

Application of Chemometric Technique in the Assessment of Groundwater Quality in Udi and its Environs, South-eastern Nigeria

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Abstract

This paper examines the factors controlling the hydrochemical facies of groundwater in the shallow marine Plain Sands aquifer in Udi and its environs, in Enugu State, Southeastern Nigeria. Twelve water samples were collected from Udi and its environs and analyzed for twenty-one parameters. The data obtained were subjected to R-mode factor analysis. Factor 1 reflects the signature of pollution factors resulting from seepages into the aquifer from the Ama Brewery and the tide-influenced Ajali River. Factor 2 has high loading values and represents the processes of natural rainwater recharge and water-soil/rock interaction. Factor 3 can be related to the dissolution of sulphides from interstratified peat within the geological formation and from heavy vehicular and brewery activities in Ama town. A broad zone of groundwater contact between water species represented by Factors 1 and 2 is thus created towards the Ajali River. The inference is that ionic concentration in the water decreases away from the banks of the river, an indication that the quality of groundwater improves away from the river. Factor 3 is enhanced in the southeastern area of the town where it is deemed to be caused by the dissolution of sulphur-bearing minerals within the geological formation, and also in the central and northwestern parts of the town, where it could be related to the rain-dissolution of sulphur-bearing compounds from gaseous emission arising from vehicular and brewery activities.

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Keywords: Aquifer, Factor Analysis (FA), Factor Loading (FL), Pollution, Water Quality Index (WQI).

1. Introduction

The study area spans the entire Udi North Local Government Area (LGA) in Enugu State, southeastern Nigeria. Udi is in the Anambra basin, a depocentre filled with Cretaceous to Recent sedimentary materials. Several boreholes exist in Udi, all tapping the prolific aquifers of the Ajali Sandstone. The quality of groundwater depends on several factors, including climate, soil characteristics, manner of circulation of groundwater through the rock type and topography of area (Rajesh et al., 2002). Chemistry of water is one of the important factors for determining its use for domestic, agricultural or industrial purposes. The chemical composition of groundwater depends not only on natural factors such as lithology of aquifer, the quality of recharge waters and types of interactions between water and aquifer, but also on human (anthropogenic) factors (activities), which can alter fragile ground water systems either by polluting them or by changing hydrological cycle (Helena et al., 2000). Several graphical methods were used to facilitate the interpretation and presentation of chemical analysis data from this study. The methods include the piper, stiff or shape and ionic

concentration diagrams. Because these methods consider only major ionic constituents, multivariate technique, such as factor analysis (FA) has been widely used as unbiased methods in the analysis of groundwater quality data to characterize groundwater composition influenced by natural and anthropogenic factors. In this work, the large dataset obtained from the hydrochemical analysis of groundwater samples collected from Udi and its immediate environs were subjected to Factor Analysis (FA), with the objective of assessing the groundwater quality as well as the hidden factors explaining the various processes that influence the water quality. Physical and chemical parameters of groundwater play a significant role in classifying and assessing water quality. Water Quality Indices (WQI) permits us to access changes in the water quality and to identify water trends (Silvia and Daniel, 2000).

1.1. Local geographic setting

The area under study covers about sixteen towns that comprise the Udi North L.G.A in Enugu State, southeastern Nigeria, and lies roughly between latitudes $6^{\circ}17'N$ and $6^{\circ}23'N$ of the equator, and longitudes $7^{\circ}16'E$ and $7^{\circ}21'E$ of GMT (Fig. 1). Udi has undulating topography. The area is drained by Oji and Dodo Rivers on the southwestern and central parts respectively while the Ajali River drains the northwest part of the area. The preferred orientation of the tributaries and subtributaries

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gives a dendritic drainage pattern, with water sources occurring as contact springs at the valley of the Udi cuesta,

joining up with other seepages to flow as streams along river valleys and extensive gully channels.

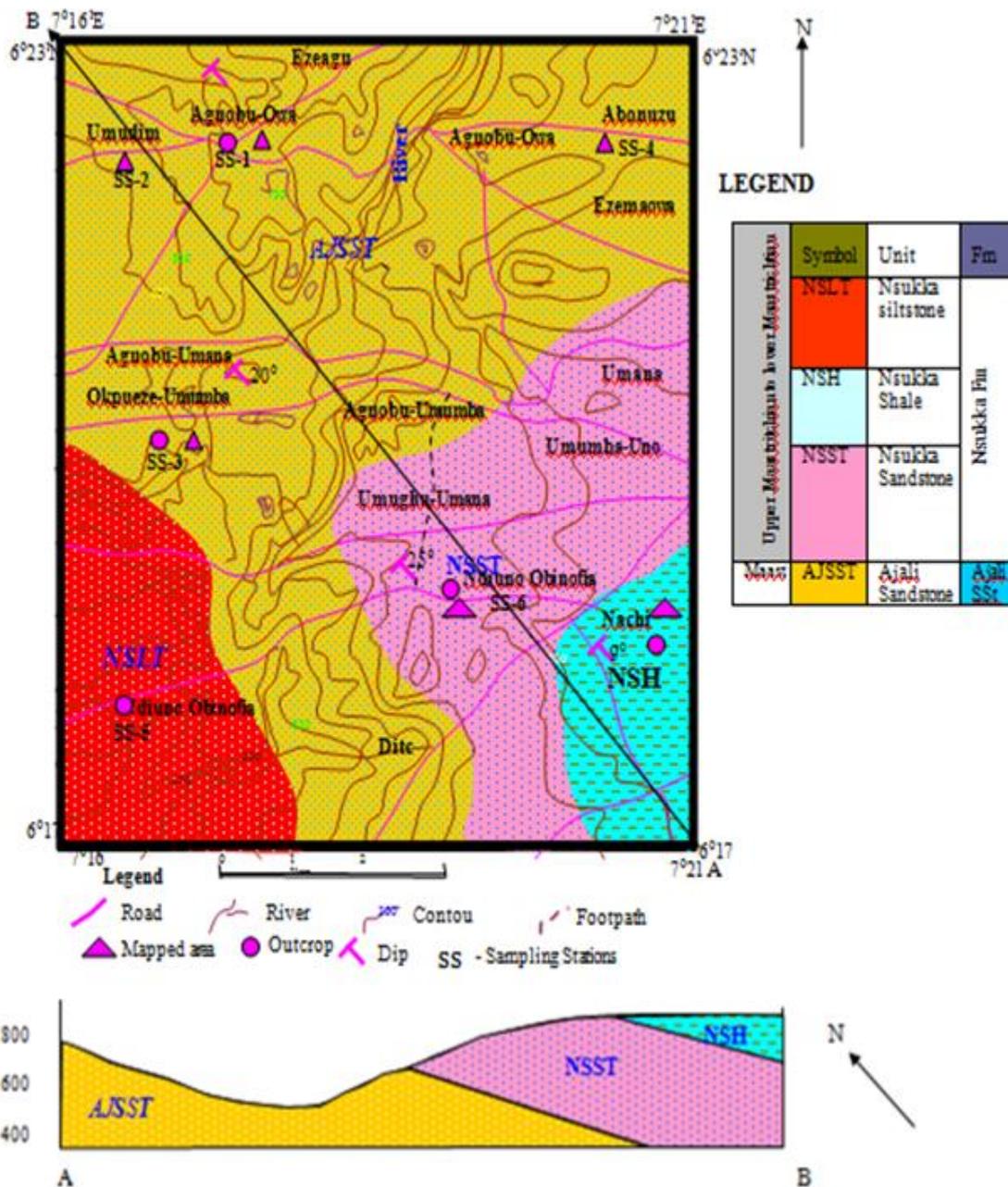


Fig. 1: Geologic map of the study area.

