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Physico Chemical Parameters and Phytoplankton Assemblages along Spatial and Temporal Gradients in Great Kwa River, Calabar, Nigeria

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ABSTRACT

The influence of physico chemical parameters on phytoplankton distribution of the Great Kwa River, south-south Nigeria was studied across temporal and spatial gradients. Mean pH, temperature, conductivity, salinity, dissolved oxygen; turbidity, total dissolved solids, BOD, COD, chloride, nitrite and sulphate are 5.74±0.42, 29.82°C± 0.70, 146.8±2.96 μS cm^{-1}, 0.70±0.05, 4.69±0.82 mg L^{-1}, 56.22±35.3 NTU, 92.41±4.22, 25.9±13.66, 38.49±20.8, 201.24±134.43, 0.18±0.05 and 13.74±22.01 mg L^{-1}, respectively. The mean and standard deviation of others phenol (0.037±0.01 mg L^{-1}), magnesium (19.76±10.68 mg L^{-1}), potassium (6.38±2.87 mg L^{-1}), sodium (107.18±111.29 mg L^{-1}), calcium (4.67±3.90 mg L^{-1}), chromium (0.12±0.04 mg L^{-1}), manganese (0.11±0.03 mg L^{-1}), lead (0.20±2.93 mg L^{-1}), zinc (0.05±1.46 mg L^{-1}), copper (0.05±0.003 mg L^{-1}), iron (1.46±0.83 mg L^{-1}), nickel (0.10±1.46 mg L^{-1}), silver (0.10±1.46 mg L^{-1}), cobalt (0.10±1.46 mg L^{-1}) and cadmium (0.01±0.01 mg L^{-1}). A total of 39 phytoplankton species spread across 4 divisions (bacillariophyta, chlorophyta, cyanophyta and dinophyta) and 18 families were recorded. Bacillariophyta with 16 species constitutes 41.05% of the total phytoplankton community, followed by cyanophyta (11 species) which constituted about 28.21%. Chlorophyta with 10 species constituted about 25.64% while dinophyta with 2 species constituted about 5.13%. Some of the dominant species are *Melosira granulate* (495 count mL^{-1}), *Synedra ulna* (170 count mL^{-1}), *Eudorina elegans* (74 count mL^{-1}), *Lyngbya contorta* (48 count mL^{-1}, *Navicula radiosa* (45 count mL^{-1}), *Staurastrum asterias* (42 count mL^{-1}), *Eunotia lunaria* (40 count mL^{-1}), *Nitschia closterium* (38 count mL^{-1}), *Zygnema* sp. (36 count mL^{-1}) and *Closterium gracile* (28 count mL^{-1}). Correlation coefficient between physic chemical parameters and phytoplankton distribution indicated a positive significant correlation between bacillariophyta abundance with sulphate (0.89), chlorophyta with turbidity (0.89), BOD (0.92), COD (0.88) and Magnesium (0.81). Positive significant correlation was also observed between dinophyta and nitrite (0.86) while none of the parameters measured exhibited any positive significant correlation with cyanophyta. The diversity indices for spatial variation typified by Margalef (1970) index and evenness ranged from 3.04 in surface station 1 to 3.49 in surface station 4 and 0.46 in surface station 5 to 0.66 in surface station 4, respectively. Bacillariophyta showed the highest margalef index of 11.83, followed by cyanophyta with 2.19, chlorophyta with 2.06 and dinophyta had 0.69. However the highest evenness index of 0.89 was recorded within the taxa, Cyanophyta and the lowest with the taxa, Bacillariophyta (0.39). Result of the temporal gradient indicated that the dry season recorded the highest number of individuals (805 count mL^{-1}) than the wet season (652 count mL^{-1}) but with lower margalef index (4.93) Of all the taxa present in the study, bacillariophyta recorded more individuals in the wet season while others recorded more in the dry season. Conclusively it was shown that phytoplankton distribution in the Great Kwa River is influenced more at the temporal gradient than at the spatial gradient. Also, species pollution index analysis showed moderate but increasing levels of pollution build-up.

Key words: Great Kwa river, Calabar, Melosira, positive correlation, diversity indices

INTRODUCTION

Discharge of wastes into water bodies is a common practice globally. More often than not, these discharges are hardly treated as humans treat the water bodies as endless reservoirs. The situation is worsened, by the economic theory that nearness to water bodies is a factor that predisposes location and localization of industries. More so, illiteracy, poverty and ignorance had triggered a belief system among rural dwellers living close to water bodies that water flows, hence anything, anytime is suitable to be dumped inside the water. Also, the need to maximize profits by companies operating near sea shores had led to increased and sustained enrichment of the water bodies. The effects of these unwholesome practices are well documented. Eutrophication, the abnormal increase in alga cells due to artificial enrichment of water habitat is one of such effects.

The Great Kwa River is one of the major tributaries of the Cross River Estuary. It takes its rise from the Oban Hills in Nigeria, flows south wards and discharge into the Cross River Estuary around (Latitude 4°45'N; Longitudes 8°20'E). The lower research of the river drains the eastern coast of the Calabar Municipality (the capital of Cross River State, Nigeria) the lower Great Kwa is characterized by semi-diurnal tides and extensive mud flats.

MATERIALS AND METHODS

Study site: The Great Kwa River flows through Cross River State, Nigeria, draining the east side of the city of Calabar. The river originates in the Oban Hills, in the Cross River National Park and flows southwards to the Cross River estuary. The river is known for the dramatic Kwa Falls in Cross River National Park (Igboekwe and Udoinyang, 2011). Its lower reaches are tidal with broad mud flats and drain the eastern coast of the city of Calabar (Fig. 1).

Sampling was carried out in June/July and December 2012/January 2013 for the study of physico-chemical parameters and phytoplankton abundance/diversity. Sampling periods were usually between 8.00 and 12.00 noon. About 1 L water samples were collected at each sampling point using acid pre-washed polyethylene bottles. Plankton samples were collected by pouring 50 L of surface water through plankton net of 60 μm mesh size and 30 cm diameter. The filtrate was concentrated to 100 mL for each station and 4% formalin added to each sample to preserve the organisms and 3 drops of Lugol's solution was added so as to allow the organisms to settle. The bottles were covered and properly labeled at each location.

Sample analysis

Physico chemical analysis: Water quality parameters and nutrients were analyzed using the standard methods of APHA (1998). Table 1 shows the various parameters analyzed for the water sample, methodology and their detection limits.

Phytoplankton analysis: Physico chemical analysis was carried out according to standard methods as described by Kadiri (1999). In brief, about 0.5 mL sub sample of the concentrated

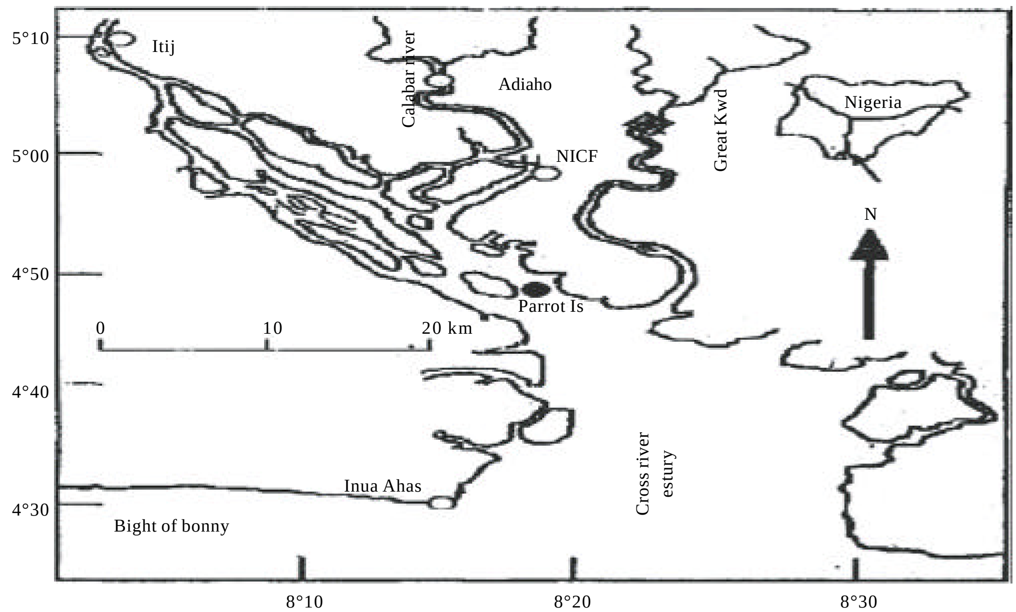

Fig. 1: Map of Cross River Estuary showing the sampling site (Great Kwa River)

