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Hydrogeology of Uburu and Environs, Southern Eastern, Nigeria

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Abstract *Uburu is a rural settlement bounded within latitudes 6° 00' N and 6° 05'N, and longitudes 7° 40'E and 7° 45'E. Water quality in Uburu area of southeastern Nigeria was investigated, applying multivariate Statgraphics Centurion XVII, ArcGIS 10.2.2 and Surfer 10 software on hydrochemical and bacteriological data. 10 water samples, ranging from boreholes, hand dug wells and surface waters were collected, to unravel the major factor controlling water quality in the study area. The study area is underlain by Abakaliki Shale, which comprises bluish grey shales with fine to medium to coarse grained sandstones. Physico-chemical and bacteriological analyses were used to assess the influence of geogenic and anthropogenic processes on the groundwater quality. Results suggest that the groundwater is acidic, hard and salty, due to salt water intrusion in the Uburu area. The water types are mainly* $Na^{+}+K^{+}$ *and* $S0_4^{2-}$ *-* Cl^{-}*. According to the W.H.O (2017) standards, the levels of the physico-chemical parameters in the groundwater indicate that the water is acceptable for domestic use; but the bacteriological analysis shows high counts of Escherichia coliform (E. coli) bacteria, which indicates poor sanitary conditions in the study area. It will be safe, therefore, to suggest that the water be treated before it is used for drinking and preparation of food, in order to avoid incidences of gastro-intestinal diseases caused by the ingestion of water contaminated by faecal matters. The groundwater and surface water cluster analysis unraveled that rock mineral dissolution, sewage and agricultural waste contaminations, are the main factors controlling the water chemistry in the area.*

Key Words: *Bacteriological parameter, faucal matter, shales, and salt water Intrusion*.

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1.0 Introduction

The use of multivariate and geochemical analyses on groundwater quality study have received wide attention among several researchers. The methods is widely acknowledged as suitable for analyses of groundwater quality and in the investigation of the mechanisms affecting groundwater quality. (Farnham *et al*.,2003; Farnham *et al*., 2000; Stetzenbach *et al*., (2001; Onwuka *et al*., 2018; Ezugwu *et al*., 2019; Onwuka and Ezugwu, 2018). The high use of fertilizers, insecticides and manure to enhance crop yield, shallow groundwater depth, none compliance methods of siting sewage systems and the salty nature of the salt lakes necessitated this research work.

The aims of this work is to obtain the general geology, and use the hydro-geochemical signatures in an integrated approach to infer the controlling geogenic factors (rock mineral dissolution and saltwater infiltration) into the groundwater and anthropogenic factors (sewage and agricultural wastes) of Etiti Uburu and environs, applying Geochemical plots, Statgraphics Centurion XVII, ArcGIS 10.2.2 and Surfer 10 software on hydrochemical and bacteriological data from 10 water samples ranging from boreholes, hand dug wells and surface waters.