2. Geology and Hydrogeology

The study area is in the Anambra basin and is directly underlain by the Ajali Sandstone (Kogbe, 1976). It is dotted in places by the Nsukka Formation, which consists of tidal estuarine deposits (Reyment, 1965). The Ajali Sandstone lies unconformably on the Mamu Formation which, in turn, is underlain by the Nkporo group. The

Nkporo group is the basal unit of the Anambra stratigraphic pile (Fig. 2). The Ajali Sandstone is a thick, friable, poorly sorted, poorly cemented and unconsolidated sandstone sequence, generally covered by lateritic soil and thick red earth overburden, typically white in colour. (Ladipo, 1987; Nwajide and Reijers, 1996). The age of the formation is Maastrichtian.

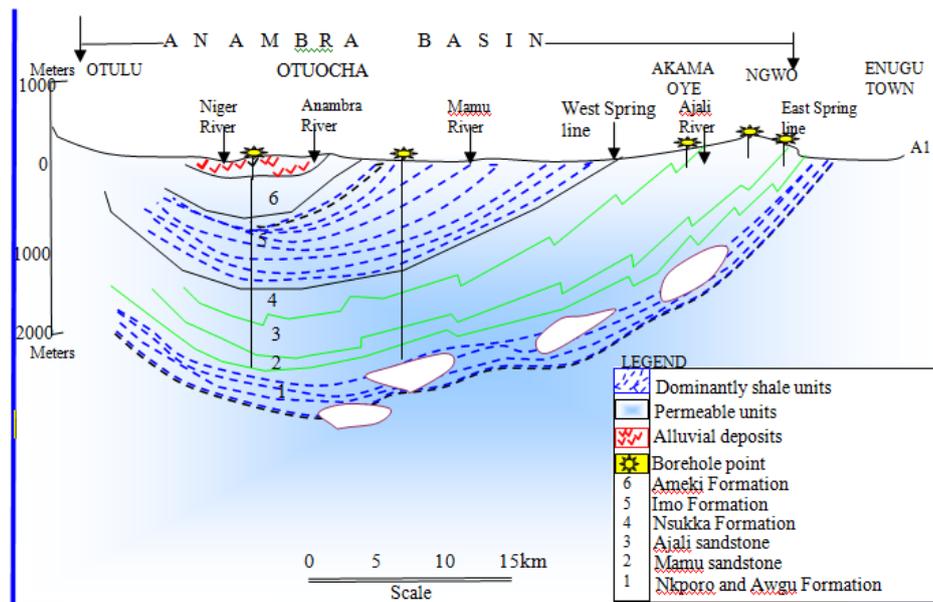


Fig 2: Schematic geological section across the Anambra basin showing the study area (Based on Reymont, 1965; Whiteman, 1982).

The Ajali Sandstone is up to 400m in places and constitutes the most prolific aquifer in the Anambra Basin (Ezeigbo, 1987). It comprises mainly a water table aquifer, but also has semi-confined aquifers where fingers of clays occur in appreciable thicknesses (Offodile, 2002). The existence of impermeable materials in the Ajali Sandstone makes possible the accumulation of groundwater at shallow depths that constitute perched aquifer system; hence the existence of hand-dug wells in parts of the study area. A number of boreholes exist in several parts of Udi, including those at the well fields that supply water to Enugu town which is basically underlain by shales. Uma *et al.* (1989) have given the hydraulic conductivity of the Ajali Sandstone to range from $1-10 \times 10^{-6}$.

3. Sampling and Analytical Procedures

3.1. Sampling and Analysis of Groundwater

The sampling network and strategy were designed to cover a wide range of determinants at key sites, which reasonably represent the groundwater quality in the study area. The representative sampling sites were chosen in order to cover areas of various anthropogenic activities, including waste disposal. The gathered background information provides sufficient details on these aspects. Groundwater samples (12 samples) were collected from hand-dug wells, springs, stream and an artesian well in March 2009 and July 2009, representing dry and rainy seasons sampling respectively. Samples for major ions and other inorganics were collected in one-liter pre-cleaned polypropylene bottles. The samples were immediately transported to the laboratory under low-temperature conditions in iceboxes and stored in the laboratory at 4°C until analysis. All the samples were analyzed for 21 parameters according to the standard methods of APHA–AWWA– WEF (1998). Details of analytical methodology followed are given in Table 1.

3.2. Factor Analysis (FA)

According to Ouyang *et al.* (2006), the purpose of FA is to reduce large analytical data of samples which are intercorrelated to a small set of ‘factors’ that are then interpretable. The factors group correlated concentrations together and they can be associated directly or indirectly with some specific source or process. The method consists of three steps, namely data standardization, factor extraction, and rotation of factor axes. Prior to analysis, the initial data are standardized by z -scale transformation as

$$Z = \frac{X_{ji} - \bar{X}_j}{S_j}$$

Where x_{ji} indicates the original value of the measured parameter, \bar{x}_j the average value of the parameter j and s_j the standard deviation of j . FA takes data contained in a correlation matrix and rearranges them in a manner that better explains the structure of the underlying system that produced the data. The starting point of FA is to generate a new group of variables from the initial dataset (the so-called factors) that are a linear combination of the original variables. The first factor obtained explains the biggest part of the variance. The following factors explain repeatedly smaller parts of the variance (Ruiz *et al.*, 1990).

Factor loadings show how the factors characterize the variables. High factor loadings (close to 1 or -1) indicate strong relationship (positive or negative) between the variable and the factor describing the variable. Then the factor loadings matrix is rotated to an orthogonal simple structure according to the varimax rotation technique. Finally, factor scores are calculated for each sample and plotted as a scatter diagram. Extreme positive factor scores ($>+1$) reflect sampling stations most affected by the process and extreme negative score (<-1) reflect those unaffected by the process explained by the factor. Near-zero scores reflect sampling stations affected to an average degree by the process (Kennel *et al.*, 2007).

3.3. Data Treatment and Chemometric Analysis

Chemometric analysis of the data was performed using FA techniques. FA is performed on standardized (z -scale transformation) experimental datasets in order to avoid misclassification due to wide differences in data dimensionality. The z -scale transformation renders the data normalized with mean and variance of zero and one

respectively. Standardization tends to increase the influence of variables whose variance is small and reduce the influence of variables whose variance is large (Lui *et al.*, 2003). Furthermore, standardization procedure eliminates the influence of different units of measurement and renders the data dimensionless. All the statistical computations were made using the SPSS 10.1 software.

