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Assessment of Physicochemical Conditions and Phytoplankton Diversity of Anambra River in Anambra State, Nigeria

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Abstract

Phytoplankton diversity and physicochemical parameters are important criteria for evaluating the suitability of water for drinking and other purposes. An assessment of physicochemical parameters and phytoplankton diversity in Anambra River, Anambra State, was conducted for a period of eight months from February 2021-September 2021. Water samples were collected from three sampling stations of the river every month in sterilized containers during the course of the study. The study stations were designated as S1 (Umueri) S2 (Anam) and S3 (Otuocha). The samples were analysed for both physicochemical attributes and plankton diversity. Phytoplankton species were determined following standard procedures. A total of twenty three species of phytoplankton were encountered in Anambra River. Chlorophyceae was the dominant group of phytoplanktons in the river, accounting for 44.8% and 38.3%. The most abundant phytoplankton species was Spirogyra, accounting for 8.9 %. There were 98, 82 and 101 phytoplanktons recorded for Station 1 (S1), Station 2 (S2) and Station 3 (S3) respectively. 14 phytoplankton species cut across the 3 stations in Anambra River while Closterium Spp and Tetraspora Spp were unique to Station 3 (S3) and Station 2 (S2) respectively. *A. bisoletiana* and *Navicula spp* were absent in S1; *Oscillatoria spp., Nodularia* and *Zygnema were absent in S2*, while *Rivularia spp.* and *Microspora were absent in S3.* Anambra River recorded high diversity indices value for Chlorophyceae = 1.26 and least value for Cyanophycaea = 1.23. The physico-chemical attributes of the river was investigated by measuring the degree of correlation with the phytoplankton diversity. The phytoplankton diversity of the river showed significant correlation with physicochemical parameters. The result revealed a deterioration of water quality of the river due to industrial, commercial and anthropogenic activities. The status of plankton diversity of Anambra River was low indicating that the river is highly polluted and the water chemistry has direct effect on plankton diversity. There is need for urgent management and conservation strategies to protect and restore the water quality of the river.

Keywords: Anthropogenic activities, Diversity, Physicochemical, Phytoplankton, Water quality

1. Introduction

Rivers are important systems of biodiversity and are among the most productive ecosystems on the earth because of the favourable conditions that supports number of flora and fauna. River ecosystem is one of the natural resource which comes into the service of mankind in many parts of the world. They play a vital role in the productivity as they are beset with varieties of flora and fauna including planktons. Urbanization, expansion of irrigation and increasing trend of industrialization has contributed towards the demand for water. Surface water is the principal source of irrigation in rural areas. Phytoplanktons are first link in nearly all aquatic food chain (Babatunde *et al.*, 2014) [3]. Without phytoplankton, the diversity and abundance of aquatic life would be impossible.

The structure and abundance of the phytoplankton populations are mainly controlled by inorganic nutrients such as nitrogen, phosphorus, and silica (Daniel, 2001) [8] and mainly available nitrogen as nitrate, nitrite and ammonia, phosphorus as soluble orthophosphate (USEPA, 2000) [26] and silicone as silicate forms. Phytoplankton have both beneficial and detrimental effect on human, the presence of algae in any kind of water body is an indicator of pollution (Hassan *et al*., 2010). Phytoplankton form the base of the food chain in aquatic ecosystems and play an important role in overall wetland productivity (Chengxue *et al*., 2019). Phytoplankton is one of the important biological tools used for the assessment of the environment (Salman *et al*., 2013; Luong and Phan, 2014) [22, 16]. Phytoplankton is used to assess the health of aquatic ecosystem, so as to enhance the effectiveness of surface water management (Bill *et al*., 2007) [4]; phytoplankton contributes to nutrient cycling and regulation of climate dynamics (Richardson and Schoeman, 2004) [21], and constrains fishery catches (Chassot *et al*., 2010) [6]. According to Reynolds *et al*. (2002) [20] and Brettum and Andersen (2005) [5], phytoplankton communities are sensitive to changes in their environment and therefore phytoplankton total biomass and many phytoplankton species are used as indicators of water quality. The aim of this study is to assess the Physicochemical Conditions and Plankton Diversity of Anambra River.

