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RESEARCH ARTICLE

PHYSICOCHEMICAL CHARACTERISTICS AND PHYTOPLANKTON ABUNDANCE OF NKISI RIVER, ANAMBRA STATE

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ABSTRACT

An assessment of Physico-chemical parameters and phytoplankton diversity in Nkisi River in 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 are Trans Nkisi (S4), Omaga Phase II (S5), and Ozalla Layout (S6). The samples were analysed for both physicochemical attributes and phytoplankton diversity. Phytoplankton species were determined following standard procedures. A total of twenty three species of phytoplankton were encountered in Nkisi River. Chlorophyceae was the dominant group of phytoplanktons in the river, accounting for 38.3% in Nkisi River. The most abundant phytoplankton species in Nkisi River was Navicula spp accounting for 6.67 %. A total of 127, 144 and 119 phytoplanktons were recorded for Station 1 (S1), Station 2 (S2) and Station 3 (S3) respectively in Nkisi River. 20 phytoplankton species cut across the 3 stations in Nkisi River while none was entirely unique to the 3 stations. Nkisi River recorded high diversity indices value for Chlorophyceae = 2.24 and least value for Cyanophyceae = 1.557. The physico-chemical attributes of the river were investigated by measuring the degree of correlation with the phytoplankton diversity. The phytoplankton diversity of the river correlated positively with physico-chemical parameters. The result revealed a deterioration of water quality of the river due to industrial, commercial and anthropogenic activities. The status of phytoplankton diversity of Nkisi River was low indicating that the river is polluted and that the water chemistry has direct effect on plankton diversity. Cyanophyceae have shown less number of phytoplankton abundance in most of the sites in the river. The discharge of industrial effluents, domestic wastes and other anthropogenic activities has altered the structure of phytoplankton community of the river. There is need for legislation and conservation strategies to restore the water quality and protect the river from further degradation.

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INTRODUCTION

Phytoplanktons are first link in nearly all aquatic food chain (Babatunde *et al.,* 2014). 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) and mainly available nitrogen as nitrate, nitrite and ammonia, phosphorus as soluble orthophosphate (USEPA 2000) 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 is one of the important biological tools used for the assessment of the environment (Salman *et al*., 2013; Luong and Phan, 2014). Phytoplankton is used to assess the health of aquatic ecosystem, so as to enhance the effectiveness of surface water management (Bill *et al.,* 2007); phytoplankton contributes to nutrient cycling and regulation of climate dynamics (Richardson and Schoeman, 2004), and constrains fishery catches (Chassot *et al*., 2010). Phytoplanktons make up the main producers in any given water body. They play a key role in the primary production and global nutrient cycles of the Earth (Daniel 2001). They are used as bio-indicators to monitor aquatic pollution. According to Reynolds *et al.* (2002) and Brettum and Andersen (2005), 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.

METHODOLOGY

Study Area: The study area is Nkisi River and environs. Nkisi Rivers is 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^{0}C. 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. Nkisi River is located in Onitsha North, which is one of the four Local Government areas of Onitsha metropolitan area. The other three Local Government areas are Onitsha South, Ogbaru and some parts of Idemili. Onitsha is the commercial nerve centre of Anambra state and one of the largest urbanized towns in Nigeria. Generally speaking, Onitsha metropolitan town houses a number of industries, hospitals, hotels and markets, including one of the biggest markets in West Africa – the Ochanja main market. Because of rapid urbanization occasioned by population explosion, refuse generation and disposal has become a serious problem in the area. Heaps of refuse dumps are a common site. Leachates from these dumps of refuse are carried as runoff into the Nkisi River. The Nkisi River passes through a number of important layouts within Onitsha city. They include: G.R.A, Trans Nkisi layout, Ozalla layout and Omagba phases I, II and III, Wolliwo layout, Odoakpu layout, and Inland town.

