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Hierarchical Cluster and Factor Analyses in Assessment of Surface Water Quality in Okitipupa Area, S.W, Nigeria

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Abstract: The surface water quality of Okitipupa area was evaluated using hierarchical cluster and factor analyses. Water quality data collected randomly a from 31 sampling stations which includes samples from rivers and streams during the dry and the rainy seasons were analyzed for 27 parameters. Hierarchical cluster analysis grouped the sampling stations into 4 clusters of similar water quality features which indicates that the water in the study area can be grouped into very low, low, moderate and high pollution. Factor analysis shows six factors which for 79.71% of the total variance of the surface water quality. The natural parameters such as temperature, weathering processes, cation exchange processes, agricultural chemicals and organic pollutants from run off and atmospheric precipitation were responsible for the variations in the water quality.

Key words: Surface water quality, precipitation, parameters, pollutants, processes

INTRODUCTION

Surface water includes water from rivers, streams, lakes and ponds. The quality of surface water within a region is governed by both natural processes and anthropogenic factors (Yilmaz *et al*., 2010; Kar *et al*., 2008; Shrestha and Kazama, 2007).

The quality of surface water is a matter of serious concern today. Rivers and streams due to their role in carrying off the municipal and industrial waste water and run off from agricultural land in their vast drainage basins are among the most valuable water bodies to pollution (Yerel, 2010). The anthropogenic discharges constitute a constant polluting source where as surface run off is a seasonal phenomenon, largely affected by climate within the basin.

Anudu *et al*. (2011) said that the basic purpose for which water is domestically required include drinking, bathing, cooking and general sanitation such as laundry, flushing of closets and other household chores whereas for agricultural purpose it is essentially used for irrigation and livestock.

In time past, people are concerned about supply of water in large quantity without reference to it quality. Since, drinking of some water particularly surface water that are polluted has caused hearth hazard to both humans and animals, consequently people begin to give attention to the quality of water for their various uses.

Cluster and factor analyses have been applied for hydro geochemical studies. Cluster and factor analysis to assess surface/groundwater hychrogeochemistry (Machado *et al*., 2008; Yilmaz *et al*., 2010; Simeonov *et al*., 2003; Pejman *et al*., 2009; Hussain *et al*., 2008; Ameh and Akpah, 2011). Cluster and discriminant analyses to asses surface water quality (Shrestha and Kazama, 2007). Hierarchical cluster analysis was employed to assess the evolution and dynamics of groundwater in Ethiopam rift (Ayenew *et al*., 2009).

The present study is borne out of the need to evaluation the surface water sources in the area, to ascertain the level and sources of concentration of each element present in the water and to identity if there is any contaminant present in the surface water in the study area. The study area encompasses Okitipupa, Ilu titun, Igbaje, Agbabu, Ode Aye, Irele, Ikoya and Igbodigo in the coastal part of Ondo state. They are located between latitudes 6°27' and 6°37'N and longitudes 4°38' and 4°54'E (Fig. 1).

The area has a tropical climate which is characterized by two seasons: the rainy and dry season. The rainy season starts from April to October while the dry season lasts between November and March. The means annual rainfall varies from 1000-1500 mm and the mean annual temperature is 27°C.

The study area lies within the Dahomey sedimentary basin of S.W, Nigeria. Omosuyi identified the predominant rock types as shales and sandstones and minor rocks as limestones and unconsolidated sediment with age range of Albian to recent. Omatsola and Adegoke (1981) proposed that Dahomey basin comprises of horst and