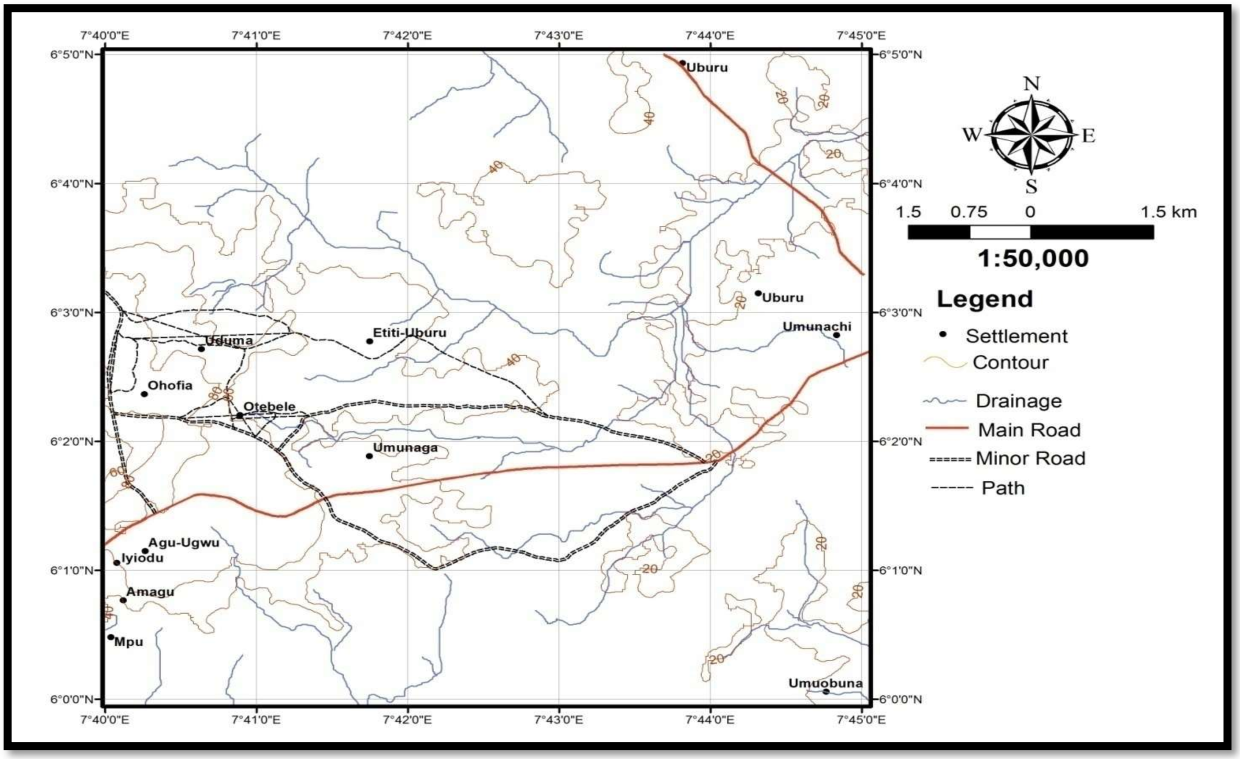
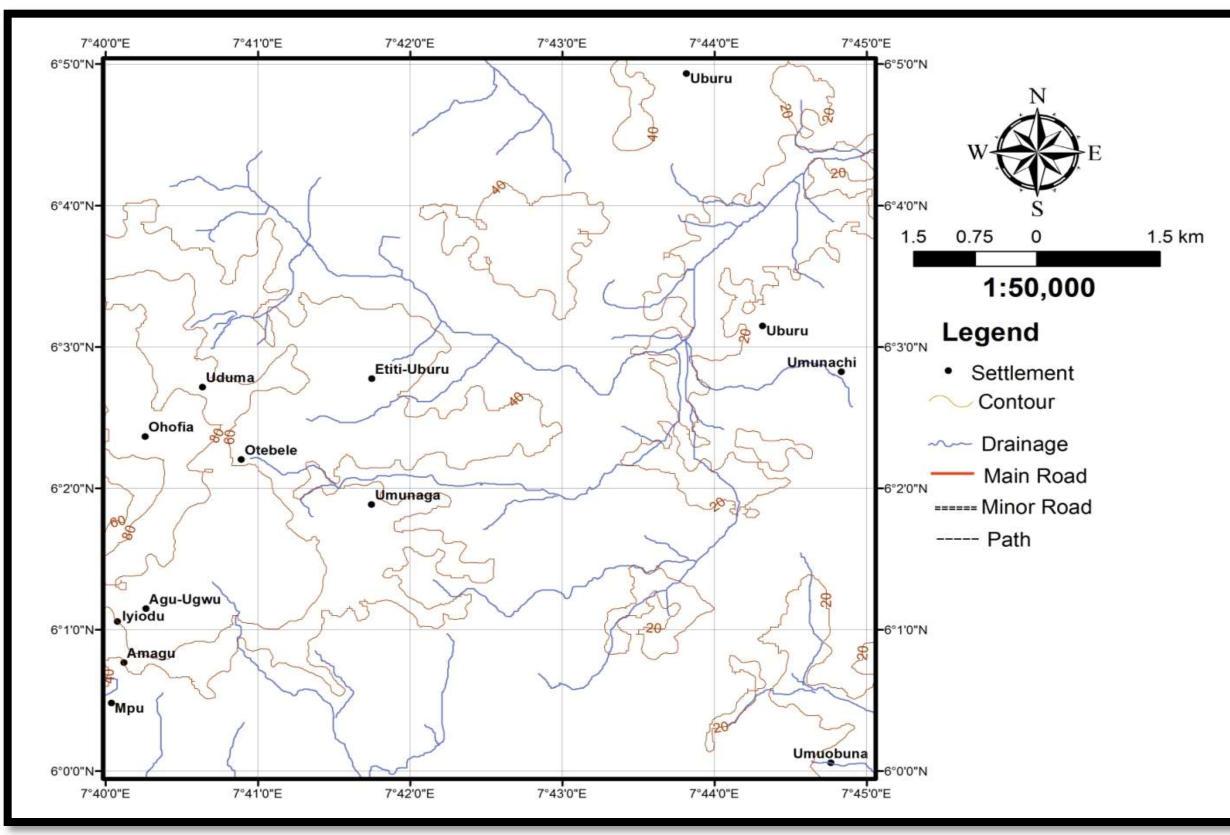