Table 1: Details of analytical methodology and basic statistics of groundwater samples collected from the study area

| Symbol | Variable | Method | Units | Detection Limit | DRY SEASON | | | | RAINY SEASON | | | |
|------------------|--------------------------------------|---------------------|---------------------|-----------------|------------|--------|--------|--------|--------------|-------|-------|--------|
| | | | | | Min | Max | Mean | SD | Min | Max | Mean | SD |
| PH | PH | Potentiometry | pH | - | 4.14 | 5.96 | 5.040 | 0.609 | 4.0 | 5.01 | 4.45 | 0.494 |
| EC | Electrical conductivity | Electrolytic | $\mu\text{mhos/cm}$ | - | 21.3 | 106.0 | 39.570 | 32.816 | 18.8 | 107.1 | 38.13 | 34.134 |
| TH | Total Hardness (as CaCO_3) | EDTA titrimetric | Mg/l | 5 | 3.0 | 28.0 | 10.330 | 13.692 | BDL | 30.0 | 6.33 | 11.827 |
| Ca | Calcium | EDTA titrimetric | Mg/l | 2 | BDL | 9.2 | 3.000 | 3.096 | BDL | 7.9 | 1.8 | 3.047 |
| Mg | Magnesium | By difference | Mg/l | 1 | 9.6 | 4.5 | 0.850 | 1.794 | BDL | 4.83 | 1.24 | 1.923 |
| Na | Sodium | Flame photometry | Mg/l | 1 | BDL | 22.8 | 15.100 | 7.238 | 3.55 | 21.97 | 12.44 | 7.563 |
| K | Potassium | Flame photometry | Mg/l | 1 | 24.9 | 222.3 | 42.090 | 89.109 | 1.67 | 11.0 | 4.39 | 3.509 |
| HCO ₃ | Bicarbonate | Titrimetry | Mg/l | 6 | 9.21 | 95.7 | 50.430 | 30.256 | BDL | 70.0 | 28.68 | 26.352 |
| CL | Chloride | Argentometry | Mg/l | 4 | 47.26 | 35.45 | 16.190 | 9.777 | 3.0 | 28.0 | 8.51 | 9.694 |
| SO ₄ | Sulfate | Nephlo-turbidimetry | Mg/l | 5 | BDL | 129.19 | 78.380 | 29.626 | 18.75 | 75.95 | 36.6 | 20.014 |
| NO ₃ | Nitrate | Spectrophotometry | Mg/l | 0.05 | BDL | 0.25 | 0.130 | 0.082 | BDL | 0.15 | 0.085 | 0.061 |

SD= standard deviation; BDL= below detection level; Min= Minimum value, Max- maximum value

4. Results and Interpretation

4.1. Graphical Methods

An important task in groundwater investigation is the compilation and presentation of chemical data in a convenient manner for visual inspection. For this purpose, several commonly used graphical methods are available.

The simplest of these is the pie chart, which represents the major ion compositions in equivalents per cubic meter or million equivalents per litre as percentages of total equivalents. The results of the water analysis (Appendix A) in this study are shown in pie charts in Figure 3 and Figure 4. Other representations are shown in Figures 4-9.

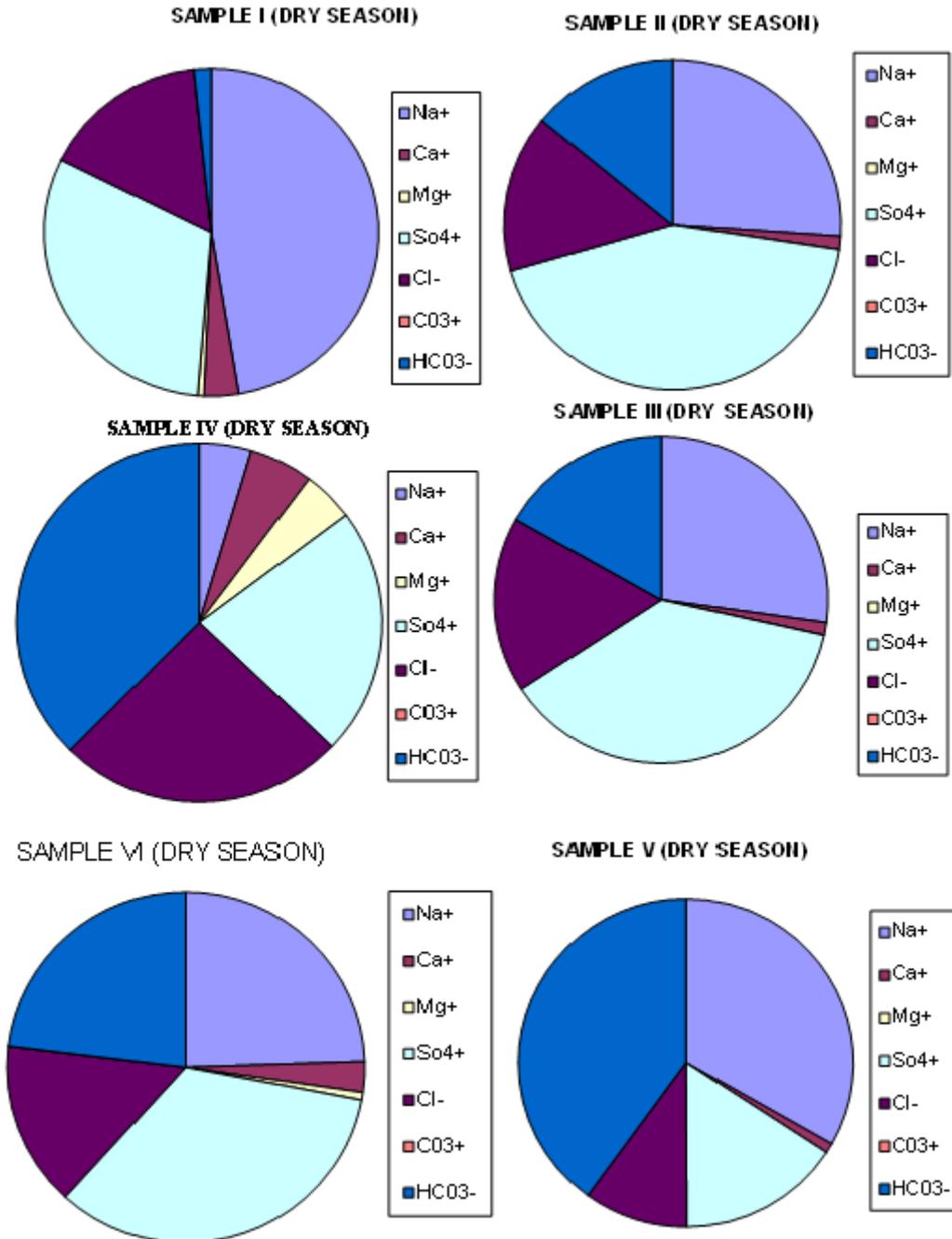


Fig. 3: Water samples for dry season.

