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Water quality index and hydrogeochemistry of Otukpo area, Benue State, North Central Nigeria

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Abstract

The research is aimed to assess the surface and groundwater quality in Otukpo area and environs, Benue State, North Eastern Nigeria. Sixteen water samples were collected from 7 boreholes, 7 hand duck wells and 2 rivers. The water samples were analysed chemically and bacteriologically using spectrophotometric, titrimetric and membrane filtration methods. Analytical results indicated that the groundwater in the area is acidic, fresh and moderately hard. The order of abundance of the cations were in $Na^+<K^+<Mg^{2+}<Ca^{2+}$ while the anions were in the order of Cl^- $<HCO_3^->SO_4^{2-}<NO_3^-$. Principal Component Analysis (PCA) identified four factors that accounts for 69.73% of the total variance. Correlation analysis, Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) revealed pollution from application of agricultural fertilizers, anthropogenic contamination and rock-water interaction as the major processes responsible for the modification of surface and groundwater chemistry of the research area. The Gibbs diagram plot shows that, the sample points fall under rock dominance and weathering zones, which suggested precipitation, induced chemical weathering with the dissolution of rock-forming minerals. The piper diagram classified groundwater samples as Ca-Mg-HCO_3 water type. Water Quality Index (WQI) values range from 22.05 to 56.13 which indicated good and excellent water category. The SAR values range from 0.02 to 0.66 the values belong to the excellent category and is suitable for irrigation. The overall result revealed that, the water in the research area is suitable for domestic, industrial and irrigation activities.

1. INTRODUCTION

Water being the source of drinking water, agricultural and industrial uses greater role in many Nigerians. Groundwater is the main source of water supply in the research area. Groundwater constitutes an important component of the water cycle, and it is partly used to maintain stream flow and wetlands, as well as being the sources of drinking water, agricultural and industrial (Harun *et al*., 2015; Nagaraju *et al*., 2016). The assessment using physical, chemical and biological parameters, gives a broad picture of water quality of the different bodies over a particular point in time, while the biota (biological property) acts as a continuous monitor and give more general view of water quality over a period of time (Tavassoli and Mohammadi, 2017). Measurement of physical attributes served as indicators of some forms of pollution, changes in temperature and the presence of certain effluents, while changes in stream and dug water width, depth and velocity, turbidity and rock size indicated dredging in the area (Chris, 2002; Tavassoli and Mohammadi, 2017). Water is one of the most important natural resources in Nigeria and around the world (EPA, 2001). It is highly important to life and provides a variety of uses from drinking water in villages, cities, to the irrigation of crops in farming areas. Water also provides recreational uses as well as habitat for wildlife. According to the EPA (2001), rivers, lakes, estuaries, wetlands are among the nation's most precious resources.

Some of the factors that influence water quality and it's chemistry across African coast are enhanced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^-, due to silicate and carbonate weathering and enhanced NO_3^- from indiscriminate waste disposal from human activities (Wotany *et al.,* 2013). The chemical quality of surface and groundwater is controlled by natural processes such as precipitation, mineral weathering and evaporation-crystallization and significantly influenced by anthropogenic processes (Wotany *et al.,* 2013; Mangoua *et al.,* 2015). The presence of the solid wastes in our environment without effective waste collection system and disposal machinery has posed a lot of threat to our water bodies. Most of these wastes, which emerged from domestic, industrial and agricultural activities have been often washed down into these water bodies during rainfall and subsequent

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runoff, thus, polluting and destroying the ecosystem. Worthy of mentioning is the pathogenic effect arising from untreated sewage disposal channelled into water ways such as river, lake and stream, which people tap and consume the water without treatment. The aim of this research was to assess water quality for drinking and irrigation purposes of Otukpo Local Government Area. This will involve determination of physical, biological, and chemical parameters of surface and groundwater in the research area.

1.1. The study area

The study area (Figure 1) is located between latitude 7º and 7º 45' North and longitude 7º 35' and 8º 30' East total study area. The population of the research area is 261,666 persons (Census, 2006). The population figure is made of up 133,347 males and 128,319 females. Well over half of the population of the area is engaged in farming activities at varying degrees. Plants mostly cultivated are yams, cassava, rice, maize, sesame and beniseed. The research area is faced with underdevelopment as functional amenities are inadequate. A Trunk 'A' federal road and the Port Harcourt-Kaduna railway line traverses the town. The land is generally low lying and gently undulating with occasional inselbergs, lateritic mesas, butes, knolls and low ridges breaking them which alternate with shallow open valleys (Nyagba, 1995; Abah, 2014). Surface drainage is generally good except near the banks of the major rivers where swampy floodplains have developed. The main rivers include Okoloko and Otobi. The smaller streams include Ukplo, Mmaba, Idikwu and Okpa Eupi. These smaller streams dry up completely during the dry season. According to Nyagba (1995), in the research area average values of water level is declining. These resultant water shortages lead to seasonal outbreaks of cholera in parts of study area as many residents lack access to water and engage in poor hygienic and domestic practices due to water scarcity.

Soils in Otukpo Local Government Area (LGA) are deeply weathered red and yellowish brown soils developed essentially on sedimentary rock. The soils are easy to cultivate but prone to excessive internal drainage and intense leaching leaving plants in the area to obviate the adverse effects of the rapid internal drainage of the soil by drawing water from the subsoil (Nyagba, 1995; Abah, 2014). The average annual temperature is 27.2 °C. In August, the average temperature is 25.5 °C, which is the lowest average temperature of the whole year. The warmest month of the year is March with an average temperature of 29.3 °C. About 1723 mm of precipitation falls annually. The driest month is December with 9 mm. Most precipitations fall in September, with an average of 282 mm.

The Study area lies within the Southern Guinea Savannah with its characteristic coarse grasses and numerous species of scattered trees. However, persistent clearance of the vegetation for arable agriculture plus the practice of bush fallowing system has led to the development of regrowth vegetation at various levels. The vegetation is sparsely distributed except in open shallow valleys where the vegetation is denser. Vegetation of economic value includes locust bean, shea tree, Mahogany, Isoberlina Doka, and fruit trees such as mango.