Table 1: Laboratory analytical methods

Parameters for water analysis	Methods	Detection limits
Temperature (°C)	APHA 2110B	-
pH	APHA 4500H$^+$B	-
Turbidity (NTU)	APHA 2130B	1.0
Salinity (mg L^{-1})	APHA 2520B	0.01
TSS (mg L^{-1})	APHA 2540D	1
TDS (mg L^{-1})	APHA 2510A	-
Conductivity (µS cm^{-1})	APHA 2510A	-
THC (mg L^{-1})	ASTM D3921	1.0
DO (mg L^{-1})	APHA 4500-O G	-
BOD (mg L^{-1})	APHA 5210A	0.5
COD (mg L^{-1})	APHA 5220D	0.8
Nitrate (mg L^{-1})	EPA 352.1	0.02
Phosphate (mg L^{-1})	APHA4500-P D	0.002
Ammonium (mg L^{-1})	APHA 4500-NH_3	0.02
Calcium (mg L^{-1})	APHA 3111B/ASTM D3561	0. 1
Magnesium (mg L^{-1})	APHA 3111B/ASTM D3561	0.1
Potassium (mg L^{-1})	APHA 3111B/ASTM D3561	0. 1
Sodium (mg L^{-1})	APHA 3111B/ASTM D3561	0.1
Lead (mg L^{-1})	APHA 3111B	0.20
Total Iron (mg L^{-1})	APHA 3111B	0.05
Copper (mg L^{-1})	APHA 3111B	0.05
Zinc (mg L^{-1})	APHA 3111B	0.05
Manganese (mg L^{-1})	APHA 3111B	0.10
Cadmium (mg L^{-1})	APHA 3111B	0.02
Total chromium (mg L^{-1})	APHA 3111B	0.10

plankton suspension was pipetted onto an improvised counting chamber and all the plankton were identified at least to generic levels and enumerated using keys provided by Whitford and Schumacher (1973), Needham and Needham (1975), Jeje and Fernando (1992), Nwankwo (2004) and plankton were counted as number per mL and then calculated as number per liter of water.

Statistical analysis: Data obtained were subjected to Duncan multiple range comparison test and Pearson correlation coefficient to determine relationship between physico-chemical parameters and phytoplankton abundance. The mean and percentage abundance by number of plankton was calculated for all sampling stations during dry and rainy seasons. Paired t-test was also used to determine if there exist significant differences between the rainy and dry season mean total abundance of plankton. Diversity of the plankton was determined using Shannon-Weiner (H), Margalef (d) and Equitability (J) diversity indices.

RESULTS

Physico-chemical parameters: The mean results and the mean seasonal differences for the physico- chemical parameters studied are presented in Table 1 and 2. Water temperature in the five locations ranged from 29.45°C at the back of Unical female hostel (station 4) to 30.65°C by Atimbo

Table 2: Results and statistical analysis of physico-chemical parameters across spatial gradient in five locations of Great Kwa Rive

Parameter	SW1	SW2	SW3	SW4	SW5	$\overline{X}$	S.D	CoV	p-value	NIS	FME	ECE
pH	5.93^{a}	6.03^{b}	6.21^{c}	5.26^{d}	5.26^{d}	5.74	0.42	7.23	0.001	6.5-8.5	6-9	5.3-9
Temperature	30.65	29.90	29.95	29.45	29.60	29.82	0.70	2.33	1.18	25	27	
Conductivity	146	145.50	150.50	150.5	146.5	146.8	2.96	2.02	0.391	1000	70	
Salinity	0.65	0.70	0.70	0.75	0.70	0.70	0.05	6.73	0.40		2000	
Dissolve O_2	4.17	5.60	4.36	4.29	4.53	4.69	0.82	17.51	0.501		8	3-7
Turbidity	50.5	64.65	61.10	53.35	49	56.22	35.3	62.8	0.10	5	1	
TDS	92.15	91.75	91.35	94.50	92.30	92.41	4.22	4.57	0.98	500	2000	
BOD	24.25	44.55	34.4	16.3	10.0	25.90	13.66	52.7	0.007		30	
COD	37.4^{a}	65.8^{ba}	52.1^{ca}	20.9^{da}	16.25^{ea}	38.49	20.8	54.07	0.013		80	3-30
Chloride	195.1	224.3	200.4	196.9	189.5	201.24	134.43	66.8	0.99	250	600	
Nitrite	0.12^{a}	0.15^{ba}	0.16^{ca}	0.23^{dbc}	0.25^{ebed}	0.18	0.05	30.54	0.02	0.2		
Sulphate	0.06	0.05	23.19	22.87	22.52	13.74	22.01	160.24	0.74	200	500	
Phenol	0.03	0.04	0.045	0.44	0,03	0.037	0.01	36.15	0.83	0.001	0.2	
Magnesium	22.8	25.35	23.1	14.78	12.79	19.76	10.68	54.05	0.80	200	200	
Potassium	7.53	7.40	7.62	5.08	4.27	6.38	2.87	44.98	0.76			
Sodium	106.29	121.59	106.21	103.23	98.58	107.18	111.29	103.83	0.10	200		
Calcium	4.6	4.37	4.66	5.27	4.46	4.67	3.90	83.56	0.01	75	200	
Chromium	0.1	0.1	0.14	0.12	0.16	0.12	0.04	34.72	0.66	0.05	<1	1-16
Manga	0.1	0.1	0.145	0.1	0.1	0.109	0.03	26.11	0.48	0.2	5	
Pb	0.20	0.20	0.20	0.20	0.20	0.20	2.93	1.46		0.01	<1	
ZInc	0.05	0.05	0.05	0.05	0.05	0.05	7.31	1.46		3		45-1200
Copper	0.05	0.05	0.05	0.05	0.05	0.05	0.003	6.20	0.49	1	<1	2-18
Fe	1.26	1.56	2.68	1.23	0.56	1.46	0.83	57.00	0.07	0.3	20	
Ni	0.10	0.10	0.10	0.10	0.10	0.10	1.46	1.46		0.02	<1	15-1400
Ag	0.10	0.10	0.10	0.10	0.10	0.10	1.46	1.46			0.1	
Co	0.10	0.10	0.10	0.10	0.10	0.10	1.46	1.46				
Cd	0.02	0.02	0.011	0.011	0.011	0.01	0.008	59.55	0.74	0.003	<1	0.07-3.9

Values containing at least one same alphabet along same row are not significantly different bridge head (station 1) with an overall mean value of 29.82±0.70 and a variation coefficient (CoV) of 2.33. When the temperature measurements at the various stations were statistically analysed at the 0.05 confidence limit, a p value 0.18>0.05 was obtained. This indicates that there were no significant temperature differences at the various stations. Result was also shown for the dry season and wet season. The dry season mean temperature (31.44°C±0.15) was significantly higher at 0.05% confidence limit (p = 0.001<0.05) than the mean for the wet season (28.2±0.86). Average temperature for the dry season was lowest at station 5 (behind UNICAL staff quarters) with 31.30°C while station 1(Atimbo head bridge) with an average dry season temperature of 31.70°C was the highest. Equally, the temperature range for the wet season was between 27.50°C for station 4 (by UNICAL female hostel) and 29.60°C for station 1 (Atimbo head bridge). Result of the correlation analysis between the mean temperature of the dry season and the wet season indicated a coefficient of 0.95 and a t-value of 8.32.

The pH of the water samples were measured at temporal and spatial gradient. It was observed that the water samples were slightly acidic in nature. For example, the pH values ranged between 5.26 at stations 4 and 5 to 6.21 at station 3 with a mean of 5.74±0.42 and a CoV of 7.23. There were statistically significant differences (p<0.001) among the pH values at the various stations measured. Multiple comparison tests such as Duncan, Turkey, LSD indicated the source of the differences to be at stations 1, 2 and 3. A comparative result for the seasonal variations in pH values was given in Table. The mean pH for the dry season was 6.46±0.80 while that for the wet season was 5.46±0.46. The result also showed that station 3 (by UNICAL library) was the most acidic (6.36) for the dry season samples as against 6.56 for station 1(Atimbo bridge head) which was the least acidic. Similarly, station 5 (by UNICAL staff quarters) was the most acidic during the wet season with a pH value of 5.00 as against station 3 (by UNICAL library) with a pH of 6.00. A correlation coefficient of 0.86 was obtained for the seasonal variations in pH values. Supportably, a statistically significant p value (0.001<0.05) was calculated between the seasonal mean pH values.

