GROUNDWATER QUALITY ASSESSMENT AT SULEJA, NORTH CENTRAL NIGERIA

Supported by tetfund TERTIARY EDUCATION TRUST FUND

Shuaibu Ahmed Mahi[1]* and Abdulhakeem Salau Bello[2]

[1]Department of Geological Sciences, Federal University Gusau, Zamfara,
[2]Center for Disaster Risk Management, Federal University of Technology, Minna, Nigeria
*Corresponding author: mahalkufr@gmail.com

Received: December 15, 2016 **Accepted:** February 26, 2017

Abstract: This research aimed at demonstrating the application of hydrochemical techniques in evaluating the effect of waste dumpsite on groundwater resources of Suleja environs. The samplings were carried out systematically in seven different well locations, from the month of May to November during wet season of the year. The total sample collected for the months of wet season were 42 in numbers, which was subjected to several standard laboratory analyses. The result revealed concentrations ranges of the analyzed parameters in the following order physical parameters such as pH (5.7 - 8.8), TDS (19.9 – 529 mg/L), conductivity (105 – 1688 mg/l), Alkalinity (25 – 214 mg/L), Total hardness (52 – 370 mg/L), Biological Oxygen Demand BOD (1 – 8 mg/L), Chemical Oxygen Demand COD (4 – 16 mg/L). The anionic parameters revealed average concentrations in the order of $SO_4 > Cl^- > HCO_3 > CO_2 > NO_3 > PO_4$, while cationic average concentration in mg/L revealed $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ respectively, the heavy metals are in the following order of their various average concentrations $Fe^{2+} > Mn^{2+} > Zn^{2+} > Cu^{2+}$. This result revealed that Sulphate/Chloride are the dominant anions present in the groundwater of the study area while Calcium/Magnesium are the most dominant anions. The parametric comparison conducted with WHO and NSDWQ water quality standard for domestic purposes indicate that the groundwater of the study area is portable for domestic usage. The results equally indicate that the source of enrichment of the solute is majorly from weathering of the lithologic compositions that underlain the area of study, with little leachate flow from waste dump sites (as indicated by slight elevated level of concentrations revealed by Mn^{2+} and Zn^{2+}). The type of water that predominate the study area is Ca + Mg-SO_4 type based on hydrochemicalfacies classification plot (Piper Trilinear Diagram). Water quality index value revealed excellent nature of the water for domestic usage though the water is classified as hard water type. The groundwater of the study area should be subject to basic water treatment before consumption.

Keywords: Groundwater, geo-statistics, hydrochemistry, water quality index, waste dump

Introduction

In Nigeria today research indicates that, majority of the common fresh water sources are polluted, resulting to serious outbreak of these and other diseases. A study by Umeh *et al.*, (2004) showed that 48% of the people in Katsina-Ala Local Government area of Benue State are affected by urinary *Schistosomiasis*, due to increase in water pollution index. Some previous investigations indicate that 19% of the whole Nigerian population is affected, with some communities having up to 50% incidence. This has raised serious concerns to World Health Organization (WHO), in an attempt to improve cultural and socio-economic standards of people in the tropical region (Umeh, 1989; Umeh *et al*., 2004).

In few years back, Olaoye and Onulide (2009) documented varying levels of microbial contaminations in drinking water from western parts of the country. Total bacteria and coliform counts were found to be between 2.86-4.45 and 1.62 log cfu/ml respectively. In addition to microbial infections, heavy metals poisoning through drinking water have also been documented. Nriagu *et al.* (1997) reported blood lead levels greater than 30 μg/dl in children from Kaduna State. The elevated levels were linearly correlated with water and air contaminations by lead emissions. Garba *et al.* (2010) reported a mean arsenic concentration of 0.34 mg/l in drinking water from hand dug wells, boreholes and taps of Karaye Logal Government area, Kano State. The arsenic levels are of serious concerns to regulatory agencies because they by far exceed the upper band (0.01 mg/l) recommended by WHO. The unreliability of water supply from government-owned water board led some of the people to resort to drilling boreholes, or wells. Some buy water from water vendors in tanks. Those who could not afford these obtain their drinking water from shallow wells, less than 5 m (16 ft) deep. Some of these shallow well waters require treatment before meeting the WHO drinking water standard, Yusuf (2007).