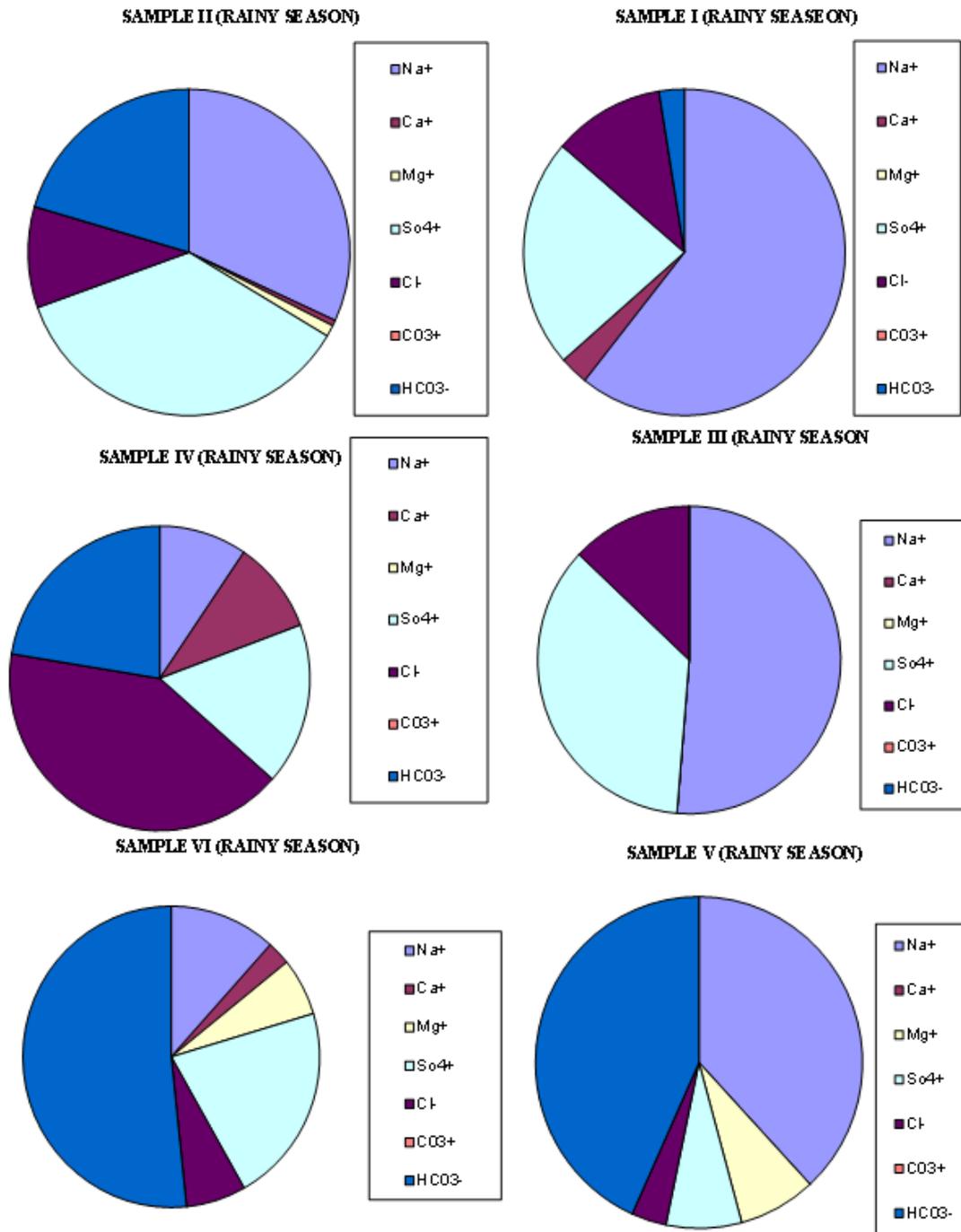


Fig. 4: Water samples for Rainy season

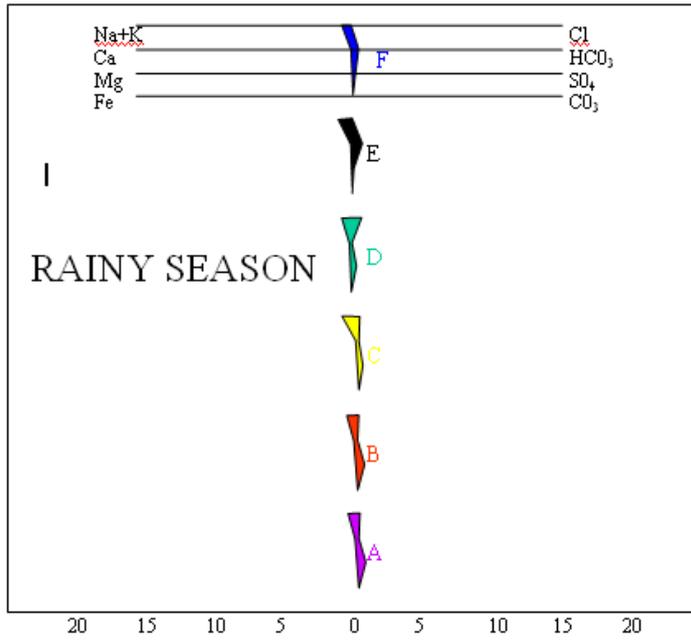


Fig. 5: Pattern diagrams for water Samples A, B, C, D, E & F (After Hem, 1989)

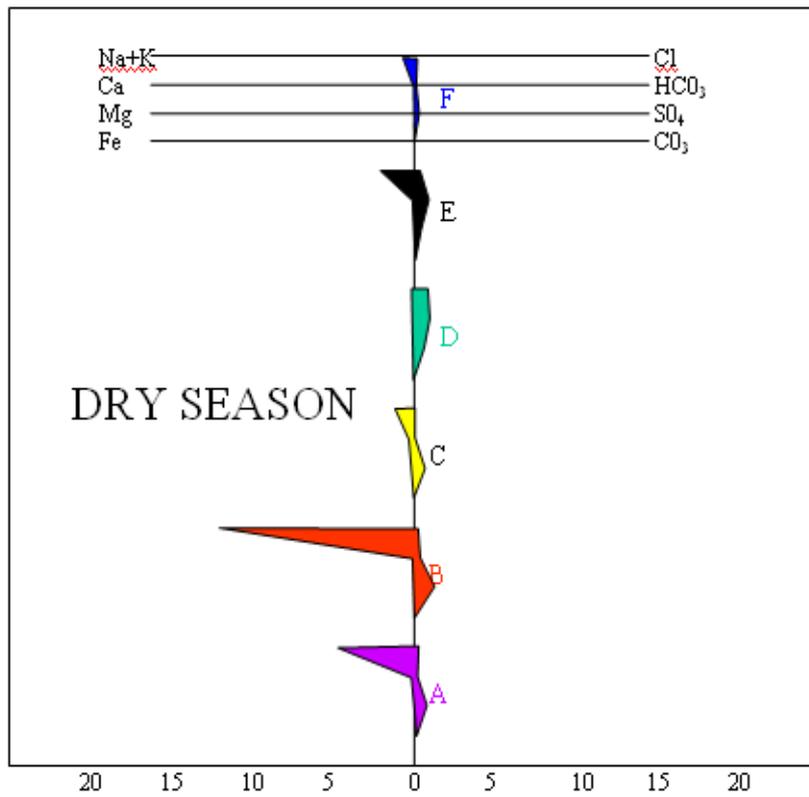


Fig. 6: Pattern diagrams for representing analysis of groundwater quality (After Hem, 1989)

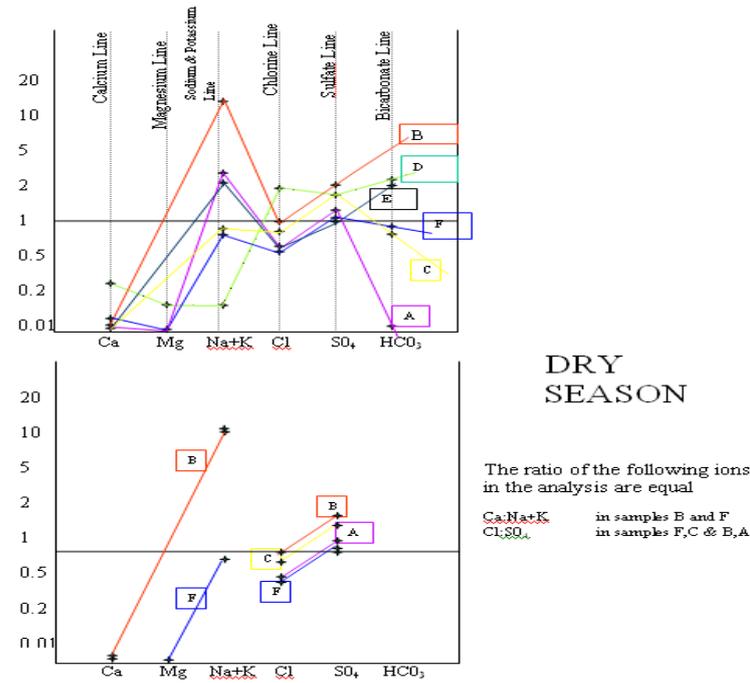


Fig. 7. Schoeller semilogarithmic diagram for representing analysis of groundwater quality (After Schoeller, 1962)

