	3.30±0.52[a]	7.75±1.77[a,b,c,d,]
WHO, (2005)	20-32	250	6.5-8.5	4-8	500	<3	500	10.00	5.00

Values are expressed as Mean ± S.D, n = 3
a = p<0.05, comparing with the month of March
b = p<0.05, comparing with the month of April
c = p<0.05, comparing with the month of May
d = p<0.05, comparing with the month of June
e = p<0.05, comparing with the month of July

Table 3: Phytoplankton Distribution at Various Months in Udo Anwankwo River

S/N	Phytoplankton	No. of cell/liter					
		March	April	May	June	July	August
	Cyanophyceae:						
1	*Oscillatoria tenuis*	9.0	9.0	9.0	9.0	9.0	10.0
2	*Microcystic aeruginosa*	6.0	6.0	7.0	7.0	7.0	7.0
	Chlorophyceae:						
3	*Closterium ehrenbergii*	4.0	6.0	6.0	6.0	7.0	7.0
4	*Cosmarium* sp	7.0	7.0	8.0	8.0	8.0	8.0
5	*Gonatozygon monotaenium*	7.0	6.0	6.0	6.0	6.0	6.0
	Bacillariophyceae:						
6	*Asterionella* sp.	1.0	2.0	2.0	2.0	2.0	2.0
7	*Coscinodiscus eccentricus*	11.0	11.0	11.0	11.0	12.0	13.0
8	*Coscinodiscus radiates*	8.0	8.0	8.0	9.0	9.0	9.0
9	*Coscinodicus concinnus*	7.0	7.0	8.0	8.0	8.0	8.0
10	*Melosura moniliformis*	3.0	3.0	4.0	3.0	4.0	4.0
11	*Navicula* sp.	20.0	20.0	21.0	21.0	21.0	22.0
12	*Pinnularia major*	11.0	11.0	11.0	11.0	11.0	11.0
13	*Synedra* sp.	18.0	18.0	18.0	19.0	18.0	20.0
14	*Surrirella* sp.	3.0	3.0	3.0	3.0	4.0	3.0

Table 4: Association between physicochemical parameters and phytoplankton abundance in Udo Nwankwo River

	OST	MIAE	CLEH	COSM	GOMONO	ASSP	COEC	CORA	COCO	MEMO	NAVSP	PIMA	SYSP	SURISP
Temperature	-.676	-.721	-.790	-.721	.515	-.515	-.862*	-.938*	-.721	-.554	-.861*	.	-.742	-.414
EC	-.174	.433	.186	.433	-.431	.431	-.261	.450	.433	-.311	.203	.	.301	-.188
pH	-.160	-.845*	-.654	-.845*	.634	-.634	-.316	-.872*	-.845*	-.288	-.667	.	-.489	-.327
DO	-.307	-.634	-.914*	-.634	.982*	-.982*	-.387	-.395	-.634	-.566	-.601	.	-.320	-.180
TDS	.337	.574	.910*	.574	-.900*	.900*	.477	.306	.574	.714	.577	.	.216	.304
BOD5	-.215	.293	-.029	.293	-.176	.176	-.315	.425	.293	-.469	.084	.	.278	-.214
Sulphate	.210	.488	.168	.488	-.043	.043	.281	.828*	.488	-.096	.449	.	.569	.156
Nitrate	.303	.756	.881*	.756	-.914*	.914*	.409	.367	.756	.745	.682	.	.274	.234
phosphate	-.047	.615	.436	.615	-.642	.642	-.079	.566	.615	-.071	.396	.	.380	-.067

Values represent the correlation coefficients (r-values)

**. Correlation is significant at 0.01 levels (2-tailed).

*. Correlation is significant at 0.05 levels (2-tailed).

