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Tidal influence on the physico-chemistry quality of Okpoka Creek, Nigeria

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Abstract
Okpoka Creek is a tidal creek, rich in fish resources and numerous human's activities are going on within and around it. This study assessed the effects of low and high tides on the physico-chemical characteristics of Okpoka Creek. Surface water samples were collected between May 2004 and April 2006 at both tides according to APHA methods. These were analysed for temperature, pH, transparency, salinity, dissolved oxygen (DO), biological oxygen demand (BOD), pH, conductivity, total dissolved solids (TDS), chlorides, magnesium, hardness, total organic carbon (TOC), total organic matter (TOM), calcium, alkalinity and nutrients (ammonia, nitrate, phosphate and sulphate). Data analyses were done using analysis of variance (ANOVA), Duncan multiple range (DMR) and descriptive statistics using statistical analysis system (SAS). Tide demonstrated significant influence on the measured physico-chemical variables: temperature, turbidity, electrical conductivity, pH, DO, BOD, TDS, calcium and hardness ($P<0.05$). The values of the measured physico-chemical parameters and nutrients were higher or lower at low tide for some parameters and vice versa. The recorded range of TOC concentrations at both tides was above the 1 to 30 mg/L for natural aquatic bodies. Phosphate and ammonia exceeded FEPA and USEPA acceptable levels of 0.01 mg/L for natural water bodies. Nitrate and phosphate had significant tidal variations ($P<0.05$). Increasing anthropogenic wastes especially dredged materials, slaughter effluents and raw human faeces lead to high organic loads. Concerted environmental management strategies to conserve the abiotic resources in order to maintain the biological integrity and fish resources of Okpoka Creek are recommended.

1. Introduction

Tides are characteristic features of marine coasts. They are the result of gravitational forces powered by the moon, and to a lesser extent the sun, on very large water bodies [1]. Tidal variations in coastal waters have been often attributed to nutrients [2]. The physico-chemical parameters (pH, temperature salinity, dissolved oxygen, biological oxygen demand, turbidity, transparency, etc) of water are very essential for the life of aquatic organisms (fishes, amphibians, reptiles, birds and mammals) and they influence these organisms. These abiotic features and biotic parameters are used to determine the health of the aquatic environment.

Okpoka Creek is one the river systems of the Upper Bonny Estuary, Niger Delta, Nigeria. It is noted for its rich fish resources. The study on the tidal influence of the physico-chemical parameters of this creek is of paramount value because of its location, and the numerous human's activities going on within and around it. The need to conserve the aquatic environments in order to maintain sustainable resources and development at the local and international levels has been of great concerns to aquatic scientists. This can only be obtained if the physico-chemical and biological integrity of the aquatic environments are maintained. There are many industries and jetties sited along the shores of Okpoka Creek. These industries (Snig, Far East paints, RIVOC, General-agro, Michelin tyres, Cocacola, Halliburton, Schlumberger, Acorn, etc), main abattoir and jetties release untreated effluents including crude oil and its products directly into the system. Apart from these wastes, domestic sources contribute to the anthropogenic wastes load of this river system. Other human activities (dredging, transportation, laundry, fishing, etc) also impact on this estuary.

Some research works had been conducted on effects of tides on sediments and biological parameters of Okpoka Creek. Davies and Ugwumba [3] studied the tidal influence on nutrients status and phytoplankton population of Okpoka Creek, Upper Bonny Estuary, Nigeria. Davies and Tawari [4] evaluated the season and tide effects on sediment characteristics of Trans-Okpoka Creek, Upper Bonny Estuary, Nigeria. Other works outside this creek are those of Mitra et al. [5] that evaluated the spatial and tidal variations of physico-chemical parameters in the Lower Gangetic Delta Region, West Bengal, India. Praveena et al. [2] also assessed the tidal and anthropogenic impacts on coastal waters of Port Dickson, Strait of Malacca, Malaysia.

This study thus investigated the effects of tides (low and high) on the physico-chemical characteristics of Okpoka Creek.

