Application of Factorial Loading in Groundwater Analysis in the Coastal Plain Sands Aquifer of Ibeno Local Government Area in Akwa-Ibom State, Nigeria

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Abstract
The study focused on the factorial analysis of boreholes in coastal plain sands aquifer of Ibeno in Akwa Ibom State due to the constant complains on the pollution of boreholes. Water samples were collected from six locations including Uyo and Etinan as controls for physiochemical analysis, and results compared to the WHO & FMEnv standards of drinking water. Data obtained were subjected to R-mode factor analysis, and physical parameters recorded four loading factors; 1:(TSS, TDS and oil), 2: (color), 3: (turbidity), 4 :(nil), as organic items that pollute aquifer, with the locational factorial loadings in order of : F4>F2>F3>F1 signifying Upenekang (58%), Iwochang (48%), Okonofiak (44%), Uyo (36%) . From the chemical background, four factors viz:1:(pH, hydrocarbon, HCO_3, EC, $CaCO_3$, Cl and NO_3), 2:(alkalinity), and 3 - 5 (nil) indicating saltwater incursion and human activities interaction with the geological matrix to alters the groundwater quality. Based on chemical parameters, contributions made by locations to the factorial loadings in the groundwater quality were in order of : F5>F3>F2>F4>F1 signifying Mpanak (79%), Upenekang (78%), Uyo (62%), Okonofiak (48%), Etinan 42% respectively and heavy metal loadings: two factors, Factor 1 (Ni, Fe, Cr and Al), Factor 2 (Pb and Cu) were extracted from the dataset representing the signatures of toxicity in aquifer. The contributions of these to factorial loadings were in order of F5>F1>F2>F3>F4 signifying Mkpanak (53%), Uyo (49%), Okonofiak (46%), Iwochang (31%), Etinan (26%) respectively, calling for best management practices for sustainable groundwater sustainability for human survival.

Keywords: Factorial loading, groundwater, coastal, plain sand, aquifer

Introduction

Water indeed is an essential component of life (Osunkiyesi, 2012). The need for water in the day to day activities of man include for cooking, washing, drinking and for industrial activities (Akpoborie *et al,* 2008), therefore the quality of water is very important to ensure that it is potable for drinking. The chemistry of groundwater is due to processes like soil/rock–water interaction during recharge and groundwater flow, prolonged storage in the aquifer, dissolution of mineral species (Sekabira *et al*., 2010). These processes are related to weathering of minerals which generally exerts an important control on groundwater chemistry (Kim, 2002), and this process generally dominates the concentration of the major cations in groundwater.

In coastal environments the influence of saltwater intrusion is often significant (Olobaniyi and Owoyemi, 2016). Studies have shown that increase in groundwater abstraction in coastal areas is largely responsible for the encroachment of seawater into coastal groundwater aquifers (Edet and Okereke, 2001; Udom *et al*, 2002). According to Edet and Okereke (2001), Babatunde (2007) the southern part of Akwa Ibom State, which contributes more than 30% of Nigeria's crude oil, is presently experiencing an increase in human and industrialization levels. Saline intrusion into coastal aquifers has become a major concern because it constitutes the

commonest of all the pollutants transfer to freshwater. The data situation according to a study Ayoade (1993) with respect to Nigeria hydrology and water resources should be improved. It has also been observed that our knowledge of the quantity, distribution and quality of Nigeria's water resources is still far from satisfactory. In Akwa Ibom State, evidence abounds that the pollution of underground and surface water resources are affected by the incessant gas flaring (Ubuoh, 2012), oil spillage and the influence of its nearness to Atlantic Ocean that aids salt water intrusion (Olobaniyi, and Owoyemi, 2016). Consistently, it is also predicted that by the year 2025, many African countries will experience water scarcity (WMO, 2008). United Nation Environmental Programmed (UNEP) (2006) reports that, degradation of groundwater is one of the most serious water resources problems in Africa and that is why its management is crucial.