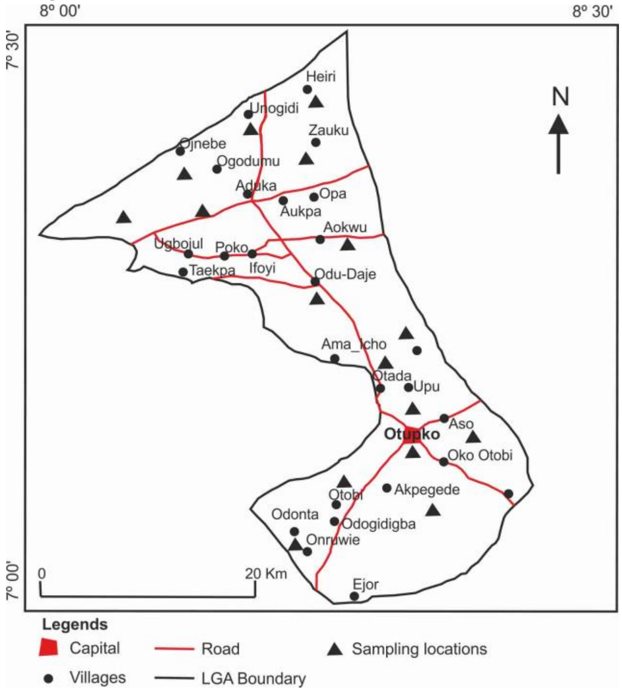

Figure 1: Map of Otukpo local government area showing sampling points

1.2. Geology of the study area

The area is underlain by the Cretaceous sediments of the Benue Trough; located in the Southern area of Benue valley (Figure 2). Lower Cretaceous sediments are presumed to overlie Precambrian basement rocks unconformable along the Benue valley (Carter *et al.*, 1963; Ogah, 2014). The Benue Trough was originated from rift faulting and the folding of the Cretaceous associated with a basement flexuring is seen as direct consequences of the opening of the South Atlantic Ocean (Carter *et al.*, 1963, MacDonald *et al.*, 2011). According to Offodile (2002), the area is made up of the Arufu limestone and the Awe formation consisting mostly of fine sandstones with carbonaceous shales. The following geological formations are outlined in the investigation carried out in Otukpo area. They are namely: Asu River formation, Eze-Aku formation and the Awgu formation.

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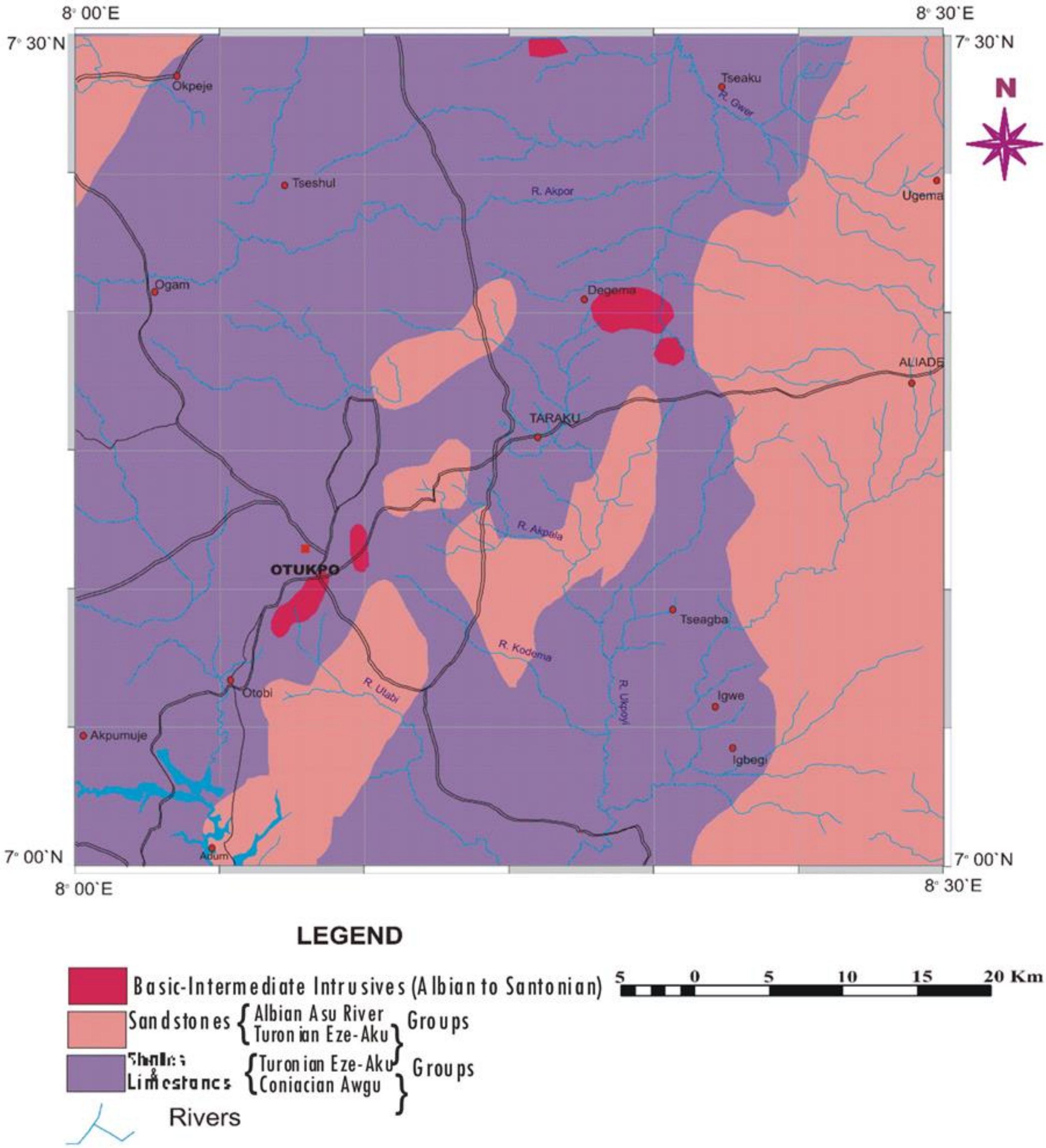

Figure 2: Geological Map of the study area (Adopted from Ogah, 2014).