Fig. 1: A map showing the location and accessibility of the study area.



Fig,2: Map showing the dendritic drainage pattern and the topography of the study area.

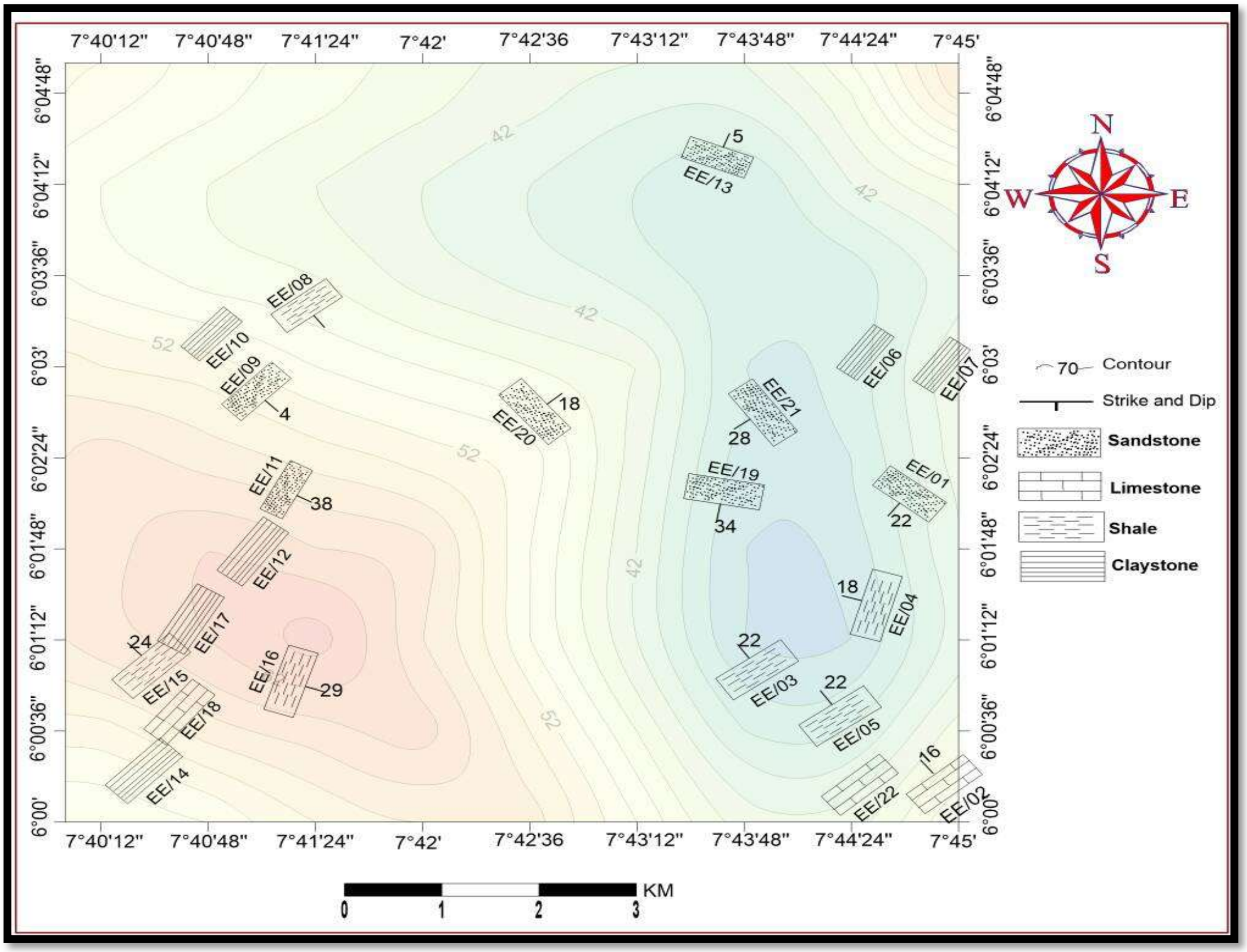


Fig. 3: Outcrop map of the study area.

1.1 Drainage of the study area

Uburu is a rural settlement bounded within latitudes 6˚ 00' N and 6˚ 05'N, and longitudes 7˚ 40'E and 7˚ 45'E (Fig1). There is a drainage divide running from the northwest through to the southeast of the map area. All the river systems on the eastern part of the divide flows southeast while those on the western part of the divide flows southwest as shown in (Fig 2). The Enugu cuesta form the most important watershed, separating the Cross River system to the east from the rivers and streams flowing westwards to the Rivers Niger and Imo.The tributaries of the two major rivers are, Ike, Inyi-Utu, Inyi-Oji, Iyiakwo-Ndiaku, Nache-Agbogugu, Uhuagu, Okpa-Amudo, Ojoruwa, Ovu, Evuna, Onyerata-Ugboka, Orinwandu, Anyuru, Iyiodu and Ofiche. Those rivers exhibit an underfit character i.e they hardly ever fill their channels, even in the peak flood times.

2.0 Materials and Methods

The study commenced with a desk study and obtaining proper permission from relevant security and legal agencies. Detailed field mapping with the objective of producing a geologic map of the area.ten (10) water samples were collected for physicochemical and bacteriological analyses from boreholes, dug wells, and salt lakes in the study area, and were taken to the laboratory within 24 hours. Each water sample was