Conductivity test for the water samples at the various stations had very close values. It ranged from 145.50 μS cm^{-1} at station 3 and station 4 to 150.5 μS cm^{-1} at station 4 resulting in an overall mean of 146.8±2.96 and a CoV of 2.02. A p>0.05 was obtained among conductivity values at the different stations. Conductivity values were averagely higher in the dry season (149.2 μS cm^{-1} 5.45) with the highest and lowest values (156 and 144 μS cm^{-1}) recorded in station 4 and station 1, respectively. A comparatively lower conductivity mean value of 144.4 μS cm^{-1} was recorded during the wet season sampling with the highest value (148 μS cm^{-1}) observed at station 1 and the lowest value (137 μS cm^{-1}) recorded at station 3. When these results were subjected to statistically analysis, the outcome indicated a significant p value of 0.001<0.05, a weak correlation coefficient (0.48) and a t value of 1.55.

The average salinity values are 0.65 g L^{-1} at station 1 and 0.75g L^{-1} at station 4 with a CoV and mean of 6.73 and 0.70±0.05, respectively. A p value of 0.40 at .05 confidence limit was obtained among the stations. Mean salinity values were also observed to be higher in the dry season (0.72±0.45) than in the wet season (0.68±0.45). The values for the dry season range from 0.70 g L^{-1} at stations 1, 2, 3 and 5 to 0.80 g L^{-1} at station 4. The highest and lowest values of 0.70 and 0.60 g L^{-1} were recorded at stations 1 and 2, 3, 4 and 5, respectively for the wet season. The result also showed a statistically significant seasonal difference in salinity values albeit a weak correlation coefficient of 0.45.

The dissolved oxygen concentration of the water samples was observed to vary between 4.17 mg L^{-1} at station 1 to 5.60 mg L^{-1} with an overall mean of 4.69±0.82 and a CoV of 17.51. The result revealed non-significant differences at .05 confidence limit among the stations under review. Mean dissolved oxygen fluctuated between 4.40 mg L^{-1} at station 1 to 4.75 mg L^{-1} at station 5 with an overall mean of 4.52±0.14. The values of dissolved oxygen in the water samples for the wet season ranged from 3.90 mg L^{-1} at station 1 to 6.80 mg L^{-1} at station 2 with a mean value of 4.86±1.20. However, correlation analysis showed a weak relationship of 0.22 between the dry and wet season samples despite a statistically significant p value of 0.001 at 0.05 confidence limits.

There were wide variations in turbidity values across the sampled stations. For example, station 5 with 49 NTU was observed as the least turbid station while station 2 with 64.65 NTU was observed as the most turbid station. The mean turbidity value for the stations was 56.22±35.3 with a CoV of 62.8. Supportably, the stations do no show a statistical significant relationship ($p>0.05$). The result for seasonal analysis also revealed wide variations. The dry season samples ranged from 9.00 NTU at station 5 to 43 NTU at station 2 resulting in a mean value of 24.4±14.62. Wet season samples for turbidity values ranged from 76 NTU at station 1 to 96.70 NTU at station 4 yielding a mean of 87.44±8.14. When the data were subjected to statistical analysis at the 0.05 confidence limits, a $p<0.001$ resulted just as the correlation coefficient showed a strong relationship ($r = 0.95$) between the wet and dry season values.

Total Dissolved Solids (TDS) had very close values. It ranged from 91.35 g L^{-1} at station 3 to 94.50 g L^{-1} at station 4 with an overall mean value of 92.41±4.22 and a CoV of 4.57. The p value of 0.98 was higher than the table value of 0.05. Water samples obtained during the dry season showed a TDS range of 86.40 g L^{-1} at station 1 to 93.60 g L^{-1} at station 4 with a mean value of 89.52±3.27. Similarly, the wet season samples had TDS values ranging from 90.30 g L^{-1} at station 3 to 97.90 g L^{-1} at station 1 resulting in an overall mean value 0f 95.3±2.93. Expectedly, there was a statistical significant difference at the 0.05 confidence limit with a relatively average correlation coefficient value of 0.72.

Biological Oxygen Demand (BOD) had values ranging from 10 mg L^{-1} at station 5 to 44.55 mg L^{-1} at station 2 with an overall mean of 25.90±13.66 and a CoV of 52.70. There was no significant difference at the 0.05 confidence limit ($p = 0.007$). Results of seasonal analysis indicated that dry season samples had values ranging from 10 mg L^{-1} at station 5 to 49.1mg L^{-1} at station 2 with a mean value of 27.8±16.76. Also, results of wet season samples had values ranging from 20 mg L^{-1} at stations 1, 4 and 5 to 40 mg L^{-1} at station 2 with a mean of 26.0±8.94. A 0.07 correlation coefficient revealed an insignificant relationship albeit a significant p value (0.01) between the dry and wet season.

Chemical Oxygen Demand (COD) values across the spatial gradient showed values that ranged from 16.25 mg L^{-1} at station 5 to 65.8 mg L^{-1} at station 2 with an overall mean value of 38.49±20.8 and a CoV of 54.07. A statistical significant p value of 0.013 was obtained among the stations resulting in a Duncan/Turkey multiple comparison tests which showed the stations with significant and insignificant differences. Similarly, results of temporal gradient showed a range of 11.8 mg L^{-1} at station 4 to 73.6 mg L^{-1} at station 2 resulting in an overall mean of 40.18±26.99. Also, the wet season samples had values ranging between 18 mg L^{-1} at station 5 to 58 mg L^{-1} at station 2 with a mean of 36.8±15.47. Correlation analysis and one- way ANOVA showed a correlation coefficient of 0.09 and a p value of 0.3, respectively.

The results of chloride content in the water samples are presented. As could be seen in table, the values ranged from 189. 5 mg L^{-1} at station 5 to 224.3 mg L^{-1} at station 2 with a mean of 201.24±134.43 and a CoV of 66.8. A p value of 0.99 was obtained. As usual, results of seasonal analysis showed 307 mg L^{-1} as the least value of chloride content and 375 mg L^{-1} as the highest value of chloride content in the dry season samples resulting in a mean of 327.6±27.18. A mean value of 74.88±2.09 was obtained for the wet season samples which had 72 mg L^{-1} at station 5 as the least chloride value and 76.80 mg L^{-1} at stations 3 and 4 as the highest chloride content. Correlation analysis revealed a strong coefficient (0.99) and a significant p ($p<0.001$) at 0.05 confidence limit.

The results of nitrate content present in the water samples across spatial gradient indicated a range of between 0.12 mg L^{-1} at station 1 and 0.25 mg L^{-1} at station 5 with a mean of 0.18±0.05 and a CoV of 30.54. A p value of 0.02 was obtained for the spatial distribution in the nitrate content where further comparison tests showed significant differences at stations 2, 3, 4 and 5. The range for dry season samples revealed 0.12 mg L^{-1} at station 1 as the minimum value and 0.27 mg L^{-1} at station 5 as the maximum nitrate content with a mean of 0.19±0.67. The range for the wet season samples are between 0.12 mg L^{-1} at station 1 and 0.22 mg L^{-1} at station 5 with a mean of 0.17±0.04. A weak coefficient of correlation (0.25) and an insignificant p value (0.38) at 0.05 confidence limit was obtained.

Sulphate content in the water samples showed a range of 0.05 mg L^{-1} at station 2 and 23.19 mg L^{-1} at station 3 with a mean value of 13.74±22.01 and a CoV of 160.24. A - 0.74 p-value across the spatial gradients was obtained. Similarly, results of sulphate content across the temporal (seasonal) gradients showed a range of 0.05 mg L at station 2 and 46.20 mg L^{-1} at station 3 resulting in a mean of 27.40±24.97. This varied widely with the mean (0.72±0.61) obtained from the wet season samples 0.03 mg L^{-1} at station 5 and 0.18 mg L^{-1} at station 3 was the least and highest values, respectively. A statistically significant p value (0.001) coupled with an average correlation coefficient (0.65) resulted when the data were subjected to correlation analysis and a student-t test, respectively.