2. Materials and Methods

2.1. Study Area

The study area is Anambra River and environs. The river is located in Anambra state of Nigeria. Anambra State lies between Longitudes $6^0 35^1$E and $7^0 21^1$E, and Latitudes $5^0 40^1$N and $6^0 45^1$N. The climate is tropical with an average yearly rainfall of 2000mm and mean temperature of 27.6^0C. Heavy rainfall occurs within the months of April to October while the months of November to February have scanty rainfall, higher temperature and low humidity.

The Anambra River is a tributary of River Niger which is the third largest river in Africa after the Nile River and the Congo River. The river flows 210 kilometres (130 mi) into the Niger River and is the most important feeder of the River Niger below Lokoja. The flow of the Anambra River is released into the Atlantic through various outlets forming the 25,000-square-kilometre (9,700 sq mi) Niger Delta region (Shahin, 2002) [23].

2.2. Collection of Samples

Collections of phytoplankton were made using a conical net of bolting nylon of 0.069mm mesh width and mouth ring diameter of 35 cm with the help of an outrigger canoe. The net was towed for ten minutes for surface hauls and the volume of water filtered through it was determined by flow meter attached to it and the net was backwashed between the stations to avoid clogging of meshes. The filtered samples were fixed and preserved in 4% formalin with a few drops of Lugol's iodine solution. For the quantitative analysis of phytoplankton, the settlement method described by Sukhanova (1978) [24] was adopted. Numerical plankton analysis was carried out using an inverted microscope. Planktons were identified and enumerated by using the methods described by Hosamani and Bharathi (1980) [13]. Water samples were also collected with sterile containers, properly labeled, stored in a refrigerator and taken to the laboratory within 72 hours of collection for analysis of physicochemical parameters of the lake.

2.3. Sample identification

Identification of the plankton was done with the use of a compound microscope. A dissecting microscope was used for sorting and counting the number of species. After they were taken to the laboratory, each preserved plankton sample was poured into a graduated centrifuge tube and centrifuged using a 'Gallen Kamp- Medico' model (90) centrifuge. This was allowed to settle and the supernatant decanted. After decanting the concentrated plankton was analyzed. The Specimens were mounted on glass slides and examined at 25-100X magnification. A pipette was used to place the concentrated plankton on a glass slide with a cover slip and then viewed under a compound. The planktons were then identified (qualitative analysis) and counted (quantitative analysis) using standard identification keys and taxonomic guide (Pennak, 1979; Jeje & Fernando, 1986) [19, 14]. The general body shape, the color (Opaque or translucent), the relative length of appendages (e.g. antennae, legs) and setae (hair-like processes) were features used in identification of the zooplankton species. The above processes were repeated five times, in order to determine the abundance and diversity of phytoplankton at the three stations (S1, S2 and S3).

2.4. Determination of parameters

The Physicochemical parameters measured were temperature, pH, turbidity, conductivity, nitrate, phosphate, BOD, COD, dissolved oxygen, total suspended solids, total dissolved solids, total solids, total alkalinity, total hardness, potassium, sodium, chloride and calcium. Temperature was determined *in situ* by using the mercury in glass thermometer in centigrade scale. A multi-purpose pH meter model D46 (pH/MV/^{O}C meter) was used to determine the pH of the water samples. Turbidity of the samples was measured in the laboratory using the LABTECH DIGITAL turbidity meters. The specific conductance of the samples was measured using the battery operated conductivity bridge model MC-1 mark V Electronic switchgear at room temperature. Total Dissolved Solids, Total Suspended Solids and Total solids were measured by gravimetric analysis. Total Alkalinity, Total Hardness, Calcium, Chloride, Dissolved Oxygen, Chemical Oxygen Demand, and Biological Oxygen Demand were analyzed by the titration method. Potassium and Sodium were determined by Flame photometer; while Phosphate and Nitrate were analyzed by UV-visible spectrophotometer.