Water contamination/pollution from various sources which always tends to degrade the quality of water in its entirety has become a pressing issue of serious concern, which if it leave unabated will jeopardize the millennium development goal according to Shuaibu and Abdullahi, (2015). Overdependence or reliance on rain water is almost impossible, due to its inadequacy and hence most people have resorted to groundwater to satisfy their water needs in Suleja environs (located on Latitude 09° 11´ 30N and 09° 06´ 30N with Longitude 07° 10´ 00E and 07° 13´ 00E).

More so the problem of solid waste management in Nigeria has become a complex issue as a result of high population growth, accelerated urbanization and industrialization (Aguwamba, 2003). This is an eminent situation of the groundwater resources in the area of study, it is therefore crucial that periodic checks are performed on groundwater to establish its physicochemical properties. Thus, this research aimed at bringing to bear the nature of water quality and the likely sources of its chemical constituents using scientific approach of hydrochemistry for the investigation. The findings of this research work will provide scientific and empirical information for environmental and health administrators on the quality of groundwater resources in Suleja and its attendant effects on the health of the populace.

Materials and Methods

Sampling techniques

This research was carried out in stages this part covered wet season (May to November). Seven representative groundwater samples were collected for six month totalling 42 water samples from the shallow (hand-dug well) aquifers and final aquifer (borehole) in different locations within the study area (Table 1). The targeted wells were the ones that high population of communal inhabitant of the area were concentrated on for their basic water needs; this is to enable accuracy in the evaluation of water quality status of the domestic water use of the area. One litre plastic containers were used to collect the samples, dry washed and rinsed with the water sample before filling it to capacity and then labeled accordingly. The sample from the same source was divided and submits as blind duplicate to access accuracy/precision of the laboratory.

After the collection, the various samples were stored in a cool box and taking to the laboratory for investigation at Water Quality Laboratory in Federal University of Technology, Minna.

Table 1: Samples locations and their geographical coordinates

Sample Locations		Easting	Northing
KwambaMaje	32	299147	1019149
KurminSarki	32	299347	1016747
AngwanKachala	32	299633	1014818
Magajia	32	299820	1014994
RafinSayin	32	303130	1011186
Bagama	32	300698	1014586
GRA	32	300443	1016510

Each of the samples collected was analysed for pH, Ec, TDS, COD, BOD, chloride, nitrate, sulphate, bicarbonate, sodium, potassium, magnesium and calcium. It also included the heavy metals such as iron (Fe), copper (Cu), lead (Pb), zinc (Zn) and chromium (Cr) using standard laboratory procedures described by APHA, (1995). The results obtained from physico-chemical analysis were subjected to multivariate statistical analysis. The physical parameters (pH, EC, TDS) were determined in the field (*in situ*) using standard equipment. After the collection, the samples were stored in a cool box and taking to the Federal University of Technology, Minna water quality laboratory for the analyses. The results obtained from the water quality laboratory were subjected to differential statistical and water quality index analyses.

Water quality index

Water quality index (WQI) is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It thus, becomes an important parameter for the assessment and management of surface water and groundwater see Table 2. WQI is a scale used to estimate an overall quality of water based on the values of the water quality parameters (Amadi, 2011). It is a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point view of the suitability of groundwater for human consumption (Lambarkis *et al*., 2004; Amadi, 2010).

Calculation of WQI

The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter qi was calculated by using this expression:

qi = $(Ci \div Si) \times 100$……………………..(i)

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100. Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter:

Wi= $I \div Si$……………………………… (ii)

The overall Water Quality Index (WQI) was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly.

WQI = $\sum_{n=1}^{i=n}$ qiwi………………………(iii)

Where: qi: the quality of the ith parameter, wi: the unit weight of the ith parameter and n: the number of the parameter considered. Generally, WQI were discussed for a specific and in-tended use of water. In this study the WQI for drinking purposes is considered and permissible WQI for the drinking water is taken as 100.

Overall, WQI = $\frac{\sum qiwi}{\sum wi}$…………………..(iv)

Table 2: Standard water quality classification scheme based on WQI value

Water quality value	Water quality	Water sample %
< 50	Excellent	12
50 – 100	Good Water	26
100 – 200	Poor Water	35
200 – 300	Very Poor	17
> 300	Unsuitable for drinking	10

Results and Discussion

Groundwater hydrochemistry for the wet season analysis

The statistical results of the analyses and the summary of the physic-chemical and biological parameters for the rainy season are presented in Table 3 and the calculated water quality index for the rainy season in Table 4, respectively.