Factorial technique (FT) which is part of principal component analysis (PCA) is the most widely used technique in science and engineering (Polkowska et al, 2005). Since the method is so dependent on the total variance of the original variables, it is most suitable when all the variables are measured in the same units (Sharma *et al.*, 2014a), unlike water quality index, which is essentially defined as a rating reflecting the composite influence of a number of parameters on the overall quality of water (Bangalore and Latha, 2008). Although, the concept of water quality index is not yet widely used in Nigeria, Egereonu and Ozuzu (2005) has used it to assess the level of pollution of River Niger, Ubuoh *et al.* (2013) applied it to determine the susceptibility of water resources to atmospheric pollutant due to petroleum exploitation while Olatunji *et al* (2015) recently used it to to assess groundwater quality in Ilorin metropolis despite its complexity in application. The FT has been used by Iyer et al. (2003) for coastal water quality assessment in south west India, Ndehedehe et al (2016) to analyze terrestrial water storage and precipitation in West Africa, Ubuoh *et al* (2017) in the assessment of atmospheric precipitation in southern, Nigeria (Gajbhiye *et al*, 2015), on open well in India, (Olobaniyi and Owoyemi, 2006) in groundwater in the deltaic plain sands aquifer of Warri, South -Western Nigeria due to its simplicity in application.
This project then focuses on the application of factorial technique in analysis of the status of water from the selected boreholes in coastal plain sands aquifer Ibeno of Akwa Ibom State, Nigeria in order to assess the extent of human activities and natural factors on underground water pollution .

Materials and Methods

Study Location

The study areas were three villages of Mkpanak, Iwuoachang and Ukpenekang all in Ibeno Local Government Area (Fig.1). The area is located between Longitude 7°.351 E and 7°.451 E of the Greenwich meridian; Latitude 6°.101 N and 8°.111 N of the equator. The climate falls within tropical equatorial (Af) type, characterized by longer wet season and shorter dry season. Temperatures and relative humidity are high throughout the year with abundance annual rainfall (Inyang, 1980). The mangrove and rainforest vegetation stretched outward along the Atlantic coast to the land. Deposits of recent alluvium and beach ridge sand occur along the coast and the estuarine of the Qua Iboe Rivers, and also along the floodplain of creeks. The geologic succession passes imperceptibly into thick sequence of clays, sands, and gravel**.** The four major oil companies operating in the area include Ashiland Nigeria Limited, Mobil Producing Nigeria, Shell development Company Nigeria and Nigeria Agip Oil Producing Company.