2. MATERIALS AND METHODS

Sixteen water samples were collected from 7 hand dug water wells, 7 hand pumps and 2 rivers from different villages in the study area (Figure 1). The type of sampling technique that was employed is random sampling. One litre plastic containers were used to collect the samples. Samples were collected from the discharge of existing wells such as hand pumps, hand-dug wells and running water such as a river. The containers for the samples were rinsed with the water to be sampled before samples were taken. The coordinates of each sample point was taken before samples were collected. Water samples were collected in a sampling bottle avoiding floating materials. The stoppers of the sample containers were closed properly to prevent outside contamination. The containers were labelled describing the name of the water body, date, time, sampling-point, and conditions under which samples were collected.

In the field, the temperature and pH measured using Pen pH and temperature meter and pH model CT 6021 Instrument. CO_3^{2-}, HCO_3^{2-} and total hardness was measured using EDTA Titremetric method (HACH Digital Titratormodel 16900 with selected titration

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catridges). TDS was measured using PENTDS Meter model CT3061 (Exact instrument) while EC was measured using Pen Conductivity Meter model CT3030 (Exact instruments). Other cations and anions were determined using HACH Digital Spectrophotometer in accordance with the international standard method model 2040 (Nazaruddin *et al.*, 2015). Turbidity was measured using turbidimetric method using mobile digital turbidity meter model SGS-200BS (PEL Medical, U.S.A). The SAR was computed using the equation:

$$SAR = \frac{Na^{2+}}{\left[Ca^{2+} + \frac{Mg^{2+}}{2}\right]^{1/2}} \quad 1$$

2.1. Pearson correlation

Pearson correlation coefficient is commonly used to measure strength between variables (Bajpayee *et al.*, 2012). According to Ishaku *et al.* (2016), samples showing correlation of r>0.7 are considered to be strongly correlated, whereas r>0.5 – 0.7 shows moderate correlation. The strong correlation is an indication of common source or origin. For the water parameters in the research area the correlations between variables were computed using SPSS statistics software (Version 16.0). The Pearson correlation formula (Ashiyani *et al.*, 2015) is given as;

$$r = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}} \quad 2$$

where r is Pearson correlation, N is number of pairs of scores,$\sum xy$ is sum of products of paired scores, $\sum x$ is sum of x scores, $\sum y$ is sum of y scores, $\sum x^2$ is sum of squared x scores and $\sum y^2$ is sum of squared y scores.

2.2. Principal component analysis

Principal Component Analysis (PCA) provides an objective way of finding indices of variance so that the variation in the data can be accounted for as concisely as possible (Ishaku, 2011; Ishaku *et al.*, 2016). PCA of the variable was performed using SPSS software to extract the significant components. PCA is generated through expression as:

$$y_{ij} = a_{i1}x_{1j} + a_{i2}x_{2j} + a_{i3}x_{3j} + a_{i4}x_{4j} + \dots + a_{im}x_{mj} \quad 3$$

where y is component score, a is component loading, x is measured value of the variable, i is component number, j is sample number, and m is total number of variables. The component weights represent correlation between the PCs and the variables (Praus, 2007).

2.3. Hierarchical cluster analysis

The Hierarchical Cluster Analysis (HCA) is being used to group objects into classes or clusters on the basis of similarities within the class or dissimilarities (Singh *et al.*, 2009; Ishaku *et al.*, 2015; Ishaku *et al.*, 2016). Short distance shows the two objects are similar or close together whereas a long distance indicates dissimilarity (Avdullahi *et al.*, 2013). The HCA according to Ward (1963) with squared Euclidean distances was applied to detect multivariate similarities in groundwater quality of the research area. The method of computing the squared Euclidean distance can be expressed as:

$$d_{ij}^2 = \sum_{k=1}^{n}(Z_{ik} - Z_{jk})^2 \quad 4$$

where, d_{ij}^2 is the squared Euclidean distance; Z_{ik} is the value of k variable for the object i;Z_{jk} is the value of k variable for the object j; and n is the number of variables.

2.4. Water quality index calculation

The water quality index (WQI) is used to access the influence of natural and anthropogenic activities based on the important parameters on groundwater chemistry (Kumar *et al.*, 2015; Ishaku *et al.*, 2016). To estimate the WQI, the weight was assigned to the physicochemical parameters according to the parameters' relative importance in the overall quality of water for drinking water purposes. The weight ranges from 1 to 5. The maximum weight of 5 was assigned to parameters such as nitrate and total dissolved solids, weight 4 for pH, EC, SO_4, weight 3 for HCO_3, TH and Cl, weight 2 for Ca, Na, K and weight 1 for Mg (Vasanthavigar et al., 2010; Ishaku *et al.*, 2016; Ishaku *et al.*, 2017). The relative weight is computed from the equation below;

$$W_i = {w_i}/{\sum_{i=1}^{n} w_i} \quad 5$$

where W_i is the relative weight w_i is the weight of each parameter n is the number of parameters.

The quality rating scale for each parameter is calculated by dividing its concentration in each water sample by its respective standards (WHO, 2011) and multiplied the results by 100, equation five.

$$q_i = (C_i/S_i) \text{ X } 100 \quad 6$$

where q_i is the quality rating C_i is the concentration of each chemical parameter in each sample in milligrams per litre S_i is the World Health Organization standard for each chemical parameter in milligrams per litre according to the guidelines of (WHO, 2011). For computing the final stage of WQI, the SI is first determined for each parameter equation six. The sum of SI values gives the water quality index for each sample, equation seven.

$$SI_i = W_i \text{ X } q_i \quad 7$$

$$WQI = \sum SI_i \quad 8$$

where SI_i is the sub-index of ith parameter qi is the rating based on concentration of ith parameter n is the number of parameters.