3. Result

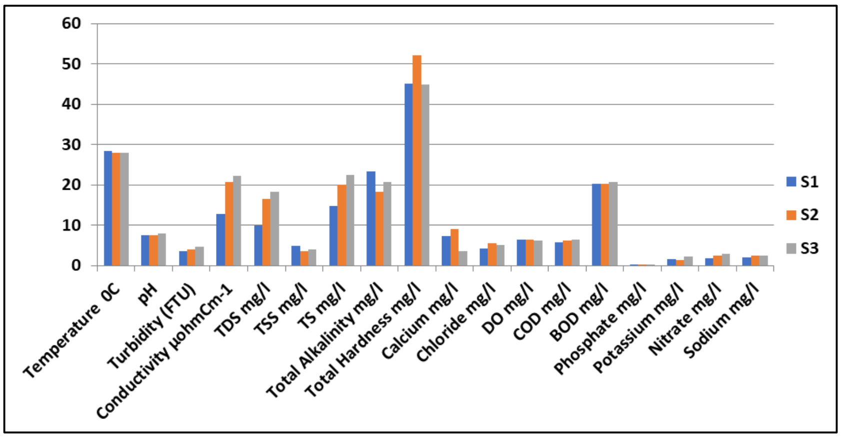

Fig 1: Mean values of physicochemical characteristics of Anambra River

The mean result of physicochemical parameters at different sampling points in Anambra River is shown in Figure 1. The mean values of temperature varied from 27.9^{0}C at S3 to 28.4^{0}C at S1. The mean values of pH ranged from 7.57 at S1 to 7.89 at S3. The mean values of TS varied from 14.8 mg/L at S1 to 22.36 mg/L at S3. The turbidity values ranged from 3.6 to 4.7 FTU. Conductivity values ranged from 12.8 at S1 to 22.3 µohmCm^{-1} at S3. The mean TDS values varied from 9.89 mg/l at S1 to 18.26 mg/l at S3. The mean TSS values ranged from 3.62 mg/l at S2 to 4.91 mg/l at S1. The mean values of TS varied from 14.8 mg/l at S1 to 22.36 mg/lat S3. The mean total alkalinity values ranged from 18.2 mg/l at S2 to 23.4 mg/l at S1. The mean values of total hardness varied from 44.8 mg/l at S3 to 52.2 mg/lat S2. The mean calcium values ranged from 3.62 mg/l at S3 to 9.15 mg/l at S2. The mean values of chloride varied from 4.14 mg/l at S1 to 5.62 mg/l at S2. The mean dissolved oxygen values ranged from 6.2 mg/l at S3 to 6.4 mg/l at S1. The mean values of COD varied from 5.8 mg/l at S1 to 6.5 mg/l at S3. The mean values of BOD ranged from 20.29 mg/l at S1 to 20.70 mg/l at S3. The mean values of phosphate varied from 0.001 mg/l at S1 to 0.005 mg/l at S3. The mean values of potassium ranged from 1.45 mg/l at S2 to 2.17 mg/l at S3. The mean values of nitrate varied from 1.9 mg/l at S1 to 2.8 mg/l at S3. The mean values of sodium varied from 2.01 mg/l at S3 to 2.5 mg/l at S2.

Table 1: Distribution of phytoplankton (Unit/l) in Anambra River during the study period

Phytoplankton	S1	S2	S3	Total
Cyanophyceae				
Anabena spp.	6	3	7	16
Oscillatoria spp.	3	0	4	7
Nostoc spp.	5	6	5	16
Spirulina	3	4	3	10
Nodularia	6	0	8	14
Rivularia spp.	10	4	0	14
Total	**33**	**17**	**27**	**77**
Chlorophyceae				
Chlorella	4	8	6	18
Cladophora	5	3	5	13
Oedogonium	0	2	3	5
Closterium spp.	0	0	4	4
Spirogyra	12	4	9	25
Ulothrix	5	3	3	11
Microspora	6	6	0	12
Zygnema	8	0	6	14
Tetraspora	0	9	0	9
Volvox	3	4	8	15
Total	**43**	**39**	**44**	**126**
Bacillariophyceae				
Achnanthes devei	2	3	5	10
A. bisoletiana	0	4	7	11
Cyclotella	4	2	3	9
Fragillaria pinnata	8	5	4	17
Diatoms	6	5	3	14
Nitzschia spp.	2	4	4	10
Navicula spp.	0	3	4	7
Total	**22**	**26**	**30**	**78**