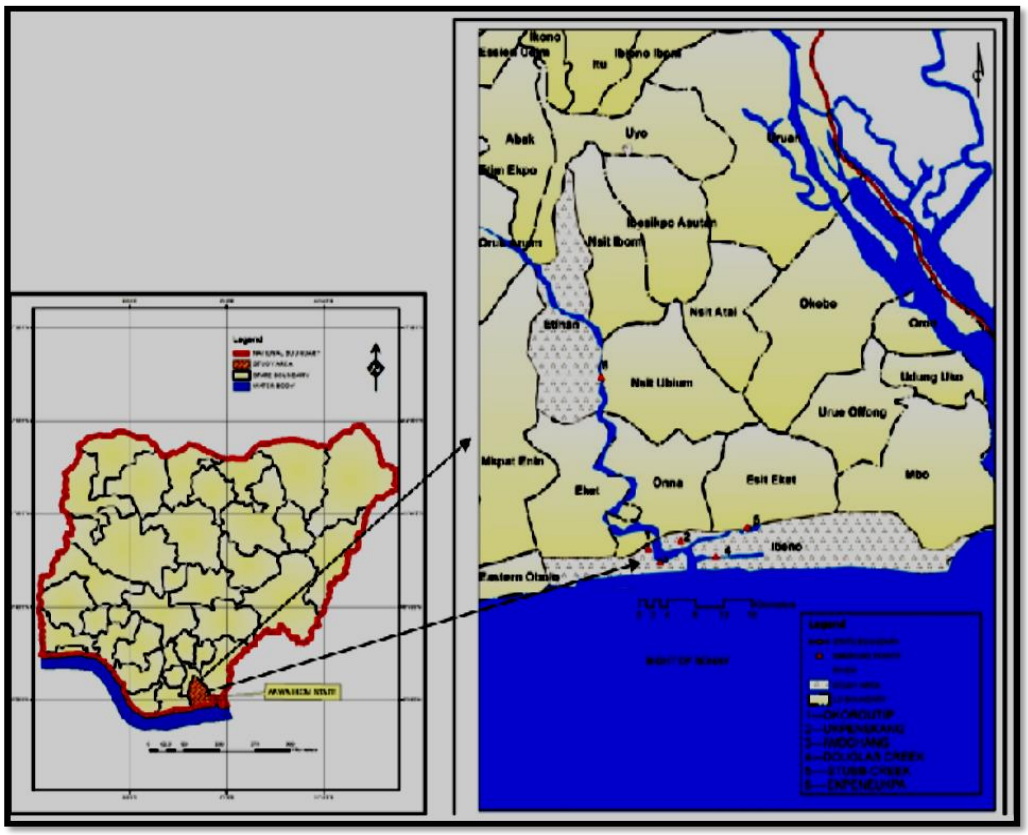


Figure 1. Map of Akwa Ibom State, Nigeria showing the study locations and sampling sites at Ibeno (see arrows): Source: Eno and Bassey (2015)

Groundwater Sampling

Water samples were collected from the selected boreholes in the month of July, 2016. Water sample was collected in 2 liter plastic containers. All samples were collected, preserved and stored for analysis (APHA, 1992) as outlined in Standard Methods for the Examination of Water and Wastewater. Six boreholes designated borehole water (BHW), with two being controls selected at random from sands plain (Table 1). All the sampled water containers were kept in ice boxes and brought to the laboratory for analysis.

Table 1: shows the sampled borehole locations in the study area

Bore hole	Sampled Locations
BHW1	Upenekang
BHW2	Iwoachang
BHW3	Mkpanak
BHW4	Okoritak
BHW5	Etinan (outside floodplain)
BHW6	Uyo (Outside floodplain)

Water Quality Determination: For borehole water samples, physical parameters chosen include; temperature, color, oil, total suspended solids (TSS), total dissolved solids (TDS) and turbidity. Selected Chemical Parameters include pH, hardness ($CaCO_3$), sulphate (SO_4^{2}), nitrate (NO_3^{-}), , hydrocarbon, bi- carbonate (HCO_3) chlorine (Cl), electrical conductivity(EC) and heavy metals include: Lead (Pb), iron (Fe), copper (Cu) and chromium (Cr) . All samples were collected, preserved and stored for analysis (APHA 1992) as outlined in

Standard Methods for the Examination of Water and Wastewater. Parameters were analyzed according to standard specifications presented by the Water quality Kit (La Motte, smart water analysis, code- 1951- 01 EX2).

Factorial Analysis: Data obtained from the laboratory analysis were used as variable inputs for factor analyzing using the SPSS package described by Nie et al. (1975). Prior to the analysis, the data were standardized to produce a normal distribution of all variables (Davis, 1973). This was followed by a preparation of a correlation matrix of the data from which initial factor solutions were extracted by the principal component analytical method. Factor extraction was done with a minimum acceptable eigenvalue as 1 (Harman, 1960). Orthogonal rotation of these initial factors to terminal factor solutions (Table 4-6) was done with Kaiser's varimax scheme (Kaiser, 1958). This method maximizes the variance of the loadings on the factors and hence adjusts them to be either near ± 1 or near zeros (Davis, 1973). Factor score coefficients are derived from the factor loadings. Factor scores are computed for each sample by a matrix multiplication of the factor score coefficient with the standardized data. The value of each factor score represents the importance of a given factor at the sample site. A factor score > + 1 indicates intense influence by the process. Very negative values (< - 1) reflect areas virtually unaffected by the process while near - zero scores reflect areas with only moderate effect of the process.

