Assessment of Temporal Fluctuations in Water Quality of the Coastal waters of Training Mole, Tarkwa Bay, Nigeria.

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Abstract: Hydrochemistry of the coastal waters of Training Mole, Tarkwa Bay was studied for a period of one year. The general water quality was found to be affected by a suite of physicochemical factors such as temperature, pH, salinity, BOD_5, DO, conductivity, precipitation, freshwater influx and nutrients (PO_4-P, NO_3-N and SO_4^{2-}). The environmental parameters were assessed monthly, compared seasonwise, and found to fluctuate with seasons. The general distributions of nutrients; PO_4-P, NO_3-N and SO_4^{2-} in raining season were within the range of 1.12-3.00mg/L, 6.95-10.00mg/L respectively compared to a range of between 1.24-2.30mg/L, 5.24-8.03mg/L and 20.10-26.30mg/L during the dry season for PO_4-P, NO_3-N and SO_4^{2-} respectively. The Principal Component Analysis (PCA) on dataset during the raining produced three significant principal components accounting for >75% cumulative variance in water quality; PC1, PC2 and PC3 contributed 59.78%, 18.78% and 16.10% variance in water quality respectively. During the dry season PCA likewise produced three significant PCs; PC1, PC2 and PC3 accounting for 54.10%, 27.38% and 13.03% variance in water quality respectively. Monthwise Cluster Analysis (CA) was used to discriminate the months with similar physicochemical behaviour. The study will be very useful for the determination of annual nutrient budget of Training Mole coastal waters and for the management of aquatic resources in the region.
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1. Introduction

The coastal waters of Training mole, Tarkwa Bay is a unique marine environment in the tropical belt with marked maritime influences due to proximity to the Gulf of Guinea. The complex dynamism in physicochemical characteristics of the coastal waters of Training Mole is related to riverine flow, upwelling, atmospheric deposition, vertical mixing and other anthropogenic sources. There is hardly any information available on the water quality characteristics of the coastal waters of Training Mole compared to other Bays along the Gulf of Guinea. The balance in the concentrations of bio-geogenic elements in coastal waters reflects the healthy status of the water, while their excess supply as observed in the shallow coastal ecosystem and upwelling areas has been found to trigger high primary productivity (Longhurst,1995 and Berger, 1989).

Nutrients are called biostimulants or fertilizers usually represented by the dissolved inorganic forms of nitrogen, phosphorus and silicon, utilized by photosynthetic organisms in the formation of organic matters (Saha, 2001 and Dutta, 2008). Nitrogen and phosphorus are described as being biolimiting elements because the concentrations of these elements limit biological growth (Ghosh, 1992 and Sundaray, 2005). In recent years, there are signs of eutrophications of Nigeria's coastal environments due to the release of nitrogen and phosphorus from excess fertilizers and sewage effluents (Ajao, 1990).

Understanding the behaviour of nutrients in coastal waters has important implications for global nutrient budget and controlling eutrophications of coastal ecosystems. Data gaps and research need to be filled in better characterization of physical factors including basic circulation, effects of weather patterns, climate change, and change in land use and resultant effect on nutrient delivery into the adjacent coastal waters.

In the present study, the distribution and seasonal variation of different physicochemical parameters such as pH, salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5) and nutrients (nitrate, phosphate and sulphate) were discussed. At present, there is no comprehensive coastal strategy to address the potentially worsening problems of estuarine and coastal nutrient enrichment in Nigeria. The results from the present study can provide the information necessary to guide the development of a comprehensive coastal strategy to reduce problems where they are presently observed and prevent further degradation of the Nigerian coastal waters.

2. Material and Methods

2.1 Description of the Study Area.

The rocky Moles of Tarkwa represent the only intertidal rocky shores in Nigeria. The rocky Moles of Tarkwa Bay were artificially constructed to protect the entrance of Lagos Harbour (Figure 1) which is one of the busiest commercial harbours in sub-Saharan Africa. The construction of the artificial breakwaters was more of economic purpose than to proffer solution to ecological problems (Nwankwo, 2004 and Ibe, 1993).