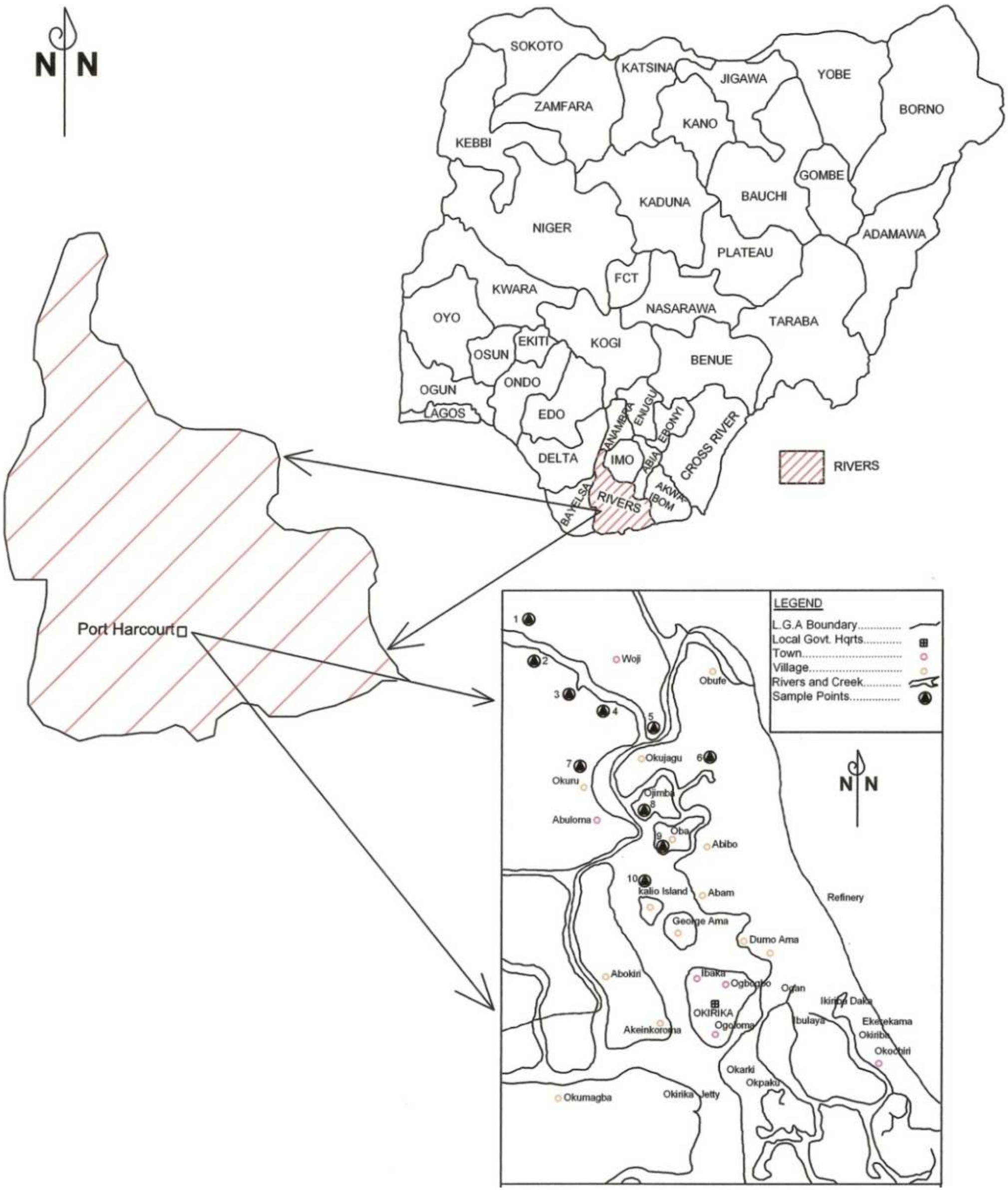

Fig. 1. *Study Area Map*

2. Materials and Methods

2.1. Study Area

The Okpoka Creek is found between longitudes 7° 00″ E and 7 ° 15 ″N and latitudes 4° 28″ E and 4° 40″ N. It is a tributary of the Upper Bonny Estuary in the Niger Delta, South-South of Nigeria (Fig.1). Nypa palm (*Nypa fructican*) and mangroves, red mangrove (*Rhizophora racemosa*) and white mangrove (*Avecennia nitida*) are the dominant plants. It transverses through many riverine communities namely: Oginigba, Woji, Azubiae, Okujagu, Okuru-ama, Abuloma, Ojimba, Oba, Kalio and Okrika.

2.2. Duration of Samplings

Surface water samples were collected following American Public Health Association (APHA) [6] method twice a month from ten stations for twenty-four months (May 2004 – April 2006) at low and high tides.

2.3. Measurements of Relevant Water Physico-Chemical Parameters

Temperature was measured in-situ with a mercury-in-glass thermometer (in Celsius) to the nearest whole number. The transparency of the water was measured in meter by a Secchi disc (20 cm diameter) following Boyd [7] method. The turbidity [Nephelometric Turbidity Unit (NTU)], electrical conductivity (µs/cm) and salinity [part per thousand (ppt, ‰)] were determined in the laboratory using conductivity meter (Horiba-U: 10µ multimeter). The pH was determined in-situ using pH-EC-TDS meter (model Hanna HI 9812; range 0.0-14.00pH) by dipping its electrode into the surface water (20 cm below) for two minutes. Dissolved oxygen, biological oxygen demand, alkalinity, total dissolved solids, total organic carbon, total organic matter, chloride, calcium, magnesium, total hardness, nitrate, sulphate, phosphate and ammonia were determined by Boyd [7] and APHA [6].

2.4. Data Analyses

Data was analysed for analysis of variance (ANOVA), Duncan multiple range (DMR), Pearson correlation coefficient and descriptive statistics using SAS [10].

3. Results

3.1. Surface Water Physical Parameters

Tide demonstrated significant influence on the measured physical variables except transparency (P<0.001, DMR). At low tide, mean temperature was 28.71±0.07 ºC and at high tide, 28.12±0.17 °C. Transparency ranged between 0.65±0.01m (high tide) and 0.70±0.03 m (low tide). Tide had no significant influence on transparency (P>0.05). Turbidity at high tide was 7.66±1.79 NTU and at low tide was 2.99±0.25 NTU (Fig. 2). Tide had highly significant impact on turbidity (P<0.001, DMR).

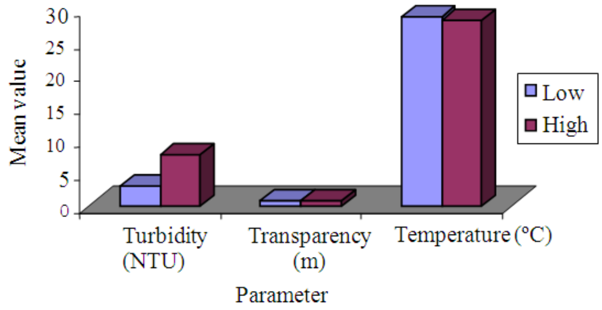

Fig. 2. *Variation of turbidity, transparency and temperature in relation to tide in Okpoka Creek*

3.2. Surface Water Chemical Parameters

The measured chemical parameters included electrical conductivity, salinity, pH, dissolved oxygen, biological oxygen demand, total dissolved solids, total organic carbon, total organic matter, alkalinity, chloride, magnesium, calcium and hardness. Tide had significant impact on electrical conductivity, pH, dissolved oxygen, biological oxygen demand, total dissolved solids, calcium and hardness (P<0.05). Low tide salinity was higher (15.26±5.88 ‰) than high tide salinity 11.11±0.66 ‰) (Fig. 3). Tidal effect on salinity was insignificant (P>0.05). Dissolved oxygen was high at low tide (5.06±0.12 mg/L) and low at high tide (4.54±0.22 mg/L). Biological oxygen demand concentration (3.39±0.11 mg/L) at low tide was higher than biological oxygen demand concentration (2.75±0.19 mg/L) at high tide. Low tide had higher pH of 5.06 ±0.12 and high tide low pH of 4.54±0.22. There was high significant tidal effect on pH (P<0.001, DMR).