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2.5. Rock-water interaction

During weathering and circulation of water in rocks and formations, ions leached out and dissolved in groundwater (Naseem *et al.*, 2010; Nur *et al.*, 2012). The geological formations, water-rock interaction and mobility of ions are prime factors influencing the geochemistry of groundwater (Nur *et al.*, 2012). Different chemical processes occur during rock-water interaction, including dissolution/precipitation, ion exchange processes, oxidation and reduction. These geochemical processes are responsible for the spatial distribution of groundwater chemistry (Ishaku *et al.*, 2016). Water-rock interaction reflects the differences in mineral composition of the aquifer, presence of fissures, faults and cracks which affect groundwater movement in the subsurface medium (Nayak and Sahoo, 2011).

2.6 Hydrogeochemical facies

Piper trilinear diagrams (Piper, 1944) were prepared to classify the water quality of selected sources of area (Piper, 1944). The diagram classified the hydro-chemical facies in account of prominent ions contributed in the water quality. These diagrams graphically represent the chemical equilibrium between cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (Cl^{-}, SO_4^{2-}, CO_3^{2-} and HCO_3^{-}) in water samples and also describe the presence of main contributor ions and chemical reactions taking place in the water. The diagram composed of two lower triangles of cations and, anions and middle quadrilateral. Quadrilateral or diamond shape indicates the combined distribution of both ions (cations and anions) and final water type of sources. Such diagrams may describe various hydro-chemical processes like base cation exchange, cement pollution, mixing of natural waters, sulfate reduction, saline water (end-product water) and other related hydro-chemical problems.

3. RESULT AND DISCUSSION

The summary of water quality results for the physical, chemical and micro-biological analysis of the sixteen (16) samples from the research area is presented in Table 1. Based on the mean values of the cations and anions the order of abundance of the cations is as $Na^{+}<K^{+}<Mg^{2+}<Ca^{2+}$ and $Cl^{-}<HCO_3^{-}>SO_4^{2-}<NO_3^{-}$ for the anoins. pH values of water samples ranged from 5.23 to 7.31 with mean value of 6.39 this suggests that, the water condition is acidic. Seven out of the sixteen water samples had pH values below the acidic limit of 6.5. pH values less than 6.5 are considered too acidic for human consumption and can cause health problems such as acidosis. The acidic nature of most of the samples might be due to high mineral rich rocks in the aquifers. This is evident in Ojinebe hand pump sample, which recorded the least pH of 5.30 of groundwater samples and Otobi River with 5.23 showed extraordinarily high values of dissolved ions. The pH values of water from the study area were generally moderate. Six percent of the sources had pH values lower than the safe limit for drinking water (6.5-8.5) as prescribed by WHO (2011). The measured temperature values of the water samples were between 20.0 – 30.9°C with an average of 26.7 °C. The electrical conductivity in water samples is an indication of dissolved ions and changes in its concentration signify water quality deterioration. Thus the higher the EC, the higher the levels of dissolved ions in the sample. TDS Concentrations ranges were between 23.19 – 312 mg/l with mean value of 89.00 mg/l this indicate the fresh groundwater (Freeze and Cherry, 1979). Total Hardness for the samples ranged from 56.7 to 162 mg/l $CaCO_3$ mg/l with mean value of 81.2 mg/l this shows that, the groundwater condition is moderately hard (Hem, 1970). The SAR values range from 0.02 to 0.66 and according to the Richards (1954) classification based on SAR values (Table 5), all of samples are belong to the excellent category. SAR can indicate the degree to which irrigation water tends to enter into cation-exchange reactions in soil.

Table 1: Summary of surface and groundwater quality in the research area

Parameters	Minimum	Maximum	Mean	Standard Deviation	WHO (2011)
Temperature (°C)	20	30.9	26.72	3.274	30 - 35
pH	5.3	7.31	6.39	0.666	6.5 - 8
Turbidity (NTU	0.013	0.901	0.35	0.309	0 - 5
TDS (mg/l)	23.19	312	89.01	71.675	0 - 500
EC (μs/cm)	55.61	236.1	112.27	55.811	0 - 1000
CO_3^{-} (mg/l)	0	3	0.92	1.113	0 - 120
HCO_3 (mg/l)	210	521.1	327.32	96.069	1 - 1000
TH (mg/l)	56.7	150	81.16	30.54	0 - 150
K^{+} (mg/l)	5.2	9.82	7.6	1.595	0 - 200
Mg^{2+} (mg/l)	23.82	39.67	31.79	4.333	0 - 200
Na^{2+} (mg/l)	0.17	4.21	1.88	1.111	0 - 200
Fe^{2+} (mg/l)	0.07	4.049	0.8	0.958	0 - 0.3
Ca^{2+}	31.02	61.51	48.69	12.959	0 - 200
Cu^{2+} (mg/l)	0.037	1.67	0.55	0.479	0 - 2
F (mg/l)	0.091	4.112	1.44	1.027	0 - 1.5
Mn^{2-} (mg/l)	0.001	0.307	0.07	0.08	0 - 0.4
Cl^{-} (mg/l)	19.67	89.52	44.47	21.892	0 - 250
SO_4^{2-} (mg/l	18.41	47.9	30.4	11.569	0 - 100
NO_3^{2-} (mg/l)	39.29	89.08	61	15.83	50 - 70
Coli forms	2	17	7.94	4.669	0 - 10

3.1 Statistical analysis

Statistical analysis was performed on the physico-chemical parameters and major ion concentration to find the relationship and differences between the surface and groundwater samples of the research area (Table 2). The correlation matrix represents the first step

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of the factor analysis (Asaad et al., 2016). Strong correlation exist between EC and TDS (r=0.897), TH and TDS (r=0.922), TH and EC (r=0.891), Fe and EC (r=0.649), Cu and pH (r=0.688), SO_4^{2-} and F (r=0.690), Coliform and TDS (r=0.779), Coliform and EC (r=0.753), Coliform and TH (r=0.863), and SAR and Na (r=0.994). Similarly moderately correlations exist between HCO_3^- and TDS (r=0.542), TH and HCO_3^- (r=0.505), Fe and TH (r=0.590), Cl^- and Turbidity (r=0.519), and coliform and Temperature (r=0.565). The strong to moderately correlations exhibited between the chemical parameters is an indication of common source. The strong correlation between TDS and EC is an approximate relationship for most natural groundwater (Richard, 1954).