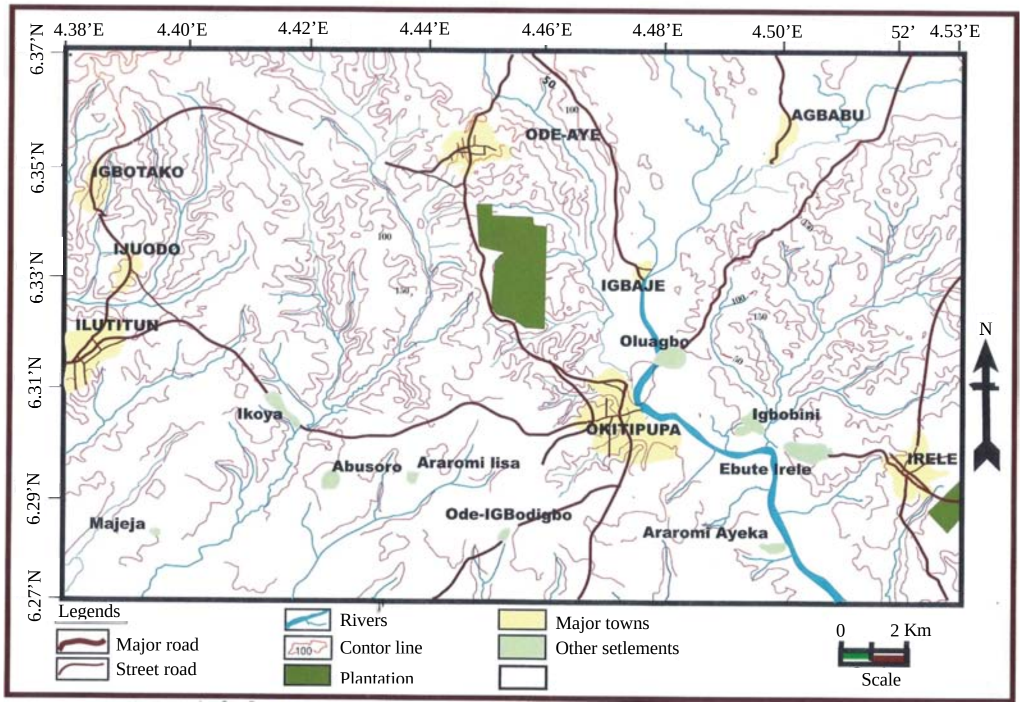

Fig. 1: Map of the study area

graben and are filled with Ise, Afowo and Araromi formation gently dipping cretaceous formation. The drainage pattern is dendritic.

MATERIALS AND METHODS

Water sampling was carried out in the month of March (peak of dry season) and October (peak of rain season). A total of 31 water samples were collected in all. Nineteen water samples were collected during the dry season and twelve in the rain season. Sampling was done randomly for both rivers and streams using 2 L polyethylene plastic bottles which were transferred to the laboratory for chemical analysis using established method for analysis (APHA, 1998). Conductivity, temperature, pH and TDS were measured *in situ* using a portable pH-2603 water quality analyzer.

The water samples were analyzed for major and some trace elements. Anions analyzed include sulfate, chloride, bicarbonate nitrate, phosphate, calcium hardness and total alkalinity, cations include calcium sodium, magnesium and potassium. Trace element includes lead, zinc, arsenic, nickel, manganese, iron, copper and cadmium. Anions were determined by titration, cations by Atomic Absorption Spectrophotometer; sodium and potassium by Flame photometry at both Central Research Laboratory of Faculty of Science, Adekunle Ajasin University, Akungba-Akoko and International Institute of Tropical Agriculture (IITA) Ibadan. Analytical data were processed with SPSS 16.0 software.

RESULTS AND DISCUSSION

Hierarchical cluster analysis: By using hierarchical cluster analysis, variables were interrelated to each other according to the maximum similarities. Results are presented as dendrogram (Fig. 2). The hierarchical method of cluster analysis which was used in this study has the advantage of not demanding any prior knowledge of the number of clusters which the non-hierarchical method does. Cluster analysis suggests four groups of surface water's.

The group 1 is composed of streams 3, 11, 9, 2, 10, 5 and 8 and this represent 36.8% of the surface water samples. This type of water has a mean concentration of EC of 18.6 $\mu S\ cm^{-1}$ which is a characteristic of fresh water. This group is bicarbonate dominated however, calcium and magnesium are also present.

Group 2 is represented by streams 4, 17, 12, 13 and 7, this account for 26.3% of surface water samples. The mean electrical conductivity for this group is 80 $\mu S\ cm^{-1}$. The dominant ion is bicarbonate though chloride is also

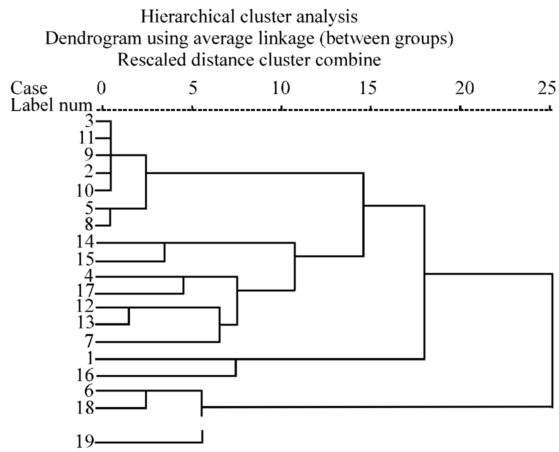

Fig. 2: Dendrogram for surface water in dry season

present. Cluster 3 is made up of stream 1 and 16 which represent 10.5% of the surface water samples. The mean electrical conductivity for this group is 35 μS cm^{-1}. This group of water is characterized with high calcium hardness. Cluster 4 represent 15.8% of the total surface water samples, this consists of stream 6, 18 and 19. The mean electrical conductivity is 110 μS cm^{-1}.

It is clearly shown that cluster 4 was characterized by the biggest Euclidean distance to the cluster in group 1-3. The dendrogram clarifies the abnormality of the observation of the stream 6, 18 and 19 which receive polluted effluents from sources such as agricultural, urban and industrial activities. This can be attributed to higher mean electrical conductivity in this group.

Factor analysis for surface water: In this study factor analysis, generated six factors which together accounted for 79.71% of the total variance. The rotated loading, eigen values, percentage of variance and cumulative percentage of variance of all the six factors are shown in Table 1 and their scree is shown in Fig. 3.