The study site lies on Latitude N06^{0}24′ 25.5″ and Longitude E003^{0}23′47.2″ along Training Mole of Tarkwa Bay, Lagos state, Nigeria (Figure 1). Training Mole was constructed with granitic boulders to bifurcate the East and West Mole. The construction of Training Mole in 1908 changed the natural configurations of the Tarkwa Bay beach to artificial assemblages of rocky shores. In all, the two principal seasons; raining and dry are experienced in the study area. The morphological structure of the environment is highly dynamic, where processes of erosion, accretion and deposition are active (Ibe, 1993 and Awosika, 1992). Anthropogenic influences are more pronounced at Training Mole compared to the other Moles due to human settlement, industries, tourists and unregulated sewage discharges.

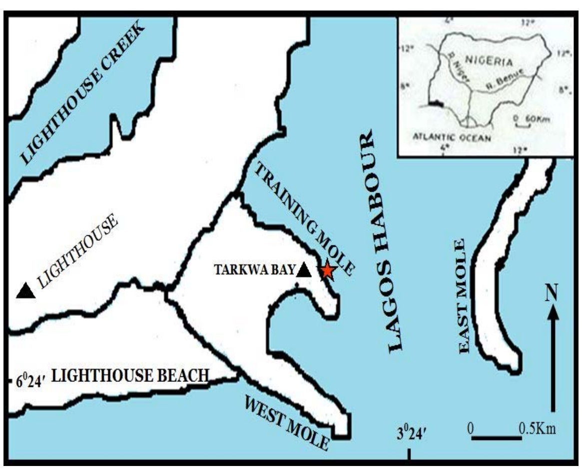

Figure 1: Map of the Study Area (the red star indicates location of the sampling station)

2.2 Collection of Water Samples.

Water samples for physical and chemical parameters determination were collected monthly from the sampling station in Training Mole at monthly interval from April, 2008 to March, 2009. The samples were collected during high tides in prelabelled polyethene bottles and later transported to the laboratory for storage and analyses (after APHA standard method, 1998).

2.3 Physicochemical Parameters Analysis.

The pH measurements were made using a portable pH meter (Perkin Elmer, accuracy ±0.01 after calibrating with NBS standard). Salinity was measured using an electrodeless induction type salinometer (DIGIAUTO model 3G, Tsurumi Seiki, Japan, accuracy ±0.001‰) after calibration with standard seawater. Dissolved Oxygen was analysed using the alkali-azide modification of Winkler's technique.

2.4 Nutrients Analyses.

Phosphate-Phosphorus (PO_4-P), Nitrate-Nitrogen (NO_3-N) and Sulphate ($SO_4{}^{2-)}$ in water samples was determined using portable datalogging spectrophotometer (HACH model) after reduction with appropriate solutions. Reagents used were of analytical grades and distilled water was used in preparation of all solutions in the laboratory.

3.0 Result and Discussions.

Descriptive statistics of the dataset for physicochemical variation in both raining and dry seasons are presented in Table 1 and Table 2. Sea surface temperature of the study station in raining seasons varied from 26.5^{0}C to 28.5^{0}C compared minimum and maximum value of 25.8^{0}C and 28.3^{0}C respectively during the dry season (Figure 2). The pH values did not show significant fluctuation during the present study with a range of 7.38 - 8.1 in the raining season and ranged between 7.0 – 8.08 in the dry season (Figure 2). The extensive buffering capacity of seawater may be the cause of change in pH within the narrow limit in the present study. As compared with other Bays along the Gulf of Guinea, tidal actions have a tremendous influence on the coastal waters of Training Mole (Ibe, 1988).

The salinity was optimum during the dry season (25.8‰ – 33.8‰) compared to a lower range during the raining season (21.95‰ -31.83‰). Salinity was influenced by continental run-off and high precipitation resulting to lower salinity values during the raining season (Figure 2).

The DO ranged between 4.6mg/L – 6.6mg/L during the raining season compared to a reduced range of 4.4mg/L – 6.1 mg/L in the Dry Season (Figure 4). Oxygenation in aquatic ecosystems is a result of an imbalance between the process of photosynthesis, degradation of organic matter, re-aeration (Aston, 1980) and oceanographic properties of water (Muller, 1988). During the present study, salinity was observed to be most important factors that controlled the level of DO in training mole coastal waters of Tarkwa. The concentration of DO in the raining season was large due to fresh water influx and photosynthetic products of water column algal species.

The range of BOD_5 in the dry season (3.0mg/L – 13.0mg/L) in the study area was higher compared to a minimum and maximum of 2.0mg/L and 4.0mg/L in the raining season respectively (Figure 4). The variation was a result of increased dilution and influx of fresh water during the raining season and sedimentation process during the dry season.