Table 3: Statistical summary of the physical, chemical and microbial analyses of groundwater samples for raining season

Parameters	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
Temperature	42	27	32	29.67	1.28	1.64	0.16	-0.64
pH	42	5.7	8.8	6.50	0.64	0.41	1.66	3.58
TDS	42	19.9	528	162.22	105.54	11140	1.52	3.38
Conductivity	42	105	1688	835.90	458.70	210400	-0.06	-1.15
TH	42	52	370	157.33	72.13	5202	0.96	0.69
Alkalinity	42	25	214	79.93	49.53	2453	1.12	0.59
COD	42	4	16	7.67	3.10	9.64	1.02	0.08
BOD	42	1	8	2.74	1.86	3.46	1.70	2.73
Cl^-	42	6.94	220	58.39	43.30	1875	1.50	3.50
HCO_3^-	42	10.3	107.3	41.93	25.74	662.60	0.85	0.03
SO_4^-	42	1.55	177.8	124.35	34.53	1192	-1.32	2.79
PO_4^-	42	0.09	0.8	0.14	0.11	0.01	5.76	35.56
CO_2	42	1.14	32.9	7.34	5.68	32.24	2.29	8.96
NO_3^-	42	0.1	0.39	0.10	0.07	0.01	0.66	-0.04
Na^{2+}	42	3.4	16.22	8.48	3.53	12.43	0.59	-0.38
K^+	42	3.7	14.09	7.83	2.58	6.65	0.47	-0.47
Mg^{2+}	42	11	67.5	33.14	15.61	243.62	0.81	-0.09
Ca^{2+}	42	18.3	120	58.30	25.89	670.31	0.72	-0.21
Mn^{2+}	42	0	3	0.27	0.70	0.63	3.11	8.57
Cu^{2+}	42	0	0.04	0.01	0.01	0	1.06	0.60
Zn^{2+}	42	0.01	0.31	0.11	0.08	0.01	1.05	0.15
Fe^{2+}	42	0.11	41	1.28	6.28	39.44	6.48	41.96
Pb^{2+}	42	ND	ND	ND	ND	ND	ND	ND
Cr^{2+}	42	ND	ND	ND	ND	ND	–	–

Table 4: WQI values of water samples during rainy season

Parameters	Ci	Si	Qi	wi	qiwi
pH	6.50	7.5	87.97	0.13	88.108
TDS	162.22	500	32.44	0.002	32.44
Conductivity	835.90	1000	83.59	0.001	83.59
TH	157.33	200	78.67	0.005	78.67
COD	7.67	10	76.74	0.1	76.83
BOD	2.74	6	45.64	0.167	45.80
Cl^-	58.39	250	23.35	0.004	23.35
HCO_3^-	41.93	100	41.93	0.01	41.94
SO_4^-	124.35	100	124.35	0.01	124.36
PO_4^-	0.14	5	2.88	0.2	3.076
CO_2	7.34	100	7.34	0.01	7.35
NO_3^-	0.10	50	0.30	0.02	0.41
Na^{2+}	8.48	200	4.24	0.005	4.24
K^+	7.83	100	7.83	0.01	7.84
Mg^{2+}	33.14	150	22.01	0.007	22.10
Ca^{2+}	58.30	200	29.15	0.005	29.15
Mn^{2+}	0.27	0.2	134.75	5	139.75
Cu^{2+}	0.01	1	1.07	1	2.07
Zn^{2+}	0.11	3	3.51	0.333	3.84
Fe^{2+}	1.28	0.3	426.2	3.333	429.53
Pb^{2+}	ND	0.01	ND	100	100
Cr^{2+}	ND	0.05	ND	20	20

Physicalparametric analysis of the groundwater samples

From Table 3, the temperature value of the groundwater during the wet season range between 27 – 32°C with mean value of 29.7, respectively. This is relatively high to that of normal ambient temperature of the groundwater; this might speed up the rate of decomposition of organic matter in the water and general chemical reaction rate. The pH of the groundwater during the wet season revealed the acidity and alkalinity concentration value that range from 5.7 – 8.8 with approximated mean value of 6.6 accordingly. This indicate neutrality of the groundwater, but generally the maximum and the minimum concentration of the groundwater pH revealed slight alkalinity and acidity in some location within the study area. The slight acidic nature may be from the direct precipitation of rain water in that vicinity. Parametric comparison shows that the groundwater mean pH is within the permissible limit for drinking water (WHO, 2006).