Results

Table 1-3 presented the univariate summaries of the borehole data of the study location ranging from the physical, chemical and heavy metal concentrations. Table 4-6 show the varimax rotated factor matrix consisting of the component factors, the loading of variables on each factor and percentage of data variance explained by each factor.

Table 1: Univariate statistical summary of Boreholes' physical parameters in the study area

Variable	Minimum	Maximum	Mean	Std. deviation
Temperature (ºC)	25.000	28.000	26.500	1.049
Colour (Pt/Co)	0.000	1.000	0.333	0.516
Turbidity (NTU)	0.400	2.100	0.898	0.608
TSS (mg/l)	0.890	27.800	13.752	12.023
TDS (mg/l)	18.700	198.700	132.127	69.055
Oil (mg/l)	0.001	0.410	0.209	0.181

Table 2: Univariate statistical summary of Boreholes' chemical parameters in the study area

Variable	Minimum	Maximum	Mean	Std. deviation
pH	5.600	8.700	6.930	1.134
Hydrocarbon (mg/l)	0.010	0.570	0.307	0.250
HCO_3 (mg/l)	0.010	88.000	53.338	41.531
EC (µ/Scm)	27.000	274.000	159.818	111.435
$CaCO_3$ (mg/l)	45.000	256.000	119.118	78.447
Cl (mg/l)	0.400	37.010	21.383	12.787
Alkalinity (mg/l)	45.100	97.000	66.700	17.112
SO_4^{2-} (mg/l)	0.020	2.890	1.713	0.949
NO_3 (mg/l)	7.600	15.010	10.698	2.748

Table 3: Univariate statistical summary of heavy metals in Boreholes in the study area

Variable (mg/l)	Minimum	Maximum	Mean	Std. deviation
Ni	0.030	0.250	0.178	0.081
Pb	0.010	15.010	2.567	6.096
Fe	0.027	17.600	10.241	8.066
Cr	0.001	0.050	0.025	0.022
Al	0.001	0.030	0.014	0.010
Cu	0.010	0.340	0.113	0.134

Comparison of Boreholes Water Quality with Standards

Analysis of the water samples are shown in Table 1-3.These tables indicated the physical, chemical and heavy metal concentrations in the selected boreholes. The results shown that, oil in boreholes ranged between 0.001-0.410 mg/l, with the mean value of 0.21mg/l (std.0.2) above the 0.05mg/l of FMEnv standard for drinking water. The pH of groundwater of the study varied from 5.6 – 8.7 with an average of 6.9 which indicates that water samples fall within slightly acidic to alkaline based on the classification by Odukoya (2015).

Hydrocarbon ranged between 0.010-0.6mg/l with the mean value of 0.31mgl (Std.0.3), above the 0.2mg/l of WHO standard for drinking water. Bicarbonate ranged between 0.010-88mg/l with the mean value of 53.34 mg/l (Std.41.5) above the 0.2mg/ the WHO 2006 STD. Chlorine ranged between 0.40-37.01mg/l with the mean value of 21.4mg/l (Std.12.8) above the 3.0-5.0mg/l WHO Std for drinking water, nickel 0.030-0.3mg/l with the mean valve of 0.18mg/l (Std.0.081); Pb 0.010-15.01mg/l with the mean of 2.57 mg/l (Std.6.10) above the 0.05mg/l FMEnv. Standards for drinking water respectively, iron 0.027-17.6mg/l, with the mean value of 10.24mg/l (Std.8.07), above1mg/l FMEnv. Std for drinking water and Cr ranged between 0.010-0.34mg/l with the mean of 0.11mg/l (std.0.3) above the 0.01mg/l of FMEnv standard for drinking water.