Table 1: Descriptive Statistics of Physicochemical parameters determined along Training Mole during the Dry Season (Apr, 08 - Mar, 09).

Parameters	Min.	Max.	Mean	S.E	S.D
Temp.	25.80	28.30	27.58	0.38	0.93
pH	7.00	8.08	7.51	0.19	0.47
Salinity	25.83	33.75	30.48	1.29	3.17
Conduct.	25.9	29.5	27.65	0.52	1.28
Sulphate	20.1	26.3	23.25	0.89	2.18
Phosphate	1.22	2.30	1.75	0.18	0.43
Nitrate	5.24	8.03	6.37	0.38	0.93
COD	7.80	21.80	12.05	2.06	5.05
DO	4.40	6.12	5.30	0.30	0.74
BOD_5	3.00	13.00	7.00	1.81	4.43

Table 2: Descriptive Statistics of Physicochemical parameters determined along Training Mole during the Raining Season (Apr, 08 -Mar, 09).

Parameters	Min.	Max.	Mean	S.E	S.D
Temp.	26.50	28.50	27.27	0.35	0.88
pH	7.38	8.10	7.79	0.11	0.28
Salinity	21.95	31.83	26.40	1.50	3.66
Conduct.	20.76	29.6	26.02	1.35	3.30
Sulphate	17.00	24.5	20.30	1.33	3.26
Phosphate	1.12	3.00	2.41	0.27	0.67
Nitrate	6.95	10.00	8.69	0.53	1.31
COD	7.50	21.3	14.94	2.61	6.39
DO	4.60	6.00	5.30	0.23	0.55
BOD_5	2.00	4-00	3.50	0.34	0.70

3.1 Seasonal Nutrient Dynamics

The assessment of nutrient levels at both seasons were significant ($P<0.05$). Phosphate values range between 1.12mg/L – 3mg/L in raining season, conversely, these values were lower in the dry season (1.22mg/L – 2.30mg/L). This was due to reduced erosive force and lower hydrodynamic forces during the dry season (Table 1, Table 2 and Figure 3).

The minimum (6.95mg/L) and maximum (10.0mg/L) value of nitrate in the raining season was higher compared to a range of between 5.24mg/L to 8.03 mg/L in the dry season(Table 1, Table 2 and Figure 3). The increase in nitrate value in the raining season is attributable to fresh water influx and predominantly the results of biologically activated reactions.

The range of sulphate in the raining season (17mg/L – 24.5mg/L) was lower compared to the dry season (20mg/L – 26.3mg/L) (Table 1, Table 2 and Figure 3). Temporal variation in sulphate in Training mole coastal waters can be attributed to several factors, more importantly the proportional physical mixing of seawater with freshwater (Ghosh, 1992), adsorption of reactive sulphate into suspended sedimentary particles in overlay waters (Praus, 2005) and biological removal by phytoplankton especially by diatoms and silicoflagellates (Dutta, 2008).

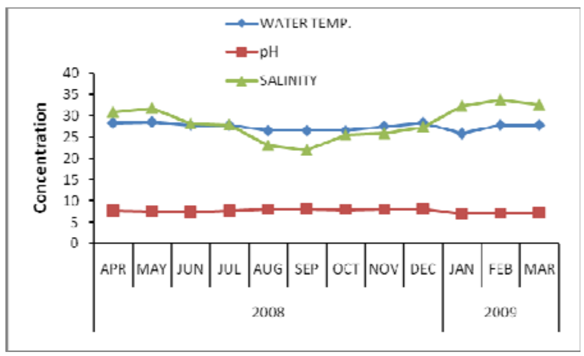

Figure 2: Variation in Temperature (^{O}C), pH and Salinity (‰).

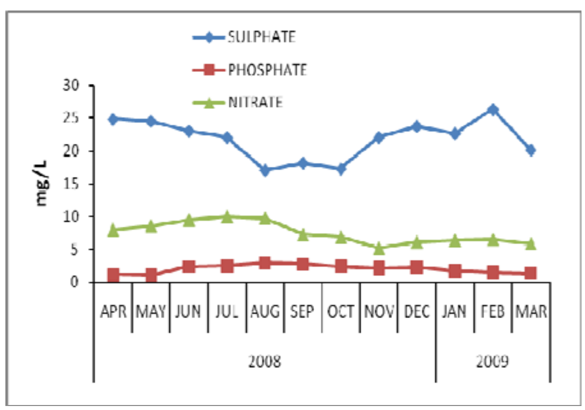

Figure 3: Variations in Nutrient (Sulphate, Phosphate and Nitrate).

