

MULTIVARIATE ANALYSIS OF SOME HYDRO-GEOCHEMICAL PARAMETERS OF RIVER NIGER FLOODPLAIN WATER, JEBBA-KPATSUWA, CENTRAL NIGERIA

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Abstract

Multivariate analysis of some hydro-geochemical parameters of floodplain water around Jebba and Kpatsuwa, central Nigeria has been established in order to delineate the level of certain hydrochemical parameters that are of health significant both for human consumption and agricultural practices. Statistical analysis such as Correlation Analysis (CA), Factor Analysis (FA), Hierarchical Cluster Analysis (HCA) and Principal Components Analysis (PCA) were used to classify the water hydro-geochemistry. The water samples were measured in-situ for physicochemical parameters such as temperature, electrical conductivity, pH and Total dissolve solid (TDS) through the use of thermometer, conductivity meter, pH meter and TDS meter respectively. Twenty-four representative samples were selected randomly showing relative abundance of major cation and anion concentrations as follows: $\text{Na}^+ + \text{K}^+ > \text{Ca}^{2+} > \text{Mg}^{2+}$ and $\text{HCO}_3^- + \text{CO}_3^{2-} > \text{Cl}^- > \text{SO}_4^{2-}$ respectively. Selected trace elements show an increasing order of $\text{Fe} > \text{Al} > \text{Mn} > \text{Pb} > \text{Zn} > \text{Ni} > \text{Cu}$ with the respective concentrations of Fe, Pb, Mn and Al as: 19.02, 0.17, 1.072 and 3.07 mg/l exceeding WHO (2012) prescribed standard in some of the water samples analyzed which is due to various anthropogenic activities and geogenic contributions into the water phase from the area of study. Correlation matrix shows that most of chemical parameters of the water have very high, high and moderate correlation. The factor obtained from Factor analysis indicated that the parameters responsible for water quality variations are mainly related to water-rock interaction (particularly weathering of aluminosilicate minerals) and anthropogenic sources. Four clusters generated from clusters analysis indicate fresh water type and interpreted as rock-water interaction.

1.0 Introduction

The sources of water for any specific purposes are not as important as the suitability of the water for the desired purpose. With increasing human population, industrialization, urbanization, agricultural activities and the consequent increase in demand for water for both domestic and industrial uses, the attendant increase in the implication of polluted water on man and the environment have been severally studied (Asiwaju-Bello and Akande, 2004; Ige et al., 2008). Waters have altered the floodplain landscape. The Jebba area is continuously shaped by the forces of water from the river Niger either eroded or built up through deposit of sediment. More recently, the landscape has been altered by human activities and development, affecting the floodplain. People have been attracted to bodies of water as places for living, agricultural practice and for recreation. The pattern of development continued as communities grew. In recent times, the development along waterways and shorelines has been spurred by the farming

activities because the land is fertile which can be used as meadowlands and for raising vegetables, feed crops, rice and other crops.

The quality of surface water is very crucial in evaluating its utility in various fields such as domestic, public water supply and agriculture. For a better appreciation and understanding of water quality characteristics of the study area, multivariate analysis is adopted for data extrapolation. A number of multivariate statistical techniques such as correlation analysis (CA), hierarchical cluster analysis (HCA), principal component analysis (PCA) and factor analysis (FA) offer significant assistance in the interpretation of complex data matrices. The outcome is thus a generally improved understanding of the water quality status of the studied systems. The application of multivariate statistical techniques also enhances the identification of possible factors that could influence water systems.

These techniques undoubtedly offer a valuable tool for reliable and sustainable management of water resources. Earlier studies indicate that the multivariate statistical techniques have successfully assisted in characterizing the surface and fresh water quality. These techniques also provide the identification of possible sources that affect the water environmental system and offer a valuable tool for reliable management of water resources. More so, the multivariate analysis provides a representative and reliable evaluation of the quality of water by explaining the relationship amongst large number of variables in terms of small number of factors without losing much information.