The amounts of phenol present in the water samples at the various stations are presented. It ranges from 0.03 μg L^{-1} at stations 1 and 5 and 0.045 μg L^{-1} at station 3 with an overall mean of 0.037± 10.01 and a CoV of 36.15. The p values of 0.83 and 0.70 showed no significant differences among the samples obtained along temporal gradients respectively. Results of seasonal analysis showed a range of 0.04 μg L at stations 1, 3 and 5 and 0.06 μg L^{-1} at station 2 with a mean of 0.046±0.009 for the dry season samples. The range for the wet season samples also showed a value of 0.02 μg L^{-1} at stations 1, 2 and 5 and 0.04 μg L^{-1} at stations 3 and 4 with a mean of 0.028±0.011. A 0.71 correlation coefficient was obtained between the dry and wet season samples.

Results for the magnesium content present in the water samples across the five stations sampled are presented. It ranged from 12.79 mg L^{-1} at station 5 to 25.35 mg L^{-1} at station 2 with a mean of 19.76±10.68 and a CoV of 54.05. A p value of 0.80 indicated no statistical significant differences among samples along the spatial gradient. Results for the dry season samples ranged from 24.60 mg L^{-1} at station 2 and 29.40 mg L^{-1} at station 4 with a mean of 26.14±1.91. On the other hand, wet season samples revealed a range of 0.15 mg L^{-1} at station 4 to 26.10 mg L^{-1} at station 2 with an overall mean of 13.39±12.30. A p value of 0.003 at 0.05 confidence limit and a correlation coefficient of 0.63 revealed further relationships between the wet and dry season samples.

Amount of Potassium ion present in the water samples taken at the various stations are presented. It ranged from 4.27 mg L^{-1} at station 5 to 7.62 mg L^{-1} at station 3 with a mean and CoV of 6.38±2.87 and 44.98, respectively. The p value for the data obtained at the various stations was 0.76, indicating statistically insignificant differences. More so, the range for the dry season sample showed a least value of 7.50 mg L^{-1} at station 2 and a highest value of 8.94 mg L^{-1} at station 4 with a mean of 8.03±0.54. Similarly the range for the wet season samples revealed a 0.82 mg L^{-1} at station 5 as the minimum value and a maximum value of 7.29 mg L^{-1} at stations 2 and 3 resulting in a mean of 4.77±3.42. The result was insignificant (0.07) at the 0.05 confidence limit while the correlation coefficient was 0.60.

The level of sodium ion present in the water samples is also shown. It ranged from 98.58 mg L^{-1} at station 5 to 121.59 mg L^{-1} at station 2 with a mean and CoV of 107.18±111.29 and 103.83, respectively. A p value of 0.10 indicated a no significant result among the stations. The dry season samples ranged 196 mg L^{-1} at station 5 to 241 mg L^{-1} at station 2 with a mean of 212.20±17.02. Additionally, the range for the wet season samples showed that station 5 with 1.16 mg L^{-1} was the least while station 3 with a value of 3.42 mg L^{-1} was the highest resulting in a mean of 2.16±0.90. The result was significant ($p<0.001$) at the 0.05 confidence limit as a strong coefficient of correlation (0.99) was obtained.

The results for calcium ion present in the water samples across the spatial gradients are shown. It ranged from 4.37 mg L^{-1} at station 2 to 5.27 mg L^{-1} at station 4 with a mean and CoV values of 4.67±3.90 and 83.56 respectively. The result was not significant ($p> 0.10$) at the .05 confidence limit. Result for the dry and wet season samples showed that the ranges are 7.84 and 9.36 mg L^{-1} at stations 2 and 4 respectively with a mean of 8.35±0.59 for the former and 0.84 and 1.18 mg L^{-1} at stations 5 and 4 respectively with a mean of 0.99±0.13 for the latter. A strong correlation coefficient (0.99) and strong significant difference ($p<0.001$) was obtained for the seasonal relationships.

Chromium ion values in the water samples varied between 0.1 mg L^{-1} at stations 1 and 2 to 0.16 mg L^{-1} at station 5 with a mean and CoV values of 0.12±0.04 and 34.72, respectively. The p-value (0.66) was not significant at the 0.05 confidence limit. The values of chromium ions for the dry season ranged from 0.10 mg L^{-1} at station 1, 2, 3 and 4 to 0.18 mg L^{-1} at station 5 with a mean of 0.12±0.34. Also, the wet season samples had values that ranged from 0.10 mg L^{-1} as station 1,3 and 5 to 0.22 mg L^{-1} at station 4 with a mean of 0.13±0.05.Correlation analysis and student -t test (at 0.05 confidence limit) between the dry and wet seasons resulted in an r and p values of 0.17 and 0.6, respectively.

The result for manganese ions across the spatial gradients showed values that ranged from 0.1 mg L^{-1} in all but one stations (0.145 mg L^{-1} at station 3) with a mean of 0.109±0.03 and a CoV of 26.11. The result does not show any significant differences ($p>0.48$) at the 0.05 confidence limit. Similarly, the results for dry season indicated a range of 0.10 mg L^{-1} at stations 12, 4 and 5 to 0.19 mg L^{-1} at station 3 with a mean of 0.18±0.40. Values for the wet season ranged were uniform at 0.10 mg L^{-1}. Expectedly, the result was statistically not significant at the .05 confidence limit while the correlation analysis between the two seasons under comparison revealed a coefficient of 0.33.

The results for ferrous ions oscillated between 0.56 mg L^{-1} at station 5 and 2.68 mg L^{-1} at station 3 with an overall mean of 1.46±0.83 and a CoV of 57.00 and a p value of 0.07. Result for dry season samples ranged from 0.52 mg L^{-1} at station 5 and 3.40 mg L^{-1} at station 3 with a mean of 1.508±1.13. Also, the values for the wet season ranged from 0.60 mg L^{-1} at station 5 to 1.96 mg L^{-1} at station 3 with an overall mean of 1.406±0.52. When the data were subjected to student- t test at the 0.05 confidence limit and correlational analysis, a p and r values of 0.86 and 0.065 were obtained.

Cadmium ion values in the water sample ranged between 0.011 mg L^{-1} at stations 3, 4 and 5 to 0.02 mg L^{-1} at stations 1 and 2 with a mean and CoV values of 0.01±0.009 and 59.55. The result was not statistically significant ($p> 0.74$) at the 0.05 confidence limit. Results for dry season samples ranged from 0.002 mg L^{-1} at stations 3, 4 and 5 to 0.02 mg L^{-1} at stations 1 and 2 with a mean of 0.009±0.010. The values for the wet season samples were uniform (0.02 mg L^{-1}). A p and r values obtained are 0.40 and 0.65.

There were uniform values across the spatial and temporal gradients for oil/grease (<1.00), lead (<0.20), zinc (<0.05), copper (<0.05), nickel (<0.10), silver (<0.10) and cobalt (<0.10) (Table 3).