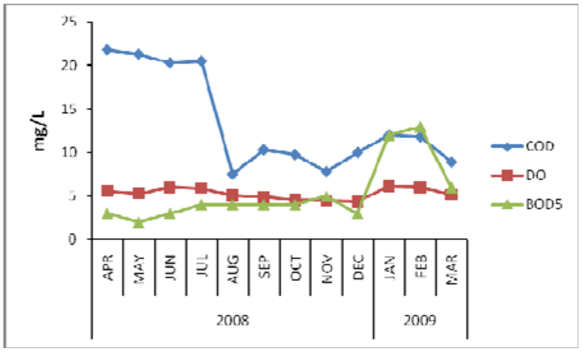

Figure 4: Variation in COD, DO and BOD_5

3.2 Statistical Analysis of Seasonal Variations of Physicochemical parameters.

3.2.1 Raining Season

Principal Component Analysis (PCA) was carried out on the dataset of physicochemical parameters obtained during the raining and dry season to determine which variable contributes significantly to the variation in water quality of the coastal waters of Tarkwa Bay. Principal Components (PCs) are associated with eigenvalues; an eigenvalue greater than 1 suggests that the corresponding PC contributes to the variance in water quality. PC loadings are either positive or negative; positive loading indicates that the contribution of the variables increase with increasing loading in dimension while a negative PC loading indicates a decrease (Aston, 1980).

PCA analysis on the dataset during the raining season resulted in 3 significant PCs (eigenvalues>1) contributing a cumulative variance of 96.44% to the water quality of the coastal waters of Tarkwa Bay during the raining season (Figure 5). PC1 contributed 59.78% of the total variance because of a strong positive loadings of temperature (0.988), pH (0.984), phosphate (0.843) and BOD_5 (0.865) compared to a strong negative loading of COD (-0.995), weak negative loading of salinity (-0.087), conductivity (-0.097) and moderate positive loading of DO (0.469), and nitrate (0.402). PC2 explains 18.78% of the total variance with a strong positive PC loading of nitrate (0.808) and a moderate positive loading of DO(0.440), sulphate (0.311) and weak loading of temperature (0.040), COD(0.031) compared to a negative loading of conductivity (-0.922), BOD5 (-0.099) and pH(-0.048). PC3 contributed 16% to the total variance in the water quality resulting from a strong positive loading of DO (0.729), weak positive loading of nitrate (0.351), BOD_5 (0.375), conductivity (0.327) and a moderate loading of phosphate (0.500) compared to a poor positive loading of temperature (0.101), pH (0.088), sulphate (0.090) and COD (0.082) and strong negative load of salinity (-0.960) (Table 5). PC1 attempts to describe nutrients variability while PC3 describes a decrease in salinization in the raining season due to increase in precipitation and consequently an increase in runoff from the continent during the raining season. The results of the Pearson correlation (Table 3) on the data matrix during the raining season show that rainfall was strongly correlated with DO(0.846) and conductivity (0.657) and moderately correlated with COD(0.582), weakly correlated with salinity (0.226), sulphate (0.475), phosphate (0.156), nitrate (0.473) and negatively correlated with pH(-0.719), BOD_5(-0.035). The positive correlation of dissolved nutrients with rainfall indicates a common allochthanous source, which means that the phosphate and nitrate content increases in low salinity water. The riverine water adds nutrients to the coastal waters of Training Mole during the raining season.

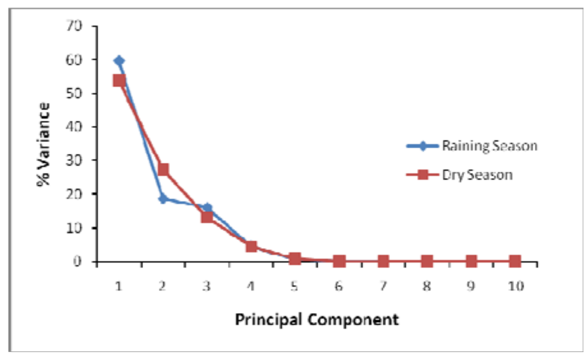

Figure 5: Scree plot between different Principal component and their corresponding percentage variance during the raining and dry season.