1.1 Location of the Area

The mapped area is the southern and northern part of Jebba which covers areas like Ndafu, Jebba, and Kpatsuwa. The mapped area covers latitude $9^{\circ}07'12''\text{N}$ to $9^{\circ}10'12''\text{N}$ to the north of the equator and longitude $4^{\circ}48'36''\text{E}$ to $4^{\circ}50'24''\text{E}$ to the East of Greenwich meridian capturing towns like Jebba, Ndafu, Kpatsuwa in the area (Figure 1.1). The study area is accessible by the main road and footpaths. topographical map, the geographical positioning system and the clinometers compass served as aids for locating the sampling points. The main occupational activity in the area is agricultural practices involving crop production, cattle rearing, irrigation and mechanized farming.

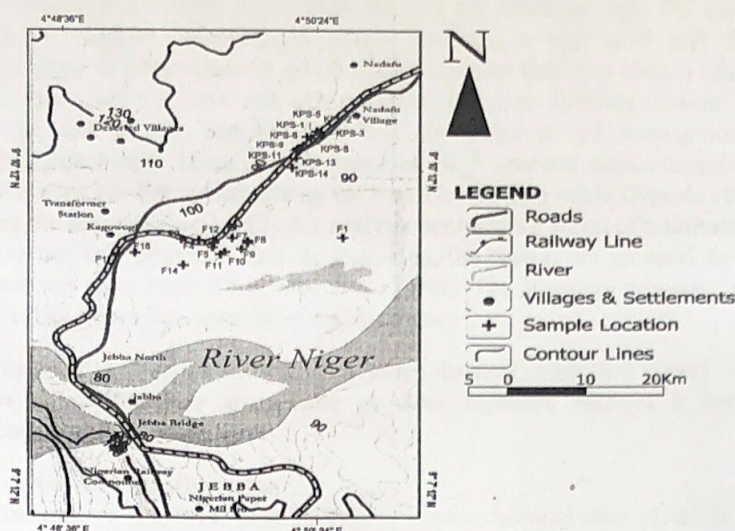


Figure 1.1: Location map of the study area showing sampling points (modified after NGSA 2008)

2.0 Methodology

A total of Twenty-four water samples were randomly taken from river Niger floodplain water using Global Positioning System (GPS) during the dry season when precipitation was very low (Figure 1.1). Water samples for cations analyses were acidified with Nitric acid to reduce the chemisorption of the metal ions into the surfaces and prevent the hydrolysis and precipitation of cations. To prevent contamination from metallic containers, plastic containers were used for the water samplings. The temperature, Total Dissolved Solid (TDS), Hydrogen ion concentration (pH), Electrical Conductivity (EC) and Geographical Positioning System (GPS) measurements of the water samples were taken in-situ and the values recorded accordingly using thermometer, TDS meter, PH-meter and Electrical Conductivity meter (Hanna instruments) respectively. The Statistical Packages for Social Sciences (SPSS) was used to carry out the statistical analyses. Correlation analysis is used to describe the degree of relationship between the hydrogeochemical parameters which gives permission in identifying the origin of solutes and the chemical evolution process of water samples. In this study, Pearson Correlation Matrix was used to determine the relationship between the variables. The classification was based on Guildford's rule of thumb (Nura et al, 2013) for interpreting the Pearson Product Moment Correlation. Very high correlation ranges between $r = 0.9-1.00$, high correlation ranges between $r = 0.7-0.89$, moderate correlation exists between $r = 0.5-0.69$ and $r < 0.5$ is low or little correlation.