Generally, electrical conductivity of the groundwater during the rainy season range between 105 – 1688 µs/cm with mean value of 835.90. The high maximum value of conductivity noticed indicate moderate dissolution of chemical component from the aquifer lithologic framework of the area (Fig. 1). However parametric comparison show that both TDS and conductivity average concentration value range bellow the permissible limit for the drinking water quality (NSDWR, 2007).

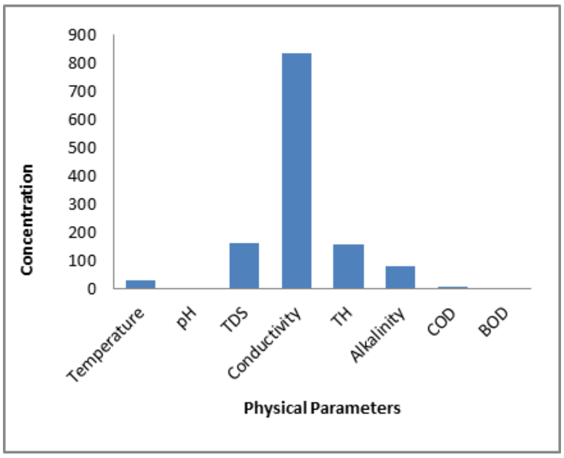

Fig. 1: Distributions of Physical Parameters of Water Samples

Total hardness (TH) for the groundwater of the study area revealed concentration that range from 52 – 370 mg/l with average mean value of 157.33, respectively, the upper limit of its concentration is higher than the maximum acceptable limit set by WHO (2006) for domestic water use, though the average of it is within the standard limit, which shows part of the area of study will notice high level of water hardness. This result lend credence to the fact that during rainy season high proportion of precipitated (rain water) percolate and infiltrate easily through the overlying continental detrital porous sediment to join water table content at shallow level which invariably result in high hardness of the water contents due to low attenuation of the water molecules.

Biochemical analysis of water samples

From Table 3, the concentrations Chemical oxygen demand range from 4 – 16 mg/l with mean value of 7.67 while biological oxygen demand range between 1 and 8 mg/l with mean value of 2.73, respectively.

Parametric comparison indicate that the average for both COD and BOD range lower to that of the permissible limit for domestic water quality (NSDWQ, 2007) but in some location within the study area the concentrations of both parameters range higher to that of its permissible limits as revealed in their various maximum concentrations (Table 3). This may be due to indiscriminate defecations and open dump refuse disposal, which result in effluent leachate discharge to the groundwater system during the rainy season as the precipitated water percolate through it during the overland flow to the saturated zone of the aquifer materials.

Anionhydrochemistry for the water samples

Among the anionic parameters analyzed sulphate show high level average concentration followed by chloride, bicarbonate, carbon dioxide, nitrate and phosphate (SO_4>Cl^-> HCO_3> CO_2> NO_3> PO_4) as presented in Table 3 and Fig. 2. All the anionic parameters revealed average concentration that range within the permissible limit according to NSWDQ, 2007 allowable water quality standard for domestic purposes. This might reveal low level anionic mobility rate in the groundwater system of the study area during the rainy season.

Cationic parametric analysis for the water samples

Generally, the concentrations of sodium and potassium are very low (3.4 – 16.22 and 3.7 – 14.09 mg/l with mean values of 8.48 and 7.83, respectively) as shown in Table 3. However this may be due to low feldspathic dissolution from the crystalline lithologic framework (granite and gneissic rocks) into the groundwater system which might suggest low groundwater mineralization.

Calcium and magnesium has the highest range of concentrations (Ca^{2+}: 18 – 120 and Mg^{2+}: 11 – 67.5 mg/l) among the anionic parameters (Fig. 2). This might be as a result of calcium carbonate ($CaCO_3$) cement in detrital overlying continental sediments or through leachate flow from calcium reach substance and the dissolution of lithological framework of the study area. These two ions combine with SO_4 to form either $CaSO_4$ or $MgSO_4$ which result in total hardness of the groundwater of the study area. The domestic user will definitely notice excess use of detergent to form foam when washing.