3.2.2 Dry Season.

Similar to the raining season, PCA on the data matrix during the dry season resulted in 3 significant PCs (eigenvalue > 1) contributing 94.50% cumulative variance in water quality of the coastal waters of Tarkwa Bay during the Dry Season (Figure 5). PC1 explains 54.10% of the total variance associated with strong positive loading of salinity (0.686), BOD5(0.849) with a moderate loading of DO (0.552) and strong negative loading of nitrate (-0.793), COD (-0.748) and poor negative loading of temperature (-0.148), pH(-0.256),conductivity (-0.258), sulphate (-0.135). PC2 accounts for 27.38% of the total variance in water quality because of strong positive loading of DO(0.771), salinity (0.686), COD (0.664) and a moderate loading of nitrate (0.570), BOD5 (0.497) and strong negative loading of water temperature (-0.985), pH (-0.987), conductivity (-0.831), phosphate (-0.798) and poor negative loading of sulphate (-0.185). PC3 contributed 13.03% of the total variance associated with a strong positive loading of sulphate (0.946) and low loading of phosphate (0.401), BOD5 (0.175) and pH (0.212) and negative loading of temperature (-0.004), conductivity (-0.040), DO (-0.141) and nitrate (-0.056) (Table 6). During this season, salinity was negatively correlated with rainfall (-0.22), phosphate (-0.77), weakly correlated with nitrate (0.43) and sulphate (0.20) (Table 4).

Table 3: Correlation Matrix between Physicochemical parameters during Raining Season.

	Temperature (°C)	pH	Salinity (‰)	Conductivity (mS/cm)	Sulphate (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)	COD (mg/L)	DO (mg/L)	BOD_5 (mg/L)	Rainfall (mm)
Temp.	1										
pH	-0.85	1									
Salinity	0.94	-0.79	1								
Conduct.	0.83	-0.86	0.81	1							
Sulphate	0.99	-0.88	0.90	0.87	1						
Phosphate	-0.79	0.50	-0.86	-0.58	-0.76	1					
Nitrate	0.44	-0.55	0.29	0.18	0.41	0.07	1				
COD	0.96	-0.89	0.88	0.93	0.97	-0.65	0.44	1			
DO	0.69	-0.85	0.51	0.68	0.73	-0.12	0.80	0.79	1		
BOD_5	-0.82	0.66	-0.82	-0.58	-0.81	0.93	-0.11	0.68	-0.30	1	
Rainfall	0.37	-0.71	0.23	0.66	0.48	0.16	0.47	0.58	0.84	-0.04	1

Table 4: Correlation Matrix between Physicochemical parameters during Dry Season

	Temperature (°C)	pH	Salinity (‰)	Conductivity (mS/cm)	Sulphate (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)	COD (mg/L)	DO (mg/L)	BOD_5 (mg/L)	Rainfall (mm)
Temp.	1										
pH	0.56	1									
Salinity	-0.25	-0.93	1								
Conduct.	0.16	-0.41	0.65	1							
Sulphate	0.26	-0.01	0.20	0.67	1						
Phosphate	-0.14	0.58	-0.77	-0.80	-0.21	1					
Nitrate	0.22	-0.16	0.43	0.94	0.57	-0.69	1				
COD	0.22	-0.04	0.28	0.87	0.52	-0.66	0.97	1			
DO	-0.50	-0.88	0.88	0.72	0.37	-0.68	0.53	0.44	1		
BOD_5	-0.65	-0.82	0.67	0.20	0.26	-0.18	-0.08	-0.19	0.76	1	
Rainfall	0.72	0.47	-0.22	0.06	0.40	0.25	0.10	-0.01	-0.44	-0.38	1

Table 5: Principal component loadings, Eigenvalues and percentage variance computed during the Raining season.