collected with specifications proposed by Todd, 1980. Samples collected were shut tight to avoid leakage and labeled properly to avoid confusion and ensure appropriate accuracy during the laboratory analysis. The Global Positioning System (GPS) were used to take the coordinates of the sample point. Water quality in the study area was investigated applying multivariate analysis, Geochemical plots, Statgraphics Centurion XVII, ArcGIS 10.2.2 and Surfer 10 software on hydrochemical and bacteriological data from 10 water samples ranging from boreholes, hand dug wells and surface waters

3.0 Results and Discussion

The detailed geologic mapping aided in the production of outcrop and geologic maps show below (Fig 3 and 4). All outcrops encountered in the study area can be grouped into: Shales, Claystone, Friable Sandstones- Indurated Sandstones, Limestone Shale Facies. This shale facies was observed at several locations in the study area forming 40% of the sedimentary rocks. Clay facies was observed at several locations in the study area, and constitutes about 10% of the sedimentary rocks found in the area. The clay contains impurities of grey mud from weathered shale and is laterally extensive. Similar findings have been reported by Mohsen & El-Maghraby (2010) for some Saudi Arabia clay. Limestone was observed at several locations in the study area, and occurred mostly along with shale facies (5%). Sandstones in the study area are forming 55% of the sedimentary rocks and are grouped into Friable sandstone facie, Indurated sandstone facie, oxidized sandstone facie