Fig. 7: Schoeller semilogarithmic diagram for representing analysis of groundwater quality for dry season water samples A,B,C & F (After

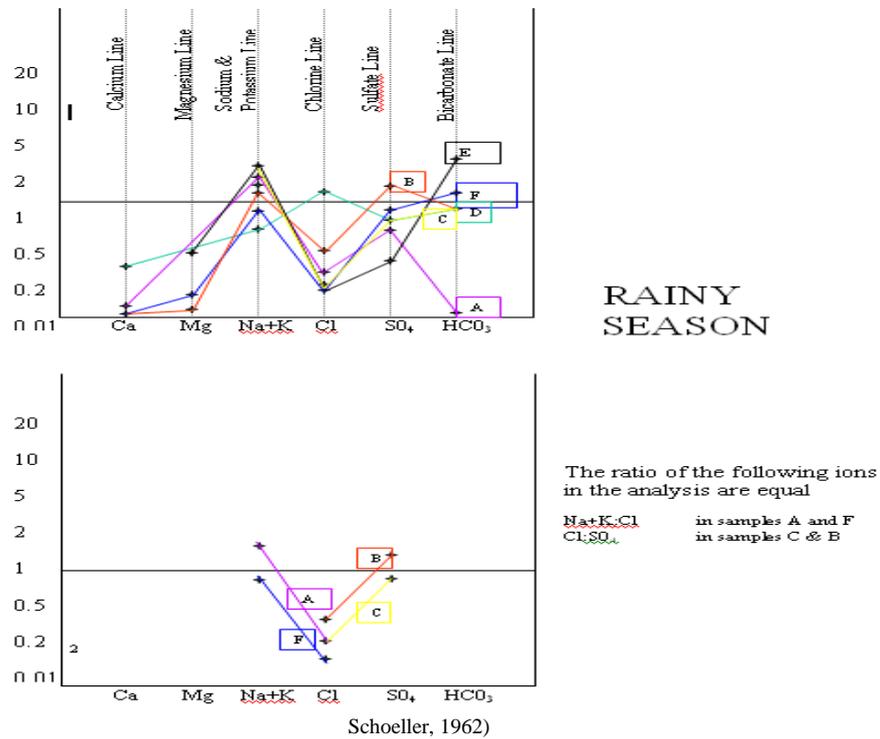


Fig. 8: Schoeller semilogarithmic diagram for representing analysis of groundwater quality for rainy season water samples (A, B, C & F) (After Schoeller, 1962)

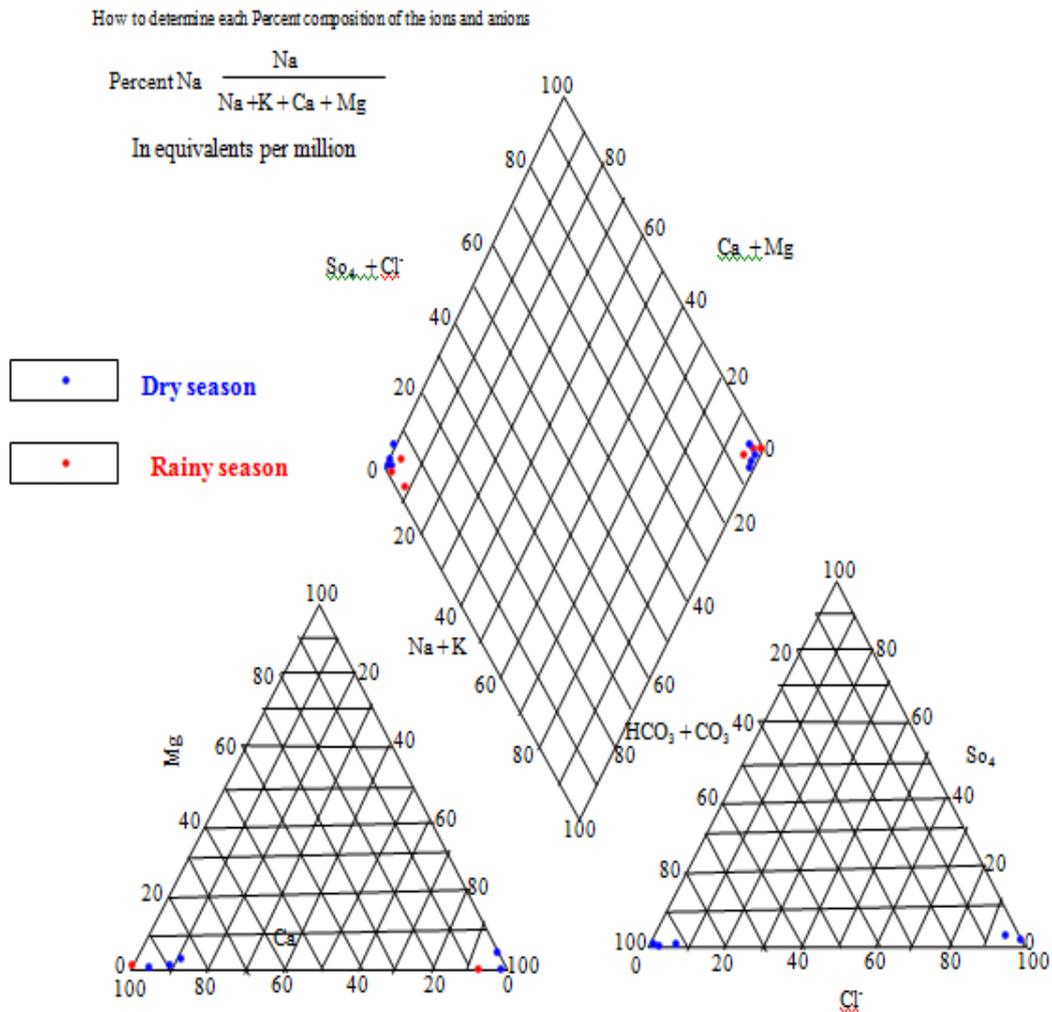


Fig. 9: Chemical analysis of water represented as percentages of total equivalents per litre on the diagram developed by Hill (1940) and Piper (1944).

4.2. Factor analysis (FA)

The Bartlett’s sphericity test carried out on the correlation matrix shows calculated $\chi^2 = 1950.5$ and 2000 for the dry and rainy seasons respectively, which are greater than the critical value of $\chi^2 = 387.3$ ($P = 0.0005$ and 300 degrees of freedom), thus proving that the Principal Component (PC) extraction can achieve a significant reduction of the dimensionality of the original dataset. Factor Analysis (FA) was applied separately to the hydrochemical dataset pertaining to dry and rainy seasons. Table 4 summarizes the sorted FA results, including the variable loadings, and variance explained by each factor for the two seasons. The factor loadings were sorted according to the criteria of Liu *et al.*(2003), into strong, moderate and weak, corresponding to absolute loading values of >0.75 , $0.75-0.50$ and $0.50-0.30$ respectively. Loading values <0.30 are insignificant. During the Dry season, Factor 1 explains 56.65% of the variance and is characterized by strong positive loadings (>0.90) of TH, EC, TDS, Cl, HCO_3 , NO_3 and Ca, and strong loadings by TH, EC, TDS, Cl, HCO_3 , NO_3 , Ca; while SO_4 shows weak loadings. Others show moderate loadings. Factor 2 explains 28.62% of the variance and has strong loadings of

Mg, K, SO_4 and P^{H} ; TH, Ca, EC, TDS, Pb, Mn, Cl, NO_3 , Cl, HCO_3 and acidity are insignificant, while Fe shows weak loadings. Considerable overlapping of variables (TH, EC, Mg, K, SO_4 , TDS, Cl, HCO_3 , NO_3 and Ca) is observed. Hence, the underlying processes explaining these two Factors are mixed. Further, major ionic constituents that are highly correlated to EC, TH, P^{H} and TDS mainly contribute to Factor 1. Hence, Factor 1 may be termed as the ‘major ion pollution factor’.