A total of twenty three species of phytoplankton belonging to three taxa were encountered in Anambra Rivers (Table 1). S1, S2 and S3 had 18, 19 and 20 species respectively. Station 1 (S1) had the highest number of individuals of species (33) belonging to the Class Cyanophyceae, followed by Station 3 (n = 27), while Station 2 (S2) had the least number of individuals of species (17) belonging to the Class Cyanophyceae. For the Chlorophyceae, the highest number of species (44) was recorded in S3, followed by S1 (43). S2 recorded the lowest value (39) of individual species of the Chlorophyceae group. The highest number (30) of individual species of Bacillarophyceae was recorded in Station 3, followed by Station 2 (26), while the least value (22) was recorded in Station 1.

Table 2: Diversity index of phytoplankton at different sampling points in Anambra River

Parameters	Number of Species			Shannon_H			Dominance_D			Evenness_e^H/S		
Sites	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Cyanophyceae	33	17	27	1.704	1.355	1.55	0.1974	0.2664	0.2236	0.9156	0.9688	0.942
Chlorophyceae	43	39	44	1.851	1.965	2.009	0.1725	0.1545	0.1426	0.9094	0.8922	0.9322
Bacillariophyceae	22	26	30	1.468	1.906	1.905	0.2562	0.1538	0.1556	0.8682	0.9596	0.9596

The result of diversity index of phytoplankton in Anambra River (Table 2) revealed that Cyanophyceae showed minimum value of phytoplankton diversity index in Station 2 (1.355) and maximum value in Station 1 (1.704). Cyanophyceae showed the highest value (0.2664) for species Dominance_D in Station 2 and the least value (0.1974) in Station 1. Evenness ranged from 0.9156 in Station 1 to 0.9688 in Station 2.

Chlorophyceae showed minimum value of phytoplankton diversity index in Station 1 (1.851) and maximum value in Station 3 (2.009). Chlorophyceae showed the highest value (0.1725) for species Dominance_D in Station 1 and the least value (0.1426) in Station 3. Evenness ranged from 0.8922 in Station 2 to 0.9322 in Station 3.

Bacillariophyceae showed minimum value (1.468) of phytoplankton diversity index in Station 1 and maximum value (1.906) in Station 2. Bacillariophyceae showed the highest value (0.1725) for species Dominance_D in Station 1 and the least value (0.1538) in Station1. Evenness ranged from 0.8682 in Station 1 to 0.9596 in Station 2 and Station 3 respectively.

The results of correlation analysis of physicochemical parameters of the river (Tables 3) revealed that temperature correlated highly positively with pH (r = 0.73361) and also highly positively correlated with BOD, COD and Na. pH correlated negatively with temperature (r =-0.40635) and highly positively correlated with turbidity, EC, TDS, TS, Ca, T Alk and nitrate. Turbidity correlated highly negatively with Temperature (r =-0.83088) and highly positively with TSS, DO, BOD, Cl^- and sodium. EC was found to be highly negatively correlated with temperature (r = -0.99909) and highly positively correlated with turbidity, BOD, COD, K and Na. TDS was found to be highly negatively correlated with temperature (r = -0.99981) and correlated highly positively with turbidity, EC, BOD, COD and Na in Anambra River. TSS correlated highly positively with temperature (r = 0.84347), COD, Ca, PO_4 and K. TSS also correlated highly negatively with pH, EC and TDS. TS correlated highly negatively with temperature (r = -0.99367) and with TSS (r = -0.7776) and correlated highly positively with turidity, EC, TDS, BOD and Na. DO highly positively correlated with temperature (r = 0.77028), with TSS, COD, Ca, PO_4, K, and NO2, and highly negatively correlated with pH, EC and TDS. BOD correlated negatively with temperature (r = -0.30571) and highly negatively with TSS and DO. COD correlated positively with temperature (r = 0.35105) and correlated highly positively with pH, Cl^-, THD and K. COD also correlated highly negatively with turbidity and negatively with EC, TDS, TSS, TS and DO. Also, Cl^- correlated highly negatively with temperature (r = -081366), with TSS and DO, and also correlated highly positively with pH, EC, TDS, TS, BOD, Ca, PO_4, K and NO_2. Ca correlated with temperature (0.65465), correlated highly positively with COD and correlated highly negatively with turbidity and TS. Ca also correlated negatively with EC, TDS, and Cl^-. T.Alk was found to be highly negatively correlated with temperature (-0.96862) and Ca (r = 0.82199) but negatively correlated with TSS, DO and COD. THD correlated highly positively with temperature (0.99419), TSS, DO, PO_4, K and Na. THD correlated highly negatively with turbidity, EC, TDS, TS and Cl^-. THD also correlated negatively with pH and BOD. PO_4 correlated negatively with temperature (r = -0.52911), pH, BOD, Cl^- and THD and correlated highly negatively with COD and Ca. PO_4 also correlated highly positively with turbidity and T.Alk.