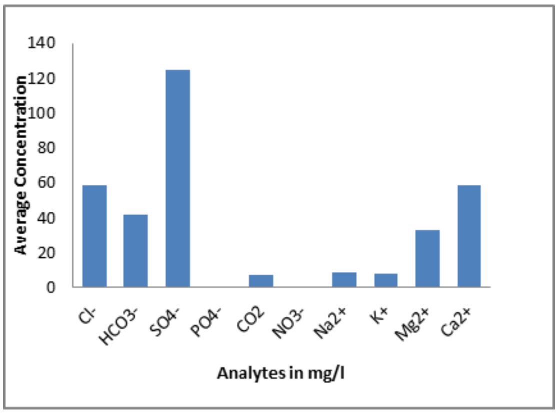

Fig. 2: Anionic hydrochemical distributions for the water samples

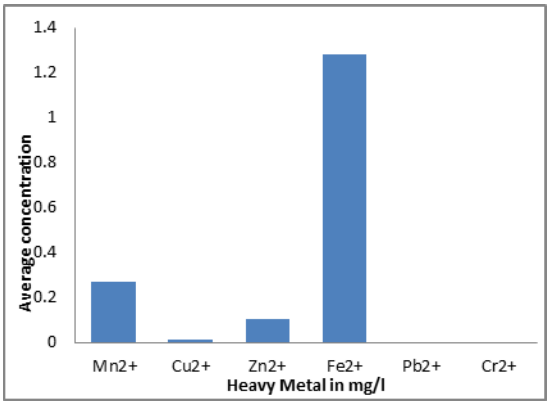

Fig. 3: Distributions of heavy metals for the water samples

Heavy metal level for the water samples

Iron (Fe^{2+}) shows high concentration among the heavy metals analyzed accompanied by Zinc and copper ions as presented in Table 3 and Fig. 3. The high concentrations of iron revealed some of the groundwater been sampled indicate that most of those wells involved are somewhat sited within or below a thick lateritic layer which most have dissolved and form an integral component of the aquifer solution kinetic as precipitated water infiltrate through it during the groundwater flow movement. The elevated level noticed from the Manganese and zinc ions could be of the leachate flow from anthropogenic sources possibly the un-sanitize waste dump of mental substances.

Water quality index analysis

All the physical, chemical, and biological parameters analyzed were used to calculate the WQI in accordance with the procedures explained above and contained in Table 7. The computed overall WQI value is 10.47 for the wet seasons respectively and this means that the groundwater in the area falls within the excellent quality as contained in Table 2.

Overall WQI (Wet season) $= \frac{\sum qiwi}{\sum wi} = \frac{1364.498}{130.3553} = 10.47$

Hydrochemicalfacies classifications

The concept of hydrocmicalfacies was developed to understand and identify the nature of water composition in different classes. Hydrochemicalfacies are distinct zones of cations and anions concentration categories. The results of cations and anions constituent were subjected to Piper trilinear diagram in Fig. 4, it revealed 90% of the samples plotting under Mg – type for cation concentration while 90% of the samples falling under SO_4 – type for anion concentration. Essentially the groundwaters of the study area are Mg-SO_4facies and Ca-Clfacies of water-types, predominantly gypsum groundwater.