Factor 1 could represent as the Ama Brewery pollution factor and the zone of water mixing at the bank of the Ajali River. The sources of major ionic constituents are the poor industrial waste system; hence, Factors 1 and 2 could be collectively called pollution factors. Factors 3 and 4 account for 14.73% of the variance of the dataset; however, the variable loadings of Factors 3 & 4 are not clearly describable. Hence the possible sources associated with these factors could not be explained. Factor 1 (major ion pollution factor) explains 59.14% of the variance and has strong loadings of EC, Ca, TH, TDS, Fe and Cl. Similar to the dry season, SO_4 showed weak loadings.

Factor 2 explains 10.78% of variance and has strong loadings of Mg, K and NO_3 ; all the rest of the ions are considered insignificant (i.e. <0.30). The variance

explained by the two factors (i.e. Factor 1 & Factor 2) accounts for 69.92% of the total variance. Similar to dry season, overlapping of variables is observed. Also, the variable loadings of Factors 3 and 4 are not clear, though they account for 30.08% of the total variance. Comparison of FA for the two seasons shows the effect of groundwater recharge caused by downpour on the two processes associated with the two factors. It appears that the major ion pollution factor shows little change during the rainy season; but there is considerable reduction in pollution load caused by the Ama pollution factor. This is evidenced by the substantial reduction in the concentration of certain metals, notably, HCO_3 and major ionic constituents, such as EC, TH, Ca, TDS, and Cl during the rainy season. The loading pattern of Factors 3 and 4 during the dry season and during the rainy season is not clear and indicates the

absence of correlation with other variables. The factor score plots of the first two factors for the dry and rainy seasons are shown in Figure 10. Comparison of the factor score plots for the two seasons shows the effect of dilution on the hydrochemical variables caused by recharge. The score plots for the two seasons show almost the same grouping of samples. The samples affected by the two factors (factor score >1) are well identified for the two seasons. During the dry season, few of the samples are clustered around the origin, indicating contamination by the two processes to an average extent. Most of the samples were not affected by the two processes and have high negative scores (<-1). The clustering of samples around the origin is less pronounced during the two seasons, indicating the effect of dilution caused by rainfall.

Table 4: R-mode varimax rotated factor loadings of groundwater parameters for dry and rainy seasons in the study area

| Variables | Factor 1 | Factor 2 | Factor 3 | Factor 4 | | Variables | Factor 1 | Factor 2 | Factor 3 | Factor 4 | |
|----------------|-------------|-------------|----------|-------------|--|----------------|-------------|-------------|-------------|-------------|--|
| PH | -1.48 | -0.11 | -0.53 | 1.51 | | PH | -1.01 | -0.71 | -0.91 | 0.34 | |
| EC | 2.02 | -0.20 | -0.34 | -0.41 | | EC | 2.02 | -0.18 | -0.31 | -0.51 | |
| TH | 2.02 | -0.46 | -0.54 | -0.17 | | TH | 2.00 | 0.00 | 0.00 | -0.03 | |
| Ca | 2.00 | -0.45 | -0.58 | -0.06 | | Ca | 2.00 | 0.00 | -0.43 | -0.07 | |
| Mg | 0.00 | 2.03 | -0.31 | -0.31 | | Mg | 0.40 | 1.87 | -0.33 | 0.00 | |
| Na | -1.51 | 0.26 | -0.11 | 0.92 | | Na | -1.09 | -0.20 | 0.40 | 0.81 | |
| K | 0.00 | 2.02 | 0.00 | -0.13 | | K | -0.09 | 1.88 | -0.78 | -0.49 | |
| HCO_3 | 1.50 | -0.76 | -0.87 | 0.06 | | HCO_3 | 0.00 | -0.03 | -0.03 | -1.01 | |
| CL | 1.97 | 0.01 | -0.21 | -0.50 | | CL | 2.01 | -0.44 | -0.10 | -0.33 | |
| SO_4 | 0.34 | 1.72 | 0.24 | -0.55 | | SO_4 | -0.16 | -0.16 | 1.97 | -0.32 | |
| NO_3 | 1.47 | -0.37 | 0.24 | 0.24 | | NO_3 | 0.24 | 1.06 | 0.24 | 0.24 | |
| Mn | 0.00 | 0.00 | 0.00 | 0.00 | | Mn | 0.00 | 0.00 | 0.00 | 0.00 | |
| Pb | 0.00 | 0.00 | 0.00 | 0.00 | | Pb | 0.00 | 0.00 | 0.00 | 0.00 | |
| TDS | 2.02 | -0.18 | -0.33 | -0.41 | | TDS | 2.02 | -0.18 | -0.31 | -0.51 | |
| ACIDITY | 0.00 | 0.00 | 0.00 | 0.00 | | ACIDITY | 0.00 | 0.00 | 0.00 | 0.00 | |
| Fe | -0.40 | 0.40 | 0.40 | 0.00 | | Fe | 1.34 | -0.80 | 0.27 | 0.80 | |
| % Variance | 56.65 | 28.62 | 4.37 | 10.36 | | | 59.14 | 10.78 | 19.30 | 10.78 | |
| Cummulative % | 56.65 | 85.27 | 89.64 | 100 | | | 59.14 | 69.92 | 89.22 | 100.00 | |

