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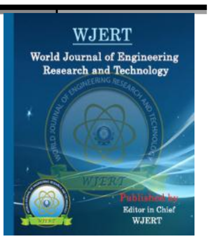

PHYSICOCHEMICAL ANALYSIS OF SURFACE WATER FOR POLLUTION SOURCE IDENTIFICATION IN THE WEST COAST OF CAMEROON: A DESCRIPTIVE AND MULTIVARIATE STATISTICAL APPROACH

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ABSTRACT

This longitudinal study assesses the seasonal variations in water quality for pollution source identification in the west coast of Cameroon using a combination of statistical techniques. A total of 13 physico-chemical parameters were collected in both the dry and wet seasons of 2017 from ten locations constituting three sampling sites (sea, rivers and springs) for analysis. Principal component analysis retained 12 significant parameters, yielding three principal components with $\lambda>1$, explaining 81.92 % of the total variance in the data sets. All the parameters were significantly correlated with seasons ($p<.01$) except pH. Mann-Whitney U-values for the parameters were found to be statistically significant with large differences between seasons: F^- ($U = 26.000$ ($Z = -3.343$: $r = -.68$), $p = .00$); pH ($U = 14$ ($Z = 3.860$: $r = .73$)), $p = .000$; SO_4^{2-} ($U = 22$ ($Z = 3.509$: $r = .66$), $p = .000$); and TDS ($U = 15$ ($Z = 3.814$: $r = .72$), $p = .000$). Discriminant analysis (independents entered together) further revealed a significant association between seasons and all predictors (Wilks $\lambda = .328$, Chi-square $= 23.981$, $df = 9$, Canonical correlation $= .82$, $p =.004$). Overall, the results revealed that while some parameters might be crucial in determining the fluctuation of pollutants for one season, the same parameter might be less crucial for another season. EC, Na^+, Mg^{2+}, F^-, Cl^-, NO_3^- and TDS were relatively higher in concentration than when compared with the WHO (2004) guidelines for drinking water quality and these abnormalities were common in in sea and rivers. This study demonstrates the usefulness of both descriptive and multivariate statistical techniques for analysis and interpretation of complex data sets. The results are important for necessary management decisions to control current and future pollution of receiving water bodies.

KEYWORDS: West coast of Cameroon, Water quality, physico-chemical parameters, Discriminant analysis; Principal component analysis.

INTRODUCTION

Water pollution has become a growing threat to human society and natural ecosystems in the recent decades. Access to safe drinking water is a fundamental requirement for effective primary health care and a precondition for success in fighting poverty, hunger, child mortality, gender inequality and environmental damage. Human and ecological use of water bodies therefore requires to be considered for both quantity and the quality (Chang, 2008). Water quality is important to assess the health of a watershed and to make necessary management decisions to control current and future pollution of receiving water bodies (Behbahaninia et al., 2009). The information on water quality and pollution sources is therefore important for implementation of sustainable water-use management strategies (Bu, et al., 2010).

Several countries have developed a series of monitoring programs and protocols to enable a reliable quantification of nutrient transport in the aquatic environment (e.g., the National Land with Water Information in Japan (Duan et al 2013; Luo et al 2011), the National Monitoring and Assessment Program in Denmark (Kronvang et al 2005), the Harmonized Monitoring Scheme in Britain (Morvan et al 2008), and the National Water-Quality Assessment in the United States (Rosen and Lapham, 2008), to generate a more comprehensive picture of water quality conditions and trends. Though these monitoring programs and protocols have served humanity and several ecosystems, they are often specific to the type of pollution or the geographical area involved and has difficulty in universal applications.

Long term surveys and monitoring programs of water quality are an adequate approach to a better knowledge of river hydrochemistry and pollution, but they produce large sets of data which are often difficult to interpret (Dixon and Chiswel, 1996). As a result, a number of approaches have been investigated for accurate interpretation of these data. Among the commonly used approaches include, water quality indices, WQI (e.g. Pesce & Wundelin 2000), univariate procedure (Dixon & Chiswell, 1996), neural networks (Bhat et al. 2013), and hydrological models (Altaf, Meraj, and Romshoo 2013). However, WQIs are often specific to the type of pollution or the geographical area involved (Rosenbeg & Resh, 1993), and do not provide evidences on the pollution sources (Pesce & Wundelin, 2000). Neural networks and hydrological models are often clouded with some degree of misinterpretations.

The problem of data reduction and interpretation of multiconstituents chemical and physical measurements can be approached through the application of multivariate statistical analysis. However, the nonlinear nature of environmental data makes spatio-temporal variations of water quality often difficult to interpret. In recent years, environmetric technics have been used to reveal the information which is concealed in the quality variables observed in water quality monitoring networks and avoid misinterpretation of large complex monitoring data (Simeonov et al . 2002). Multivariate statistical techniques have been applied to characterize and evaluate freshwater quality; they are useful in verifying temporal and spatial variations caused by natural and anthropogenic factors linked to seasonality (Singh et al., 2005; Shrestha and Kazama 2007).

In this study, the west coast of Cameroon was chosen for water quality assessment. In this region, large number of physical and chemical processes occurs as spring and river water mix with seawater throughout the year, altering water quality. The area also faces an increasing number of ecological problems due to the population increase, land-use change from forest to croplands and suffers from severe soil erosion, and the resulting rapid economic development. These problems lead to an excess of nutrients from industrial and municipal waste water as well as from forest and agricultural products. Nutrient loads discharge into the water bodies and cause eutrophication, which affects biological communities. Thus, there is a growing concern about the potential effects of extensive land-use change and resultant changes in hydrological conditions on the availability and quality of the water from this area. Therefore, this study attempts to facilitate the understanding of system behavior with respect to water quality issues and management within the area. Specifically, the research aims to:

- Identify key physicho-chemical pollutants structuring water quality in the west coast of Cameroon,
- Assess how these pollutants vary with respect to the different water bodies in the area and with respect to seasonal changes using a combination of statistical approaches, and

- Identify water bodies whose pollutant levels meet the limits set aside by WHO inorder to reduce potential impacts of water borne diseases in the area.