Table 4: Varimax rotated factor loading matrix for physical parameters of Borehole in Ibeno

Variables	Factor Loadings			
	Factor 1	Factor 2	Factor 3	Factor 4
Temperature (°C)	0.757	-0.597	-0.089	-0.134
Colour (Pt/Co	0.588	0.784	0.137	-0.100
Turbidity (NTU)	0.680	0.240	0.691	0.031
Total Suspended Solid (TSS) (mg/l)	0.753	-0.544	0.332	0.113
Total Dissolved Solids (TDS) (mg/l)	0.816	0.101	-0.455	-0.305
Oil (mg/l)	0.748	0.207	-0.484	0.405
Eigenvalue	**3.173**	**1.378**	**1.056**	**0.299**
Variability (%)	**52.885**	**22.973**	**17.593**	**4.984**
Cumulative %	**52.885**	**75.857**	**93.450**	**98.434**

Factorization of physical parameters of the sampled boreholes

Factor 1: Factor 1 recorded the total variance of 52.89% of the entire physical parameters of boreholes sampled with the high loadings of temperature, TSS, TDS and oil (Table 4).

Factor 2: Factor 2, which explains 22.97% of the total variance, include colour only (Table 4). The most favorable environments for high coloration in the underground water include elevated organic activity with algal growth and presence of soluble minerals (iron and manganese) in the vicinity of a water body.

Factor 3: This factor explains 17.59% of the total variance that include only turbidity (Table 4)**.** Turbidity is a measure of relative clarity of water from suspended substances. The increase in turbidity may contribute in high coliform count and risk to human health (Mahessar *et al,* 2015). From the physical parameters point of view, the following locations contributed highest percentages to the factorial loadings as follows: In Factor 1 Uyo (36%) as control, Factor 2 Iwochang (48%), Factor 3 Okonofiak (44%), and Factor 4 Upenekang (58%). The contributions that came from locations to the factorial loadings were in order of **F4>F2>F3>F1** (Table 4). Except Uyo as control, the proximity of these areas to the sea fosters a high rainfall that encourages rapid chemical weathering and the liberation of cations into groundwater.

Table 5: Varimax rotated factor loading matrix for chemical parameters of Boreholes in Ibeno

Variables	Factor Loadings				
	Factor 1	**Factor2**	**Factor3**	**Factor4**	**Factor 5**
pH	0.731	-0.381	0.528	-0.182	-0.096
Hydrocarbon (mg/l)	0.955	-0.216	-0.055	-0.163	-0.110
Hydro carbonate ($HCO_{30)}$ (mg/l)	0.935	-0.185	-0.088	-0.203	0.206
Electrical Conductivity (EC) (µ/Scm)	0.939	-0.198	-0.104	-0.174	-0.194
Calcium Carbonate ($CaCO_3$) (mg/l)	0.923	-0.133	-0.019	0.335	-0.131
Chlorine (Cl) (mg/l)	0.932	0.228	0.266	-0.078	0.048
Alkalinity (mg/l)	0.027	0.977	0.177	-0.030	-0.109
Sulphate (SO_4) (mg/l)	0.398	0.915	0.021	-0.045	0.046
Nitrate (NO_3) (mg/l)	0.837	-0.231	0.447	0.189	0.102
Eigenvalue	**5.783**	**2.181**	**0.603**	**0.288**	**0.145**
Variability (%)	**64.254**	**24.234**	**6.698**	**3.201**	**1.613**
Cumulative %	**64.254**	**88.488**	**95.186**	**98.387**	**100.000**