Factor analysis is a frequent common statistical technique adopted in hydrochemical studies (Subbarao et al., 1996, Adami et al., 1997, Davis, 1986). The main goals of factor analysis are: to reduce the number of variables; to detect structure in the relationships between variables (analytical parameters) and/or cases (sampling points in our study). The Principal Component analysis is used to reduce a large number of variables into a smaller number and for further investigation of the relationships between the elements/parameters. The Principal Component

(PCs) with Eigen Values larger than one (1) are extracted with PC loadings rotated for the maximum variance. Hierarchical cluster analysis is also used and this is based on the classification of observation to group of homogenous data into classes (clusters) on the basis of similarities within a class and dissimilarities between different classes. It is a powerful and essential tool in the identification and the selection of homogenous groups from the hydrochemical data. There are two types of HCA analysis which include R and Q-modes. R-mode reveals the interaction among the variables studied while Q-mode reveals the interrelation among the samples studied. Cluster analysis comprises a series of multivariate methods which is used to find true groups of data. In clustering, the objects are grouped such that similar objects fall into the same class (Danielson et al., 1999). The levels of similarity at which observations are merged are used to construct a dendrogram.

In this study, a standardized space Euclidian distance is adopted (Davis, 1986). A low distance shows the two objects are similar or close together, whereas a large distance indicates dissimilarity.

3.0 Results and Discussion

The descriptive statistical overview of the hydrochemical data of water sampled in Jebba is presented in Table 1. The distributions of the water quality parameters were assessed by determining minimum, maximum, average, variance and standard deviation for each of 18 variables selected from the result of the hydrochemical analysis. The EC and TDS ranged from 100 to 1100 $\mu\text{S}/\text{cm}$ and 20 to 170 ppm respectively. Areas with heavy agricultural practices indicate higher level of EC and TDS respectively. This is as a result of mechanized farming in which various agrochemical materials are being used for farming operations. The high values of variance (52516 $\mu\text{S}/\text{cm}$ and 17953 ppm) computed for the EC and TDS show contributions from both anthropogenic and geogenic activities in the study area. The pH ranged from slightly acidic (6.9) to alkaline (8.6) in nature. As slated on Table 1, average values of Al (3.1 mg/l), Fe (19 mg/l), Pb (0.2 mg/l) and Mn (1.1), exceeded the prescribed limit of WHO, making the water unfit for domestic consumption. The relatively high concentrations of Al, Fe, Pb and Mn is suggested to be from weathering of aluminosilicate minerals from the rock types in the study area and also contributions from various anthropogenic activities in the study area (Tijani, 2007)

Table1: Descriptive statistics for physiochemical, chemical and trace element analysis of the water in Jebba.

Parameters	Average	Minimum	Maximum	Standard Deviation	Variance	WHO Highest desirable	WHO Max permissible	NAFDAC, 2012
Ec ($\mu\text{S}/\text{cm}$)	266.7	100.0	1100.0	229.2	52516.1	900	1200	1000
TDS (ppm)	151.3	20.0	170.0	134.0	17953.3	500	1500	500
Temp ($^{\circ}\text{C}$)	29.5	23.0	36.0	3.5	12.2	27	27	27
pH	7.7	6.9	8.6	0.4	0.2	7.0-8.9	6.5-9.5	6.5-8.5
HCO_3^- (mg/l)	154.6	39.0	336.0	107.7	11597.1	100	500	100
SO_4^{2-} (mg/l)	10.3	3.0	26.0	5.5	30.7	250	500	100
Cl^- (mg/l)	21.1	<1.00	110.0	32.1	1032.3	200	250	100
Ca^{2+} (mg/l)	34.0	4.5	344.6	68.0	4619.9	75	75	75
Mg^{2+} (mg/l)	11.9	1.3	112.0	22.2	493.3	20	20	20
Na^+ (mg/l)	34.5	3.2	158.0	40.7	1656.5	200	250	200
K^+ (mg/l)	13.8	0.9	117.0	22.9	522.6	200	200	-
Al (mg/l)	3.1	0.1	26.2	6.8	46.1	0.2	0.2	0.5
Fe (mg/l)	19.0	0.1	300.9	61.0	3718.5	1	1	3
Cu (mg/l)	0.0110	0.0010	0.0550	0.0190	0.0004	0.5	2	1
Pb (mg/l)	0.2	0.0	4.0	0.8	0.7	0.01	0.01	0.01
Zn (mg/l)	0.04	0.00	0.52	0.11	0.01	0.01	3	5
Mn (mg/l)	1.1	0.0	12.9	2.6	6.8	0.1	0.4	20
Ni (mg/l)	0.0	0.0	0.3	0.1	0.0	0.02	0.02	0.02