MATERIALS AND METHODS

Study Area

The West Coast of Cameroon is located on the south western flank of mount Cameroon in the South West Region of Cameroon. It lies between latitude 4^0 4′ 17″ N and longitude $9^0$3′80″E. The study area runs from Bakingili $4^0$4′17″N and $9^0$2′28″E to Idenau/Sanje 4^0 12′ 36″N and $9^0$3′80″E. It is bounded to the north by Bamusso, to the east by the Cameroon Mountain and to the south by the Atlantic Ocean (Fig.1).

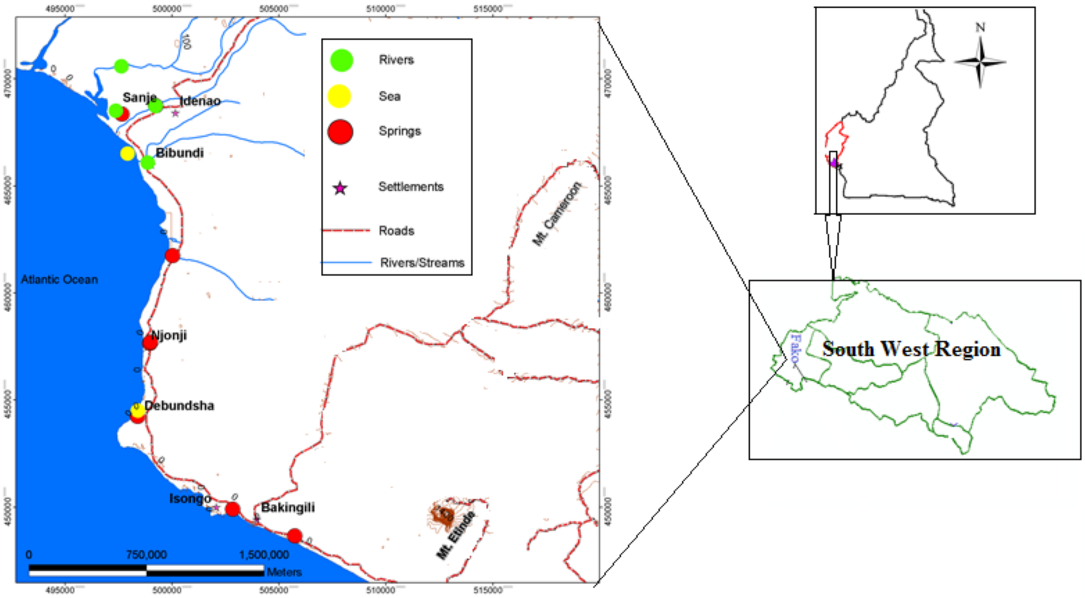


Figure 1: Location of Study Area.

The western slope is probably the most diverse and richest area of the mountain and appears to be the only area in West and Central Africa where there is an unbroken vegetation gradient from evergreen lowland rainforest at sea-level, through montane forest, to montane grassland and alpine grassland near its summit. This link between ecosystems largely accounts for the biological diversity of the region.

The rich volcanic soils, coupled with the accessibility of the area by road and waterway accounts for increasing immigration into the area. The area is inhabited by a population of about 300,000 persons, 75 percent dependent on exploitation of land and forest resources for their livelihood and health care. Only 23% of the population is autochthon: Bakweri and Bomboko.

There is a period of heavy rains occurring between the months of June and October, and a dry period extending from November to May. Idenau receives an annual average precipitation of 8392 mm while Debundscha (the second wettest place in the World) receives 9086 mm (Frasèr et al., 1997). The mean air temperature is 26.78 ^{0}C, with monthly values ranging from 24.98 ^{0}C in August, the rainiest month, to 28.1^{0}C in February. The stream passes through a large area of high socioeconomic importance to region. The stream serves as a life line of this vast area as it serves as a source of water for both domestic and agricultural purposes. The current study is therefore a step forward in addressing the deteriorating conditions of water resources so as to recommend concrete measures for its sustainable management.

Sampling

Spatial variation in water quality is one of the main features of different types of water bodies, and is largely determined by the hydrodynamic characteristics of the water body. Water quality varies in all three dimensions which are further modified by flow direction, discharge and time. Consequently, water quality cannot usually be measured in only one location within a water body but may require a network of sampling sites. In this regard, this longitudinal study collected a total of 28 monthly water samples (14 samples per sampling period) from different sites (springs, rivers and sea water) from the dry season (January to March), and the rainy season (June to August) of 2017 from Sanje to Bakingili (Table 1).

Table 1: Distribution of samples according to sites.