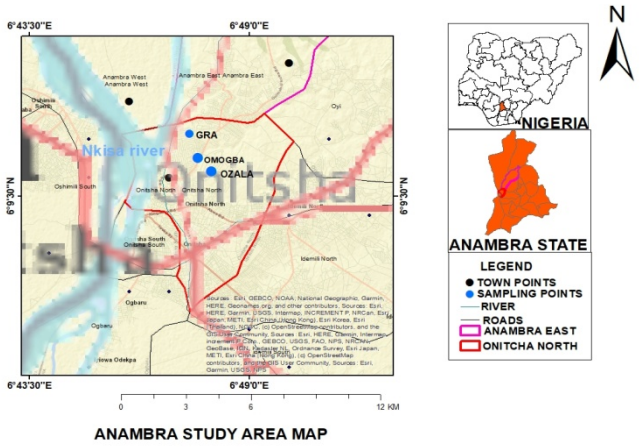

Figure 1. Map of study area showing Nkisi River

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) was adopted. Numerical plankton analysis was carried out using an inverted microscope. phytoplanktons were identified and enumerated by using the methods described by Hosamani and Bharathi (1980). The water samples were 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.

Sample identification Identification of the pytoplankton 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 phytoplankton 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 phytoplankton was analyzed. The Specimens were mounted on glass slides and examined at 25-100X magnification. A pipette was used to place the concentrated phytoplankton 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). 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) of Nkisi River.

Determination of Parameters: The Physico-Chemical 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. The Physico-Chemical 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.

RESULTS

The mean result of physico-chemical parameters at different sampling points in Nkisi River is shown in Table 3.1.

Table 3.1 Mean values of the physico-chemical characteristics of Nkisi River

Parameters Locations	Nkisi River		
	S1	S2	S3
Temperature ^{0}C	27.0	27.4	27.6
pH	7.24	7.18	7.32
Turbidity (FTU)	2.5	2.0	2.5
Conductivity µohmCm^{-1}	30.3	35.0	12.6
TDS mg/L	4.37	3.71	5.00
TSS mg/L	2.0	2.4	2.2
TS mg/L	6.37	6.11	7.2
Total Alkalinity mg/L	10.0	15.0	12.5
Total Hardness mg/L	36.4	33.1	40.1
Calcium mg/L	2.44	1.87	3.21
Chloride mg/L	3.46	2.05	2.45
DO mg/l	19.2	13.7	21.7
COD mg/L	4.8	5.3	4.0
BOD mg/L	10.85	15.20	10.24
Phosphate mg/L	0.001	0.00	0.01
Potassium mg/L	2.55	2.1	2.6
Nitrate mg/L	1.0	1.4	2.0
Sodium mg/L	1.00	1.15	1.34

The mean values of temperature varied from 27.0^{0}C at S1 to 27.6^{0}C at S3. The pH ranged from 7.18 at S2 to 7.32 at S3. TS varied from 6.11 mg/L at S2 to 7.2 mg/L at S3. The turbidity values ranged from 2.0 to 2.5 FTU. Conductivity values ranged from 12.6 at S3 to 35.0 µohmCm^{-1} at S2. The mean TDS values varied from 3.71 mg/L at S2 to 5.00 mg/L at S3. TSS values varied from 2.0 mg/l at S1 to 2.4 mg/l at S2. The mean values of TS varied from 6.11 mg/L at S2 to 7.2 mg/L at S3. The mean total alkalinity values varied from 10.0 mg/L at S1 to 15.0 mg/L at S2. The mean values of total hardness varied from 33.1 mg/L at S5 to 40.1 mg/L at S6. The mean calcium values varied from 1.87 mg/L at S2 to 3.21 mg/L at S3. The mean values of chloride varied from 2.05 mg/L at S5 to 3.46 mg/L at S1. The mean dissolved oxygen varied from 13.7 mg/L at S2 to 19.2 mg/L at S3. The mean values of COD varied from 4.0 mg/L at S3 to 5.3 mg/L at S2. The mean values of BOD varied from 10.24 mg/L at S3 to 15.20 mg/L at S2. The mean values of phosphate varied from 0.00 mg/L at S2 to 0.01 mg/L at both S1 and S3. The mean values of potassium varied from 2.10 mg/L at S2 to 2.60 mg/L at S3.