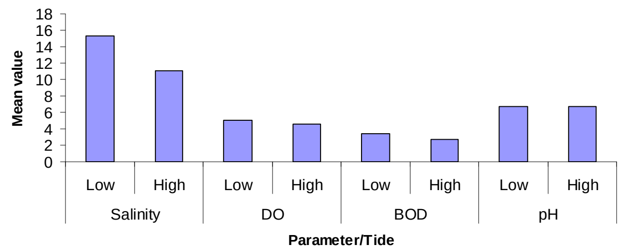

Fig. 3. *Variation of surface water chemical parameters in relation to tide in Okpoka Creek*

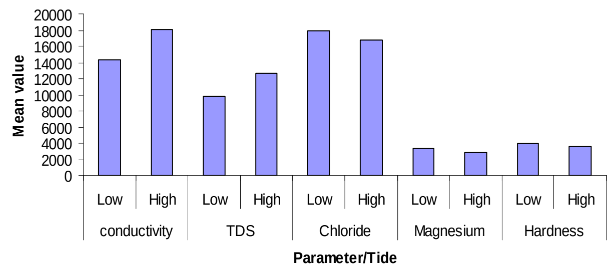

Fig 4. *Variation of surface water chemical parameters in relation to tide in Okpoka Creek*

From Fig. 4, tidal influence on conductivity was higher at high tide (18090±980 µs/cm and lower at low tide (14280±600 µs/cm). There was significant tidal variation (P<0.001, DMR) on conductivity. At high tide, total dissolved solids (12670±690 mg/L) was higher than at low tide total dissolved solids (9760±380 mg/L) and tidal effect was significant (P<0.001, DMR). Low tide chloride level (17935.45±587.54 mg/L) was higher than that of high tide chloride (16834.90±1468.24 mg/L). Tide showed insignificant impact on chloride concentrations (P>0.05). Low tide influence on magnesium level (3309.91±226.56 mg/L) was higher than the high tide level (2796.93±248.40 mg/L). At high tide, hardness concentration (4058.31±169.01 mg/L) was higher than at low tide 3563.66±259.52 mg/L). Tidal variations were significant (DMR).

Total organic carbon values at low (106.04±2.45 mg/L) and high tides (102.75±3.43 mg/L) were similar (P>0.05) (Fig. 5). Low tide total organic matter (182.81±5.82 mg/L) was higher than that of high tide (181.07±13.40 mg/L) and the difference was not significant (P>0.05). Calcium concentration at low tide (912.42±28.25 mg/L) exceeded that of high tide (735.71±50.51 mg/L). Tidal influence was also significant (DMR). Low tide alkalinity value was 84.21±1.60 mg/L (higher) and high tide value was 83.45±2.97 mg/L (lower). Tide had significant effect on alkalinity (P<0.05).

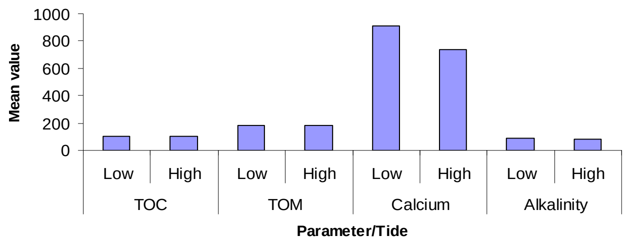

Fig 5. *Variation of surface water chemical parameters in relation to tide in Okpoka Creek*

3.3. Nutrients of Surface Water from Okpoka Creek

Table 1. *Variations of water nutrients in relation to tide in Okpoka Creek*

Tide	Ammonia (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Sulphate (mg/l)
Low	0.17 ±0.01[a]	0.68 ±0.02[a]	0.77 ± 0.05[a]	586.11 ± 36.42[a]
High	0.19 ± 0.02[a]	0.48 ± 0.04[b]	0.29 ± 0.07[b]	459.09 ± 33.89[a]

Means with the same letter in the same column are not significantly different (P>0.05)

The measured water nutrients were ammonia, nitrate, phosphate and sulphate. High tide ammonia level (0.19±0.02 mg/L) was insignificantly higher than low tide ammonia (0.17±0.01 mg/L) (P>0.05) (Table1). Nitrate concentration (0.68±0.02 mg/L) was high at low tide and low (0.48±0.04 mg/L) at high tide. Tidal effect was highly significant (P<0.001, DMR). Low tide phosphate level (0.77±0.05 mg/L) was significantly higher than that of high tide (0.29±0.07 mg/L) (P<0.05, DMR). However, tide influence on the sulphate concentrations was insignificant (P>0.05). Low tide mean sulphate level was 586.11±36.42 mg/L (higher) and high tide level was 459.09±33.89 mg/L (lower).

3.4. Relationships between Surface Water Physical Parameters and Chemistry

Transparency had low negative correlation with turbidity (-0.058). Relationship was not significant (Table 2). Temperature exhibited low negative correlation with turbidity (-0.08511) and low positive correlation with transparency (0.164). Relationship between temperature and turbidity was not significant but significant for temperature and transparency (P<0.001). Temperature exhibited negative correlation with dissolved oxygen (-0.060), biological organic demand (-0.0291), salinity (-0.506), total organic carbon (-0.0277) and total organic matter (-0.0278) but relationships were insignificant except salinity at P<0.001. Temperature had positive correlation with pH (0.302), total dissolved solid (0.397), calcium (0.321), hardness (0.213), alkalinity (0.165), chloride (0.217), magnesium (0.064) and conductivity (0.372). The relationships were significant with all these parameters (P<0.001) except magnesium (P>0.05).

Turbidity showed positive correlation with total organic carbon (0.002), total organic matter (0.008), dissolved oxygen (0.062), chloride (0.017), alkalinity (0.019), biological oxygen demand (0.003), conductivity (0.026) and total dissolved solid (0.026). Its relationships with these parameters were not significant (P>0.05). However, turbidity had negative correlations with magnesium (-0.105), salinity (-0.024), hardness (-0.176), calcium (-0.149) and pH (-0.112). Significant relationships were found with all parameters (P<0.05, 0.01, 0.001) except salinity (>0.05). Transparency correlated negatively with the following parameters; dissolved oxygen (-0.031), chloride (-0.004), biological oxygen demand (-0.105) but relationships were insignificant except biological oxygen demand (P<0.05). It showed positive relationship with other parameters and it is significant for salinity, calcium, conductivity and total dissolved solid (P<0.05, 0.001).

Dissolved oxygen had negative correlations with total organic carbon (-0.120), total organic matter (-0.120), alkalinity (-0.107) and calcium (-0.006). Correlations were significant (P<0.05) except with calcium (P>0.05). Dissolved oxygen exhibited positive relationships with magnesium (0.041), Chloride (0.199), biological oxygen demand (0.415), salinity (0.107), hardness (0.027), conductivity (0.081), total dissolved solid (0.105) and pH (0.115) and correlations were significant (P<0.05) except magnesium, hardness, calcium and conductivity (P>0.05). Total organic carbon correlated positively with total organic matter (0.994), alkalinity (0.091), conductivity (0.012) and total dissolved solid (0.025). However, total organic carbon was negatively correlated with magnesium (-0.154), dissolved oxygen (-0.120), chloride (-0.141), biological oxygen demand (-0.093), salinity (0.031), hardness (-0.145), calcium (-0.048) and pH (-0.012). Total dissolved solid showed positive correlations with total organic carbon (0.025), total organic matter (0.025), dissolved oxygen (0.105), chloride (0.135), alkalinity (0.163), salinity (0.781), hardness (0.016), calcium (0.199), conductivity (0.917) and pH (0.255) but negative correlations with magnesium (-0.074), biological oxygen demand (-0.162). pH had positive correlations with magnesium (0.029), dissolved oxygen (0.115), chloride (0.225), alkalinity (0.286), salinity (0.379), hardness (0.140), calcium (0.225), conductivity (0.2253) and total dissolved solid (0.255) but correlated negatively with total organic carbon (-0.012), total organic matter (-0.009) and biological oxygen demand (-0.052).