ID	Location	Number of samples	Source of sample
S01	Sanje	1	spring
S02	Soden Camp	1	river
S03	Rochtfluss	2	Spring, River
S04	Idenau	2	River, Sea
S05	Bibundi	1	River
S06	Isobe	1	spring
S07	Njonji	2	spring
S08	Debundscha	2	Spring, sea
S09	Wete-wete	1	spring
S10	Bakingili	1	spring
	Total	14	

The samples collected were made up of the following physico-chemical parameters: pH, temperature (^{0}C), Sodium ions(Na^+, mg/L), Potassium ions (K^+, mg/L), Magnesium ions (Mg^{2+}, mg/L), Calcium ions (Ca^{2+}, mg/L), Fluorides(F^-, mg/L), Chlorides (Cl^-, mg/L), Nitrate Nitrogen (NO_3-N, mg/L), Sulphates (SO_4^{2-},mg/L), Bicarbonates (HCO_3^-,mg/L), Total

Dissolved Solids (TDS, mg/L), and Electrical Conductivity (EC, µS/cm). Temp, pH and EC were measured with a portable millimeter in the field. All other parameters were determined in the laboratory according to standard protocols (APHA, 1998). Samples were collected into 750mL pre-washed (distilled water) polyethylene bottles and each labeled according to their geo-spatial location/sites and transported to the CBC COMPLEX (PLANTICAM) at Ekona, South western Cameroon. All sampling sites selected can cover a wide range of whole determinants at key sites, which reasonably represent hydrological characteristics of the area. Because collected samples can be contaminated by inadequately or inappropriately cleaned glassware, filters, filter apparatus, chemicals used for preservation, great care was taken in the cleaning of equipment using deionize water and in the checking for purity of chemicals used. In particular, the sampling, preservation, transportation as well as analysis of these water samplings followed standard methods (ASTM, 2001). Because of the spatial-temporal variations in hydrochemistry of rivers, it was necessary to sample regularly for reliable estimates of the water quality.

Data Analyses

Seasonal variations of the water quality parameters were first evaluated through season-parameter correlation matrix, using the Spearman correlation coefficient (Spearman r). To do this, a specific integer number was assigned to each season (Dry = 1, wet = 2). Then Spearman correlation was established between all of the water quality parameters and the ordinal variables. Descriptive statistics using graphs and tables was used to show how the water quality parameters vary with seasons and with sampling sites. The distribution free test, Mann-Whitney U test was used to determine if there was any significant difference in concentration levels of the parameters between the seasons. Multivariate statistical techniques including discriminant analysis (Shrestha and Kazama, 2007), principal component analysis (PCA, Deb et al., 2008) were also employed to identify the possible factors / sources that influence water quality, and to further explain seasonal variations and interpretation of water quality data set. In order to minimize the influences of different measurement units and variance of variables and to turn into the data dimensionless, all log-transformed datasets were z-scale standardized (the mean and variance were configured to 0 and 1, separately) before PCA was conducted. A discriminant analysis (DA) was conducted to determine whether pollutant concentrations discriminate between seasons and sampling sites or not. Predictor variables (water-quality data set) were those retained from PCA. In the DA, the seasons (and sampling sites) were considered as temporal grouping variables. These grouping variables were used in the analysis as dependent variables, while the water quality parameters were considered independent variables. DA was performed to determine the most significant water quality parameters associated with the differences between the seasons. All mathematical and statistical computations and graphical displays were made using SPSS package version 21.0.

RESULTS AND DISCUSSION

Identification of potential pollution sources in sampling sites

Principal component analysis was carried out to extract the most important physicochemical parameters affecting the water quality. Initially, the factorability of the 13 parameters was examined. All 13 parameters correlated at least .3 with at least one other item, suggesting reasonable factorability. Secondly, the Kaiser-Meyer-Olkin measure of sampling adequacy was .539 (miserable), which is adequate though below the commonly recommended value of .6, and Bartlett’s test of sphericity was significant (χ^2 (66) = 755.663, p = .000< .05), indicating that the correlation matrix is significantly different from an identity matrix, in which correlations between variables are all zero. The diagonals of the anti-image correlation matrix were also all over .5. Finally, with the exception of temperature, all the other parameters had communalities that were greater than .3. Given these overall indicators, factor analysis was deemed to be suitable with 12 parameters. PCA was performed on the normalized data sets containing 12 variables, separately for four different seasons, to compare the compositional pattern between water quality parameters and to identify the factors influencing them. PCA yielded three PCs with eigenvalues > 1, explaining more than 81.92 % (PC1 = 49.963%; PC2 = 21.36% and PC3 = 10.60%) of the total variance in respective water quality data sets. An eigenvalue gives a measure of the significance of the PC; thus the PCs with the highest eigenvalues are the most significant. Eigenvalues of 1.0 or greater are considered significant (Shrestha and Kazama, 2007). The Scree Plot (Fig. 2) shows the initial Eigenvalues.

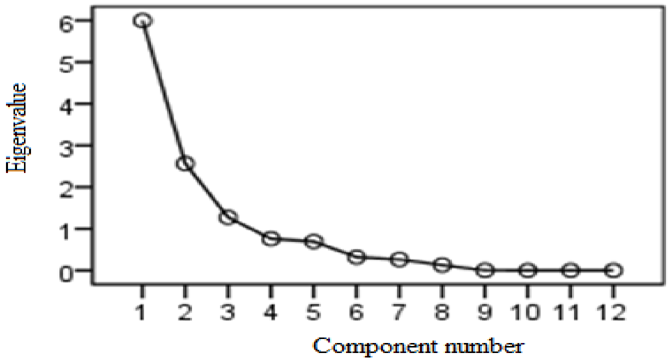


Figure 2: Scree plot for the initial Eigenvalues.

The scree plot flattens out after the second component. However, the third component is very poorly defined, relating only to one variable. Both the scree plot and the eigenvalues support the conclusion that these 12 variables can be reduced to three components. Three components were rotated, based on the eigenvalues over 1 criterion and the scree plot. After rotation, the first factor accounted for 42.04% of the variance, the second factor accounted for 28.992%, and the third factor accounted for 10.889%. Table 2 displays the parameters and factor loadings for the rotated factors.

Table 2: Rotated Component Matrixa.