Principal Component Analysis (PCA) was performed on the sixteen (16) data set (Table 3) to identify the major variables affecting surface and groundwater quality in the research area and it indicates four factors. Factor 1 account for about 25.01% of total variance and is characterised by strong positive loading of TDS, EC, HCO3, TH and Coliforms, and moderate positive loading with respect to Fe and Temperature. Factor 1 is interpreted as salinity and total hardness influenced by EC and Fe (Usman et al., 2014; Ishaku et al., 2016; Ankidawa and Seli, 2018). Factor 2 account for about 15.14% of total variance and is characterized by strong positive loading with respect to Cu, Cl and SO4, and moderate positive loading with respect to pH and Turbidity, and moderately negative loading of Ca. Factor 2 is interpreted as anthropogenic contamination. Factor 3 accounts for about 14.87% of total variance and is characterized by strong positive loading of NO3 and strong negative loading of Mn, and moderate positive loading of F, and moderate negative loading of K. The combination of Mn and F is an indication of weathering of bed rock materials that resulted from igneous rocks. Factor 4 accounts for about 14.70% of total variance and is characterized by strong positive loading with respect to Mg, Na and SAR. The high positive loading with respect to Na suggests pollution from application of agricultural fertilizers on the farm lands (Ogunribido and Kehinde-Philips, 2011; Asaad et al., 2016).

The result of cluster analysis is shown in Figure 3, and indicates two clusters. Cluster 1 is subdivided into two sub clusters. Sub cluster 1 comprises of sodium, SAR, copper, manganese, chloride, sulphate, fluoride and turbidity and sub cluster 2 comprises of conductivity (EC), total hardness, coliforms, TDS and iron. Cluster 1 is ascribed as rock-water interaction (Ishaku et al., 2015; Ishaku et al., 2016). Cluster 2 is subdivided into two clusters; the sub cluster 1 comprises of potassium, magnesium, temperature and pH, and the second sub cluster shows similarities between bicarbonate, calcium and nitrate. Cluster 2 is interpreted as anthropogenic contamination (Ishaku et al., 2016; Ishaku et al., 2017).

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Table 2: Correlation of physical, chemical and micro-biological parameters for the surface and groundwater in the research area

Parameters	Temp (°C)	pH	Turb	TDS (mg/l)	EC (µS/cm)	HCO3 (mg/l)	TH (mg/l)	K (mg/l)	Mg (mg/l)	Na (mg/l)	Fe (mg/l)	Ca (mg/l)	Cu (mg/l)	F (mg/l)	Mn (mg/l)	Cl (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	Coli form	SAR (mg/l)
Temp	1																			
pH	-0.188	1																		
Turb	-0.084	0.179	1																	
TDS	0.436	-0.4	-0.387	1																
EC	0.371	-0.419	-0.441	**0.897****	1															
HCO3	0.253	0.065	-0.048	**0.542***	0.344	1														
TH	0.368	**-.554***	-0.3	**0.922****	**0.891****	**0.505***	1													
K	-0.029	0.057	0.268	-0.225	-0.48	0.193	-0.314	1												
Mg	-0.361	0.121	0.278	-0.407	-0.472	-0.105	-0.379	0.467	1											
Na	-0.039	0.055	0.015	-0.037	-0.183	0.442	0.096	0.247	0.491	1										
Fe	0.124	**-.551***	-0.32	0.462	**0.649****	0.169	**0.590***	-0.341	-0.143	-0.127	1									
Ca	0.012	-0.25	-0.148	-0.153	-0.04	0.168	-0.073	0.132	-0.32	-0.246	0.227	1								
Cu	-0.382	**0.688****	0.421	-0.249	-0.26	0.154	-0.288	0.216	0.24	0.011	-0.127	-0.222	1							
F	-0.262	0.138	0.33	-0.224	-0.106	-0.151	-0.239	-0.25	0.35	-0.158	0.144	-0.098	0.264	1						
Mn	0.104	0.471	-0.018	-0.229	-0.375	0.04	-0.399	0.476	0.003	0.089	-0.334	-0.126	0.362	-0.393	1					
Cl	**-.498***	0.248	**0.519***	-0.21	-0.177	-0.121	-0.083	-0.274	0.036	-0.179	-0.024	-0.18	0.491	0.288	-0.221	1				
SO4	-0.104	0.109	0.442	-0.135	-0.008	-0.385	-0.121	-0.351	-0.058	-0.43	-0.003	-0.242	0.278	**0.690****	-0.24	0.44	1			
NO3	-0.069	-0.251	0.275	-0.263	0.06	-0.395	-0.073	-0.367	0.187	0.006	0.218	0.001	-0.15	0.443	-0.404	-0.018	0.353	1		
Coli form	**0.565***	-0.347	-0.153	**0.779****	**0.753****	0.491	**0.863****	-0.288	**-.595***	0.075	0.393	-0.041	-0.164	-0.409	-0.112	-0.103	-0.045	-0.096	1	
SAR	-0.034	0.048	0.029	-0.003	-0.16	0.421	0.126	0.201	0.487	**0.994****	-0.143	-0.326	-0.009	-0.15	0.049	-0.142	-0.406	0.003	0.09	1

Table 3: Rotation Principal Component Analysis (PCA) loading matrix

Parameters	Component			
	1	2	3	4
Temperature	**0.463**	-0.339	-0.15	-0.078
pH	-0.308	**0.562**	**-0.546**	-0.008
Turbidity	-0.295	**0.598**	0.066	0.099
TDS	**0.932**	-0.13	0.014	0.012
EC	**0.888**	-0.135	0.267	-0.156
HCO3	**0.593**	0.043	-0.348	0.432
TH	**0.943**	-0.129	0.21	0.117
K	-0.363	-0.164	**-0.518**	0.347
Mg	-0.527	0.174	0.176	**0.659**
Na	0.02	-0.045	-0.08	**0.956**
Fe	**0.519**	-0.152	0.473	-0.086
Ca	-0.103	**-0.476**	-0.002	-0.323
Cu	-0.128	**0.788**	-0.36	0.043
F	-0.251	**0.518**	**0.578**	-0.06
Mn	-0.219	-0.007	**-0.793**	0.01
Cl	-0.052	**0.761**	0.129	-0.156
SO4	-0.074	**0.634**	0.417	-0.413
NO3	-0.207	0.032	**0.771**	0.036
Coliforms	**0.915**	-0.066	-0.049	-0.003
SAR	0.047	-0.012	-0.054	**0.959**
% of Variance	25.009	15.142	14.874	14.703
Cumulative %	25.009	40.151	55.025	69.728