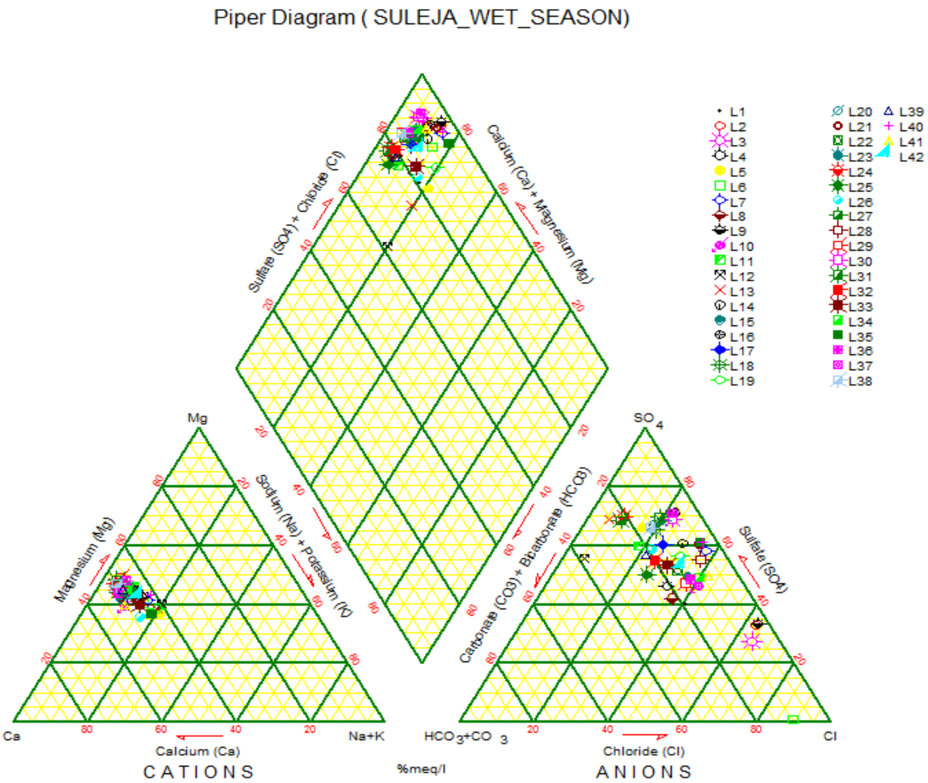

Fig. 4: Hydrochemical characterization of groundwater of Suleja plotted on piper trilinear diagram

Conclusion

The type of water that predominate the study area is Ca + Mg-SO4 type. This may be from the dissolution of geological compositions of the area which comprises igneous rocks of crystalline nature in which the major units are gneisses and granites.

The water quality index (WQI), used to evaluate the suitability of the groundwater for domestic purposes was computed as 10.47 showing that the groundwater of the area of study is excellent for domestic usage, though this is basically empirical. It is observed from statistical point of view that most analytical parameters shows an acceptable average concentration while some their maximum concentration may be a little bit elevated above the threshold of permissible limit of (WHO, 2006). It is found from the classification of water samples based on their total hardness, most of the water samples are categorized as hard water. The elevated level noticed from the Manganese and zinc ions could be of the leachate flow from anthropogenic sources possibly the un-sanitize waste dump of mental substances.

The groundwater constituents of the study area are dominantly influence by three major factors such as lithological framework of the area, anthropogenic impact and the aquifer solution kinetics/climate variability. The results obtained equally revealed little evidence of leachate flow from waste dump to the groundwater.

Acknowledgement

We wish to sincerely thank the Nigeria Tertiary Education Trust Fund through the Directorate of Research Innovations and Development, Federal University of Technology, Minna to have provided adequate funding that enabled us carried out this particular research work.

Reference

Aguwamba JC 2003. Optimization of solid waste collection system in Onitsha, Nigeria. *J. Envt.*, 1(1): 124-135.

Amadi AN 2010. Effects of urbanization on groundwater quality: A case study of Port-Harcourt, Southern Nigeria. *Natural & Appl. Sci. J.*, 11(2): 143 – 152.

APHA 1995. Standard methods for the Examination of Water and Waste Water (APHA). In: American Public Health Association (Ed.), *Manual of Water Quality Analysis* (p. 1467). Washington DC.

Garba ZN, Hamza SA & Galadima A 2010. Arsenic level speciation in fresh water from Karaye Local Government Area, Kano State, Nigeria.*Int. J. Chem.*, 20(2): 113-117.

Lambarkis N, Antonakos A & Panagopoulos G 2004. The use of multi-component statistical analysis in hydrogeological en-vironmental research. *Water Res*., 38(7): 1862-1872.

Nigerian Standard for Drinking Water Quality (NSDWQ) 2007. *Nigerian Industrial Standard*, 554: 1-14.

Nriagu J, Oleru NT, Cudjo C & Chino A 1997. The Science of the Total Environment, 197: 13- 19.

Olaoye OA & Onulide AA 2009. Assessment of microbial quality of sachet-packaged drinking Water in Western Nigeria and its public health significance.*Public Health*, 123, 729-734.

Umeh JC 1989. Farmer co-operative union and rural life quality in Nigeria. *Journal of Rural Co-operation*, 17: 151-166.

Umeh JC, Amali O & Umeh EU 2004. The socio-economic effects of tropical diseases in Nigeria. *Economics & Human Bio.*, 2: 245-263.

Shuaibu AM & Abdullahi IN 2015. Hydrochemical characterization of groundwater aquifer using multivariate analysis, Minna, North Central Nigeria. *Nig. J. Techn. Res.*, 10(1): 25–31, Doi:http://dx.doi.org/10.4314/njtr.vl10i1.5.

WHO 2006. Revision of the World Health Organization guide lines for drinking water quality: Report of the Final Task Group Meeting WHO, Geneva, p. 307.

Yusuf KA 2007. Evaluation of groundwater quality characteristics in Lagos-City.*J. Appl. Sci.,* 7(13): 1780-1784.