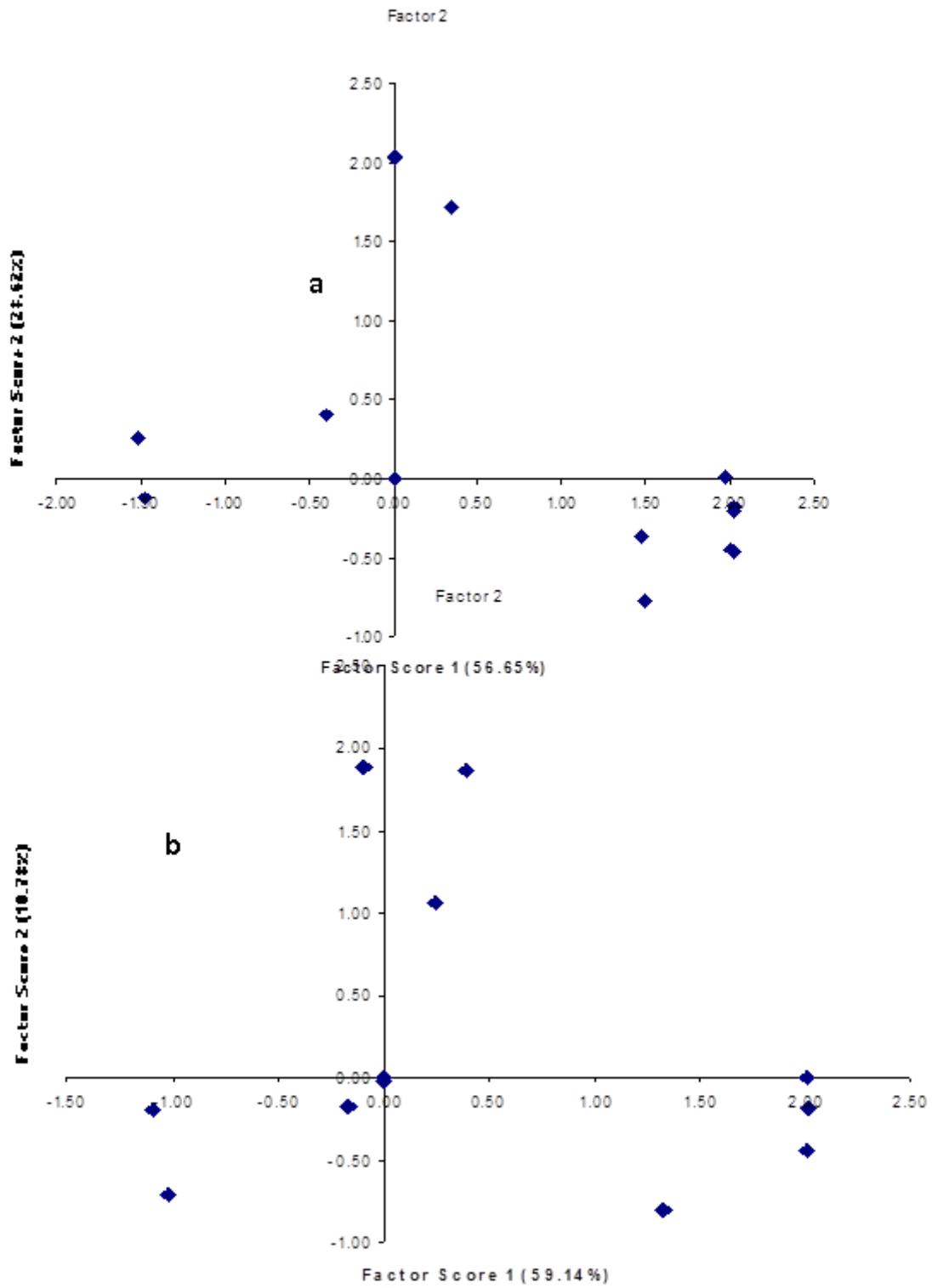


Fig. 10: Factor score plot of Factors 1 and 2 for (a) Dry season and (b) Rainy season

4.3. Water Quality Index (WQI)

The evaluation of water quality index in this study was based on the calculation proposed by Pesce and Wunderlin (2000). Water quality rating was assessed by considering the following ranges:

- WQI < 40 = fit for human consumption.
- WQI 40-70 = moderately polluted
- WQI 70-100 = excessively polluted
- WQI > 100 = severely polluted

A critical study of the WQI reveals the status of pollution of groundwater in the study area. WQI values for all the sampling sites A, B, C, D, E and F are below 40 WQI (Figure 11).

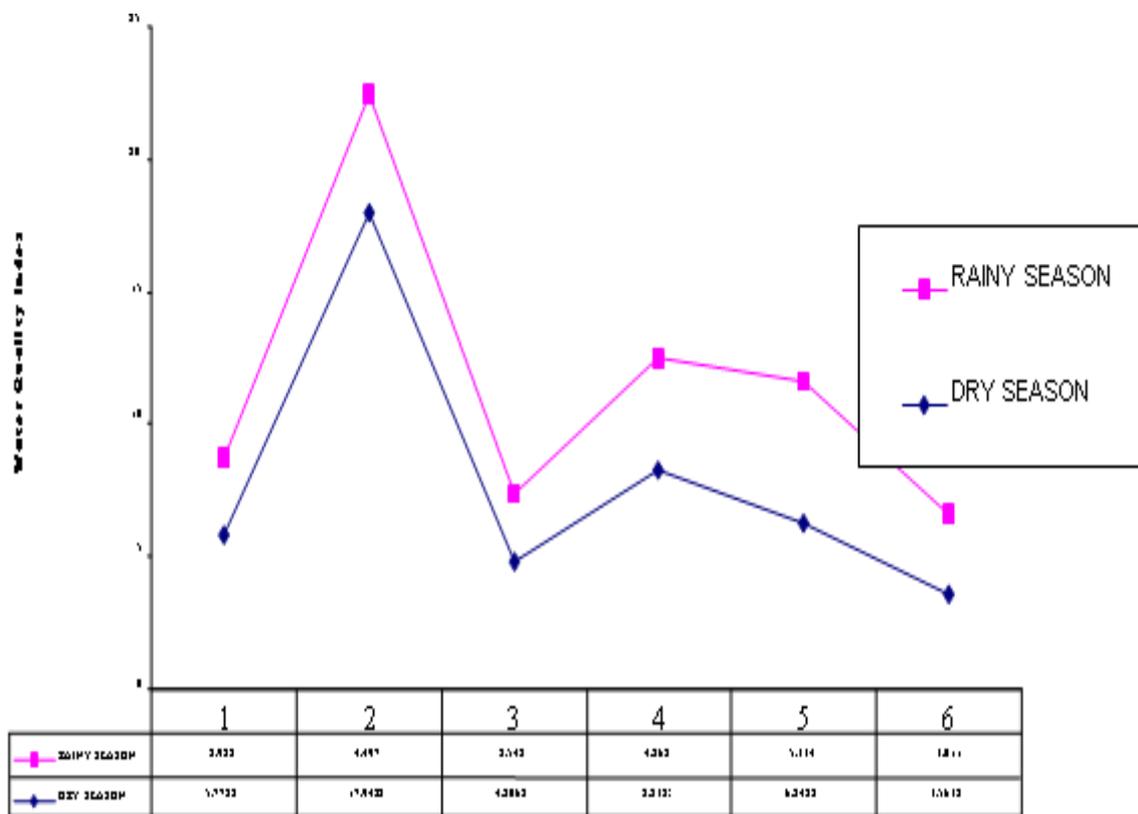


Figure 11: Variation in Water Quality Index (WQI) in the study area.

5. Summary and Conclusion

This paper demonstrates the effectiveness of factor analysis in sorting out otherwise ambiguous hydrogeochemical processes and in showing the spatial influence of such processes. Graphical methods, which include piper diagrams, stiff or shape diagrams, ionic concentration diagram and scattered diagram, were used to facilitate the presentation and interpretation of chemical analysis of groundwater in Udi, southeastern Nigeria. Virtually all diagrams were calculated in terms of equivalents per million or milliequivalents, which express the concentration of ions in solution in terms of their chemical equivalents. The application of the multivariate statistical analysis provided an insight into the underlying controlling hydrochemical processes in the area. Factors 1 and 2 represent ions with dominant concentrations and therefore the main contributors to the groundwater

pollution. Factor analysis (FA) identified two polluting processes, namely a zone of mixing of the two water types especially close to the bank of Ajali River pollution factor and Ama pollution factor, responsible for groundwater pollution in the area. The polluting processes associated with factors 3 and 4 during the rainy and dry seasons could not be identified because variable loadings of these factors were not clear. FA predicted that temporal changes in water quality are due to anthropogenic activities, as caused by the Ama pollution factor. However, it could not differentiate between the unpolluted and moderately polluted stations clearly. The findings of the study indicate the need for proper industrial planning and the safe disposal of industrial and urban wastes, which otherwise would lead to severe environmental degradation. Though several ‘pump and treat’ techniques could be used to make the water fit for its intended use, aquifer remediation techniques may be suitable for this type of small area.