Factorization of chemical parameters in the sampled boreholes

Factor 1: Factor 1, which explains 64.25%.83% of the total variance, includes pH, hydrocarbon, HCO_3, EC, $CaCO_3$, Cl and NO_3 (Table 4). Based on the contribution to the factorial loading, Etinan 42% to F1, Uyo 62% to F2, Upenekang 78% to F3, Okonfiak 48% to F4, and Mpanak 79% to F5 respectively. Low pH in water generally is said to be slightly acidic, which is characteristic of groundwater in most parts of the Niger Delta region (Udom *et al* 1998, Ubuoh, 2012). This acid percolates into the groundwater system and increases the acidity of the water, thereby reducing the pH. High loading of conductivity depends on the quantity of dissolved salts present in a water body and is approximately proportional to the TDS content (FEPA, 1997). This could be affected by several environmental factors which include climate, the local biota, bedrock, geology and other anthropogenic factors.

Factor 2
Factor 2, which explains 24.234% of the total variance, include alkaline only. Alkalinity refers to the capacity of water to neutralize acid. Alkalinity is reported as the equivalent amount of calcium carbonate Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH (Benjamin, 2015). The contributions made by locations to the factorial loadings in the groundwater quality were in order of: F3>F5>F2>F4> F1. From the loadings, these reflect the signatures of natural water recharge and water-soil/ rock interaction in the study area.

Table 6: Varimax rotated factor loading matrix for Heavy Metals in Boreholes in Ibeno

Variables	Factor Loadings				
	Factor 1	Factor2	Factor 3	Factor 4	Factor 5
Nickel	0.891	-0.146	0.170	0.391	0.053
Lead (Pb)	0.357	-0.752	0.487	-0.204	0.166
Iron (Fe)	0.925	0.269	0.136	0.030	-0.229
Chromium (Cr)	0.889	-0.183	-0.259	-0.277	-0.180
Aluminum (Al)	0.728	0.520	-0.247	-0.093	0.361
Copper (Cu)	**-0.077**	**0.842**	**0.518**	**-0.127**	**-0.031**
Eigenvalue	**3.104**	**1.672**	**0.681**	**0.297**	**0.246**
Variability (%)	**51.734**	**27.874**	**11.346**	**4.943**	**4.103**
Cumulative %	**51.734**	**79.608**	**90.954**	**95.897**	**100.000**

Factorization of heavy metals in the sampled boreholes
The result of the heavy metals in groundwater (Table 6) is summarized through the factorial loading as follows:

Factor 1: Factor 1 of heavy metals loading explains 51.73% which includes nickel, iron, chromium and aluminum. Iron is a naturally occurring metal that is widely present in soils, rocks, and groundwater. Dissolved iron can exists in either an oxidized (ferric) or reduced (ferrous) state. Iron is a secondary cause of hardness in water. High loading of higher concentrations of iron produces objectionable odor, taste, color, staining, corrosion, and scaling (Ubuoh, 2012).

Factor 2: This explains 27.87%, which includes lead and copper. Lead is negatively loaded in sampled water, while copper is positively loaded**.** Copper is a metal that occurs naturally in ore deposits, but only at very low concentrations in most soils and rocks. From the contribution made by locations to heavy metals loading in groundwater quality, Uyo 49% to F1, Okonofiak 46% to F2, Iwochang 31% to F3, Etinan 26% and Mkpanak 53% to F5. The contributions were in order of F5>F1>F2>F3>F4.

Discussions
Hydro chemical processes show to have an influence on the prevalence of anthropogenic and natural contaminant in coastal environment (Zilberbrand *et al.,* 2001; Park *et al*., 2005 and Mondal et al., 2010). It is evident from the literature that infiltration of effluents has led to the contamination of aquifers in different parts of India (Pujari and Deshpande 2005 and Naik *et al.,* 2007). At a high TDS concentration, water becomes saline, emanating from seawater in the area (Ademoroti,1996).Water with high TDS (carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic) often has a bad taste and/or high water hardness, and could result in a laxative effect (Ubuoh, 2012). This result is consistent with the finding of Olobaniyi and Owoyemi (2015) who

observed that the intrusion of seawater into the aquifer system which increases the concentrations of ions and hence values of the dissolved solids. High loading of oil in the borehole is suspected to be due to oil exploration and exploitation, since this area is dominated by oil companies like Mobil and Shell oil.