Table 2. *Correlation matrix between surface water physical and chemical parameters*

	Turb.	**Trans.**	**Temp.**	**TOC**	**TOM**	**Magnesium**	**DO**	**Chloride**
Turbidity	1.00000							
Transparency	-0.05800^{ns}	1.00000						
Temperature	-0.08511^{ns}	0.16400***	1.00000					
TOC	0.00176^{ns}	0.01990^{ns}	0.02772^{ns}	1.00000				
TOM	0.00808^{ns}	0.01170^{ns}	0.02278^{ns}	0.99443***	1.00000			
Magnesium	-0.10467*	0.02285^{ns}	0.06425^{ns}	-0.15380**	-0.14945**	1.00000		
DO	0.06163^{ns}	-0.03098^{ns}	-0.05998^{ns}	-0.11973*	-0.12063**	0.04090^{ns}	1.00000	
Chloride	0.01699^{ns}	-0.00419^{ns}	0.21695***	-0.14128**	-0.13988**	0.00411^{ns}	0.19931***	1.00000
Alkalinity	0.01932^{ns}	0.07895^{ns}	0.16508***	0.09133^{ns}	0.09250^{ns}	-0.06526^{ns}	-0.10667*	0.12865**
BOD	0.02940^{ns}	-0.10540*	0.02868^{ns}	-0.09289^{ns}	-0.09979*	0.07544^{ns}	0.41494***	0.14913**
Salinity	-0.02390^{ns}	0.20664***	-0.50604***	-0.03142^{ns}	-0.02780^{ns}	0.00677^{ns}	0.10746*	0.26842***
Hardness	-0.17563***	0.06615^{ns}	0.12332***	-0.14468**	-0.14016**	0.88554***	0.02735^{ns}	0.02687^{ns}
Calcium	-0.14894**	0.10755*	0.32081***	-0.04806^{ns}	0.04613^{ns}	-0.25704***	-0.00561^{ns}	0.08249^{ns}
Conductivity	0.02591^{ns}	0.16718***	0.37201***	0.01182^{ns}	0.01439^{ns}	-0.04933^{ns}	0.08123^{ns}	0.12698**
TDS	0.02630^{ns}	0.19712***	0.39736***	0.02488^{ns}	0.02535^{ns}	-0.07443^{ns}	0.10494*	0.13505**
pH	-0.11169*	0.06286^{ns}	0.30235***	-0.01243^{ns}	-0.00867^{ns}	0.02924^{ns}	0.11544*	0.22527***

Table 2. *Continue*

	Alkalinity	**BOD**	**Salinity**	**Hardness**	**Calcium**	**Conductivity**	**TDS**	**pH**
Turbidity								
Transparency								
Temperature								
TOC								
TOM								
Magnesium								
DO								
Chloride								
Alkalinity	1.00000							
BOD	0.02185^{ns}	1.00000						
Salinity	0.30697***	-0.00537^{ns}	1.00000					
Hardness	0.07167^{ns}	0.07967^{ns}	0.11535*	1.00000				
Calcium	0.27044***	0.00550^{ns}	0.23837***	0.19454***	1.00000			
Conductivity	0.14316***	-0.14968**	0.71198***	0.02958^{ns}	0.17296***	1.00000		
TDS	0.16335***	-0.16145***	0.78112***	0.01563^{ns}	0.19858***	0.91728***	1.00000	
pH	0.28587***	-0.05208^{ns}	0.37919***	0.13977**	0.22451***	0.22534***	0.25476***	1.00000

* - Significant at $P<0.05$
** - Significant at $P<0.01$
*** - Significant at $P<0.001$
ns - Not Significant

3.5. Correlations Matrix between Water Physical Parameters and Nutrients

Table 3 reveals the relationships between water physical parameters and nutrients. Temperature correlated negatively with nitrate (-0.334) and phosphate (-0.163) and positively with ammonia (0.085) and sulphate (0.125). Relationships were significant (P<0.05, 0.01) except with ammonia (P>0.05). Transparency had negative correlations with ammonia (-0.021) and phosphate (-0.182) and positive relationships with nitrate (0.005) and sulphate (0.037). Significant correlation was observed only for transparency and phosphate (P<0.01).

Table 3. *Correlation matrix between surface water physical parameters and nutrients*

	Turbidity	Transparency	Temperature	Ammonia	Nitrate	Phosphate	Sulphate
Turbidity	1.00000						
Transparency	-0.05830 ns	1.00000					
Temperature	-0.08511 ns	0.16387***	1.00000				
Ammonia	-0.03167 ns	-0.02047 ns	0.08464 ns	1.00000			
Nitrate	0.06216 ns	0.00512 ns	-0.33347***	-0.10870 ns	1.00000		
Phosphate	0.02839 ns	-0.18180**	-0.16331**	0.05901 ns	0.07410	1.00000	
Sulphate	-0.03056ns	0.03694 ns	0.12493**	-0.03603 ns	-0.13170 ns	-0.04891 ns	1.00000

** - Significant at P<0.01
*** - Significant at P<0.001
ns - Not Significant

3.6. Relationship between Water Chemistry and Nutrients

Dissolved oxygen exhibited positive correlations with ammonia (0.064) and sulphate (0.139) but negative relationships with nitrate (-0.121) and phosphate (-0.005) (Table 4). Dissolved oxygen relationships with these nutrients were only significant for nitrate and sulphate (P<0.05, 0.01) respectively). Biological oxygen demand had positive relationships with these nutrients except nitrate (-0.069) and these were only significant for phosphate (P<0.05). pH correlated positively with ammonia (0.078), phosphate (0.031) and sulphate (0.196) but negatively with nitrate (-0.216). Relationships of pH with these nutrients were significant (P<0.001) except ammonia and phosphate. Salinity showed negative correlation with these nutrients except sulphate (0.389). Its relationships with nitrate, phosphate and sulphate were significant (P<0.05, 0.01).