Parameters	**Components**		
	1	**2**	**3**
Ca^{2+}	**0.609**	**0.722**	0.124
Cl^-	**0.878**	0.013	-0.061
EC	**0.876**	0.247	0.099
F^-	0.019	**0.832**	-0.106
$HCO3^-$	0.089	**0.877**	-0.017
K^+	**0.744**	**0.632**	0.093
Mg^{2+}	**0.928**	0.256	0.015
$N03^-$	0.073	**0.92**	0.113
Na^+	**0.927**	0.144	0.05
pH	-0.004	-0.169	**0.802**
$SO4^{2-}$	0.082	0.194	**0.772**
TDS	**0.918**	-0.194	0.055
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 4 iterations.			

Classification of factor loading is ‘strong’, ‘moderate’ and ‘weak’, corresponding to absolute loading values of > 0.75, 0.75-0.50 and 0.50-0.30, respectively (Liu et al., 2003)

The first principal component is strongly correlated with seven of the original variables. The first principal component increases with increasing Mg^{2+}, Na^{+}, K^{+},TDS, Cl^{-} , EC and Ca^{2+} scores. This suggests that these seven parameters vary together. If one increases, then the remaining ones tend to as well. The second principal component increases with five of the values with Ca^{2+} being more correlated than in the first component, while the third principal component increase with pH and SO_4^{2-} (Fig. 3).

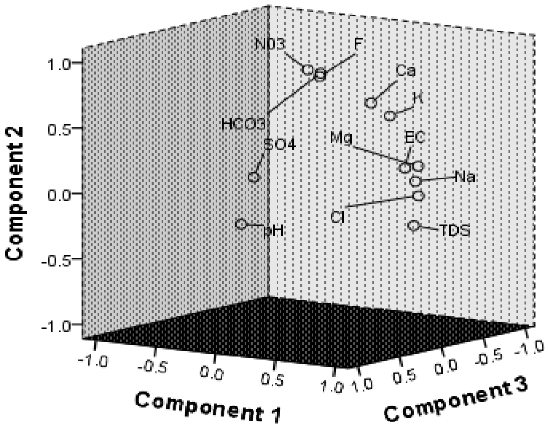


Figure 3: Loadings of the water quality parameters on the principal axes.

Seasonal variations of water quality parameters

Evaluation of seasonal variations in water quality parameters through season-parameter correlation matrix showed that except pH, all other parameters are significantly correlated at p<.01(Table 3).

Correlation matrix of water quality for wet and dry seasons

Table 2: Dry season.

	pH	**EC**	**K^+**	**Na^+**	**Mg^{2+}**	**Ca^{2+}**	**TDS**	**F^-**	**Cl^-**	**NO_3^-**	**Temp**	**SO_4^{2-}**	**HCO_3^-**
pH	1												
EC	.302	1											
K^+	.247	**.900**	1										
Na^+	.262	**.876**	**.582**	1									
Mg^{2+}	.282	**.997**	**.881**	**897**	1								
Ca^{2+}	.216	**.800**	**.982**	.417	.775	1							
TDS	.388	.449	.141	**.620**	. 421	-.001	1						
F^-	.444	**.765**	**.686**	**.616**	**.715**	**.610**	**.772**	1					
Cl^-	.294	**.998**	**.922**	**.850**	**.993**	**.831**	.405	**.753**	1				
NO_3^-	.257	**.678**	**.909**	.246	**.631**	**.954**	.065	**.685**	**.710**	1			
Temp	.318	**.625**	**.825**	.219	**.64**	**.63**	.244	.794	.649	.968	1		
SO_4^{2-}	.301	**.998**	**.920**	**.852**	**.993**	**.829**	.417	**.763**	**.99**	**.711**	**.654**	1	
HCO_3^-	..487	.457	.408	.376	.440	.368	.379	**.513**	.442	.370	.406	.448	1

Table 3: Wet season.

	pH	**EC**	**K^+**	**Na^+**	**Mg^{2+}**	**Ca^{2+}**	TDS	**F^-**	**Cl^-**	**NO_3^-**	**Temp$^-$**	**SO_4^{2-}**	**HCO_3^-**
pH	1												
EC	-.290	1											
K^+	-.274	**.977**	1										
Na^+	-.275	**.973**	**.998**	1									
Mg^{2+}	-.290	**.937**	**.997**	**.999**	1								
Ca^{2+}	-.295	**.961**	**.995**	**.997**	**.999**	1							
TDS	-.416	.351	.336	.307	. 347	.350	1						
F^-	.100	-.131	-.151	-.131	-.149	-.160	-.393	1					
Cl^-	-.287	**.909**	**.935**	**.910**	**.913**	**.913**	.478	-.262	1				
NO_3^-	-.089	.576	.479	.519	.510	.483	.158	.201	.185	1			
Temp$^-$	.044	.031	-.038	.027	-.028	-.054	.053	-.160	-.009	-.086	1		
SO_4^{2-}	-.276	**.990**	**.996**	**.993**	**.992**	**.986**	.333	-.157	.932	.512	.(a)	1	
HCO_3^-	-.086	.073	.087	.063	.047	.045	-.173	.386	.198	-.209	.(a)	.076	1

NB: All correlations >=.5aresignificant at .01 level of significance while those between .4 and .5 are significant at the .05 level.

Discriminant analysis (independents entered together) revealed a significant association between seasons and all predictors (Wilks λ = .328, Chi-square = 23.981, df = 9, Canonical correlation = .82, p =.004). Furthermore, Mann-Whitney U-values for the parameters were found to be statistically significant with large differences between seasons: F^- (U = 26.000 (Z = -3.343: r = -.68), p = .00); pH (U = 14 (Z = 3.860: r = .73)), p = .000; SO_4^{2-} (U = 22 (Z = 3.509: r = .66), p = .000); and TDS (U = 15 (Z = 3.814: r = .72), p = .000. Seasonality in various water quality parameters could be explained in terms of seasonal variations in hydrologic characteristics associated with the wet and dry seasons. In the dry season for example, high tides from the sea, runoff and river inflow from upstream have decreasing trends and there is an increasing trend for salt water intrusion which mainly appears in the junction of rivers and oceans from October to the following March.