Table 3: Mean and range of physico-chemical parameters across temporal gradient in five locations of Great Kwa River

	Dry season			Wet season							
Parameter	Mean	SD	Range	Mean	SD	Range	$\bar{x}$	S.D	CoV	p-value	F
pH	6.46	0.8	6.36 6.56	5.26[d]	5.26[d]	5.00-6.00	5.74	0.42	7.23	0.001	
Temperature	31.44	0.15	31.30 31.70	29.45	29.6	27.50-29.60	29.82	0.7	2.33	1.18	1.928
Conductivity	149.2	5.45	144 156	150.5	146.5	137.00-148.00	146.8	2.96	2.02	0.391	1.14
Salinity	0.72	0.45	0.70 0.8	0.75	0.7	0.60-0.70	0.7	0.05	6.73	0.4	1.25
Dissolve O_2	4.52	0.14	4.40 4.75	4.29	4.53	3.90-6.80	4.69	0.82	17.51	0.501	0.96
Turbidity	24.4	14.62	9.00 43.00	53.35	49	76.00-96.70	56.22	35.3	62.8	0.1	0.04
TDS	89.52	3.27	10 49.1		92.3	90.30-97.90	92.41	4.22	4.57	0.98	0.1
BOD	27.4	16.76	11.8 73.6		10	20.00-40.00	25.9	13.66	52.7	0.007	13.36
COD	40.18	26.99	307 375	16.3	16.25[ea]	18.00-58.00	38.49	20.8	54.07	0.013	10.19
Chloride	327.6	27.18	20.12 0.27	20.9da	189.5	72.00-76.80	201.24	134.43	66.8	0.99	0.01
Nitrite	0.194	0.67	0.04 0.06	196.9	0.25[ebed]	0.12-0.22	0.18	0.05	30.54	0.02	8.46
Sulphate	27.4	24.97	24.60 29.40	0.23dbc	22.52	0.03-0.18	13.74	22.01	160.24	0.74	0.5
Phenol	0.046	0.009	750 894	22.87	0,03	0.02-0.04	0.037	0.01	36.15	0.83	0.36
Magnesium	26.14	1.91	196 241	0.44	12.79	0.15-26.10	19.76	10.68	54.05	0.8	0.4
Potassium	8.03	0.54	784 9.36	14.78	4.27	0.82-7.29	6.38	2.87	44.98	0.76	0.46
Sodium	212.2	17.02		5.08	98.58	1.16-3.42	107.18	111.29	103.83	0.1	0.1
Calcium	8.35	0.59	4.66 0.14	103.23	4.46	0.84-1.18	4.67	3.9	83.56	0.01	0.1
Chromium	0.116	0.34	0.45	5.27	0.16	0.10-0.22	0.12	0.04	34.72	0.66	0.64
Manganese	0.118	0.4	0.05	0.12	0.1	0.1	0.109	0.03	26.11	0.48	1
Cupper	0.052	0.0045	0.27	0.1	0.05	0.05	0.05	0.003	6.2	0.49	1
Fe	1.508	1.13	0.0.68	0.05	0.56	0.60-1.96	1.46	0.83	57	0.07	4.29
Cd	0.09	0.010	0.002	1.23	1,2,3,4,5	0.02	0.0	0.02	2.45	0.65	0.4

Values for Pb, Zn, Ni and Ag are uniform across temporal and spatial gradients

Results for the phytoplankton assemblage: Checklist of the phytoplankton assemblages obtained from temporal and spatial gradients over the one-year study period in the Great Kwa River showed a total of 39 species spread across 26 genera, 18 families and four divisions (Fig 2).

The identified divisions and the number of species they comprise are Bacillariophyta (16 species), Chlorophyta (10 species), Cyanophyta (11 species) and Dinophyta (2 species) while some of the families include nostocaceae, oscillatoriaceae, diatomataceae, baccillariaceae, eunotiaceae, fragilariaceae, navicularioaceae amongst others. Table 4: Phytoplankton assemblage of Great Kwa River.

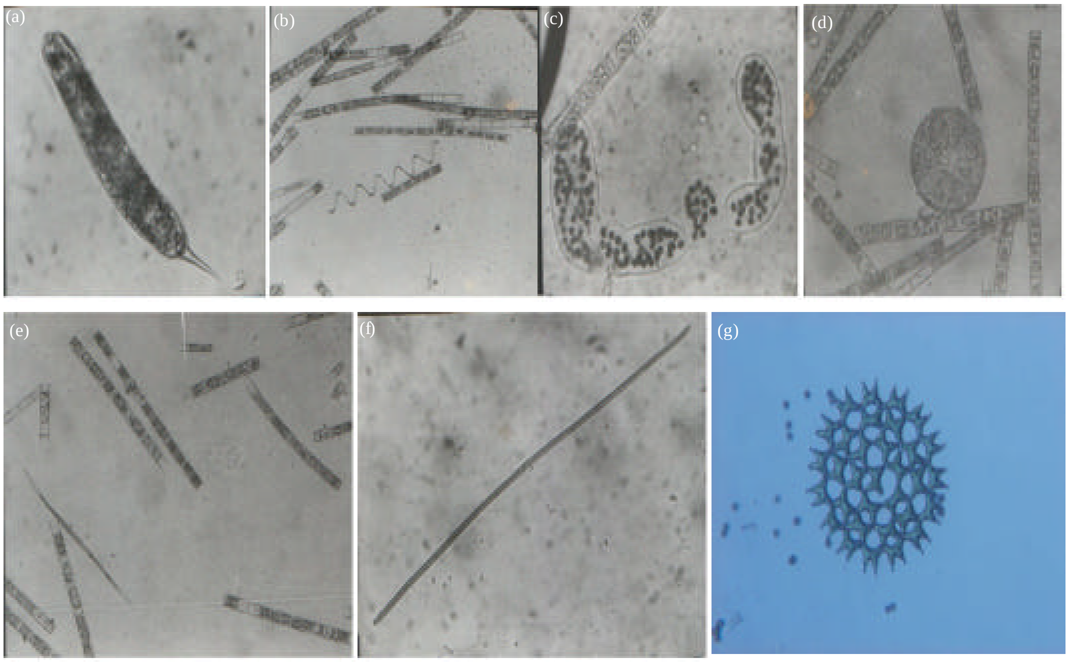

Fig. 2(a-f): Identified phytoplankton species in the Great Kwa River (a)*Euglena* sp. (b) *Melosira* and *Spirulina* species, (c) *Melosira* and *microcystis*, (d) *Melosira* and *Cyclotella*, (e) *Melosira* and *Nitzchia oscilatoria* and (f) *Pediastrum duplex*

Table 4: Check list and abundance of phytoplankton in Great Kwa River across spatial gradient

			SW										Total
Division	Family	Species	1	1	2	2	3	3	4	4	5	5	count (mL^{-1})
Cyanophyta	Nostacaceae	*Anabaena flosqua*					8	5		12			25
		Anabeana spiroides		2					8			6	16
	Oscillatoriaceae	*Lyngbya contorta*	8	10	8	8	4	6				4	48
		Lyngbya cylindricum							8				8
		Lyngbya limnetica		6						2	4	6	18
		Oscillatoria limnetica				2					4		6
		Oscillatoria limosa			6			10		4		2	22
		Spirulina platensis						4					4
		Phormidium fragile						4			15		19
		Phormidium tenue	6		6								12
	Rivulariaceae	*Rivularia* spp.						10					10
Bacillariophyta	Bacillariophyceae	*Nitschia acicularis*				8	6						14
		Nitschia closterium	6	8		2		10	10		2		38
		Nitschia palea			6						6		12
	Diatomaceae	*Tabellaria floculosa*				4					10	8	22
	Eunotiaceae	*Eunotia lunaria*	12					6	10	4		8	40
		Eunotia gracilis		4		8	8						20
	Fragilariaceae	*Fragilaria construens*	10					15					25
	Lauderiaceae	*Lauderia annulata*								12			12
	Melosiraceae	*Melosira granulata*	60	42	48	36	40	52	60	28	65	64	495
	Naviculaceae	*Gomphonema acuminatum*	4			2		8	8				22
		Navicula oblonga			12							8	20

Table 4: Continue

Division	Family	Species	SW 1	1	2	2	3	3	4	4	5	5	Total count mL^{-1}
		Navicula radiosa	10			6	10	4	15				45
	Rhizosoleniaceae	*Proboscia alata*								14			14
	Thallasi onemataceae	*Synedra delicatissima*						6	10				16
		Synedra ulna	28		18	12	24	32	28		28		170
	Thalassiossiraceae	*Cyclotella* sp.								14			14
Dinophyta	Peridiniaceae	*Peridinium balticum*							2			8	10
		Peridinium cintum		8							2		10
Chlorophyta	Desnidiaceae	*Closterium gracile*				4		2		10	12		28
		Closterium monileferum		6	12								18
		Micrasterias sp.				8	10	8					26
		Staurastrum asterias	8		15				15	4			42
	Hydrodictyaceae	*Pediastrum duplex*	8							6			14
		Pediastrum simplex				6	8						14
	Oocystaceae	*Ankistrodesmus* sp.									2		2
		Eudorina elegans		12	12	6	12	8	8	4	12		74
		Volvox aureus	10					6					16
	*Zygnem*ataceae	*Zygnema* sp.			8				10			18	36