PRINICIPAL COMPONENTS	PC1	PC2	PC3	PC4	PC5
TEMPERATURE (^{O}C)	0.988	0.043	0.101	-0.093	0.056
pH	0.984	-0.048	0.089	-0.080	0.121
SALINITY (‰)	-0.087	0.116	-0.960	0.238	0.016
CONDUCTIVITY(mS/cm)	-0.097	-0.922	0.327	0.141	-0.119
SULPHATE (mg/L)	-0.764	0.311	0.090	-0.552	-0.083
PHOSPHATE (mg/L)	0.843	0.040	0.500	0.191	-0.017
NITRATE (mg/L)	0.402	0.808	0.351	0.233	-0.095
COD (mg/L)	-0.996	0.031	0.082	0.014	0.031
DO (mg/L)	0.469	0.440	0.729	0.153	-0.177
BOD_5 (mg/L)	0.865	-0.099	0.375	0.253	0.193
EIGENVALUE	4.212	1.623	1.402	0.452	0.064
%VARIANCE	59.78	18.78	16.10	4.57	0.75
CUMULATIVE VARIANCE	59.78	78.56	94.66	99.23	99.98

Table 6: Principal component loadings, Eigenvalues and percentage variance computed during the Dry season.

PRINCIPAL COMPONENTS	PC1	PC2	PC3	PC4	PC5
TEMPERATURE (^{O}C)	-0.148	-0.985	-0.004	0.056	-0.073
pH	-0.256	-0.907	0.212	0.255	0.044
SALINITY (‰)	0.686	0.336	-0.633	-0.122	0.026
CONDUCTIVITY(mS/cm)	-0.258	-0.831	-0.040	0.462	0.168
SULPHATE (mg/L)	-0.135	-0.185	0.946	-0.229	0.032
PHOSPHATE (mg/L)	0.149	-0.798	0.401	0.271	0.327
NITRATE (mg/L)	-0.793	0.570	-0.056	-0.046	0.202
COD (mg/L)	-0.748	0.664	0.015	0.021	-0.008
DO (mg/L)	0.552	0.771	-0.141	0.283	0.025
BOD_5 (mg/L)	0.849	0.497	0.175	0.045	-0.012
EIGENVALUE	4.411	2.438	1.296	0.451	0.110
%VARIANCE	54.09	27.38	13.03	4.48	1.01
CUMULATIVE VARIANCE	54.09	81.47	94.50	98.98	99.99

3.3.3 Cluster Analysis (CA).

Cluster analysis can be used as an important tool for analysing water quality data (Praus, 2005) to understand the relationship among seasons (months).

Monthwise CA was carried on the data matrix of physicochemical parameters using Ward's method to group months based on similarity distance. The result of the CA shows 2 clusters; clusters 1 comprising of the dry season months of Nov 08, Jan 09, Feb 09, Mar 09 and Apr 08 while cluster 2 comprises of the raining season month(Sep 08, Jun 08, Aug 08 and Oct 08) with the exception of Dec 2008 (Figure 6). The result of CA was able to discriminate physicochemical behaviour of the coastal waters of Tarkwa Bay into the two seasons operating in the study area; raining and dry season.

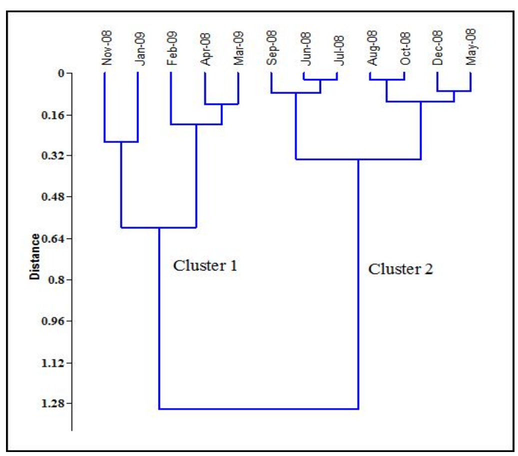

Figure 6: Monthwise cluster Analysis grouping month with similar physicochemical behaviour.

4.0 Conclusion.

The present study summarizes the seasonal fluctuations in physicochemical parameters in the coastal waters of the Training Mole. The result showed that the physicochemical properties of the Bay where significantly affected by fresh water influx during the raining season. The highest concentration for all the nutrients and DO were recorded during the raining season. Conversely, salinity and conductivity were at their minimum level during the raining season. The distribution of dissolved inorganic nutrients in this tropical coastal water may be very much influenced by factors like tidal and physical stirring by currents and benthic invertebrates as well as drainage discharged from industries and human settlement around the Training Mole. A significant increase in nitrate, phosphate, BOD_5 and conversely sulphate, DO and conductivity were noticed during the dry season in the present study. CA and PCA were able discriminates temporal variability and significant physicochemical variables contributing significantly to the variance in water quality respectively.

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