Table 4. *Relationship between surface water chemistry and water nutrients*

	TOC	TOM	Mg	DO	Cl.	Alk.	BOD	Sal.	Hardness
TOC	1.000								
TOM	0.994***	1.000							
Mg	-0.154**	-0.150**	1.000						
DO	-0.120**	-0.121*	0.041 ns	1.000					
Cl.	-0.141**	-0.140**	0.004 ns	0.199***	1.000				
Alk.	0.091 ns	0.093 ns	-0.065 ns	-0.107*	0.129**	1.000			
BOD	-0.093 ns	-0.100*	0.075 ns	0.415***	0.149**	0.022 ns	1.000		
Sal.	-0.031 ns	-0.028 ns	0.007 ns	0.108*	0.268***	0.307***	-0.005 ns	1.000	
Hardness	-0.145**	-0.140**	0.0889***	0.027 ns	0.027 ns	0.072 ns	0.080 ns	0.114*	1.000
Cal.	0.048 ns	0.046 ns	-0.257***	-0.006 ns	0.083 ns	0.270***	0.006 ns	0.238***	0.195***
EC	0.012 ns	0.014 ns	-0.049 ns	0.081 ns	0.127**	0.143**	-0.150**	0.712***	0.030 ns
TDS	0.025 ns	0.025 ns	-0.074 ns	0.105*	0.135**	0.163***	-0.162***	0.781***	0.016 ns
pH	-0.012 ns	-0.009 ns	0.029 ns	-0.115*	0.225***	0.286***	-0.052 ns	0.379***	0.140***
NH_4	0.030 ns	0.032 ns	0.009 ns	0.064 ns	0.130*	0.225***	0.045 ns	-0.054 ns	-0.019 ns
$N0_3$	0.134**	0.138**	-0.104*	-0.121*	-0.180***	-0.270***	-0.069 ns	-0.514***	-0.173***
$P0^{2-}_3$	0.091 ns	0.090 ns	0.092 ns	-0.005 ns	0.005 ns	0.189***	0.122*	-0.180**	0.108 ns
Sulphate	0.010ns	0.011 ns	-0.119*	0.139**	0.122*	0.097 ns	0.051 ns	0.389***	-0.011 ns

***Table 4.** Continue*

	Cal.	EC	TDS	pH	NH_4	$N0_3$	$P0^{2-}_3$	Sulphate
TOC								
TOM								
Mg								
DO								
Cl.								
Alk.								
BOD								
Sal.								
Hardness								
Cal.	1.000							
EC	0.173***	1.000						
TDS	0.199***	0.917***	1.000					
pH	0.225**	0.225***	0.255***	1.000				
NH_4	-0.049 ns	-0.112*	-0.112*	0.078 ns	1.000			
$N0_3$	-0.158**	-0.370***	-0.449***	-0.216***	-0.109*	1.000		
$P0^{2-}_3$	0.035**	-0.235***	-0.244***	0.031 ns	0.059 ns	0.074 ns	1.000	
Sulphate	0.230***	0.343***	0.372***	0.372***	-0.036 ns	-0.132 ns	-0.049 ns	1.000

* - Significant at P<0.05
** - Significant at P<0.01
*** - Significant at P<0.001
ns - Not Significant

Electrical conductivity demonstrated negative correlations with the observed nutrients except sulphate (0.343) and these were significant (P<0.05, 001) for all nutrients. Total organic carbon and total organic matter exhibited positive relationships with these nutrients but their relationships were only significant for nitrate (P<0.01). Total dissolved solid had negative correlations with these nutrients except sulphate (0.372). The relationships between these nutrients and total dissolved solid were significant (P<0.05, 0.001). However, other water chemical parameters showed varied correlations with ammonia, nitrate, phoshapte and sulphate.

4. Discussion

4.1. Surface Water Physico-Chemical Parameters

In estuaries, temperatures are less significant than variations in salinity and types of substratum in determining distribution patterns and relative abundance of species [9]. The observed temperature demonstrated narrow amplitude of variation. It showed the characteristic of the tropical environment and falls within the acceptable ranges [10, 11, 12]. Tide had significant influence on temperature, higher at low tide than at high tide. The reason could be the reduced water volume at low tide which invariably reduced the water depth of the creek thus receiving sun intensity. Naturally, transparency is inversely proportional to turbidity. This was evident by the negative correlation between transparency and turbidity in this study. The observed transparency values at both tides might be attributed to the clearness and cloudiness of the water at low and high tides respectively. The present study agreed with transparency values in Ajao [13] of 0.3 m to 1.9 m in Lagos Lagoon and, Sikoki and Zabbey [12] of 0.6 m-1.5 m in Imo River, Nigeria. Chrzanowski and Grover [14, 15, 16] and Roelke et al. [17] reported that balance of light energy is assumed to regulate algae ecosystem structure. Turbidity is an important water quality parameter due to sediment loading and the concomitant effect it has on the light available for phytoplankton and epiphyton growths as well as other aquatic life [18]. There has been no standard range of values assigned to turbidity of natural waters [19]. Turbidity controls the dynamic of phytoplankton [20]. The record of this present study did not exceed the level found in natural water bodies. Boyd [7] reported that turbidities in natural waters seldom exceed 20,000 mg/L and even muddy waters usually have less than 2000 mg/L. Also, the observed turbidity level in this study agrees with the range of 2 NTU to 47 NTU reported by Asonye et al. [21] for the turbidity of Nigerian rivers, streams and waterways. The observed turbidity might be attributed to plankton. Swann [22] reported that plankton is one of the causes of turbidity. However, the higher tidal influence on turbidity at high tide might be linked to the introduced suspended particulate matters that negatively affected the biological communities.

Salinity affects the distribution patterns and relative abundance of organisms [23, 24]. Its variations that could be expected are due to the distribution of rainfall. The observed salinity in this study disagreed with the report of Praveena *et al*. [2] that salinity at high tide was higher than at low tide. The salinity of the coastal water is usually in the range of 34.40 ‰ to 34.50 ‰ although lower values do occur [19]. The present study record of salinity is within this acceptable range for coastal waters. It is also within the range reported by Chindah and Nduaguibe [25] of 11.5±1.8 ‰ to 20.3±3.0 ‰ for Lower Bonny River, Chindah [26] of 0.0 ‰ to 10.50 ‰ for New Calabar River and Hart and Zabbey [11] of 0.0 ‰ to 12.70 ‰ for Woji Creek. Higher evaporation and low volume of water at low tide might be the possible reason for the higher salinity at low tide.