Overall, samples collected during the rainy season had lower concentrations at all locations than those collected during the dry season and these values were highest at sea sites and lowest at spring sites (Fig. 4).

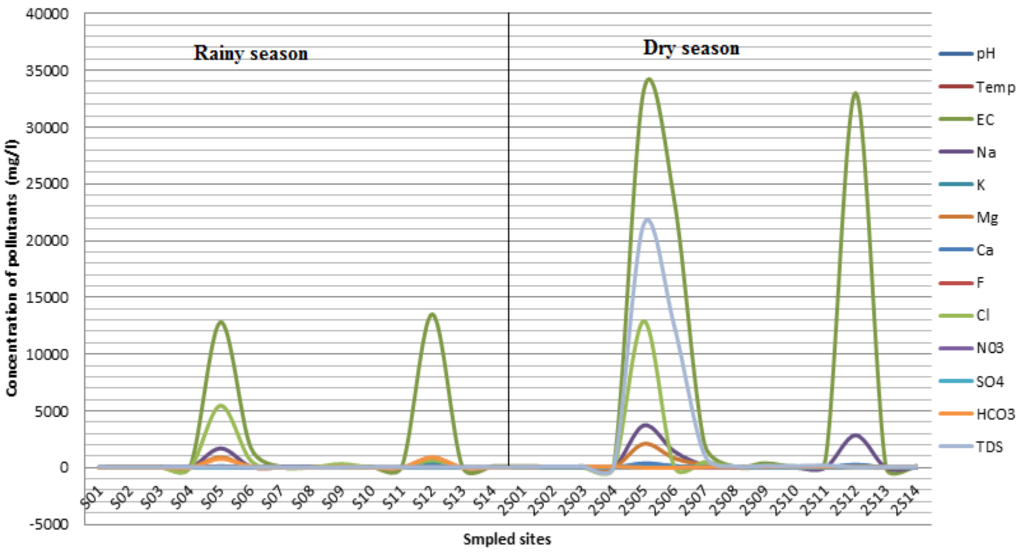


Figure 4: Variation of water quality concentration parameters levels with sampling sites.

S05, S12, 2S05 and 2S12 correspond to sea sampling sites and are sites of high EC, Cl^- and Na^+. While sites S05-S06, that is, the Rochtfluss River, Idenau (sea), Idenau (River) and Bibundi (River), showed relatively higher levels of pollutants, sites SO1-SO3, SO7-S10, corresponding to springs had relatively the lowest.

As it can be seen in Figure 4, highest values of EC, $Cl^-$and SO_4^{2-} were observed in the dry season and lower values in the rainy season. These parameters are reactive components that are partially of anthropogenic origin (Khazheeva et al., 2007). EC qualitatively reflects the status of inorganic pollution and is a measure of TDS in waters (McCutcheon et al., 1993). High EC values are observed as a result of decreased rainfall /discharge and increased agricultural land-use and built-up intensity in the river catchment. Higher Cl^- concentrations in the dry season could indicate the hydrologic effect and anthropogenic pollution with NaCl, as observed in comparison with the Na^+ concentrations. Dissolved SO_4^{2-} can be derived from the dissolution of sulphate minerals; oxidation of pyrite and other forms of reduced S; oxidation of organic sulfides in natural soil processes; and anthropogenic inputs (Grasby et al., 1997). Sulphur-based fertilizers are not commonly used in the west coast of Cameroon and plausible origin of SO_4^{2-} in water could be either as a result of sea transportation or weathering of the sedimentary rocks. Hence, seasonal variations of dissolved SO_4^{2-} could be attributed to either the rate of surface/spring water recharge by the sea, or changes in the intensity of weathering process.

Similar pattern in seasonal variation of HCO_3^- is possibly due to dissolution of minerals such as calcite and dolomite through HCO_3^- weathering process. This process is represented by the following simplified reaction (Cai et al., 2007):

$CaCO_3 + CO_2 + H_2O \leftrightarrow Ca^{2+} + 2HCO_3^-$

The reaction of HCO_3^- minerals with dissolved carbon dioxide releases HCO_3^- and Ca^{2+}in the water bodies.

Variation in water quality parameters with sampling sites

On average, springs had relatively the lowest concentrations of water quality parameters while the sea sites had the highest (Fig. 5).