K correlated negatively with temperature (r = -0.467), pH, BOD, Cl^-, and THD, and correlated highly negatively with COD and Ca. K also correlated highly positively with turbidity and PO_4. NO_2 correlated highly positively with temperature (0.86603), COD, Ca, THD and Na, and also correlated highly negatively with turbidity, EC, TDS, TS, T.Alk, PO_4 and K. Na correlated negatively with temperature (-0.1594), turbidity, TSS, T.Alk, PO_4 and K; and also correlated highly negatively with DO and K. Na correlated highly positively with pH, BOD, COD and Cl^-.

Table 3: Correlation Analysis of Physicochemical Parameters of Anambra River

	Temp	pH	Turb	EC	TDS	TSS	TS	DO	BOD	COD	Cl^-	Ca	T Alk	T HD	PO_4	K	NO_2	Na
Temp		0.73361	0.37568	0.02721	0.012313	0.36102	0.07169	0.44024	0.80221	0.77165	0.39494	0.54563	0.15991	0.068649	0.64505	0.69067	0.33333	0.89809
pH	-0.40635		0.89071	0.7064	0.74592	0.37259	0.8053	0.29337	0.068605	0.49474	0.33866	0.72077	0.89351	0.66496	0.62134	0.57573	0.93306	0.16448
Turb	-0.83088	-0.17083		0.40289	0.36337	0.7367	0.30399	0.81592	0.82211	0.39597	0.77062	0.16995	0.21577	0.44433	0.26937	0.31499	0.042347	0.72623
EC	-0.99909	0.44502	0.80634		0.039523	0.33381	0.0989	0.41303	0.775	0.79886	0.36773	0.57284	0.18712	0.041439	0.67226	0.71788	0.36054	0.87088
TDS	-0.99981	0.3886	0.84148	0.99807		0.37333	0.059377	0.45255	0.81452	0.75934	0.40725	0.53332	0.14759	0.080962	0.63274	0.67835	0.32102	0.9104
TSS	0.84347	-0.83357	-0.4019	-0.86565	-0.83292		0.43271	0.079216	0.44119	0.86733	0.03392	0.90665	0.52093	0.29237	0.99392	0.94831	0.69435	0.53707
TS	-0.99367	0.30109	0.88814	0.98796	0.99565	-0.77776		0.51193	0.8739	0.69996	0.46663	0.47394	0.088216	0.14034	0.57336	0.61898	0.26164	0.96978
DO	0.77028	-0.89569	-0.28514	-0.79682	-0.7578	0.99227	-0.69374		0.36197	0.78811	0.045296	0.98587	0.60014	0.37159	0.91471	0.8691	0.77357	0.45785
BOD	-0.30571	0.9942	-0.27581	0.34612	0.28724	-0.76932	0.19678	-0.84266		0.42614	0.40727	0.65216	0.96212	0.73356	0.55274	0.50712	0.86446	0.095879
COD	0.35105	0.71292	-0.81272	-0.31072	-0.36909	-0.2069	-0.45404	-0.32672	0.78421		0.83341	0.22602	0.61175	0.8403	0.1266	0.080986	0.43832	0.33026