Dissolved oxygen is probably the most universal applied water quality criterion. The observed dissolved oxygen concentrations were within the acceptable range. IJC [27] recommended that dissolved oxygen concentration above 4 mg/L is good while below 4 mg/L is detrimental to the aquatic life. Also, it is within the concentration expected to be found in natural surface water. The recorded desirable of dissolved oxygen might be traced to tide. Tide helps to circulate the atmospheric air containing oxygen within the water column. McNeely et al. [19] reported that natural surface water has dissolved oxygen less than 10 mg/L. The tidal influence on dissolved oxygen, higher at low tide than at high tide might be traced to the high primary productivity (high transparency) of algae at low tide.

Biological oxygen demand is of vital importance in pollution monitoring. The recorded biological oxygen demand is within the acceptable range for aquatic environments. Waters with biological oxygen demand levels less than 4 mg/L are regarded clean and those with levels greater than 10 mg/L are considered as polluted as they contain large amounts of degradable organic material [19]. However, the present biological oxygen demand range was less than that reported Hart and Zabbey [11] of 0.2 mg/L to 98.9 mg/L for Woji creek. This indicated that the biological oxygen demand load in this present study did not pose a threat to the aquatic environment. However, the higher biological oxygen demand at low tide might be attributed to the higher decomposition of organic matter enhanced by high temperature and reduced water volume.

The pH is an index of hydrogen ion concentration and a very important environmental factor. Surface water generally tends to be alkaline while ground waters are more acidic. The range of pH is broader in freshwater than in seawater [19]. Obunwo et al. [28] reported 5.91 to 6.30 for Minichinda stream. Moreso, Obiri *et al.* [29], Chindah and Nduaguibe [25], Chindah [26] and Hart and Zabbey [11] to mention but a few workers reported similar pH ranges. The present pH range was also within the acceptable limit of International Standard. IJC [27] suggested a pH range of 6.5 to 9. The difference between the highest and lowest pH recorded was not up to 0.5 pH units. This is an indication that the various anthropogenic inputs did not alter the ambient pH. According to IJC [27], waste discharges should not alter the ambient pH by more than 0.5 pH unit. The narrow pH range recorded favours many chemical reactions inside aquatic organisms (cellular metabolism) that are necessary for their survival and growth [30]. The observed higher tidal influence at high tide on pH may be attributed to high inflow of seawater into the creek. The seawater pH ranges from 8.0 to 8.3 [19]. The seawater mixed with the creek water to increase its pH.

Conductivity is the ions capacity of the water and how these ions are be conducted or distributed. This ability depends on the presence of ions and on their total concentration, mobility and valence [6]. Carbonates and other charged particles increased the conductivity of a water body. It naturally increases towards the sea like salinity. The observed conductivity of this creek might be due to its brackish nature. The higher conductivity concentrations at high tide may be attributed to the high surge of water from the sea to the creek. However, the recorded conductivity in this study was in accordance with the observation of Praveena et al. [2] that conductivity at high tide was higher than at low tide.

The total dissolved solid is an index of the amount of dissolved substances from anthropogenic sources in a water body. The presence of such solutes alters the physical and chemical properties of water. The observed total dissolved solid load is higher than the recommended 1,001-10,000 mg/L for brackish water [19]. This is an indication of organic pollution from anthropogenic sources. The higher total dissolved solid concentration at high tide could be explained by the high organic matter discharges into the river and probably by the high sea influence on the creek.

The higher chloride at low tide could be linked to its significant positive correlation with salinity. Salinity was also high at low tide. It could further be attributed to reduce effects of municipal runoff and high evaporation rate of water from the creek at low tide. The mean chloride concentration in Okpoka creek agrees with the acceptable concentration of less than 19,000 mg/L in seawater though higher levels may occur [19]. Pillard et al. [31] reported mean values of 20,000 mg/L and 19,000 mg/L respectively for Amococadiz oil spill in United States of America. The mean magnesium concentration in this study exceeded that have been recorded in seawater (1000 mg/L). The tidal variation with higher values at low tide could be linked with higher salinity concentrations at this period. Salinity had positive relationship with magnesium in this study. Hardness of water from this creek is high based on the calcium and magnesium concentrations. The range of total hardness observed in this study is characteristic of brackish environment. Dambo [32] observed a range of total hardness from 3395.15 mg/L to 4710.23 mg/L for Lower Bonny Estuary. The present observation of water hardness is in agreement with these workers reports. Water with hardness less than 120 mg/L calcium carbonate can be deemed desirable for most uses, but only if hardness exceeds 500 mg/L can be labeled undesirable for both industrial and domestic uses [33]. The possible reasons for tidal variation of magnesium and calcium might be applicable for hardness concentrations in this creek.

The total organic carbon contains the dissolved and particulate organic carbon. The recorded range of total organic carbon concentrations was above the 1 to 30 mg/L for natural water. Higher levels in water indicate pollution and results from anthropogenic inputs [19, 34]. Water with less than 3.0 mg/L total organic carbon is said to be relatively clean [19]. However, the higher total organic carbon concentration at high tide is an indication of increased anthropogenic inputs in the creek. Also, the high tide introduced into the creek numerous organic materials. The total organic matter concentration is directly proportion to total organic carbon level in the creek. It had a very high positive correlation with total organic carbon. Based on this, the reasons for the observed tidal variation of total organic carbon levels might be appropriate for total organic matter concentrations in this creek.

High concentrations of calcium in water are relatively harmless to all organisms and may reduce toxicity of certain chemical compounds to fish. The observed calcium concentration in this study was higher than the expected concentrations in seawater, usually 400 mg/L [19]. The tidal variation with higher values at low tide might be traced to high salinity, water evaporation and transparency, and it was in agreement with Praveena et al. [2]. Alkalinity is the buffering (alkaline) capacity of the water. The range of alkalinity observed is characteristic of estuarine environment. Waters with high alkalinity are undesirable because of the associated excessive hardness or high concentrations of sodium salts. The reported alkalinity in this present study is within the acceptable range for natural surface water. Department of National Health and Welfare [33] recommended a acceptable range of 30 mg/L to 500 mg/L for natural waters. For the aquatic environment to be protected, guidelines stipulate that alkalinity must be maintained at natural background levels with no sudden variation [35]. The water of this creek is desirable for aquatic life and industrial uses as it has alkalinity above 30 mg/L. The results of alkalinity in this study are higher than the alkalinity levels reported by Obunwo et al. [28] for five streams in the Niger Delta. Generally, brackish water alkalinity is greater than freshwater alkalinity. The present observation of alkalinity agrees with those studies on estuarine environment [36]. The observed higher concentrations of alkalinity at high tide suggested that increased runoffs and discharges had increased the alkalinity of the creek.