*Correlation coefficient (r) = 0.44, p>0.46

The result revealed that a total of 1457count mL^{-1}. Cyanophyta (blue green algae) accounted for 188 count mL^{-1} representing 12.90%, bacillariophyta (diatom) accounted for a total of 779 count mLv representing 53.47%, chlorophyta (green algae) accounted for a total of 470 count mL^{-1} representing 32.26% while dinophyta (dino flagellate) accounted for a total of 20 count mL^{-1} representing 1.37%. The total count mL^{-1} for each family revealed that melosiraceae (495 count mL^{-1}), thallasionemataceae (186 count mL^{-1}), oscillatoriacaeae (137 count mL^{-1}), oocystaceae (92 count mL^{-1}) and naviculariaceae (87 count mL^{-1}) are the most abundant families. On the hand, rivulariacaeae (10 count mL^{-1}), lauderiacaeae (12 count mL^{-1}), rhizosoleniaceae and Thalassiossiraceae (14 count mL^{-1} each), Peridiniaceae (20 count mL^{-1}) and diatomaceae (22 count mL^{-1}) represented families with the least abundance. The result of the study also showed that *Melosira granulata* (495 count mL^{-1}), *Synedra ulna* (170 count mL^{-1}), *Eudorina elegans* (74 count mL^{-1}), *Lyngbya contorta* (48 count mL^{-1}; *Navicula radiosa* (45 count mL^{-1}), *Staurastrum asterias* (42 count mL^{-1}), *Eunotia lunaria* (40 count mL^{-1}), *Nitschia closterium* (38 count mL^{-1}), *Zygnema* sp. (36 count mL^{-1}) and *Closterium gracile* (28 count mL^{-1}) are the species with the highest abundance. Conversely, species with the least coun mL^{-1} include *Ankistrodesmus* sp. (2 count mL^{-1}), *Spirulina platensis* (4 count mL^{-1}), *Oscillatoria limnetica* (6 count mL^{-1}), *Lyngbya limnetica* (8 count mL^{-1}), *Peridinium balticum*, *Peridinium cintum* and *Rivularia* sp. (10 count mL^{-1} each), *Lauderia annulata*, *Nitschia palea*, *Phormidium tenue* (12 count mL^{-1} each), *Pediastrum simplex*, *Pediastrum duplex*, *Cyclotella* sp. *Proboscia alata* and *Nitschia acicularis* (14 count mL^{-1} each).

The result for spatial abundance revealed that stations 2, 3 and 4 with 21 species each had a population count of 263, 326 and 306 count mL^{-1}, respectively. Stations 1 and 5 with 18 and 19 species each had populations of 268 and 294 count mL^{-1}, respectively (Fig. 3).

Correlation analysis and student t test between species abundance and number of species per each spatial gradient showed an r value of 0.44 and p value of 0.46, respectively.

Results of frequency analysis across the spatial and temporal gradients were also checked. The result revealed that *Melosira granulata*, *Eudorina elegans*, *Synedra ulna*, *Lyngbya contorta* and

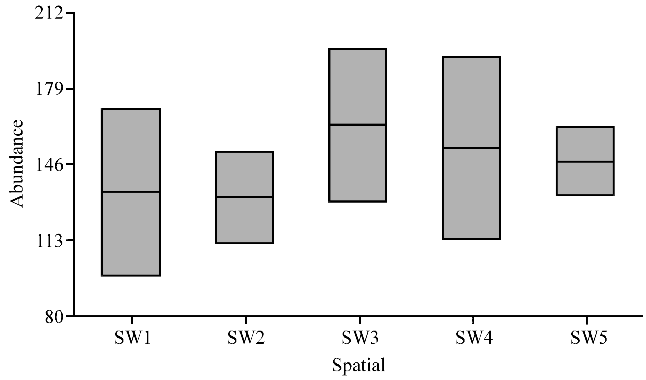

Fig. 3: Relationship between abundance and total phytoplankton abundance across spatial gradient

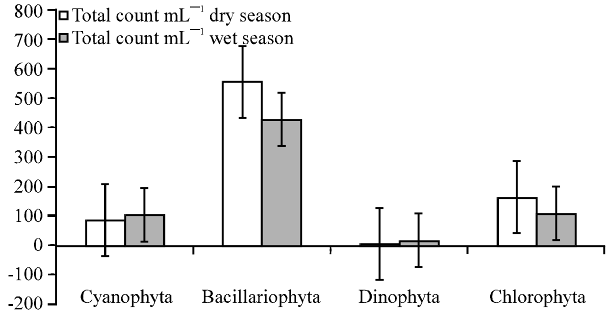

Fig. 4: Relationship between phytoplankton taxa and abundance across temporal gradient

Nitschia closterium with frequencies of 10, 8, 7, 7 and 6 were five species with the highest occurrence. In the same vein, seven species occurred once. These species are *Ankistrodesmus* sp. *Cyclotella* sp., *Lauderia annulata*, *Lyngbya cylindricum*, *Peridinium balticum*, *Proboscia alata* and *Spirulina platensis*.

Results for seasonal analysis are presented in Table 5. As could be seen, each season is composed of the four identified divisions albeit different numbers of alga families, alga species, total count mL^{-1} and frequency. For example, wet season samples is composed of all but one family (oocystaceae) while four families-lauderiaceae, rhizosoleniaceae, rivulariaceae and thallassiosiraceae were absent in the dry season samples. Expectedly, *Rivularia* sp., *Lauderia annulata*, *Proboscia alata* and *Cyclotella* sp. are members of the four aforementioned families that were present in the wet season samples but absent in the dry season samples. *Spirulina platensis* was the other species present in the wet season samples that were absent in the dry season samples despite being represented by other members of the family Oscillatoriaceae. On a genera note, the dry season samples are composed of a total of 34 species while the wet season samples are composed of a total of 35 species. Species present in the dry season samples but absent in the wet .The result also revealed some species present in the dry season samples but absent in the wet season samples. They include *Ankistrodesmus* sp., *Lyngbya limnetica* and *Phormidium tenue*.

There are a population of 805 counts mL^{-1} (170, 151, 130, 192 and 162 individuals for 1, 2, 3, 4 and SW5, respectively), for the dry season samples as against 652 counts mL^{-1} (98, 112, 196, 114, 132 individuals for SW1, SW2, SW3, SW4 and SW5, respectively) for the wet season samples (Fig. 4).

Table 5: Checklist and abundance of phytoplankton in Great Kwa River across spatial gradient

Division	Family	Species	Dry season SW 1	2	3	4	5	Total count (mL^{-1})	Freq.	Wet season SW 1	2	3	4	5	Total count (mL^{-1})	Freq.
Cyanophyta	Nostacaceae	*Anabaena flos-qua*			8			8	1			5	12		17	2
		Anabeana spiroides				8		8	1	2				6	8	2
	Oscillatoriaceae	*Lyngbya contorta*	8	8	4			20	3	10	8	6		4	28	4
		Lyngbya cylindricum				8		8	1							
		Lyngbya limnetica					4	4	1	6			2	6	14	3
		Oscillatoria limnetica					4	4	1		2				2	1
		Oscillatoria limosa		6				6	1			10	4	2	16	3
		Spirulina platensis										4			4	1
		Phormidium fragile					15	15	1			4			4	1
		Phormidium tenue	6	6				12	2							
	Rivulariaceae	*Rivularia* spp.										10			10	1
Bacillariophyta	Bacillariophyceae	*Nitschia acicularis*			6			6	1		8				8	1
		Nitschia closterium	6			10	2	18	3	8	2	10			20	3
		Nitschia palea		6			6	12	2							
	Diatomaceae	*Tabellaria floculosa*					10	10	1		4			8	12	2
	Eunotiaceae	*Eunotia lunaria*	12			10		22	2			6	4	8	18	3
		Eunotia gracilis			8			8	2	4	8				12	2
	Fragilariaceae	*Fragilaria construens*	10					10	1			15			15	1
	Lauderiaceae	*Lauderia annulata*											12		12	1
	Melosiraceae	*Melosira granulata*	60	48	40	60	65	273	5	42	36	52	28	64	222	5
	Naviculaceae	*Gomphonema acuminatum*	4			8		12	2		2	8			10	2
		Navicula oblonga		12				12	1					8	8	1
		Navicula radiosa	10		10	15		35	3		6	4			10	2
	Rhizosoleniaceae	*Proboscia alata*											14		14	1
	Thalla	*Synedra delicatissima*				10		10	1			6			6	1
	sionemataceae	*Synedra ulna*	28	18	24	28	28	126	5		12	32			44	2
	Thalassiossiraceae	*Cyclotella* sp.											14		14	1
Dinophyta	Peridiniaceae	*Peridinium balticum*				2		2	1					8	8	1
		Peridinium cintum					2	2	1	8					8	1
Chlorophyta	Desnidiaceae	*Closterium gracile*					12	12	1		4	2	10		16	3
		Closterium monileferum			12				12	1	6					6
		Micrasterias sp.			10			10	1		8	8			16	2
		Staurastrum asterias	8	15		15		38	3				4		4	1
	Hydrodictyaceae	*Pediastrum duplex*	8					8	1				6		6	1
		Pediastrum simplex			8			8	1		6				6	1
	Oocystaceae	*Ankistrodesmus* sp.					2	2	1							
		Eudorina elegans		12	12	8	12	44	3	12	6	8	4		30	4
		Volvox aureus	10					10	1			6			6	1
	Zygnemataceae	*Zygnema* sp.		8		10		18	2					18	18	1