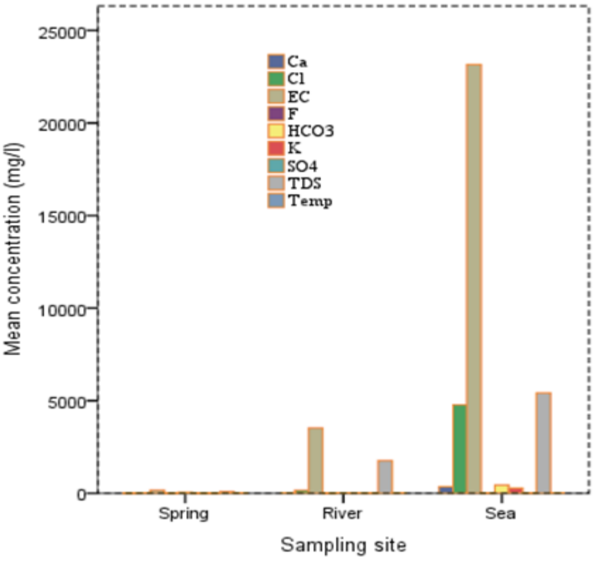
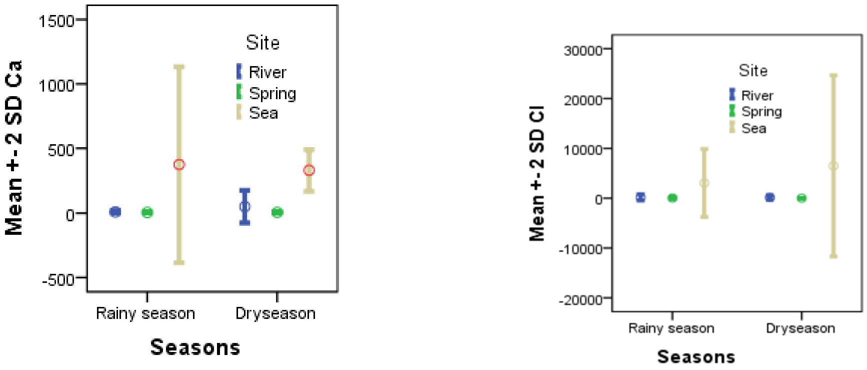
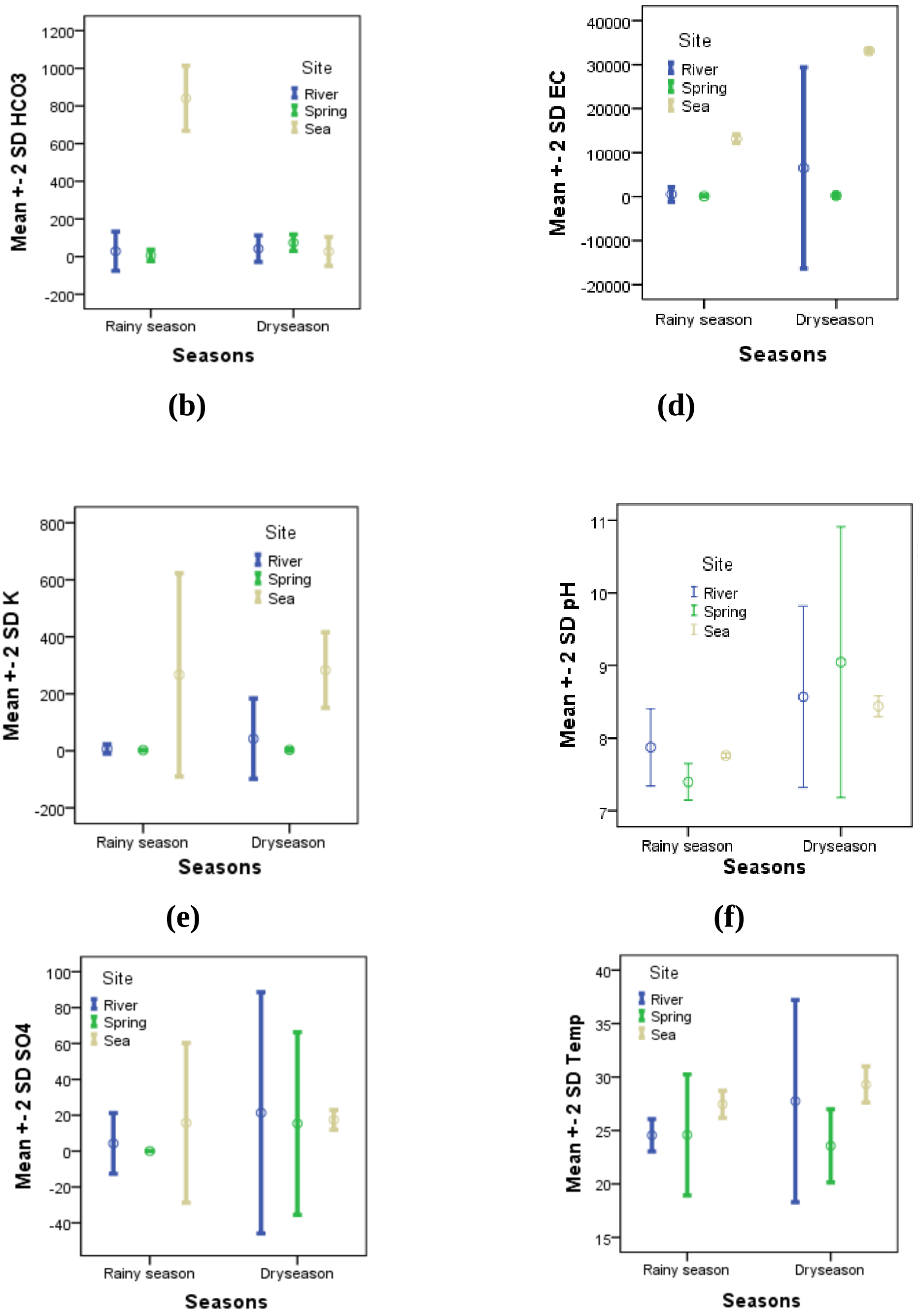


Figure 5: Spatial distribution of water quality parameters according to sampling site.

Descriptive statistics using clustered error bars (Fig. 6a-h) further provided more evidences not only on the effect of seasonality but of sampling sites.