Similar to TSS, high concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature. Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. Turbidity itself is not a major health concern, but high turbidity can interfere with disinfection and provide a medium for microbial growth. Waters with low alkalinity are very susceptible to changes in pH (Ubuoh, 2012). The color is suspected to be caused by the nature of the geological formation in the area which is supported by Olobaniyi and Owoyemi (2015).

Acidity of groundwater in the Niger Delta is partly caused by gas flaring (Ubuoh et al, 2013; Nwankwoala.et al, 2014), and the presence of organic (Offing and Edet, 1998). The gas flaring from industrial activities releases carbon dioxide and other gases like sulphide which reacts with atmospheric precipitation to form carbonic and sulphuric acids (Udom *et al,* 2002; Ubuoh *et al*, 2013; Nwankwoala.et al, 2014; Ubuoh *et al,* 2017). Petroleum hydrocarbons are complex mixtures of chemicals that are the primary constituents in oil, gasoline, diesel fuel, and other solvents or types of oil. Note that gasoline compounds (benzene, toluene, ethyl benzene and xylene, or BTEX) are included in the Volatile Organic Compound (VOC). Hydrocarbon is suspected from the angle of oil exploitation. Infiltrating rain recharge water dominated by HCO3 flows in the aquifer towards the river valley causing groundwater pollution. Bi-Carbonate (HCO_3) loading was high in water sampled. This parameter is resulting from CO_2 in the atmosphere and biota production in the soil (Nwankwoala *et al,* 2014).. High loading of Cl is due to more saline river water rich percolates the aquifer, most especially during high tide and is an indicative of salt water encroachment. This chloride water type is widely reported within the coastal tract of Nigeria (Udom *et al,* 1999). Increase of chloride content beyond the safe limit does not pose any significant health problem except the test. (Leghari, 2013); Mahessar *et al*, 2015).Total Hardness (TH) is expressed as $CaCO_3$, and it is generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (MN^{2+}), may also contribute to the hardness of water, but are generally present in much lower concentrations, particularly in surface waters. Hardness of water occurs due to entry of water through leaching process of rocks and its high content may cause hardness of water (Ubuoh *et al,* 2013), as observed in the high loading in the presence study. Hard water is generally considered as hard water when containing large quantities of dissolved salts, for example, calcium and magnesium ions (Beka and Udom, 2014). Hardness describes the capacity of water to precipitate an insoluble residue when soap is used. Hard water reduces the ability of soap to clean clothes; leaves a sticky film on skin, clothes, and hair; and deposits scale in water heaters, boilers, and industrial equipment. The origin of nitrate in groundwater is commonly from fertilizer as a major source, industrial effluent, plant decomposition, and human sewage (Beka and Udom, 2014).

Nitrate in high concentration in drinking water results in a disease known as blue baby syndrome or methemoglobinemia in infants (Twort *et al,* 2007). This disease is characterized by blood changes and cyanosis in which the hemoglobin apparently becomes incapable of transporting oxygen (Ofoma *et al,* 2005). Chromium is a naturally occurring metal that is generally found at very low concentrations in soils and rocks.