Cl^-	-0.81366	0.86181	0.35256	0.83776	0.80227	-0.99858	0.74318	-0.99747	0.80225	0.25871		0.94057	0.55485	0.32629	0.96	0.91439	0.72827	0.50315
Ca	0.65465	0.42469	-0.96458	-0.62176	-0.66915	0.14611	-0.73545	0.0222	0.5196	0.93763	-0.093217		0.38572	0.61428	0.099425	0.14504	0.2123	0.55628
T Alk	-0.96862	0.16649	0.94311	0.95712	0.97325	-0.68348	0.99041	-0.5876	0.059471	-0.57276	0.64364	-0.82199		0.22856	0.48515	0.53076	0.17343	0.942
T HD	0.99419	-0.50232	-0.76616	-0.99788	-0.99192	0.89638	-0.9758	0.83444	-0.40641	0.24823	-0.8715	0.56949	-0.93624		0.7137	0.75932	0.40198	0.82944
PO_4	-0.52911	-0.56034	0.91181	0.49237	0.54542	0.0095425	0.62111	0.13357	-0.64617	-0.98029	-0.062783	-0.98783	0.72341	-0.43471		0.045612	0.31172	0.45686
K	-0.467	-0.6182	0.88007	0.4288	0.48402	0.081101	0.56341	0.20418	-0.69915	-0.99192	-0.13407	-0.97416	0.67213	-0.36912	0.99743		0.35733	0.41124
NO_2	0.86603	0.10495	-0.99779	-0.84387	-0.87553	0.46187	-0.91673	0.34822	0.21131	0.77219	-0.41398	0.94491	-0.96312	0.80718	-0.8825	-0.84657		0.76858
Na	-0.1594	0.96681	-0.4169	0.20143	0.14027	-0.66476	0.047452	-0.75234	0.98868	0.86843	0.7036	0.64191	-0.090974	-0.26472	-0.75337	-0.79851	0.35556	

Temp = Temperature, Turb = Turbidity, EC = Electrical Conductivity, TDS = Total Dissolved Solids, TSS = Total Suspended Solids, TS = Total Solids, DO = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, Cl^- = Chloride, Ca = Calcium, T Alk = Total Alkalinity, T HD = Total Hardness, PO_4 = Phosphate, K = Potassium, NO_2 = Nitrate, Na = Sodium

Table 4: Pearson Correlation (r-values) calculated between phytoplankton diversity and physicochemical parameters of Anambra River

	Temp	pH	Turb	EC	TDS	TSS	TS	DO	BOD	COD	Cl^-	Ca	T Alk	T HD	PO_4	K	NO_2	Na
Bacillariophyta	-0.85472	0.00992	0.38168	0.000785	0.002029	0.56681	0.019097	0.00093024	3.8881E-06	0.12972	-0.42541	0.004954	-0.49182	1.922E-05	0.001982	0.083999	0.6627	0.79569
Cyanophyta	-0.79815	0.593	-0.8090	0.015289	0.048684	0.74009	0.10448	0.092372	0.0074302	0.28064	0.10358	0.010837	0.87942	0.017035	0.012364	0.025165	0.59677	0.40318
Chlorophyta	0.3327	0.094447	-0.8855	0.55257	0.39475	-0.49341	-0.6565	0.24171	0.41267	0.40902	0.065181	0.96307	0.001492	0.57211	0.46914	0.17517	0.72752	0.14836

Temp = Temperature, Turb = Turbidity, EC = Electrical Conductivity, TDS = Total Dissolved Solids, TSS = Total Suspended Solids, TS = Total Solids, DO = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, Cl^- = Chloride, Ca = Calcium, T Alk = Total Alkalinity, T HD = Total Hardness, PO_4 = Phosphate, K = Potassium, NO_2 = Nitrate, Na = Sodium

Tables 4 shows the relationship between physicochemical parameters and planktonic biomass in Anambra River. The phytoplanktons were the Bacillariophyta, Cyanophyta and Chlorophyta. In Anambra River Bacillariophyta showed negative correlation with temperature (-0.85472), Cl^- (-0.42541) and alkalinity (-0.49182). However, a positive relationship was found between Bacillariophyta and other parameters in the river. Cyanophyta correlated negatively with temperature (-0.79815) and turbidity (-0.8090) but correlated highly positively with TSS (0.74009) and T.Alk (0.879412). There was low positive correlation between Cyanophyta and pH, EC, TDS, TS, Do, BOD, COD, Cl^-, Ca, THD, PO^4, K, NO_2 and Na. Chlorophyta correlated negatively with turbidity (-0.8855), TSS (-0.49341), and TS (-0.6565), and correlated highly positively with Ca and NO_2, and also correlated positively with the other parameters.