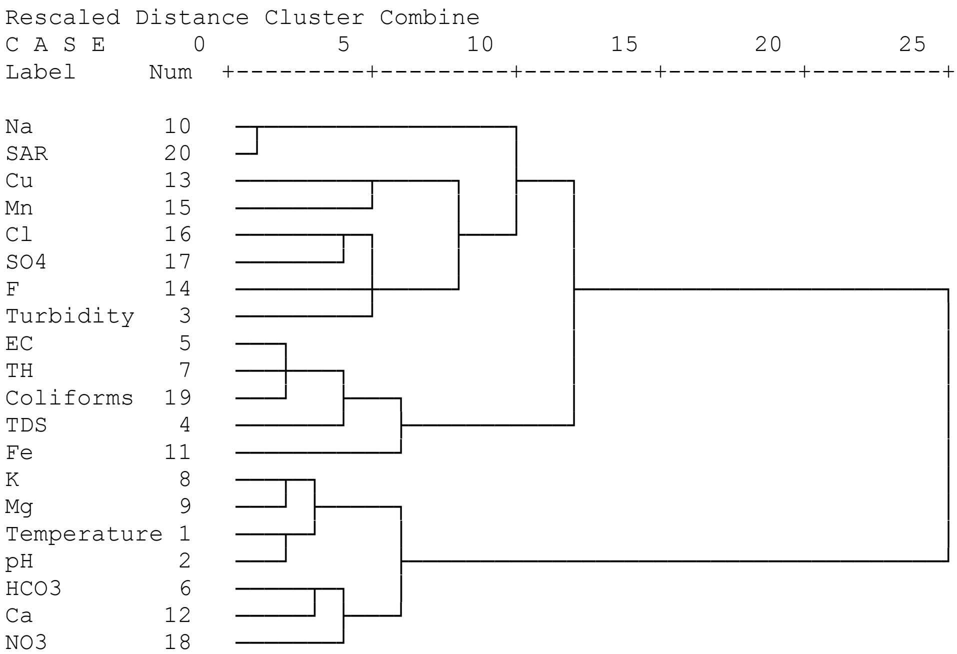

Figure 3: Dendrogram using Ward Method of groundwater samples in the study area

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3.2 Rock-water interaction

The use of scattered plots for Log TDS vs Na/(Na+Ca) and Log TDS vs Cl/(Cl+HCO3) (Gibbs, 1970) is used to interpret the effect of hydrogeochemical processes such as precipitation, rock–water interaction and evaporation on groundwater geochemistry. Figures 4 and 5 indicate that most points plotted in the region of rock-dominance and weathering zones, thus indicating precipitation derived from rock-water interaction (Nur *et al.*, 2012).

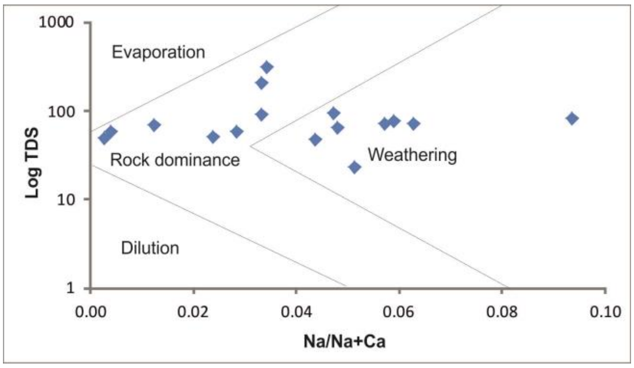

Figure 4: Cations plot in Gibbs (1970) diagram

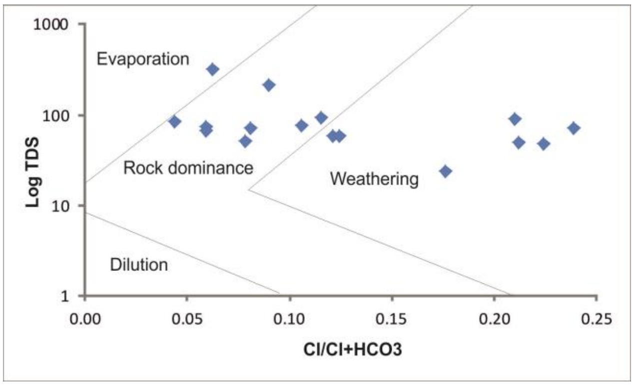

Figure 5: Anions plot in Gibbs (1970) diagram

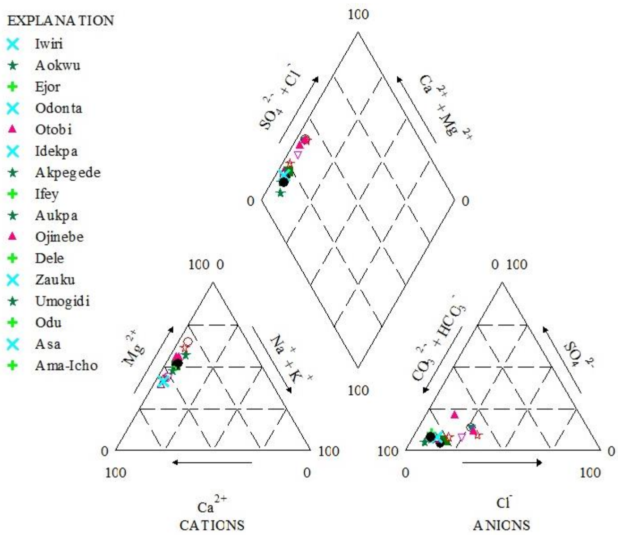

Figure 6: Piper Diagram Showing Water Classification

The characterization of the water in the study area using piper diagram (Figure 6) indicates that all samples were plotted in the region of Ca-Mg-HCO_3. The Ca-Mg-HCO_3 facies is the dominant water type and belongs to the normal alkaline group, and is related to the geology of the area (Nton *et al.*, 2007).