Chromium is rare in groundwater that is not affected by point-source contamination. Chromium compounds are readily sorbed onto soil particles, which limit its mobility. The largest sources of chromium emissions are the chemical manufacturing industry and combustion of natural gas, oil, and coal. It may also be released from landfills or other solid- waste disposal site. Short-term exposure to chromium concentrations above this can result in skin irritation or ulceration, whereas long-term exposure can damage the liver and kidneys. Aluminum occurs ubiquitously in natural waters as a result of the weathering of aluminum-containing rocks and minerals. Of the known geochemical responses to environmental acidification, the best documented is the mobilization of aluminum from terrestrial to aquatic environments (Campbell *et al.* 1992). It is never found free in nature and is found in most rocks, particularly igneous rocks as aluminosilicate minerals (Lide,2005). Dissolved aluminum concentrations in surface and groundwater vary with pH and the humid acid content of the water. Aluminum has no known physiological role in the human body (Nayak, 2002), and may corrode the skin, irritate the mucous membranes in the eyes, and cause perspiration, shortness of breath and coughing. Short-term exposure to copper in drinking water can lead to gastrointestinal distress; long-term exposure can lead to liver or kidney damage.

Lead is a metal found widely disseminated at very low concentrations in soils and bedrock and concentrated in natural ore deposits. Lead can cause a variety of adverse health effects when people are exposed to it for relatively short periods. These effects may include interference with red blood-cell chemistry; delays in normal physical and mental development in babies and young children; deficits in attention span, hearing, and learning abilities of children; and increases in the blood pressure of adults. Long- term exposure to lead has the potential to cause stroke, kidney disease, and cancer (NIS, 2007).
The sources of nickel, iron, chromium, aluminum, lead and copper identified as heavily loaded in ground water quality in the area are attributed to the fact that the aquifer is very shallow and hence proximity to the land surface and couple with the fact that the ground water flow direction is generally from hinterland in the North to the coastal area in the South, thus making the groundwater vulnerable to heavy metal pollution (Longe and Enekwechi, 2007). In addition, the enhanced concentration may also be attributed to metal leaching from garbage and solid waste dumps (Netcom et al., 1993) into the groundwater system in the hinterlands before being transported to the coastal areas.

Conclusion and Recommendations

The result of the multivariate statistical analysis, as applied to the physical, chemical and heavy metal concentrations in groundwater in coastal plain sands aquifer in Ibeno, Akwa Ibom State **p**rovided an insight into the underlying controlling factors as regards to water pollution as follows:

- Based on the physical parameters, four factors including Factor 1(TSS, TDS and oil), Factor 2 (color), Factor 3 (turbidity), and Factor 4 (nil) were extracted from the dataset representing organic constituent that seeped through the sandy soil to aquifer. The contributions that came from locations to the factorial loadings were in the order of relative abundance: F4**>**F2>F3>F1. Here control being F1 recorded the least loading due to the distance from the activities of oil companies.

- From the chemical point of view, Four factors: Factor 1(pH, hydrocarbon, HCO_3, EC, $CaCO_3$, Cl and $NO_{3)}$, Factor 2(alkalinity), Factor 3 - 5 (nil) extracted from the dataset representing saltwater incursion and human activities such as oil exploitation, interaction with the geological matrix and dissolution of NO_3 that alters the quality of water in aquifer related compounds respectively in the groundwater, with alkalinity resisting change in pH in aquifer. The contributions made by locations to the

factorial loadings in the groundwater quality were in order of: F3>F5>F2>F4>F1.

- Based on heavy metal loadings, two factors, Factor 1 (Ni, Fe, Cr and Al), Factor 2 (Pb and Cu) were extracted from the dataset representing the signatures of toxicity in aquifer which is unhealthy when taken alongside water. The contributions of these to factorial loadings were in order of F5>F1>F2>F3>F4. Here the two control F1 and F5 (Etinan and Uyo) recorded the highest loading of heavy metals which is suspected to be the dumping of solid wastes and other human activities in the urban area.

  From the findings, it is recommended that constant monitoring and remediation processes of groundwater system should be given top priority for water quality assurance for the teeming population in the study locations where indiscriminate waste dumping in urban and salt intrusion in the coastal areas is the order of the day. Indiscriminate waste dump should be checked for proper disposal. Also, water from the boreholes should be boiling for domestic uses such as drinking, bathing etc.

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