3.1 Correlation Analysis

The correlation matrix of chemical data of the water in the study area is presented in Table 2. The variables having correlation value (r) = 0.9-1.00 has a very high correlation, r = 0.7-0.89 has high correlation, r = 0.5-0.69 has moderate correlation, and r < 0.5 has low correlation according to Guildford 's rule of thumb (Kura et al, 2013). The correlation matrix (Table 2) describes the inter-relationship between variables and the results for 17 hydrochemical parameters show that very high positive correlation exist between Mg^{2+} and Ca^{2+} , Na^+ and HCO_3^- , K^+ and Ca^{2+} , K^+ and Mg^{2+} , Fe and Ca^{2+} , Fe and Mg^{2+} , Fe and K^+ , Pb and Ca^{2+} , Pb and Mg^{2+} , Pb and K^+ , Pb and Fe, Zn and Ca^{2+} , Zn and Mg^{2+} , Zn and K^+ , Zn and Fe, Zn and Cu, Zn and Pb, Mn and Ca^{2+} , Mn and Mg^{2+} , Mn and K^+ , Mn and Fe, Mn and Pb, Mn and Zn, Ni and Ca^{2+} , Ni and Mg^{2+} , Ni and K^+ , Ni and Fe, Ni and Pb, Ni and Zn, Ni and Mn, and high positive correlation exist between Cl^- and HCO_3^- , Ca^{2+} and HCO_3^- , Mg^{2+} and HCO_3^- , Na^+ and Cl^- , Na^+ and Ca^{2+} , Na^+ and Mg^{2+} , K^+ and HCO_3^- , K^+ and Cl^- , K^+ and Na^+ , Al and SO_4^{2-} , Fe and Na^+ , Cu and Ca^{2+} , Cu and Mg^{2+} , Cu and K^+ , Cu and Fe, Pb and Cu, Mn and Na^+ , Mn and Cu, Ni and Cu.

EC and TDS have a very high positive correlation of ($r = 0.981$) with each other. EC has a very high, high, and moderate correlation with Cl^- , Na^+ , HCO_3^- , K^+ , Mg^{2+} , Ca^{2+} , Mn, Fe, Ni, Pb, Zn, Cu respectively. TDS has a very high, high and moderate correlation with HCO_3^- , Na^+ , Cl^- , Mg^{2+} , K^+ , Ca^{2+} , Mn, Fe, Ni, Pb, Zn, Cu respectively. These suggest that EC and TDS are controlled by these ions. pH has a negative correlation with all the elements. Ca^{2+} , Mg^{2+} , and HCO_3^- are the most abundant ions in natural water, while Na^+ and Cl^- are the most abundant ions in seawater; a high correlation exists between Na^+ - Cl^- which may be due to interaction of water with rocks. A very high correlation exists between Ca^{2+} and Mg^{2+} which explains the dissolution of soil and

mineral in the sediments containing floodplain water. Moderate correlations exist between Ca^{2+} and Cl^- as a result of simple hydrochemical mixing and reverse cation exchange. Mg^{2+} and Cl^- has a moderate correlation which results from anthropogenic contamination.

From Table 2, it is quite clear that most of the parameters were significantly correlated with HCO_3^- , which could be an indication that the water may have experienced various processes such as ion exchange, water-rock interaction and weathering of the aquifer's parent materials, therefore making HCO_3^- a dominant ion in the water chemistry. A high correlation exists between HCO_3^- and Na; this is an indication of interaction between fresh and saltwater.