4. Discussion

Planktons exist under a wide range of environmental conditions, and are sensitive to physicochemical changes in their marine environment (Hays *et al.*, 2005). It has been reported that many plankton species are limited by dissolved oxygen, temperature, salinity and other physicochemical factors (Jeje & Fernando, 1986; Esenewo, Ugwumba & Akpan, 2017) [14]. Temperature is a very important physical parameter used in determining water quality. There were slight variations in the mean values of temperature at all the sites in Anambra River. The mean values of the water temperature of the river was within the NESREA recommended range limits of 25^0C - 31^0C for surface water in the tropical region (Esenowo *et al.*, 2017). The high mean values of temperature recorded in Anambra River could have contributed to the dominance and abundance of algae species (Chlorophyceae) in the river. This agrees with the findings of O'Connor *et al*. (2009) who reported that increased temperature has been shown to have a positive effect on algae's growth due to a faster nutrient uptake.

In this present study, the highest mean pH value in Anambra River was recorded in S2. The high pH value (7.89) recorded indicated that the river is slightly alkaline. Phytoplanktons thrive better in alkaline conditions. This could explain the reason for greater diversity of plankton species in most sample points with high pH values.

Anambra River recorded highest values of total suspended solids in S3. S3 was the point of waste discharge in the river. Conductivity is an early indicator of change in a water system. Conductivity change can indicate pollution. The maximum mean conductivity value (22.3 µohmCm^{-1}) was recorded at S3. Electrical conductivity is good indicator of water quality (Gaikwad *et al.*, 2008). The highest value of TDS was recorded at S3 (18.26 mg/L) and the least value was recorded at S1 (9.89 mg/L). The mean TSS value for the river was highest at S1 (4.91 mg/L) and lowest at S2 (3.62 mg/L). TSS may decrease water's natural dissolved oxygen levels and increase water temperature thereby affecting plankton diversity. TS is a measure of suspended and dissolved solids in water. The highest value of TS in the river was recorded at S3 (22.36 mg/L) and the lowest value was recorded at S1 (14.8 mg/L). The total solids value in Anambra River was within the NESREA recommended limit. Higher total solids can reduce the passage of light through water, thereby slowing photosynthesis by phytoplanktons.

Alkalinity is the buffering capacity of water body. It is a measure of the ability of water body to neutralize acids and bases and thus maintain a fairly stable pH level. The highest total alkalinity value in Anambra River was recorded at S1 (23.4 mg/L) and the lowest value was recorded at S2 (18.2 mg/L). Water hardness and alkalinity are fairly similar. Total hardness is a measurement of the mineral content in a water sample that is irreversible by boiling. It is chiefly a measure of calcium and magnesium. Most aquatic organisms can tolerate a broad range of calcium hardness concentrations, but a desirable range is 75 mg/L to 250 mg/L with a minimum concentration of 20 mg/L (Fouzia & Amir, 2013). Anambra River recorded the highest value of total hardness at S2 (52.2 mg/L) and the lowest value at S3 (44.8 mg/L). The highest calcium value in the river was recorded at S2 (9.15 mg/L) and the lowest at S3 (3.62 mg/L). The highest value of chloride in the river was recorded at S2 (5.62 mg/L) and the lowest value was recorded at S1 (4.14 mg/L). Dissolved oxygen is the amount of oxygen that is present in water. It is an important indicator of water quality. The highest value of dissolved oxygen value in Anambra River was recorded at S1 (6.4 mg/L) while the lowest value was recorded at S3 (6.2 mg/L). Dissolved oxygen is essential for survival of aquatic organisms. It determines the occurrence and abundance of aquatic life. Aquatic organisms are found in areas of high oxygen concentration (WHO, 2006). The lower dissolved oxygen level in the river could be due to chemical and biological oxidation processes in water (Anago, Esenowo and Ugwumba, 2013) [2]. The mean value of DO in Anambra River was in line with the findings of Zakariya, Adelanwa and Taminu (2013) [29]. The mean DO concentration was within the limit for drinking water put at 5mg/L to 9mg/L (UNESCO, UNEP, WHO, 1996). COD is the amount of oxygen required to oxidize all soluble and insoluble organic compounds in water. The highest COD value in Anambra River was recorded at S3 (6.5 mg/L) which was the point of waste discharge in the river, while the lowest COD value was recorded at S1 (5.8 mg/L). High COD indicates lower amount of DO which can in turn lead to death of aquatic life forms.