The Water Quality Index (WQI) ranges from 51 to 73.96 (Table 4). WQI <50 is excellent; 50 to 100 is good water; 100 to 200 poor water; 200 to 300 is very poor water and >300 indicates water that is unsuitable for human consumption (Batabyal and Chakraborty, 2015; Kumar *et al.*, 2015; Ishaku *et al.*, 2016). The WQI values obtained range between 22.05 and 65.07 which suggest that, the water in the research area falls in the range of good and excellent water and are suitable for human consumption and irrigation activities. Only acidity of water has effect on WQI.

Table 4: Computed Water Quality Index (WQI) for Individual Surface and Groundwater Samples

Sample points	Water Quality Index	Remarks
Iwiri (HDW)	45.03	Excellent water
Aokwu (HP)	35.96	Excellent water
Ejor (HDW)	38.31	Excellent water
Odonta (HP)	47.5	Excellent water
Otobi (River)	42.28	Excellent water
Idekpa (HP)	65.07	Good water
Akpegede (HDW)	34.58	Excellent water
Ifey (HDW)	45.08	Excellent water
Aukpa (HP)	47.09	Excellent water
Ojinebe (HDW)	36.83	Excellent water
Dele (HP)	31.64	Excellent water
Zauku (HP)	22.05	Excellent water
Umogidi (HDW)	44.23	Excellent water
Odu (River)	25.16	Excellent water
Asa (HDW)	56.13	Good water
Ama-Icho (HP)	43.92	Excellent water

4. CONCLUSION

The surface and groundwater quality of Otukpo area and environs has been assessed for its hydrogeochemical and found suitable for both human consumption and irrigation purposes. Hydrogeochemical result reveal that the water acidic, fresh and moderately hard. The sequence of the abundance of the major ions is in the following order: Na^+<K^+<Mg^+<Ca^+ for the major cations. On the other hand, for the major anions, the order was Cl^-<HCO_3^->SO_4^{2-}<NO^{3-}. PCA and HCA identified anthropogenic contamination and rock-water interaction, cation exchange as the major processes responsible for the modification of groundwater chemistry. Gibbs diagram indicates that most points plotted in the region of rock-dominance and weathering, thus suggesting precipitation induced chemical weathering along with the dissolution

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of rock-forming minerals. Piper diagram indicates that the water from all selected sources is predominantly influenced by Mg^{2+} and HCO_3^- ions i.e. Ca-Mg-HCO_3 hydrochemical facies. Sodium Absorption Ratio (SAR) result reveal that the water in the area fall in excellent category and is suitable for agricultural purposes. The present study reveals that the investigated water sources are mostly potable and can be consumed without serious treatment. Nonetheless, seven water sources identified to be unsafe should be treated before consumption due acidic nature of the water.

REFERENCES

Abah, R. C. (2014). Rural perception to the effects of climate change in Otukpo, Nigeria. Journal of Agriculture and Environment for International Development, 108 (2), 153-166.

Ankidawa, B.A. and Seli, A.B. (2018). Dar Zarrouk Parameters for Delineation of Groundwater Potential Zones in Geriyo Irrigation Floodplain of River Benue, Adamawa State, Northeastern Nigeria. Current Journal of Applied Science and Technology, vol. 27, issue 5, pp. 1-15.

Asaad, M. A., Abdelazin, N., Oliver, C. S. V. (2016). Groundwater Quality Investigation Using Multivariate Analysis. Case Study: Western Nile Delta Aquifer, Egypt. International Journal of Environmental Science and Development, 7 (1), 1-9.

Ashiyani, N., Parekh, F., Suryanarayana, T. M. V. (2015). Analysis of Physico-Chemical Properties of Groundwater. International Journal of Innovative Research in Science, Engineering and Technology, 4 (3), 1094-1098.

Avdullahi, S., Fejza, I., Timava, A. (2013). Evaluation of groundwater pollution using multivariate statistical analysis: A case study from Burimi area, Kosovo. Journal of Biodiversity and environmental Science, 3 (1), 95-102.

Bajpayee, S., Das, R., Ruj, B., Adhikari, K., Chatterjee, P. K. (2012). Assessment by multivariate statistical analysis of groundwater geochemical data of bankura. International Journal of environmental Sciences, 3 (2), 870-880.

Batabyal, A. K., Chakraborty, S. (2015). Hydrogeochemistry and Water Quality Index in the Assessment of Groundwater Quality for Drinking Uses. Water Environmental Research, 87 (7), 607-617.

Carter, J. D., Barber, W., Tait, E. A. (1963). The Geology of parts of Adamawa, Bauchi and Bornu Provinces in North-Eastern Nigeria. Geological Survey of Nigeria Bull 30, 1-109.

Census (2006). Details of the Breakdown of the National and State Population Census, Benue State, Nigeria.

Chris, K. (2002). Water Quality Control and Assessment, Centre for Education Technologies Wheeling Jesuit University USA.

Environmental Protection Agency, EPA (2001). Protecting and Restoring American's Watersheds: Status Trends and Initiatives in Watershed Management. EPA-840-R-00-001, 5-7.

Freeze, R. A., Cherry, J. A. (1979). Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, 604p.

Gibbs, R. J. (1970). Mechanisms Controlling World's Water Chemistry. Science, 170 (3962), 1088-1090.

Harun, S., Uja, N., Fikri, A. H. (2015). Water Quality and Phytoplankton Distribution of the Lower Kinabatangan River Catchment, Sabah. Journal of Tropical Resources and Sustainable Science, 3, 204-207.

Hem, J. D. (1970). Study and chemical interpretation of the chemical characteristics of the natural water. U.S. Geological Survey. Water Supply Paper 1473, Reston, VA. 363p.

Ishaku, J. M., Ankidawa, B. A., Abbo, A. (2015). Groundwater Quality and Hydro-geochemistry of Toungo Area, Adamawa State, North Eastern Nigeria. American Journal of Mining and Metallurgy, 3 (3), 63-73.

Ishaku, J. M. (2011). Assessment of groundwater quality index for Jimeta-Yola area, Northeastern Nigeria. Journal of Geology and Mining Resources, 3 (9), 219-231.