A very high- high correlation exist between Pb and Fe, Zn and Fe, Zn and Cu, Zn and Pb, Mn and Fe, Mn and Pb, Mn and Zn, Ni and Fe, Ni and Pb, Ni and Zn, Ni and Mn, Cu and Fe, Pb and Cu, Mn and Cu and Ni and Cu indicating that these trace elements in water had similar hydrochemical characteristics in the study area and are contributed to the water as a result of Anthropogenic activities such as discharge of sewage from agricultural runoff which support the contamination of floodplain water.

Table 2: Correlation Matrix of the hydrochemical parameters.

	EC	TDS	pH	HCO_3^-	SO_4^{2-}	Cl	Ca^{2+}	Mg^{2+}	Na^+	K^+	Al	Fe	Cu	Pb	Zn	Mn	Ni
EC	1.00																
TDS	0.98	1.00															
pH	-0.51	-0.51	1.00														
HCO_3^-	0.92	0.94	-0.61	1.00													
SO_4^{2-}	0.19	0.18	-0.20	0.37	1.00												
Cl	0.94	0.92	-0.29	0.77	0.03	1.00											
Ca^{2+}	0.82	0.78	-0.51	0.75	0.32	0.70	1.00										
Mg^{2+}	0.83	0.79	-0.54	0.77	0.34	0.64	1.00	1.00									
Na^+	0.92	0.92	-0.58	0.94	0.27	0.83	0.77	0.78	1.00								
K^+	0.83	0.79	-0.47	0.74	0.31	0.73	0.99	0.99	0.76	1.00							
Al	0.14	0.15	-0.35	0.30	0.70	0.02	0.23	0.26	0.17	0.21	1.00						
Fe	0.73	0.68	-0.50	0.66	0.33	0.12	0.99	0.98	0.70	0.97	0.26	1.00					
Cu	0.61	0.59	-0.55	0.64	0.58	0.10	0.84	0.86	0.60	0.83	0.68	0.87	1.00				
Pb	0.71	0.66	-0.44	0.61	0.22	0.09	0.97	0.96	0.68	0.96	0.10	0.99	0.78	1.00			
Zn	0.67	0.63	-0.51	0.64	0.46	-0.02	0.95	0.95	0.65	0.94	0.45	0.98	0.95	0.93	1.00		
Mn	0.74	0.71	-0.53	0.70	0.34	0.21	0.99	0.99	0.71	0.97	0.27	0.99	0.87	0.97	0.97	1.00	
Ni	0.71	0.66	-0.49	0.65	0.35	0.01	0.98	0.98	0.69	0.96	0.30	1.00	0.88	0.98	0.98	0.99	1.00

3.2 Hierarchical Cluster Analysis

The main result of the HCA performed on the 22 water samples is the dendrogram. The hierarchical cluster analysis performed using the Wards Linkage method with squared Euclidean distance as a measure to create a dendrogram which ascertains the relation among the sample sites. The dendrogram obtained shows four major clusters (Figure 2). Cluster I is composed of the samples KPS1, KPS2, KPS5, KPS6, KPS8, KPS9, KPS11, KPS13, KPS14 and concern 40.91% of the water samples. This type of water with a mean EC of 111.11 $\mu\text{S}/\text{cm}$ has low value compared to the clusters II, III and IV. It has an average TDS concentration of 45.56 mg/l indicating little dissolution of ions in the water. This cluster is basically HCO_3^- dominated and contains relatively low concentration of Ca^{2+} , Mg^{2+} , and Na^+ . The cluster is interpreted as precipitation source with little geogenic sources (rock-water interaction) which results in the low concentration of the major ions (Table 4). Cluster II is represented by the samples F4, F5, F11, F12, F14, F16, F17 and it occupies 31.82% of the water samples. This cluster of water with mean EC of 200 $\mu\text{S}/\text{cm}$, has high value compared to the clusters I but lower than III and IV. It has an average TDS concentration of 130 mg/l which is characteristic of fresh water. This water cluster