BOD measures the amount of oxygen consumed by microorganisms in decomposing organic matter in water. The highest value of BOD in Anambra River was recorded at S3 (20.7 mg/L) and the lowest value was recorded at S1 (20.29 mg/L). The high BOD value recorded at S3 could be due to organic matter degradation which utilized oxygen within the river. This is in line with the findings of Kolo and Yisa (2000) [15]. The result of the present study revealed heavily polluted water body going by the classification of water bodies: BOD < 1.0 mg/L (unpolluted); BOD < 10.0 mg/L (moderately polluted) and BOD > 10.0 mg/L (Heavily polluted) (Adakole, Balogun and Lawal, 2002; Zakariya *et al*., 2013) [1, 29].

Anambra River recorded highest value of phosphate at S3 (0.005 mg/L) and lowest value at S1 (0.001 mg/L). Phosphate and nitrate are two major nutrients implicated in the eutrophication of water bodies. Nutrient enrichment stimulates phytoplankton growth (Chen *et al*., 2008) [7]. The highest value of nitrate in Anambra River was recorded at S3 (2.8 mg/L) which could be as a result of discharge of wastes, especially agricultural input, at that portion of the river; while the lowest value of nitrate in the river was recorded at S1 (1.9 mg/L). The high level of nitrate detected is in line with the findings of Wolfhard and Reinhard (1998) [27]. The highest value of potassium in Anambra River was recorded at S3 (2.17 mg/L) and the lowest value at S2 (1.45 mg/L). The highest value of sodium in the river was recorded at S2 (2.5 mg/L) and the lowest value at S3 (2.01 mg/L). There was slight variation in sodium concentration in the different sampling points of the river.

The abundance of phytoplankton in Anambra River was in the order: Chlorophyceae (44.84%) > Bacillariophyceae (27.76%) > Cyanophyceae (27.4%). The most abundant phytoplankton species in Anambra River was Spirogyra, accounting for 8.9 % while the least were Closterium Spp (1.42 %), Oedogonium (1.78%), Navicula (2.49 %), Oscillatorial Spp (2.5 %) and Tetraspora (3.2 %). The dominance of Chlorophyceae in the present study was in line with the findings of Ndebele-Murisa *et al*. (2010) [17] who reported that Chlorophyta and Cyanophyta, as well as diatoms in some cases, generally dominate tropical waters; however, it was at variance with the findings of Onyema (2008) [18] and Esenowo and Ugwumba (2010) [9] who reported that diatoms are the most obvious representatives of the phytoplankton in rivers, seas, and lakes. Though in this study, diatoms were in abundance but were not the dominant phytoplankton species in the river.

The result of phytoplankton analysis in Anambra River revealed that high values of Shannon-Wiener Index_H were recorded for Chlorophyceae (2.009) and low values for Cyanophyceae (1.355). Highest values for species dominance_D were recorded for Cyanophyceae (0.2664) and lowest for Chlorophyceae (0.1426). Evenness ranged from 0.8682 in Bacillariophyceae to 0.9688 in Cyanophyceae (Table 2).

5. Conclusion

The present study provides important information on phytoplankton distribution and abundance of Anambra River which may provide insight on the energy turnover of the river. The dominant phytoplankton assemblage of the river reflects its trophic level. The study revealed that the abundance and diversity of plankton species differ based on the locations which could be attributed to varying human activities in the catchment of the river. Activities around the catchment of the river should be monitored since they have significant effect on the water quality as revealed by the variations in physicochemical characteristics and phytoplankton diversity.

6. References

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