Factor 1 represent 17.86% of the total variance of 79.71% with positive high loading of Ca, total hardness and calcium hardness. The high correlation coefficient between Ca and total hardness suggest that calcium is responsible for the temporary hardness as observed in the surface water in the study area. The sources of calcium in the water may be associated with dissolution of carbonate minerals such as calcite.

Factor 2 represent 15.22% of the total variance of 79.71% and is the second major factor with high positive loading of TDS and EC. The high correlation coefficient between TDS and EC (r = 0.85) suggests that the high loading of TDS may be as a result of ions present in the water which might have come from atmospheric precipitation.

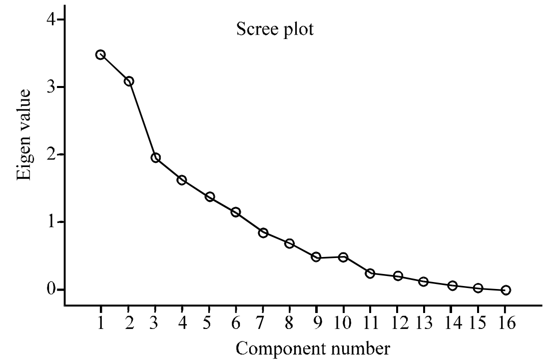

Fig. 3: Scree plot for surface water

Table 1: Rotated varimax matrix for surface water in dry season

Parameters	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
HCO_3	0.22	-0.13	-0.01	0.20	-0.66	0.43
Cl	0.01	-0.16	0.07	0.86	-0.20	0.06
NO_3	-0.02	0.10	-0.78	0.24	-0.21	0.02
PO_4	0.21	-0.53	0.08	-0.02	0.72	-0.03
SO_4	-0.05	-0.47	0.60	0.04	0.31	-0.04
Ca	0.82	-0.16	0.16	-0.05	0.16	-0.16
Ca hard	0.90	0.00	-0.10	0.08	0.03	0.16
Total hard	0.96	-0.02	-0.06	0.10	0.04	0.07
Mg	0.28	0.16	-0.17	0.60	-0.35	-0.42
Oil and grease	0.33	-0.03	0.24	0.02	0.77	0.13
Na	-0.03	-0.02	0.16	-0.83	-0.19	-0.15
K	-0.40	0.23	0.41	-0.03	0.00	0.51
pH	0.00	0.24	0.06	0.09	-0.07	0.89
EC	-0.07	0.91	-0.01	-0.06	-0.07	0.00
TDS	-0.07	0.93	-0.02	-0.01	0.01	0.11
Temp	0.00	0.10	0.91	0.05	-0.04	0.04
Total	2.86	2.44	2.12	1.91	1.91	1.52
% of variance	17.86	15.22	13.28	11.95	11.93	9.47
Cumulative	17.86	33.08	46.36	58.31	70.23	79.71

Factor 3 account for 13.28% of the total variance with high loading of temperature, moderate loading of SO_4 and weak loading K. High temperature suggest high rate of weathering of geologic formation to which the surface water have contact with. Presence of SO_4 and K ions suggest atmospheric precipitation.

This factor represents 11.95% of the total variance with high loading of Cl with moderate loading of Mg. This variance have revealed that the chemistry of the surface water can be traced to the reaction of these water with rocks in the study area and soluble minerals present in the runoff that flow through on site sewage system. Magnesium chloride therefore was responsible for the increase in the salinity of the water. Chloride is a good indicator of sewage impacts because it is not subject to adsorption, ion exchange or redox reactions (Alyamani and Sabtan, 2008). Factor 5 which explains 11.93% of the total variance, includes high loading of oil and grease, moderate loading of PO_4 and low loading of SO_4. The high loading of oil and grease may be attributed to oil spillage, discharge of effluent water directly into the flowing streams and other anthropogenic factors. The runoff that flow through places where oil and grease are found has also increase the concentration of oil and grease in the surface water in the study area. The source of SO_4 in the surface water may be traced to environmental and atmospheric precipitation.

Factor 6 represent 9.47% of total variance of 79.71% with positive loading of pH and HCO_3. This factor reflects the signatures of natural water recharge and water soil interaction. Surface water charged with atmospheric and biogenic CO_2 aggressively attack aluminosilicates including feldspars and micas present in the soil or rock formation liberating some cations into the water. A consequence of this incongruent dissolution is a rise in pH and HCO_3 concentration of the water (Freeze and Cherry, 1979).

CONLUSION

In this study, hierarchical cluster and factor analyses were utilized to evaluate variation in the surface water quality of Okitipupa area. Cluster analysis grouped the sampling stations into 4 cluster groups that can be described as very low, low, moderate and high pollution. Factor analysis assisted to extract and recognized the factors or origin responsible for the variations in the chemistry of the surface water in both the dry and the rainy seasons of the year. Temperature, weathering process, cation exchange processes, agricultural and organic chemicals from run off and atmospheric precipitation were responsible for variation in the water quality during the dry and rainy seasons of the year.

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