II is being dominated by HCO_3^- . It has concentration of Ca^{2+} , Na^+ , Mg^{2+} , Cl^- , and SO_4^{2-} . It represents an intermediate water type and is interpreted as rock-water interaction or natural mineralization. (Table 4). Cluster III includes samples F9, F10 and concerns 9.09% of the water samples. The mean EC of the cluster is $250\mu\text{S}/\text{cm}$ and it has an average TDS of 145 mg/l which is the characteristic of fresh water. This water cluster III is being dominated by HCO_3^- . It has relatively high concentration of Ca^{2+} , Na^+ , Mg^{2+} , and Cl^- compared to other cluster. This is the characteristic of fresh water with sources of ions from rock-water interaction (weathering of rocks). Cluster IV is composed of the samples F1, F2, F6, F8 concern 18.18% of the water samples. This type of cluster has a mean EC of $575\mu\text{S}/\text{cm}$ and it has a highest TDS value of 342.5 mg/l , indicating dissolution of ions in the water. HCO_3^- is dominant in this cluster. It contains Ca^{2+} , Cl^- , and Na^+ . As a result, water sample in cluster IV and III are higher concentrated compare to water samples in clusters I and II, indicates the water quality in the clusters IV and III is slowly getting to degradation. Cluster IV is interpreted as rock-water interaction.

HIERARCHICAL CLUSTER ANALYSIS

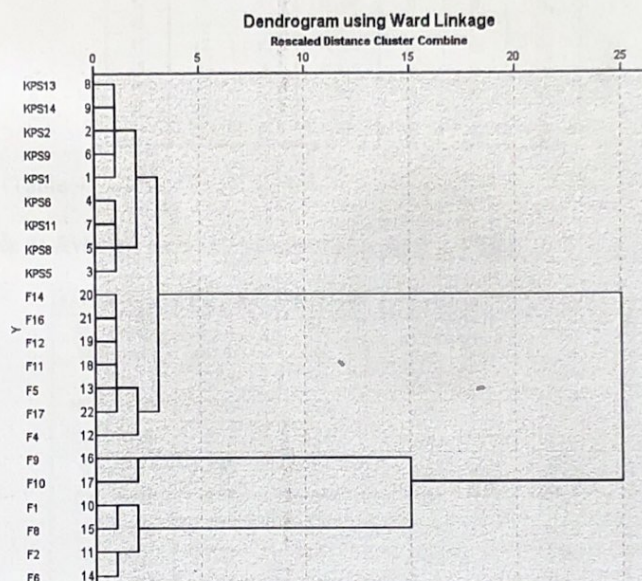


Figure 2: Dendrogram from cluster analysis (Q-mode) of water samples

Table 3: Cluster Analysis of Observations

Agglomeration Schedule						
Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	8	9	0.087	0	0	4
2	2	6	0.352	0	0	4
3	4	7	0.796	0	0	6
4	2	8	1.375	2	1	8
5	20	21	2.735	0	0	7
6	4	5	4.114	3	0	11
7	19	20	6.008	0	5	10
8	1	2	7.995	0	4	18
9	10	15	10.736	0	0	16
10	18	19	13.636	0	7	12
11	3	4	16.686	0	6	18
12	13	18	20.251	0	10	13
13	13	22	24.821	12	0	17
14	11	14	29.755	0	0	16
15	16	17	37.588	0	0	20
16	10	11	45.888	9	14	20
17	12	13	54.789	0	13	19
18	1	3	64.915	8	11	19
19	1	12	83.086	18	17	21
20	10	16	184.7	16	15	21
21	1	10	357	19	20	0