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Appendix

ANALYSIS RESULTS

Sample Description:

Analysis Required: Physical, Chemical, and Microbiological

Data Collected: 19/08/09 Lab. Sample No.:

| 1 | PARAMETER | UNIT | WHO std. | VALUES | | | | | |
|---|--------------------------------------|------------------------|-------------|--------|-------|-------|-------|-------|-------|
| | | | | A | B | C | D | E | F |
| | PHYSICAL ANALYSIS | | | | | | | | |
| | Odour | | | -ve | -ve | -ve | -ve | -ve | -ve |
| | Turbidity | NTU | - | 1.50 | 1.0 | 2.5 | 2.0 | 1.0 | NIL |
| | PH value | | 6.5-9.0 | 4.62 | 4.00 | 4.10 | 3.95 | 5.0 | 5.01 |
| | Conductivity | Microhms/cm | 100 | | | | | | |
| 2 | CHEMICAL ANALYSIS | | | | | | | | |
| | Acidity | Mg/L CaCO ₃ | - | - | - | - | - | - | - |
| | Alkalinity | Mg/L CaCO ₃ | 30-500 | - | 3.00 | - | - | 10.10 | 9.10 |
| | Total Solids | Mg/L | - | 11.62 | 15.50 | 18.01 | 59.96 | 10.55 | 12.65 |
| | Dissolved Solids | Mg/L | 500 | 11.60 | 15.40 | 18.00 | 59.95 | 10.53 | 12.63 |
| | Suspended Solids | Mg/L | - | 0.10 | 0.04 | 0.005 | 0.005 | 0.008 | 0.035 |
| | Calcium | Mg/L | 75 | 1.60 | .05 | 0.0 | 7.9 | 0 | 0.8 |
| | Magnesium | Mg/L | Not >30 | NIL | 0.6 | NIL | NIL | 4.83 | 2.00 |
| | Total Hardness | Mg/L CaCO ₃ | 100-200 | 6.00 | NIL | NIL | 30.0 | NIL | 2.0 |
| | Calcium Hardness | Mg/L | 200 | 7.00 | 2.50 | 2.0 | 18.0 | 2.0 | 4.0 |
| | Magnesium Hardness | Mg/L | 12 | NIL | 1.0 | NIL | NIL | 10.0 | 2.0 |
| | Iron | Mg/L | 0.3 | 0.40 | 0.3 | 0.1 | NIL | 0.5 | 0.2 |
| | Manganese | Mg/L | 0.1-0.5 | NIL | NIL | NIL | NIL | NIL | NIL |
| | Lead | Mg/L | 0.01 | NIL | NIL | NIL | NIL | NIL | NIL |
| | Chloride | Mg/L | 250 | 5.33 | 7.50 | 4.25 | 28.0 | 3.0 | 3.0 |
| | Sulphate | Mg/L | 250 | 30.11 | 75.95 | 33.33 | 33.35 | 18.75 | 28.09 |
| | Nitrate | Mg/L | 50 | 0.1 | NIL | NIL | 0.1 | 0.15 | 0.1 |
| | Potassium | Mg/L | | 2.67 | 1.67 | 11.0 | 4.67 | 1.67 | 4.67 |
| | Carbonate | Mg/L | | NIL | NIL | NIL | NIL | NIL | NIL |
| | Bicarbonate | Mg/L | | 2.10 | 2.80 | 0.0 | 28.0 | 70.0 | 44.0 |
| | Sodium | Mg/L | | 18.53 | 15.43 | 10.95 | 4.20 | 21.97 | 3.55 |
| 3 | MICROBIAL ANALYSIS | | | | | | | | |
| | E-Coli/100ml | Per 100ml | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| | Coliform/100ml | Per 100ml | 3 | 180 | 140 | 99.0 | 120 | 75 | 200 |
| | Total Plate Count @ 35°C after 24hrs | Per ml | 100 | 100.0 | 87.20 | 99.0 | 120.0 | 180.0 | 30.0 |

Comments: Results of the samples are not consistent with the WHO maximum permissible level for potable water

ANALYSIS RESULTS

Sample Description:**Analysis Required:** Physical, Chemical, and Microbiological

Data Collected: 02/04/09

Lab. Sample No.:

| 1 | PARAMETER | UNIT | WHO std. | VALUES | | | | | |
|---|--------------------------------------|------------------------|----------|--------|--------|--------|--------|--------|--------|
| | | | | A | B | C | D | E | F |
| | PHYSICAL ANALYSIS | | | | | | | | |
| | Odour | | | -ve | -ve | -ve | -ve | -ve | -ve |
| | Turbidity | NTU | - | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 | Nil |
| | PH value | | 6.5-9.0 | 5.96 | 4.97 | 4.72 | 4.14 | 5.33 | 5.12 |
| | Conductivity | Microhms/cm | 100 | 26 | 33.0 | 28.5 | 106.0 | 21.3 | 22.6 |
| 2 | CHEMICAL ANALYSIS | | | | | | | | |
| | Acidity | Mg/l CaCO ₃ | - | - | - | - | - | - | - |
| | Alkalinity | Mg/l CaCO ₃ | 30-500 | 15.0 | 15.0 | 20.1 | 10.0 | 20.0 | 25.0 |
| | Total Solids | Mg/l | - | 14.59 | 18.50 | 16.02 | 59.40 | 12.0 | 12.69 |
| | Dissolved Solids | Mg/l | 500 | 14.56 | 18.48 | 16.02 | 59.36 | 11.93 | 12.66 |
| | Suspended Solids | Mg/l | - | 0.03 | 0.02 | 0.004 | 0.10 | 0.082 | 0.033 |
| | Calcium | Mg/l | 75 | 2.8 | 1.6 | 1.2 | 9.2 | 1.2 | 2.0 |
| | Magnesium | Mg/l | Not >30 | 0.3 | Nil | NIL | 4.5 | Nil | 0.3 |
| | Total Hardness | Mg/l CaCO ₃ | 100-200 | 8.0 | 4.0 | 3.0 | 38.0 | 3.0 | 6.0 |
| | Calcium Hardness | Mg/l | 200 | 7.00 | 4.0 | 3.0 | 23.0 | 3.0 | 5.0 |
| | Magnesium Hardness | Mg/l | 12 | 1.0 | Nil | NIL | 15.0 | Nil | 1.0 |
| | Iron | Mg/l | 0.3 | 0.08 | 0.1 | 0.1 | 0.06 | 0.15 | Nil |
| | Manganese | Mg/l | 0.1-0.5 | NIL | NIL | NIL | NIL | NIL | NIL |
| | Lead | Mg/l | 0.01 | NIL | NIL | NIL | NIL | NIL | NIL |
| | Chloride | Mg/l | 250 | 11.34 | 16.31 | 14.18 | 35.45 | 10.64 | 9.22 |
| | Sulphate | Mg/l | 250 | 62.19 | 129.19 | 85.55 | 88.33 | 47.26 | 57.75 |
| | Nitrate | Mg/l | 50 | 0.15 | 0.1 | NIL | 0.15 | 0.25 | 0.15 |
| | Potassium | Mg/l | | 30.24 | 222.3 | Nil | Nil | Nil | Nil |
| | Carbonate | Mg/l | | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| | Bicarbonate | Mg/l | | 52.20 | 27.30 | 24.90 | 95.70 | 77.10 | 25.40 |
| | Sodium | Mg/l | | 21.78 | 17.91 | 14.32 | 4.18 | 22.80 | 9.60 |
| 3 | MICROBIAL ANALYSIS | | | | | | | | |
| | E-Coli/100ml | Per 100ml | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| | Coliform/100ml | Per 100ml | 3 | 27.0 | 26.0 | 33.0 | 17.0 | 13.0 | 49.0 |
| | Total Plate Count @ 35°C after 24hrs | Per ml | 100 | 107.0 | 87.0 | 112.0 | 138.0 | 102.0 | 59.0 |

Comments: Results of the samples are not consistent with the WHO maximum permissible level for potable water