4.2. Nutrients of Surface Water from Okpoka Creek

Nutrients availability especially phosphorus structures the algae assemblage [14, 17, 20, 23, 37]. Ammonia contributes to the fertility of water since nitrogen is an essential plant nutrient. It is also one of the most important pollutants in aquatic environment because of its relative high toxic nature and its ubiquity in surface water systems [38]. Ammonia enters natural water systems from several sources including industrial wastes, sewage effluents, coal gasification and liquefaction conversion process plants and agricultural discharge including feedlot runoff.

The study ammonia exceeded the concentration of less than 0.1 mg/L found in natural waters [19]. This possibly indicated anthropogenic and domestic inputs as also reported by Praveena et al. [2]. The mean ammonia concentration was also higher than the level of 0.02 mg/L unionized ammonia (NH_3) required for the protection of aquatic life [34]. Fish cannot tolerate large quantities of ammonia since it reduces the oxygen-carrying capacity of the blood and thus the fish may suffocate. The recorded range of ammonia in this creek was within the range of 0.093 mg/L to 2.65 mg/L reported by Chindah and Nduaguide [25] and Obunwo et al. [28] in the Niger Delta. However, tidal differences might be attributed to high discharges from municipal sources.

The observed mean nitrate was below the more than 100 mg/L expected to be found in natural surface water. Nitrogen is most often limiting in marine systems [39]. The reason being that molybdenum, phoshorus or energy constraint can be limiting to nitrogen fixers, which makes for lower nitrogen fixation [40]. There is also significantly higher denitrification in marine sediments. The low pH generally makes nitrate available to primary producers. This might be ascribed to the recorded nitrate level in the creek. The recorded high nitrate at low tide might be linked to low pH at low tide. The range of nitrate recorded in this study was below the statutory limit of 25–50 mg/L given by the European Economic Community (EEC) [41] and 20 mg/L United State Environment Protection Agency (USEPA) [42]. Nitrate does not pose a health threat but it is readily reduced to nitrite by the enzyme Nitrate reductase which is widely distributed and abundant in both plants and micro-organisms [43]. Nitrite causes cancer and methaemoglobinaemia (blue-baby syndrome) in human beings [19].

The recorded phosphate concentrations in this study were higher than the acceptable limit of 0.10 g/L in flowing waters as recommended by USGS [44]. This observation agreed with that of 0.43 to 3.52 mg/L of Chindah and Nduaguibe [25]. Praveena et al. [2] attributed the higher values of phosphate in the coastal waters of Port Dickson, Strait of Malacca, Malaysia to anthropogenic impact thus this could be the possible reason for the higher phosphate values in Okpoka Creek.

McNeely et al. [19] observed 2650 mg/L sulphate in seawater. The recorded sulphate was below the sulphate values in seawater, that is, within the acceptable levels. The observed higher sulphate at low tide could be attributed to the higher biological oxygen demand at this period. Oxidation of the organic materials and burning of fossil fuel used up oxygen thereby exerting higher biological oxygen demand in the creek.

5. Conclusion

Tides (low and high tides) have significant or insignificant influences on temperature, turbidity, transparency, salinity, DO, BOD, pH, TOC, TOM, conductivity, TDS, chloride, calcium, magnesium, hardness, alkalinity, ammonia, nitrate, phosphate and sulphate. The values of the measured physico-chemical parameters and nutrients were higher or lower at low tide for some parameters and vice versa. The recorded range of TOC concentrations at both tides was above the 1 to 30 mg/L for natural aquatic bodies. Phosphate and ammonia exceeded FEPA and USEPA acceptable levels of 0.01 mg/L for natural water bodies. Increasing anthropogenic wastes especially dredged materials, slaughter effluents and raw human faeces lead to high organic loads.

References

[1] Chapter 2: Physico-chemical characteristics of water bodies. http://www.ucl.ac.uk/~ucbt212/chapter2.htm.

[2] Praveena SM., Siraj SS, Aris AZ, Al-Bakri, NM, Suleiman AK, Zainal AA. 2013. Assessment of Tidal and Anthropogenic Impacts on Coastal Waters by Exploratory Data Analysis: An Example from Port Dickson, Strait of Malacca, Malaysia. Environmental Forensics, 14(2), 146-154.

[3] Davies OA, Ugwumba OA. 2013. Tidal influence on nutrients status and phytoplankton population of Okpoka Creek, Upper Bonny Estuary, Nigeria. Journal of Marine Biology, Volume 2013 2013, Article ID 684739, 16 pages http://dx.doi.org/10.1155/2013/684739.

[4] Davies OA, Tawari CC. 2010. Season and tide effects on sediment characteristics of Trans-Okpoka Creek, Upper bonny Estuary, Nigeria. Agriculture and Biology Journal of North America, 1(2), 89-96.

[5] Mitra A, Mondal K , Banerjee K. 2011. Spatial and Tidal Variations of Physico-Chemical Parameters in the Lower Gangetic Delta Region, West Bengal, India**.** Journal of Spatial Hydrology, 11(1), 52-59.

[6] American Public Health Association (APHA). 2001. Standard methods for the examination of water and waste water. American Public Health Association, Washington, D.C., pp. 1-874.

[7] Boyd CE. 1981. Water quality in warmwater fish ponds. 2nd ed. Alabama: Craftmaster.

[8] Statistical analysis system (SAS) 2003. Statistical analysis system. User's Guide SAS/STA-t version, 8th edition, Published by SAS Institute, Inc. Cary, N. C., USA.

[9] Rueda M. (2001). Spatial distribution of fish species in a tropical estuarine lagoon: a geostatistical appraisal. Marine Ecology progress Series, 222, 217–226.

[10] Chindah AC, Braide SA, Onwuteaka JN. 2005. Vertical distribution of periphyton on woody substrate in a brackish wetland embayment of Bonny River, Niger Delta. Niger Delta Biologia, 5(11), 97-108.

[11] Hart AI, Zabbey N. 2005. Physico-chemistry and benthic fauna of Woji Creek in the Lower Niger Delta, Nigeria. Environment and Ecology, 23(2), 361 – 368.

[12] Sikoki FD, Zabbey N. 2006. Environmental gradients and benthic community of the middle reaches of Imo River, South-Eastern Nigeria. Environment and Ecology, 24(11), 32 –36.

[13] Ajao EA. 1998. The influence of domestic and industrial effluents on the population of sessile and benthic organisms in Lagos Lagoon. PhD. Thesis. Dept. of Zoology. University of Ibadan. 411pp.

[14] Chrzanowski T H, Grover JP. 2001a. Effects of mineral nutrients on the growth of bacterio– and phytoplankton in two Southern reservoirs. Limnology and Oceanography, 46(6),1319 – 1330.