Table 4: Average concentrations of chemical constituent for each cluster

PARAMETERS	CLUSTER I	CLUSTER II	CLUSTER III	CLUSTER IV
EC (uS/cm)	111.11	200	250	575
TDS (mg/l)	45.56	130	145	342.5
PH	7.99	7.63	7.35	7.53
HCO ₃ ⁻ (mg/l)	62.11	152	212	286
SO ₄ ²⁻ (mg/l)	8.78	8.71	23	9.5
Cl ⁻ (mg/l)	4.89	12	15	81
Ca ²⁺ (mg/l)	8.78	15.49	47.28	45.15
Mg ²⁺ (mg/l)	2.78	5.97	18.91	16.52
Na ⁺ (mg/l)	7.35	33.12	38.26	72.46
K ⁺ (mg/l)	6.74	5.16	16.69	19.2
Al (mg/l)	0.36	1.15	24.56	1.79
Fe (mg/l)	1.29	4.18	39.91	8.71
Cu (mg/l)	0.0033	0.0046	0.044	0.0077
Pb (mg/l)	0.0034	0.0047	0.028	0.0065
Zn (mg/l)	0.0098	0.0076	0.15	0.011
Ni (mg/l)	0.127	0.561	1.98	0.93
Mn (mg/l)	0.0016	0.0035	0.049	0.0049

3.3 Factor Analysis

Kaiser (1960), applied to determine the total number of factors for each datasets in the analysis. Under this criterion, only factors with Eigen values greater than 1 or equal to 1 will be accepted as possible sources of variance in the data, with the highest priority ascribed to factor that has the highest eigenvector sum. Principal component extraction method with varimax rotation and Kaiser's normalization was used in interpretation. Two (2) components were retained and interpreted on the basis of Kaiser's criterion of Eigen values. The result of the two components (Table 5) from Rotated component matrix explains 84.756% of the total variance in the datasets (Table 7), which is quite good and can be relied upon to identify the main sources of variation in the hydrochemistry. The first Eigen value is 9.777 which accounts for 45.624% of the total variance and this constitutes the first and main factor. The second Eigen value is 4.631 and this account 39.132% of the total variance.

Factor 1 has high positive loading for SO_4^{2-} , Al, Fe, Cu, Pb, Zn, Mn and Ni and accounts for 45.624% of the variance in the hydrochemistry in the area. SO_4 , Al, Fe, Cu, Pb, Zn, Mn and Ni showing positive loadings under factor 1 and derived from domestic and agricultural waste in the study area. The source of SO_4^{2-} may be associated with precipitation and evapo-transpiration. Al, Cu, Pb, Zn, Mn, Ni and Fe which suggests anthropogenic sources such agricultural practices, domestic waste, industrial waste from the study area. Factor 2, which accounts for 39.132% of the total variance, contains high positive loading for EC, TDS, HCO_3 , Cl^- , Ca^{2+} , Mg^{2+} , K^+ and Na^+ and represents alkalinity, average loading of total hardness and it also indicates weathering processes. Ca^{2+} , Mg^{2+} and Na^+ may be released into the water as a result of weathering of plagioclase, amphiboles and microcline from surrounding rocks. Bicarbonate concentration may be due to seasonal changes associated with chemical reactions during rainstorm. The presence of chloride may be associated with environmental and atmospheric precipitation.

3.4 Principal Component Analysis

The principal component (PCs) with Eigen values larger than 1 are extracted with the PC loadings rotated for the maximum variance. A total of two Principal Components are extracted for the water samples, which account for 84.756% of the total variance. The Principal component from the 24 sampling stations indicated that in floodplain water altogether two factors were satisfactory to explain 84.756% of the variance for correlation. The total variances explained in the two components are 57.515 by PC1 and 27.241 by PC2. The component loading was classified (Liu, 2003), which was categorized as component loading strong (>0.75), moderate (0.75-0.50) and weak (0.50-0.40).