(a) **(b)**



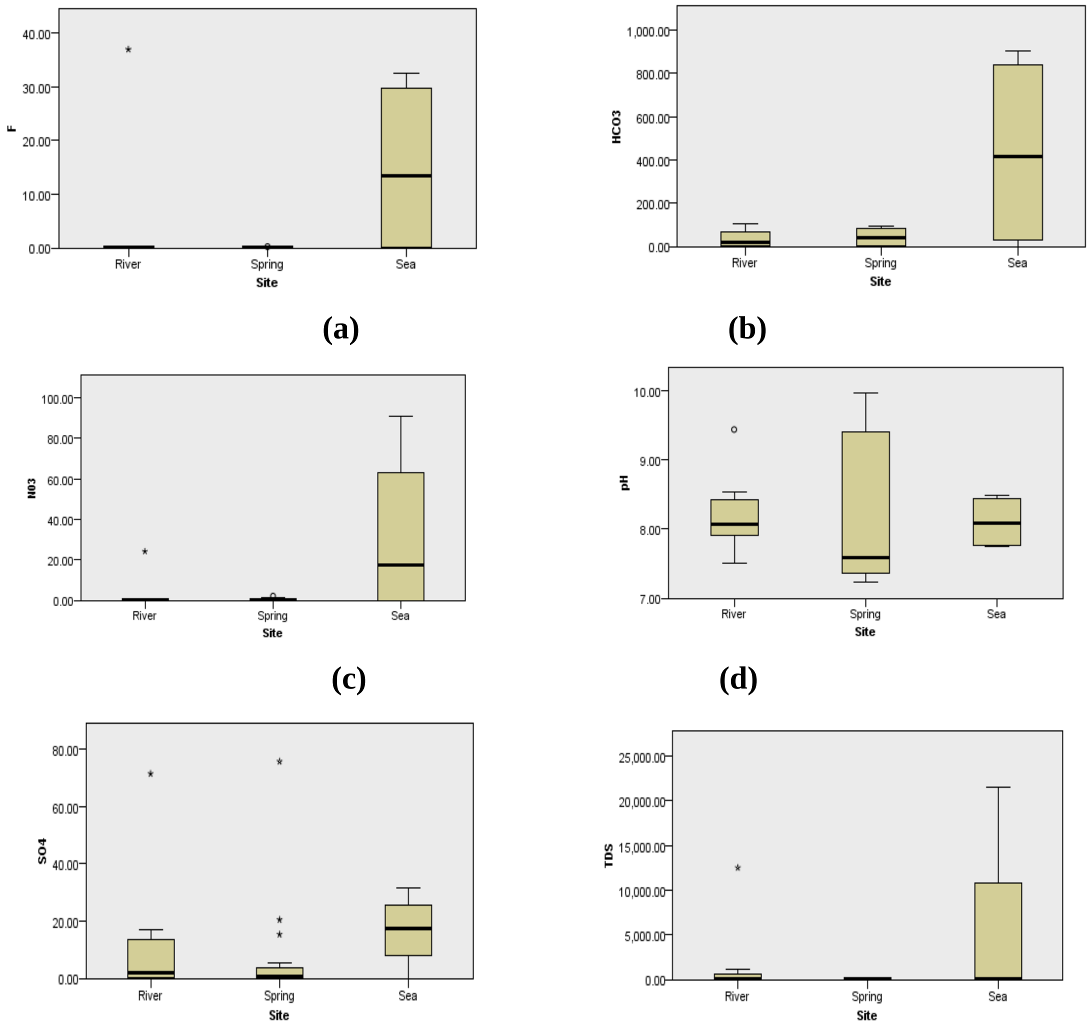
(b) **(d)**

(e) **(f)**

(g) **(h)**

Figure 6a-h: Relationship between water quality parameters with seasons and sampling sites.

Furthermore, discriminant analysis was used to conduct a multivariate analysis of variance test of the hypothesis that springs, rivers and sea differ significantly on a linear combination of the physic-chemical parameters. The overall Chi-square test was significant (Wilks λ = .003, Chi-square = 120.983, df = 18, Canonical correlation = .998, p <. 001). The value, Wilks λ = .003 is close to 0 indicating that almost all of the variability in the discriminator variables is due to site differences. The chi-square test based on lambda indicates whether the variability that is systematically related to site differences is statistically significant. The high canonical correlation indicates that the function discriminates well. The discriminate function accounted for 99.6% of the variance in water quality parameter, confirming the hypothesis. However, the mean concentrations of certain parameters did not differ significantly among the sampling sites (Fig. 7a-f).



(a) **(b)**

(c) **(d)**

(e) **(f)**

Figure 3: Figure 7a-f: Variations of physico-chemical parameters of the west coast of Cameroon with sampling sites from January to December 2017: a) F^- b) HCO_3^- c) NO_3^- d) pH e) SO_4^{2-} f) TDS.

Similar seasonal variation in concentration of water quality parameters had been reported in the Fuji river basin, Japan by Shrestha and Kazama (2007). The higher correlations in the wet seasons might be induced by run offs and floods which often sweep waste materials and fertilisers and inflow of other pollutants from the sea (Atlantic Ocean). In this region, precipitation is different in dry and wet seasons, (except in Debundscha where rainfall is very high and almost constant throughout the year), there is a large amount of rainfall in wet season from April to September, but little from October to March. The changes of river water discharge are mostly related to rainfall in this region.

Comparison of physico-chemical parameters with WHO limits

EC, Na^+, Mg^{2+}, F^-, Cl^-, NO_3^- and TDS were relatively higher in concentration than when compared with the WHO (2004) guidelines for drinking water quality and these abnormalities were common in in sea and rivers (Fig. 8).