Table 3.2. Distribution of phytoplankton (Unit/l) in Nkisi River during the study period

Phytoplankton	S4	S5	S6	Total
Cyanophyceae				
Anabena spp.	5	2	2	9
Oscillatoria spp.	0	8	3	11
Nostoc spp.	6	3	7	16
Spirulina	4	6	4	14
Nodularia	10	7	3	20
Rivularia spp.	8	3	6	17
Total	33	56	25	114
Chlorophyceae				
Chlorella	12	6	6	24
Cladophora	7	10	5	23
Oedogonium	6	2	5	13
Closterium spp.	3	6	4	13
Spirogyra	3	6	4	13
Ulothrix	2	5	5	12
Microspora	7	10	5	22
Zygnema	5	3	12	20
Tetraspora	0	4	8	12
Volvox	4	0	6	10
Total	49	52	60	161
Bacillariophyceae				
Achnanthes devei	8	5	3	16
A. bisoletiana	4	8	6	18
Cyclotella	6	4	2	12
Fragillaria pinnata	2	10	4	16
Diatoms	3	4	8	15
Nitzschia spp.	10	1	1	12
Navicula spp.	12	4	10	26
Total	45	36	34	115

The mean values of nitrate varied from 1.0 mg/L at S1 to 2.0 mg/L at S3. The mean values of sodium varied from 1.00 mg/L at S1 to 1.34 mg/L at S3.

A total of twenty three species of phytoplankton belonging to three taxa were encountered in Nkisi River (Table 3.2). S1, S2 and S3 recorded 21, 22 and 23 species respectively in the River. Station 2 (S2) had the highest number of individuals of species (56) belonging to the Class Cyanophyceae, followed by Station 1 (n = 33), while Station 3 (S3) had the least number of individuals of species (25) belonging to the Class Cyanophyceae. For the Chlorophyceae, the highest number (60) of individual species was recorded in Station 3 (S3), followed by Station 2 (52). Station 1 recorded the lowest number (49) of individual species of the Chlorophyceae group. The highest number (45) of individual species of Bacillarophyceae was recorded in Station 1, followed by Station 2 which recorded 36 species; the least value (34) was recorded in Station 3. The result of diversity index of phytoplankton in Nkisi River (Table 3.3) revealed that Cyanophyceae showed minimum value of phytoplankton diversity index in Station 1 (1.557) and maximum value in Station 3 (1.703). Cyanophyceae showed the highest value (0.2213) for species Dominance_D in Station 1 and the least value (0.1968) in Station 3. Evenness ranged from 0.8926 in Station 2 to 0.9489 in Station 1. Chlorophyceae showed minimum value of phytoplankton diversity index in Station 1 (2.068) and maximum value in Station 3 (2.24). Chlorophyceae showed the highest value (0.142) for species Dominance_D in Station 1 and the least value (0.1144) in Station 3. Evenness ranged from 0.8785 in Station 1 to 0.9397 in Station 3. Bacillariophyceae showed minimum value (1.743) of phytoplankton diversity index in Station 3 and maximum value (1.796) in both Station 1 and Station 2. Bacillariophyceae showed the highest value (0.199) for species Dominance_D in Station 3 and the least value (0.1836) in Station 2. Evenness ranged from 0.8162 in Station 3 to 0.8612 in Station 1.