Table 6: Correlation coefficient between phytoplankton abundance and physic-chemical parameters in the great Kwa river

Physico-chemical parameter	Bacillariophyta	Chlorophyta	Cyanophyta	Dinophyta
pH	-0.22	0.20	0.71	-0.82
Temperature	-0.37	0.21	-0.18	-0.73
Conductivity	0.41	-0.18	-0.24	0.33
Salinity	0.43	0.08	0.08	0.47
Dissolved oxygen	-0.73	0.47	-0.38	0.23
Turbidity	-0.25	0.89*	0.08	-0.35
Total dissolved solid	0.28	-0.22	-0.37	0.37
BOD	-0.46	0.92*	-0.08	-0.56
COD	-0.47	0.88*	-0.04	-0.57
Chloride	-0.65	0.85	-0.38	-0.17
Nitrite	0.43	-0.62	0.19	0.86*
Sulphate	0.89*	-0.43	0.71	0.37
Phenol	0.40	0.03	-0.23	0.20
Magnesium	-0.46	0.81*	-0.08	-0.77
Potassium	-0.30	0.75	-0.06	-0.89*
Sodium	-0.72	0.86	-0.34	-0.30
Calcium	0.60	-0.01	-0.07	-0.02
Chromium	0.63	-0.67	0.75	0.53
Manganese	0.61	0.29	0.87	-0.53
Iron	0.33	0.70	0.57	-0.75
Cadmium	-0.88*	0.45	-0.70	-0.39

Values marked * along column are significantly different at 0.05

Species composition breakdown indicated that *Melosira granulata* was the most abundant species for the two seasons. *Synedra ulna*, *Eudorina elegans* are other species with high abundance values in both seasons under investigations. The result of the correlational analysis and student t test revealed a correlation coefficient of 0.94 and a significant p value ($p<0.001$) at the 0.05 confidence limit for seasonal data while a correlational coefficient of 0.21 and a non-significant p value of ($p = 0.56$) was observed across the stations.

The result of the correlation coefficients between phytoplankton and physico-chemical parameters at the Great Kwa River is shown in Table 6.

The bacillariophyta were observed to have negative and insignificant ($p>0.05$) correlation with pH, temperature, dissolved oxygen, turbidity, BOD, COD, chloride, magnesium, potassium and sodium while it showed positive and insignificant correlation with the other parameters under investigation except sulphate ($p<0.045$) where it showed significant correlation. The cyanophyta taxa showed negative and insignificant correlations with all the parameters except pH, salinity, turbidity, nitrate, sulphate, chromium and iron. Chromium on the other hand, was the only chemical parameter that showed significant ($p<0.049$) correlation with the cyanophyta taxa. Correlation analysis between chlorophyta taxa and the various physic chemical parameters indicated that pH, temperature salinity, dissolved oxygen, turbidity (significant), BOD, COD (significant), chloride, phenol, magnesium, sodium, manganese, iron and cobalt had positive and insignificant correlations. Potassium, on the other hand, had negative but significant correlation ($r= -0.89$; $p< 0.041<0.05$).The taxa, Dinophyta, showed negative correlation with pH, temperature, turbidity,BOD, COD, chloride, magnesium, potassium, sodium, calcium, manganese, iron and cadmium. The other parameters (nickel, lead, silver and zinc) could not be correlated since no variance exists among their results.

Results on diversity indices: Three indices were used to obtain the estimate of species diversity in the samples analyzed: Species richness index (d) (Margalef, 1970), Shannon-Weiner index (H1) (Shannon and Weiner, 1963) and Species evenness (j) (Pielou, 1975). Table 7 showed the results for these indices for the spatial distribution while Table 8 showed the indices for the temporal (seasonal) variation. As could be seen from Table 7, the Shannon-wiener index and margalef index for SW1, SW2 and SW3. SW4 and SW5 are 2.32 and 3.04; 2.45 and 3.42; 2.53 and 3.46; 2.64 and 3.49 and 2.16 and 3.17, respectively while the species evenness for the aforementioned surface water stations are 0.56,0.58,0.60,0.66 and 0.46, respectively.

Phytoplankton taxa diversity indices showed that bacillariophyta taxa was the most diverse (16 species), showed highest margalef index (2.18) and was the most abundant (979 individuals) while cyanophyta had the greatest equitability(0.91), evenness (0.81) and Shannon (2.19) indices. On the other hand, dinophyta was the least diverse (2 species), least abundant (2o individuals), least values of Shannon (0.69) and margalef (0.33) indices. The seasonal variations in phytoplankton taxa also followed similar trend (Table 8).

For instance, the number of individuals in the wet season for the bacillariophyta taxa was the most abundant (554 species), cyanophyta species in the dry season showed the highest Shannon index, bacillariophyta taxa of the wet season sample had the highest margalef index, cyanophyta taxa of the dry season samples was the most evenly (0.89) and equitably distributed (0.95) as bacillariophyta taxa of the wet season was the most diverse (15 species). Conversely, the taxa, Dinophyta showed the least of all the measured diversity indices. Seasonal comparison for total phytoplankton diversity indices as shown in table revealed that the wet season results with 35 species had a much fewer number of individuals (652) than the dry season sample with 805 individuals and 34 species. Similarly, the Shannon index (2.84), evenness (0.49) and margalef index (5.25) of the wet season was higher than those of the dry season-2.63, 0.41 and 4.93 for Shannon, evenness and margalef indices, respectively.

Similarly, the Shannon wiener index and margalef index for the phytoplankton assemblages for the dry season are 2.63 and 4.93 while that for the wet season are 2.84 and 5.25, respectively. The species evenness for the dry and wet seasons was 0.41 and 0.49, respectively. Diversity t test for the seasonal comparison indicated a value of -2.91.

Table 7: Diversity index value for phytoplankton across spatial gradient

	SW				
Index	1	2	3	4	5
Taxa	18	20	21	21	19
Abundance	268	257	326	306	294
Shannon-wiener	2.32	2.45	2.53	2.64	2.16
Margalef	3.04	3.42	3.46	3.49	3.17
Evenness	0.56	0.58	0.60	0.66	0.46

Table 8: Diversity index value for phytoplankton taxa across temporal gradient

Taxa	Bacillariophyta	Chlorophyta	Cyanophyta	Dinophyta
Index				
Species diversity	16	10	11	2
Margalef	11.83	2.06	2.19	0.69
Evenness	0.39	0.79	0.81	1
Equitability	0.66	0.90	0.91	1
Abundance	979	270	188	20