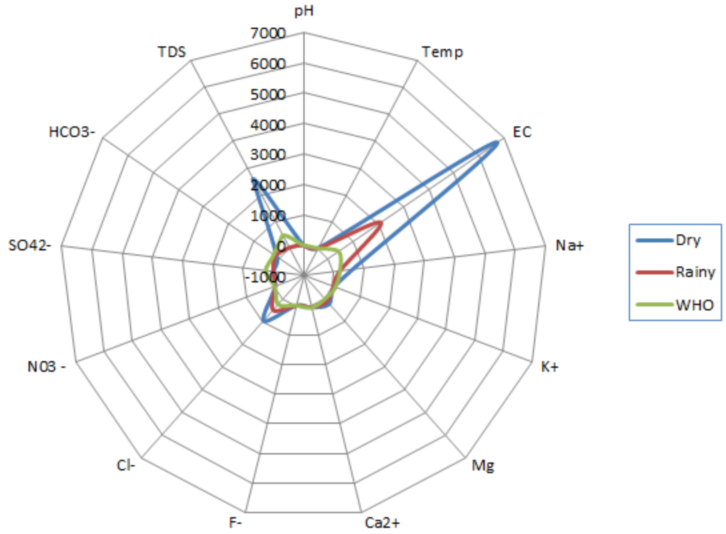


Figure 8: Field water quality compared with WHO limits.

Chlorides are common constituents of all natural waters (Kataria et al. 2004) and levels in excess (>250 mg/L) imparts a salty taste to water and have laxative effect on consumers (WHO 2004). The mean concentrations of 974.89mg/l (in the dry season) and 504.53 mg/l in the rainy season suggest that water resources in the area might be recharged by sea waters. In fresh waters the sources could include soil and rock formations and waste discharges. Because sewage is such a rich source of chloride, a high result may indicate pollution of water by a sewage effluent.

The mean EC values ranged from 6718.12 µS/cm in the dry season to 2084.00 µS/cm in the rainy season. This is probably because of the high concentrations of fluorides, chloride, nitrate, sulfate, anions (negative ions) and the sodium, magnesium, calcium cations (positive ions). Health studies have shown that the addition of fluoride to water supplies in levels above 0.6 mg/l F leads to a reduction in tooth decay in growing children and that the optimum beneficial effect occurs around 1.0 mg/l. At levels markedly over 1.5 mg/l an inverse effect occurs and mottling of teeth (or severe damage at gross levels) will arise.

Relatively little concentration of nitrates (2.88 mg/l in the dry season and 8.75 mg/l in the rainy season) were found. Higher values were recorded in river and sea waters. The presence of nitrates could be of mineral origin, most coming from organic and inorganic sources, the latter including waste discharges and the latter comprising chiefly artificial fertilisers. In rivers high levels of nitrates could be the result of run-off from the agricultural dominant lands or bacterial oxidation and nitrogen fixation by plants. High nitrate levels in fresh or potable waters could be hazardous to infants as they could be converted to nitrites, which then react with blood haemoglobin to cause methaemoglobinaemia and cyanosis (Nkansah et al. 2010).

Similarly, recorded levels of fluoride also fell below WHO limit. Fluoride has a significant mitigating effect against dental caries. However, continuous consumption of higher concentrations in the order of 4 mg/L or more can cause dental fluorosis(WHO 1993) and in extreme cases even skeletal fluorosis.

With the exception of Ca^{2+} (65.07mg/l in dry season and 59.13mg/l in rainy season) the concentrations of Mg^{2+}**(**244.12mg/l in dry season and 135.66mg/l in rainy season), Na^{+}(592.31mg/l in dry season and 177.40mg/l in rainy season**),** K^{+} (54.31mg/l in dry season and 41.24mg/l in rainy season) were far above the recommended limits set by the WHO. The presence of these cation exchange parameters The utility of water for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 250 mg/l SO_4^{2-}.

The effect of temperature, and especially changes in temperature, on living organisms can be critical and the subject is a very wide and complex one. Increase temperatures may favour rates of chemical reactions, increase solubility of certain solutes, increase electrical conductivity because of more dissolved constituents, and increase the toxicity of some compounds. Steep temperature gradients can have directly harmful effects on fish. It is for the latter reason that changes in temperature are subject to limits.

On average, TDS ranged from 2592.9 mg/l in the dry season to 45.69 mg/l in the rainy season. The mean value in the dry season is far above the mean value of 1000 mg/l recommended by WHO. Drinking water containing TDS levels above 500mg/l usually has a disagreeably strong taste (Apau et al.2014) and high levels of TDS can lead to gastro-intestinal irritation and (Olusiji and Adeyinka 2011).

CONCLUSION

This research employed a combination of statistical approaches to assess water quality parameters in the west coast of Cameroon, inorder to understand the linkages between spatio-temporal variability and water quality. Most of the sampled parameters indicated significant spatiotemporal variability and strong correlations between parameters. From descriptive statistics, non-parametric statistics and multivariate analysis it could be construed that water quality in the west coast of Cameroon vary with seasons and source/sites (sea, river or spring). Values of pH, temperature, EC, Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-} and TDS were higher in the dry season than in the rainy season for all sites. The results from PCA suggested that while some parameters might be crucial in determining the fluctuation of water quality for one season, this same parameter might be less crucial for another season. Discriminant analysis and descriptive statistical technics revealed that the concentration of the pollutants is a function of seasons and the sampling sites, with sea samples being the most polluted, followed by rivers and springs. EC, Na^+, Mg^{2+}, F-, Cl^-, NO_3^- and TDS were relatively higher in concentration than when compared with the WHO (2004) guidelines for drinking water quality and these abnormalities were common in in sea and rivers. The analytical results indicate that water bodies in the study area are a unique example for the compound impact of point source and non-point source pollutants resulting from weathering, hydrologic and anthropogenic processes. The chemical composition of surface water in each season is strongly influenced by water bodies' dilution and anthropogenic inputs. This study demonstrates the usefulness of both descriptive and multivariate statistical techniques for analysis and interpretation of complex data sets, and also for identification of pollution sources and better understanding of seasonal variations in water quality for effective river water quality management.

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