The results of correlation analysis of physico-chemical parameters of Nkisi River (Table 3.4) revealed that temperature correlated highly positively with pH, turbidity, TDS, BOD, COD, T Alk THD and K. pH correlated positively with temperature (r = 0.40389) and correlated highly positively with TSS, DO and Cl^-. Turbidity correlated correlated negatively with temperature (r = -0.18898) and correlated highly positively pH, N and Na. EC was found to be negatively correlated with temperature (r = -0.61057) and turbidity (-0.6623) and highly negatively correlated with pH (r =-0.9711), but highly positively correlated with TSS, DO and Cl^-. TDS correlated positively with temperature (r = 0.31461) and highly positively with pH and turbidity, and also correlated highly negatively with EC. TSS correlated positively with temperature (0.65465), correlated highly positively with TS, COD, Ca, T.Alk, PO_4, NO_2, and Na, but correlated highly negatively with turbidity. TS correlated positively with temperature (0.58647) and highly positively correlated with pH, TDS, DO, Cl^- and PO4. TS also highly negatively correlated with EC (r = -0.99955). DO correlated with temperature (r = 0.65465), highly positively correlated with COD, Ca, T.Alk, PO_4, NO_2 and Na. DO also correlated highly negatively with turbidity, and correlated negatively with pH, TDS and TS. BOD correlated positively with temperature (0.35831) and highly positively with pH, turbidity, TDS, TS and Cl^-. BOD also correlated highly negatively with EC and negatively with TSS and DO. COD correlated with temperature (r = 0.40724) and highly positively with pH, turbidity, TDS, TS, BOD, and Cl^-; also COD correlated highly negatively with EC and correlated negatively with TSS and DO. Also, Cl^- correlated highly negatively with temperature (r = -0.81833), TSS (r = -0.97019) and DO (r = -0.97019); and also correlated highly positively with turbidity, Ca, T.Alk and PO_4. Ca correlated highly positively with temperature (r = 0.76796), pH, TDS, TS, BOD, COD and THD. Ca also correlated highly negatively with EC (r = -0.97615) and negatively with Cl^-. T.Alk was found to be negatively correlated with temperature (-0.44925) and highly negatively correlated with pH, Turbidity, TDS, TS, BOD and COD. T.Alk was also found to be highly positively correlated with EC. THD correlated positively with temperature (0.29851) and correlated highly positively with TSS, DO, T.Alk, NO_2 and Na. THD also correlated highly negatively with pH, turbidity, TDS, BOD, COD and Cl^-. PO_4 correlated positively with temp (0.69338) and highly positively with pH, TDS, TS, BOD, COD, and Ca.

K correlated negatively with temperature (r = -0.09905) and highly negatively with EC, TSS, DO, T.Alk, and THD. K also correlated highly positively with pH, turbidity, TDS, TS, BOD, COD, NO_2 and Na. NO_2 correlated highly positively with temperature (0.95382), TS, Ca and PO_4. NO_2 also correlated highly negatively with EC and negatively with Cl^-, T.Alk and THD. Na correlated highly positively with temperature (0.96692), TS, Ca, PO4, and NO_2. Na also correlated highly negatively with EC and negatively with Cl^- and T.Alk. Tables 3.5 shows the relationship between physicochemical parameters and phytoplankton biomass in Nkisi River. Bacillariophyta correlated negatively with temperature, pH, EC, TDS, TSS, BOD, COD, Ca and T.Alk, and correlated highly positively with DO and showed low correlation with turbidity, TS, Cl^-, T.Alk, NO_4 and Na; and moderate positive correlation with THD, PO_4 and K. Cyanophyta correlated negatively with temperature, turbidity, EC, TDS, DO and BOD, and correlated highly positively with TS, Cl^- and Ca, and positively with pH, TSS, COD, T.Alk, THD, PO_4, K, NO_2 and Na. Chlorophyta correlated negatively with temperature and highly negatively with pH and turbidity. There was also high positive correlation between Chlorophyta and TDS, TSS, TS, BOD, Cl^-, Ca, THD, and Na; Chlorophyta also correlated positively with EC, DO, COD, T.Alk, PO_4, K, and NO_2.