[15] Chrzanowski TH, Grover JP. 2001b. The light: nutrient ratio in lakes: a test of hypothesized trends in bacterial nutrient limitation. Ecology letters, 4,453-457

[16] Chrzanowski TH, Grover JP. 2005. Temporal coherence in limnological features of two Southwestern reservoirs. Lake and Reservoir Management, 21(1), 39-48.

[17] Roelke DL, Errera RM, Kiesling R, Brooks BW, Grover JP, Schwierzke L, UrenaBeck BW, Baker J, Pinckney JL. 2007. Effects of nutrient enrichment on *Prymnesium parvum* population dynamics and toxicity: results from field experiments, Lake Possum Kingdom, U.S.A. Aquatic Microbiology and Ecology, 46,125-140.

[18] International Association of Dredging Companies (IADC) 2007. Facts about turbidity. An information update from the IADC. Retrieved Sept. 29th, 2007, from http://www.iadc-dredging. Com/index.php?option=com_content &in\d=1088itemi.

[19] McNeely RN, Neimanis VP, Dwyer L. 1979. Water quality sourcebook: A guide to water quality parameters. Ottawa: Inland waters directorate, water quality branch.

[20] Chen,Y, Qin B, Teubner K, Dokulil MT. 2003. Long-term dynamics of phytoplankton assemblages: *Microcystis* – domination in Lake Taihu, a large shallow lake in China. Journal of Plankton Research, 25(4): 445 – 453.

[21] Asonye CC, Okolie NP, Okenwa EE, Iwuanyanwu UG. 2007.Some physico-chemical characteristics and heavy metal profiles of Nigerian rivers, streams and waterways. African Journal of Biotechnology, 6(5),617-624.

[22] Swann L.2006. A fish farmer's guide to understanding water quality in aquaculture. Retrieved Feb.20, 2006 from, http://www.aquanic.org.publicat/state/il-inas-503.html

[23] Frankovich TA, Gaiser EE, Zieman JC, Wachnicka AH. 2006. Spatial and temporal distributions of epiphytic diatoms growing on *Thalassia testudinum* Banks ex Köńig: relationships to water quality Hydrobiologia, 569,259-271.

[24] Sharipova MY. 2005. Changes in epiphyton of the Usolka River (tributary of the Belaya River) along a gradient of Salinity (Bashkortostan Russia). International Journal on Algae, 7(4), 374-387.

[25] Chindah AC, Nduaguibe U. 2003. Effect of tank farm wastewater on water quality and periphyton of Lower Bonny River Niger Delta, Nigeria. Journal of Nigerian Environmental Society, 1(2), 206 – 222.

[26] Chindah AC. 2004. Response of periphyton community to salinity gradient in tropical estuary, Niger Delta. Polish Journal Ecology, 52(1), 83-89.

[27] International Joint Commission (IJC) 1977. New and revised specific water quality objectives. Vol 11. Great Lakes Water Quality Board Report.

[28] Obunwo CC, Braide SA, Izonfuo WAL, Chindah AC. 2004. Influence of urban activities on the water quality of a fresh water stream in the Niger Delta, Nigeria. Journal of Nigerian Environmental Society, 2(2), 196 – 209.

[29] Obire O, Tamuno DC, Wemedo SA. 2003. Physico-chemical quality of Elechi Creek in Port Harcourt, Nigeria. Journal of Applied Science and Environment Management, 7, 43-49.

[30] California State Water Resources Control Board (SWRCB) (2004). Guidance compendium for watershed monitoring and assessment, version 2.0.Retrieved Aug.25, 2006, from http://www.swrcb.ca.gov/nps/volunteer.html.

[31] Pillard DA, Dufresne DL, Candle DD, Tietge JF, Evans JM. 2002. Predicting the toxicity of major ions in seawater to Mysid shrimp (*Mysidopsis bahia*, sheephead minnow (*Cyprinodom variegatus*) and inland Silverside Minnow (*Menidia deryllina*). Environmental Toxicology and Chemistry, 19(1),183-191.

[32] Dambo WB. 1992. Tolerance of periwinkles *Pachymelania aurita* (Muller) and *Tympanotonus fuscatus* (Linne) to refined oils. Journal of Environmental Pollution, 79, 293-296.

[33] Department of National Health and Welfare.1969.*Canadian Drinking Water Standards and Objectives* 1968.1st ed. Washington D.C.: MacGrawhill.

[34] Saad MAH, Amuzu AT, Biney C, Calamari D, Imevbore, AM, Naeve H, Ochumba, PBO. 1994. Domestic and industrial organic loads. *Review* of Pollution in the African Aquatic environment. Calamari, D. and Naeve H Eds. CIFA Technical paper, 23, 1-118.

[35] Environmental Studies Board 1973. Water quality criteria 1972. Committee of Water Quality Criteria, Environmental Protection Agency, Washington, D.C. EPA – R3-73-033.

[36] Chindah A,C Braide SA. 2001. Crude oil spill and the phytoplankton community of a swamp forest stream. African Journal of Environmental Studies, 2(1),1 – 8.

[37] Passy SI. 2007a. Diatom ecological guilds display distinct and predictable behaviour along nutrient and disturbance gradients in running waters. Aquatic Botany, 86,171-178.

[38] Thurston, R.V. and Russo, R.S.1981.Ammonia toxicity to fishes.Effect of pH on toxicity of the un-ionized ammonia species. *American Chemical Society* 15(7):837-842.

[39] Creswell J, Karasack R, Johnson R, Shayler H.2001.Nitrogen and phosphorus in Mill and Green ponds and the effects of nutrient enrichment. Macalester Environmental Review, 1-31.

[40] Vitousek PM, Howarth RW.1991.Nitrogen limitation on land and in the sea:How can it occur? Biogeochemistry, 13,87-115.

[41] European Economic Community (EEC) 1979. Council directive on the quality of freshwater needing protection or improvement in order to support fish life. *Offshore Journal of European Commununities* (L259):1-10.

[42] United States Environmental Protection Agency (USEPA) 2002. Water quality monitoring for Coffee Creek (Porter County, Indiana). Retrieved Sept. 29, 2006, from, http://www.USEPA/Research/Research.htm.modecode=62-28-00-00.

[43] Glidewell C 1990. The nitrate/nitrite controversy. Chemical Britanica, 26(2), 137-140.

[44] United States Geological Survey (USGS) (2007) Relation between selected water quality variables and climatic factors. Retrieved Sept. 12, 2006, from, http://www.pubs.water.usgs.gov/sir20075117.