Ishaku, J. M., Ankidawa, B. A., Pwalas, A. J. D. (2016). Evaluation of Groundwater Quality Using Multivariate Statistical Techniques, in Dashen Area, North Eastern Nigeria. British Journal of Applied Science & Technology, 14 (6), 1-17.

Ishaku, J.M., Ankidawa, B.A. and Bello, Y. (2017). Hydrogeochemistry and Ground Water Quality Index in Hong and Environs, Adamawa State, North Central Nigeria. International Journal of Integrated Engineering, vol. 9, no. 3, pp. 58-71.

Kumar, S.K., Logeshkumaran, A., Magesh, N.S., Godson, P.S. and Chandrasekar, N. (2015). Hydro-geochemistry and application of water quality index (WQI) for groundwater quality assessment, Anna Nagar, part of Chennai City, Tamil Nadu, India. *Applied Water Science*, 5, pp. 335-343.

MacDonald, A. M., Bonsor, H. C., Calow, R. C., Taylor, R. G., Lapworth, D. J., Maurice, L., Tucker, J., O'Dochartaigh, B. E. (2011). Groundwater resilience to climate change in Africa. British Geological Survey Open Report, 1-32.

Mangoua, M. J., Gone, D. L., Kouassi, K. A., N'guettia, K. G., Douagui, G. A., Savane, I., Biemi, J. (2015). Hydrogeochemical assessment of groundwater quality in the Baya watershed (Eastern of Côte d'Ivoire). African Journal of Agricultural Research, 10 (49), 4477-4489.

Nagaraju, A., Sreedhar, Y., Thejaswi, A. (2016). Assessment of ground water quality of Udayagiri area, Nellore, District, Andhra Pradesh, South India. International Journal of Scientific and Engineering Research, 7 (2), 653-668.

Naseem, S., Hamza, S., Bashir, E. (2010). Groundwater geochemistry of winder agricultural farms, Balochistan, Pakistan and Assessment for Irrigation Water Quality. European Water, 31, 21-32.

Nayak, K. M., Sahoo, H. K. (2011). Assessment of Groundwater Quality in Tangi-Choudwar and Cuttack Blocks of Cuttack District, Orissa, India. International Journal of Earth Sciences and Engineering, 4 (6), 986-994.

Nazaruddin, D. A., Zulkarnain, Z., Fadilah, N. S. Md., Khan, M. M. A., Bahar, A. M. A. (2015). Study on Geoheritage and Water Quality of Pos Hendrop Hot Spring, Lojing Highlands, Kelantan, Malaysia. Journal of Tropical Resources and Sustainable Science, 3, 222-232.

Nton, M. E., Adejumo, S. S., Elueze, A. A. (2007). Hydrogeochemical Assessment of Surface water and groundwater quality in Agbowo-Orogun area of Ibadan, South western.

Nur, A., Ishaku, J. M., Taiyib, A. (2012). Spatial distribution of chemical facies using geographical information system (GIS) in Michika, Northeastern Nigeria. Research Journal in Engineering and Applied Sciences, 1 (2), 102-109.

Nyagba, J. L. (1995). Soils and Agriculture of Benue State. In: Denga D.I., Editor. Benue a Land of Great Potentials. A Compendium, Calabar Rapid Educational Publishers Ltd., 1-84.

Offodile, M. E. (2002). Groundwater supply and development in Nigeria, Meco Geology and Engineering Services (Jos).

Ogah, V. E. (2014). Metallic Mineral Exploration in Otukpo Area of Benue State. Published PhD Thesis, Department of Geology, Faculty of Physical Sciences, University Of Nigeria, Nsukka, 142pp.

Ogunribido, T. H. T., Kehinde-Philips, O. O. (2011). Multivariate statistical analysis for the assessment of hydrogeochemistry of groundwater in Agbabu Area, S.W. Nigeria. Proceedings of the Environmental Management Conference, Federal University of Agriculture, Abeokuta, Nigeria, 425-435.

Piper, A. M. (1944). A graphic procedure in the geochemical interpretation of water analyses. Transactions – American Geophysical Union, 25, 914-928.

Praus, P. (2007). Urban water quality evaluation using multivariate analysis, Acta Montanistica Slovaca, 12 (2), 150-158.

eISSN Number: 2462-2389

Richards, L. A., (1954). Diagnosis and Improvement of Saline Alkali Soils: Agriculture, Handbook, US Department of Agriculture, Washington DC, 160.

Singh, S. K., Singh, C. K., Kumar, K. S., Gupta, R., Mukherjee, S. (2009). Spatial-Temporal monitoring of groundwater using multivariate statistical techniques in Bareilly District of Uttar Pradesh, India. Journal of Hydrology Hydromechanical, 57 (1), 45-54.

Tavassoli, S., Mohammadi, A. (2017). Groundwater quality assessment based on WQI and its vulnerability to saltwater intrusion in a coastal city, Iran. Journal of Geoscience and Environmental Protection, 5, 88-98.

Usman, U. N., Toriman, M. E., Juahir, H., Abdullahi, M. G., Rabiu, A. A., Ishiyaka, H. (2014). Assessment of groundwater quality using multivariate statistical techniques in Terrengganu. Science and Technology, 4 (3), 42-49.

Vasanthavigar, M., Srinivasamoorthy, K., Rajiv, Gantha, R., Vijayaraghavan, K., Sarma, V. S. (2010). Characterization and quality assessment of groundwater with special emphasis on irrigation utility: Thirumanimuttar sub-basin, Tamil Nadu, India. Arabian Geoscience Journal, 1-14.

Ward, J. H. (1963). Hierarchical grouping to optimize objective function. Journal of American Statistical Association, 69, 236-244.

World Health Organization (2011). Guidelines for Drinking Water Quality. 4th ed. World Health Organization, 294-433.

Wotany, E. R., Ayonghe, S. N., Fantong. W. Y., Wirmven, M. J., Ohba, T. (2013). Hydrogeochemical and anthropogenic influence on the quality of water sources in the Rio del Rey Basin, South Western, Cameroon, Gulf of Guinea. African Journal of Environmental Science and Technology, 7 (12), 1053-1069

eISSN Number: 2462-2389