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 species of plankton are limited by dissolved oxygen, temperature, salinity and other physico-chemical factors (Esenewo, Ugwumba & Akpan, 2017; Jeje & Fernando, 1986). 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 Nkisi River. The mean values of the water temperature of the river were within the NESREA recommended range limits of 25^0C - 31^0C for

Table 3.3. Diversity index of phytoplankton at different sampling points in Nkisi 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	29	25	1.557	1.678	1.703	0.2213	0.2033	0.1968	0.9489	0.8926	0.9151
CHLOROPHYCEAE	49	52	60	2.068	2.094	2.24	0.142	0.1339	0.1144	0.8785	0.9019	0.9397
BACILLARIOPHYCEAE	45	36	34	1.796	1.796	1.743	0.1842	0.1836	0.199	0.8612	0.8609	0.8162

Table 3.4. Correlation Analysis of Physico-chemical Parameters of Nkisi River

	pH	Turb	EC	TDS	TSS	TS	DO	BOD	COD	Cl^-	Ca	T Alk	T HD	PO_4	K	NO_2	Na	
Temp		0.73532	0.87896	0.58188	0.79625	0.54563	0.60104	0.54563	0.76671	0.73298	0.38981	0.44255	0.70338	0.80702	0.51225	0.93684	0.19422	0.16421
pH	0.40389		0.38572	0.15344	0.060936	0.71906	0.13428	0.71906	0.031394	0.002335	0.87488	0.29277	0.031934	0.45766	0.22307	0.32785	0.54109	0.5711
Turb	-0.18898	0.82199		0.53916	0.32479	0.33333	0.52	0.33333	0.35433	0.38806	0.48916	0.67849	0.41766	0.071939	0.60879	0.057875	0.92681	0.95682
EC	-0.61057	-0.9711	-0.6623		0.21437	0.87249	0.019161	0.87249	0.18483	0.1511	0.97168	0.13933	0.1215	0.6111	0.069632	0.48129	0.38765	0.41766
TDS	0.31461	0.99542	0.87266	-0.94384		0.65812	0.19521	0.65812	0.029543	0.063271	0.81394	0.35371	0.09287	0.39673	0.28401	0.26691	0.60203	0.63204
TSS	0.65465	-0.42712	-0.86603	0.19895	-0.51158		0.85333	9.0032E-0	0.68766	0.72139	0.15582	0.98818	0.75099	0.26139	0.94213	0.39121	0.73985	0.70984
TS	0.58647	0.97784	0.68455	-0.99955	0.95335	-0.22835		0.85333	0.16567	0.13194	0.99084	0.15849	0.10234	0.59194	0.088792	0.46212	0.40681	0.43683
DO	0.65465	-0.42712	-0.86603	0.19895	-0.51158	1	-0.22835		0.68766	0.72139	0.15582	0.98818	0.75099	0.26139	0.94213	0.39121	0.73985	0.70984
BOD	0.35831	0.99878	0.84907	-0.95815	0.99892	-0.47117	0.96633	-0.47117		0.033728	0.84349	0.32416	0.063328	0.42627	0.25446	0.29645	0.57248	0.6025
COD	0.40724	0.99999	0.8199	-0.97196	0.99507	-0.4238	0.9786	-0.4238	0.9986		0.87721	0.29043	0.0296	0.46	0.22074	0.33018	0.53876	0.56877
Cl^-	-0.81833	0.19528	0.71905	0.044466	0.28811	-0.97019	-0.014383	-0.97019	0.24338	0.19168		0.83235	0.90681	0.41722	0.90205	0.54703	0.58403	0.55402
Ca	0.76796	0.89611	0.48383	-0.97615	0.84958	0.018573	0.96917	0.018573	0.87314	0.89773	-0.26031		0.26083	0.75043	0.069699	0.62062	0.24832	0.27833
T Alk	-0.44925	-0.99874	-0.79241	0.98184	-0.98938	0.38125	-0.98711	0.38125	-0.99506	-0.99892	-0.14585	-0.91723		0.4896	0.19114	0.35978	0.50916	0.53917
T HD	0.29851	-0.75254	-0.99362	0.57359	-0.81203	0.91688	-0.59798	0.91688	-0.78408	-0.75012	-0.79283	-0.38206	0.71857		0.68073	0.12981	0.99875	0.97124
PO_4	0.69338	0.93924	0.57656	-0.99402	0.90213	-0.090784	0.99029	-0.090784	0.92117	0.94049	-0.15325	0.99401	-0.95527	-0.48075		0.55092	0.31802	0.34803
K	-0.099054	0.8703	0.99587	-0.72758	0.91339	-0.81706	0.7479	-0.81706	0.89352	0.86849	0.65299	0.56128	-0.84451	-0.97928	0.64835		0.86894	0.89895
NO_2	0.95382	0.66003	0.11471	-0.82026	0.58521	0.39736	0.80268	0.39736	0.62219	0.66278	-0.60789	0.92488	-0.69686	-0.00194	0.8778		0.20442	0.030011
Na	0.96692	0.62389	0.067767	-0.7924	0.54634	0.44016	0.77368	0.44016	0.58461	0.62675	-0.64464	0.90594	-0.66229	0.045167	0.85425	0.15806	0.99889	