Table 5: Factor Analysis

Rotated Component Matrix^a

	Component	
	1	2
EC	-.007	.977
TDS	.016	.977
Ph	-.337	-.386
HCO ₃	.240	.921
SO ₄	.746	.074
Cl	-.091	.941
Ca	.548	.807
Mg	.595	.771
Na	.036	.889
K	.399	.766
Al	.978	.082
Fe	.957	.232
Cu	.962	.130
Pb	.936	.122
Zn	.981	.025
Mn	.798	.365
Ni	.965	.092

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

**Table 6: Principal Component Analysis
Component Matrix^a**

	Component	
	1	2
EC	.606	.766
TDS	.625	.751
Ph	-.504	-.089
HCO ₃	.764	.567
SO ₄	.628	-.410
Cl	.519	.790
Ca	.932	.285
Mg	.947	.228
Na	.585	.670
K	.791	.347
Al	.814	-.549
Fe	.891	-.419
Cu	.832	-.502
Pb	.806	-.491
Zn	.780	-.595
Mn	.850	-.215
Ni	.810	-.533

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

The principal component 1(PC 1) accounts for 57.515% of the total variance and is associated with strong positive loading of HCO_3^- , SO_4^{2-} , Mg^{2+} , Ca^{2+} , K^+ , Al, Fe, Cu, Pb, Zn, Mn and Ni suggesting a common source, the loading factor indicated the significant contribution of Mg^{2+} and Ca^{2+} to total hardness of the floodplain water in the area.

The high positive loading Mg ions for the first principal component indicate for the source of the weathering of ferro-magnesium minerals. Fe could arise from weathering of iron bearing minerals such as amphibole and rocks in the course of migration from the main river. However, iron at high concentration can alter the taste, color and turbidity of the water. K^+ indicates the effect of drainage of agricultural and storm water that is washing out the top soil with its different impurities and chemical fertilizer. High HCO_3^- concentration may be due to seasonal changes associated with chemical reactions during rainstorm. Also high SO_4^{2-} is related to the long-history of evaporation process and also the effect of industrial pollution.

The principal component 2 accounts for 27.62% of the total variance and is associated with strong positive loading of EC, TDS, Cl and Na. Enrichment of Na and Cl is also possibly, related to urban wastewaters and high rate of evapo-transpiration. High loading of Na and Cl signified geogenic ionic solute input in the floodplain water system. However, high Cl concentration in the floodplain may also indicate pollutions by sewage, industrial waste. The high Na may be due to weathering of minerals such as plagioclase, amphibole etc. In summary the two extracted PC, representing different processing are reflecting the effect of agricultural activities, weathering of aluminosilicate minerals and ions exchange processes, wastewater pollution from sewage and industrial waste.

Table 7: Factor and Principal Component Analysis

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.777	57.515	57.515	9.777	57.515	57.515	7.756	45.624	45.624
2	4.631	27.241	84.756	4.631	27.241	84.756	6.652	39.132	84.756
3	0.937	5.514	90.27						
4	0.529	3.111	93.381						
5	0.436	2.567	95.948						
6	0.304	1.789	97.738						
7	0.176	1.036	98.774						
8	0.079	0.463	99.237						
9	0.044	0.256	99.493						
10	0.033	0.195	99.688						
11	0.025	0.146	99.834						
12	0.012	0.071	99.905						
13	0.008	0.044	99.95						
14	0.006	0.034	99.983						
15	0.001	0.009	99.992						
16	0.001	0.005	99.997						
17	0	0.003	100						

4.0 Conclusions

In the study, different multivariate statistical techniques were used to evaluate the hydro-geochemical data of floodplain water of Jebba-Kpatsuwa Central Nigeria. Correlation analysis (CA) was used to interpret the source of the ion and Hierarchical cluster analysis indicate four cluster analysis of which the water sample in the area are grouped according to their homogenous class(sources). The factor analysis (FA) generated two factors which together account for 84.756% of total variance and in principal component analysis the first two factors explains 84.226% of the total variance, their loading allows the interpretation of hydrochemical processes that take place in the area. The results of this study clearly demonstrate the usefulness of multivariate statistical analysis as useful tools to determine quality of floodplain water.

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