Key:

OST= *Oscillaria tenuis*
MIAE= *Microcystic aeruginosa*
CLEH= *Closterium ehrenbergii*
COSM= *Cosmarium*
GOMONO= *Gonatozygon monotaenium*
ASAP= *Asterionella sp.*
COEC= *Coscinodiscus eccentricus*
CORA= *Coscinodiscus radiates*
COCO= *Coscinodicus concinnus*
MEMO= *Melosura moniliformis*
NAVSP= *Navicula sp.*
PIMA= *Pinnularia major*
SYSP= *Synedra sp.*
SURISP= *Surrirella sp.*

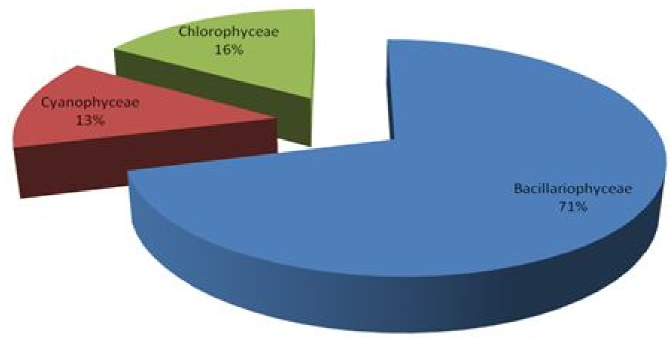

Figure 2: Phytoplanton Abundance in Udo Anwankwo River

Changes in pH of water was also observed. However, the pH values recorded were well within the preferred pH levels (6.5 - 8.5) for biological productivity. However, dissolution of CO_2 by rain water in the wet months may have been responsible for lowering the pH. Introduction of waste water, photosynthesis and other metabolic processes have also been shown to lower the pH of rivers (King and Ekeh, 1990). Akpan (2004) and Essien-Ibok *et al*. (2010) also attributes variations in pH to evapo-transpiration process and rainfall run-off, causing dilution of chemical substances and biological processes in water.

The levels of conductivity obtained in this river corroborates with result recorded for River Nun by Ogamba *et al*. (2015). The EC values recorded in this study were within the recommended standards of 100 µS/cm (WHO, 2005). The nutritive salts (sulphates, nitrates and phosphates) levels of the water body were relatively high. This may be ascribed to runoff during the rains. Contrarily, Akpan and Akpan, (1994) reported a low nitrate value in wet months and suggested that high plankton density during the dry periods utilize available nutrients in the water ecosystem. However, Nwankwo *et al*. (2003) recorded high phosphate values during wet months and opined that the higher phosphate levels was due to nutrient production increase due to run off from agricultural lands, livestock and human wastes.

The most abundant phytoplankton group in the river during the study period was the Bacillariophyceae (freshwater diatoms). Diatom dominance within the Niger delta region has been reported in other studies (Akpan, 1991). Abundance of diatoms in the wet months have been ascribed to increase in cycling of nutrients which normally boost the growth and subsequent abundance of the algae (Agale *et al*., 2013; Ekeh and Sikoki, 2003).

Correlation analysis has revealed strong associations between phytoplanktons and some physicochemical attributes such as DO, TDS and surface water temperature. The fluxes in phytoplankton abundance is an indication that the freshwater ecosystem can easily be destabilized by alterations in the levels of the physiochemical parameters. This position is shared by many similar works (Akpan and Akpan, 1994; Akpan, 2004 and Agwa, *et al*., 2013). Negative correlations are of the judgement that low values of these physicochemical parameters did not support the growth of planktons.*Microcystis aeruginosa* is one of the main indicators of water pollution as its presence pose a threat to aquatic ecosystem (Lindholm *et al*., 2003). According to Mischke and Nixdorf (2003), the presence of *Oscillatoria* species indicates beginning of biological pollution. Low density of planktons could be due to the dilution effect of the rain as well as drifting of algae along with the water. The diatoms constitute an important component of the freshwater and marine planktons and their abundance and species richness is influenced by both the environmental and biological factors prevalent in water (Agale *et al*, 2013).

CONCLUSION AND RECOMMENDATION

The research findings have revealed slight variations in the physicochemical properties of tropical freshwater ecosystem during the rainy season. The fluxes of some attributes though within the permissible limits as recommended by WHO (2005) affected the abundance of phytoplankton. The study has shown that DO, TDS and surface water temperature were the main physicochemical determinants of plankton abundance in tropical stream while the influence of pH and nutritive salts were species dependent. Also encountered in the perturbed ecosystem were pollutant tolerant species of as *Microcystis aeruginosa* and *Oscillatoria tenius.* This indicates that though the Udo Anwankwo River was not polluted at the time of the survey, the river has strong potential to be polluted from the myriad of anthropogenic activities within its catchment. Hence, routine monitoring of the water quality is recommended to ensure that life forms in the freshwater body are protected

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