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 3.5. Pearson Correlation (r-values) calculated between phytoplankton diversity and physicochemical parameters of Nkisi River

	Temp	pH	Turb	EC	TDS	TSS	TS	DO	BOD	COD	Cl^-	Ca	T Alk	T HD	PO_4	K	NO_2	Na
Bacillariophyta	-0.83511	-0.54838	0.07516	-0.18833	-0.3391	-0.20137	0.43897	0.96308	-0.71641	-0.57084	0.17057	-0.56892	- 0.3662	0.61211	0.53944	0.5251	0.40861	0.47176
Cyanophyta	-0.54838	0.07516	-0.18833	-0.3391	-0.20137	0.43897	0.96308	-0.71641	-0.57084	0.17081	0.82287	0.88747	0.3952	0.298	0.038542	0.49662	0.35366	0.57544
Chlorophyta	-0.4792	-0.73546	-0.89628	0.43269	0.72812	0.74203	0.82923	0.47757	0.77894	0.41443	0.79982	0.72085	0.038352	0.80825	0.0053783	0.66294	0.25647	0.9587

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

surface water in the tropical region (Esenowo *et al.,* 2017). However, the slightly higher mean values of temperature recorded in Stations 2 and 3 compared to Station 1, could have contributed to the dominance and abundance of algae species (Chlorophyceae) in both stations of 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. Though pH has no direct adverse effects on health but it has impact on the dissolved oxygen level in water, the sensitivity of organisms to pollution, parasites and disease (FWPCA). The range of pH values recorded in this study were in line with the pH range recorded in some other studies (Odo, 2004; Attama, 2003). In this present study, the highest mean pH value (7.32) in Nkisi River was recorded in S3, indicating that the river is slightly alkaline. Planktons thrive better in alkaline conditions. This could explain the diversity of phytoplankton species in most sample points with high pH values. Nkisi River recorded the highest value of total suspended solids at S3 which was the point of waste discharge in the river. The high plankton diversity in Nkisi can be attributed to the relatively low turbidity value of the river. Though turbid water may provide more nutrients, consequently it reduces the light penetration in the water column, thereby reducing phytoplankton growth and primary productivity (APHA, 1988). Conductivity is an early indicator of change in a water system. Conductivity change can indicate pollution. The maximum mean conductivity value recorded for Nkisi River was 35.0 µohmCm^{-1} at S2. Electrical conductivity is good indicator of water quality (Gaikwad *et al.,* 2008). The highest value of TDS was recorded at S3 (5.00 mg/L) and the lowest value was recorded at S2 (3.71 mg/L). The mean TSS value was highest at S2 (2.4 mg/L) and lowest at S1 (2.0 mg/L). TSS may decrease water's natural dissolved oxygen levels and increase water temperature thereby affecting phytoplankton diversity.