DISCUSSION

The water quality standards formulated by the Nigerian Institute of Standards (NIS), Federal Ministry of Environment (FME) and the Ecosystem approach (ECA) were used to evaluate the results obtained from the analysis of water quality of the Great Kwa River. The NIS protocol serves standard for drinking water, FME criteria serves to regulate effluent discharge into surface waters while ECA stipulates maximum limits for the maintenance of aquatic lives. These three standards were selected since the inhabitants of the area utilize the water resources of the Great Kwa River for consumption (drinking and cooking), fishing and deposition of human fecal matter. The evaluation of the results indicated that the spatial variations in pH, salinity, dissolved oxygen, TDS, chloride, sulphate, magnesium, calcium, manganese and zinc were below the minimum permissible limits spelt out by NIS and FME although the value obtained for zinc ions across all the measured spatial gradients were below its baseline limit for the maximum maintenance of aquatic live. Ellis *et al*. (2004) attributed this phenomenon to the in situ purification mechanisms inherent in water bodies. Arguably, processes such as domestic waste disposal and washing of cooking utensils and clothes in the water which could predispose the water body to higher and damaging levels of the aforementioned parameters are negligible. Conversely, the value obtained for the other parameters such as temperature, conductivity, turbidity, BOD, COD, nitrite, phenol, chromium, lead, iron, nickel and cadmium are either above the upper limits of any of the three standards at all or some of the measured spatial and temporal gradients. Similar studies in different parts of Nigeria had reported increased amounts of some or all of these physico-chemical parameters in water bodies used by artisans and rural dwellers (Ideriah *et al*., 2010; Adejuwon and Adelakun, 2013; Chinyem, 2013). They suggested increased waste load (domestic and agricultural) beyond the natural in situ recovery mechanism into the water bodies as a possible cause. Possible ecosystem distortion and fracture such as sudden overharvesting/overkill of a species or introduction of alien and invasive species could hinder natural recovery processes in water bodies leading to accumulated higher nutrient levels over time, regardless of its carrying capacity. Increased levels beyond the permissible limits in phenol and phenolic compounds, nickel, lead, chromium, cadmium, iron have been shown to induce carcinogenic effect while increased nitrite levels could induce cyanosis and asphyxia. This is particularly disturbing since these increased levels were observed in site close to the Obufa Esuk Orok community which utilizes the water resources for their cooking, drinking and fishing needs.

Phytoplankton distribution of the Great Kwa River varied more between season (dry and wet-spatial) than surface stations (temporal). Literatures are replete with studies on the temporal and spatial gradients of phytoplankton distribution pattern in Nigeria. For instance, Imevbore (1965), Akpata *et al*. (1993) and Nwankwo (1986, 1994) reported the dominance of bacillariophyta and cyanophyta species in water bodies in western part of Nigeria while Holden and Green (1960) showed the abundance of chlorophyta and bacillariophyta members in springs and lakes around the Sokoto basin. The presence and diversity of bacillariophyta, euglenophyta and cyanophyta in rivers and streams in eastern Nigeria had been reported (Akoma, 2008). As expected, studies on phytoplankton diversity and abundance in the southern part of the country showed the dominance of bacillariophyta, cyanophyta, chlorophyta, euglenophyta, chrosophyta, xantophyhyta and dinophyta (Akpan, 1995; Chinda and Pudo, 1991; Egborge, 1994; Erondu and Chindah, 1991; Kadiri, 1999; Nwadiaro and Ezefili, 1985; Tawari *et al*., 2008; Yakubu *et al*., 2000). Generally, phytoplankton taxa and abundance was observed to be comparatively lower with 3 taxa and 10 species) reported values in most Niger delta waters. For example, Ezekiel *et al*. (2011) reported 5 taxa, totaling 43 species (bacillariophyta 18, Chlorophyta -14, cyanophyta -8, xanthophyta -2 and chrosophyta 1), Yakubu *et al.* (2000) had recorded 17, 20 and 34 species for Nun, Orashi and Nkisa rivers, respectively, (Erondu and Chindah (1991) reported 27 species from New Calabar River, Flora *et al.* (2007) identified 43 species and 47 species for dry and wet seasons respectively in Ekole river and Zabby 103 species in Imo river. The result from this study compared favorably with the reported 39 species in Lubara Creek by Nabowei *et al.* (2008) and 36 species of phytoplankton from the Lagos Lagoon (Nkwoji *et al.*, 2010). It however, varies considerably from some other studies in Nigeria. Ogamba *et al.* (2004) reported 143 species in Elechi creek. Davies and Otene (2009) recorded 169 species in Elechi Creek and Emmanuel and Onyema (2007) reported 82 species in Lagos Lagoon. Furthermore, Edoghotu and Aleleye-Wokomo (2007) reported 198 species from Ntawogba Creek, Portharcourth, Olele and Ekelemu (2008) reported 10 species in Onah lake around Asaba while Essien ibok (2013) reported 102 species in Mbo river. Edward and Ugwumba (2010) attributed the dominance of diatoms to nutrient levels and temperature while Ezekiel *et al.*, (2011) included velocity of current and light penetration. The nutrient levels observed in the Great Kwa River was generally higher in the dry season than in the wet season. This agrees with studies on Sobrieno and Nun rivers. The significant positive correlations between bacillariophyta and sulphate could be adduced to the high diatom abundance. This is particularly instructive as the Great Kwa River is a fresh water environment with high nutrient input from the near-by rural dwellers. The effect of high nutrient (sulphate and phosphate) levels on pennate diatoms had been variously observed (Adesalu, 2010; Nkwoji *et al.*, 2010; Edward and Ugwumba, 2010).

The abundance of diatoms in the wet season (15 species; Table 9) was supported by Ugwumba and Ugwumba (1993). They suggested recycling of nutrients during heavy rainfall as the likely reason.

Chlorophyta and cyanophyta, the other dominant taxa in the river was observed to be more abundant in the dry season than in the wet season (Table 9) this data agrees with Nwankwo (1986), Ugwumba and Ugwumba (1993), Akpan (1995) and Edward and Ugwumba (2010). The significant positive correlations of chlorophyta with turbidity, BOD COD and magnesium were a result of heavy organic waste load.

In contrast to most other studies where the dominant blue green algae was microcystis (Burgis *et al.*, 1973; Egborge, 1981; Ugwumba and Ugwumba, 1993) and Oscillatoria (Edward and Ugwumba, 2010), the dominant blue green algae in the Great Kwa river was *Lyngbya contorta* followed closely by the *Oscillatoria limosa*. The abundance of *Lyngbya limnetica* in Sobrieno River had been reported by Ezekiel *et al.* (2011). Lyngbya species had often been correlated with polluted environment (Akin-Oriola, 2003). In the same vein, the absence of any significant

Table 9: Diversity index value for phytoplankton taxa across temporal gradient

Taxa	Bacillariophyta		Chlorophyta		Cyanophyta		Dinophyta	
Index	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Species diversity	13	15	10	9	10	9	2	2
Shannon-wiener	1.68	1.88	2.02	1.99	2.18	1.97	0.69	0.69
Margalef	1.9	2.31	1.77	1.71	1.98	1.73	0.72	0.36
Evenness	0.41	0.44	0.75	0.81	0.89	0.79	1	1
Equitability	0.65	0.70	0.88	0.90	0.95	0.89	1	1
Abundance	554	425	162	108	95	103	4	16

correlation between cyanophyta and any of the physico chemical parameter could not be explained while significant correlation between dinophyta with nitrite and phosphate is a result of high nutrient regime.

The diversity indices across spatial gradient showed that sampling station 4 with Shannon, margalef and evenness indices of 2.64, 3.49 and 0.66, respectively was not only the highest in terms of species richness but also the highest in terms of species used as pollution index. Some of the species observed here included Microcystis, Lyngbya and Spirulina. Nkwoji *et al.* (2010) reported Shannon index of between 0.48 and 1.10 in Lagos lagoon. The higher Shannon index recorded in this study was in consistent with that of Edward and Ugwumba (2010). Similarly diversity indices across temporal gradient showed that the wet season had a higher Shannon, margalef and evenly distributed species than the dry season in spite of having lesser number of individual (652). Nwankwo and Onyema (2003) and Essien-Ibok (2013) observed also observed higher diversity indices in the wet season than the dry season. However, the taxon Cyanophyta with the highest diversity indices among all the taxa in the dry season could be explained in the light of higher number of individuals and high turbidity.

CONCLUSION

Conclusively it was observed that both clean water and polluted water species were recorded in the Kwa river across both gradients. The diatoms which accounted for about half of the species in the study site had frequently been used as index of pollution. The huge presence of Melosira, Nitschia, Navicula and Synedra are indicators of sewage pollution and eutrophic conditions while the green alga, Spirogyra also indicates eutrophic conditions. The blue green algae Microcystis, Oscillatoria and Anabaena are potential candidates of organic pollution. This may lead to a structural shift in planktonic community resulting in the dominance of a few stress tolerant species.

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