TS is a measure of suspended and dissolved solids in water. The highest value of TS was recorded at S3 (7.2 mg/L) and the lowest value at S2 (6.11 mg/L). 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 was recorded at S2 (15.0 mg/L) and the lowest value was recorded at S1 (10.0 mg/L). Alkalinity results from the dissolution of calcium carbonate ($CaCO_3$) from limestone bedrock which is eroded during the natural processes of weathering. 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). The highest value of total hardness at was recorded at S3 (40.1 mg/L) and the lowest at S2 (33.1 mg/L). The highest calcium value was recorded at S3 (3.21 mg/L) and the lowest at S2 (1.87 mg/L); while the highest value of chloride in the river was recorded at S1 (3.46 mg/L) and the lowest at S2 (2.05 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 was recorded at S3 (21.7 mg/L) and the lowest was located at S2 (13.7 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 mean DO concentration exceeded 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 the river was recorded at S2 (5.3 mg/L) and the lowest at S3 (4.0 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 was recorded at S2 (15.20 mg/L) and the lowest at S3 (10.24 mg/L). The higher 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). The result of the present study revealed heavily polluted water bodies 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). The highest value of phosphate in the river was recorded at both S1 (0.01 mg/L) and S3 (0.01 mg/L) while phosphate was not recorded at S2 (0.00 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). The mean phosphate value for the river was within expected concentration range of natural waters of 0.090 mg/L (UNESCO, UNEP, WHO, 1996). The highest value of nitrate was recorded at S3 (2.0 mg/L) while the lowest value was recorded at S1 (1.0 mg/L). The mean values of nitrate were above the concentration range of unpolluted waters of 0.1 mg/L (UNESCO, UNEP, WHO, 1996). However, the values were below the Nitrate concentration of 4.41 mg/L and 8.8 mg/L recorded by Odo (2004) and Anyanwu (2009) respectively in Anambra River. High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants less than six months. The highest value of potassium was recorded at S3 (2.60 mg/L) and the lowest value was recorded at S2 (2.10 mg/L). The highest value of sodium was also recorded at S3 (1.34 mg/L) and the lowest value at S1 (1.00 mg/L). There was slight variation in sodium concentration in the different sampling points of the rivers.

The abundance of phytoplankton in Nkisi River was in the order: Chlorophyceae (38.3%)> Cyanophyceae (34.3%) > Bacillariophyceae (27.4%). The most abundant phytoplankton species in the river was Navicula spp accounting for 6.67 % while the least were Anabena Spp. (2.31%), Volvox (2.57 %), Oscillatoria Spp (2.82 %), Ulothrix (3.08 %), Tetraspora (3.08 %), Cyclotella (3.08 %), Nitzschia Spp (3.08 %). Nkisi River recorded 114 individuals of Cyanophyceae, 161 individuals of Chlorophyceae, and 115 individuals of the Bacillariophyceae group. The result of phytoplankton analysis revealed that high values of Shannon-Wiener Index_H were recorded for Chlorophyceae (2.094) and low values for Cyanophyceae (1.557). Highest values for species dominance_D were recorded for Cyanophyceae (0.2213) and lowest for Chlorophyceae (0.1144). Evenness ranged from (0.8162) in Bacillariophyceae to (0.9489) in Cyanophyceae (Table 3.5). The results of correlation analysis of physico-chemical parameters of the two rivers revealed high positive and negative correlation among the parameters and between the parameters and the planktonic species.

CONCLUSION

Sampling Station 1 had higher density of phytoplankton compared to other sampling stations. The degradation of the water quality could be due to anthropogenic activities, such as agriculture, waste disposal, laundry, bathing, commercial activities and cottage industries, in the study area. The physicochemical parameters of Nkisi River have been significantly impacted by human activities thus resulting in reduction of phytoplankton diversity.

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