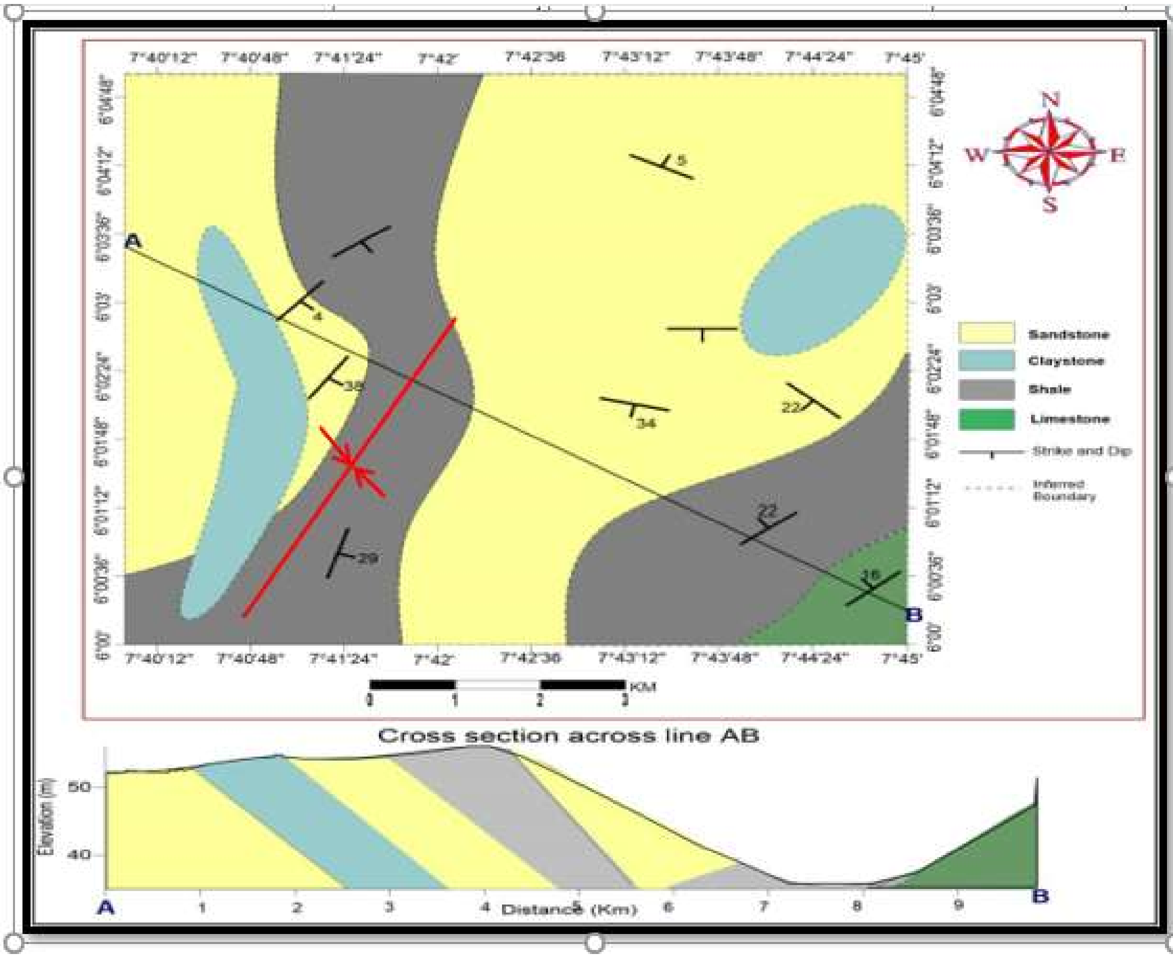


Fig. 4: Geologic map of the study area.

3.1 Hydro-geochemical analysis

The hydro-geochemical investigations involve the appraisal of both the ground and surface water in the study area. Hydro geochemistry refers to the geochemical properties, their behaviors and principles that govern the characters of the dissolved constituents in both surface and sub-surface water. It deals with the relative and absolute abundance of elements in surface and groundwater, their mobility and the laws governing the behavior of the dissolved constituent in them. The surface and groundwater discussions were made based on the WHO 2017 classification for domestic water qualities (Table 1-4).

Table 1: Hydro-Geochemical results for water samples collected in the study area

Samples	SW1	HDW1	BH1	LW1	SW2	LW 2	BH3	SW3	HDW2	HDW3
pH	6.69	6.74	7.08	7.11	6.66	7.30	6.68	7.4	6.90	6.87
T(˚C)	28.1	28.0	27.8	27.4	28.6	27.2	25.0	26.8	30.1	20.7
Ec (µS/cm)	0.13	0.28	0.38	0.49	0.09	151.58	120.00	120.00	360	840
TDS(mg/l)	84.5	182	247	31,900	58.5	90,852	40.00	40.00	2.366	546
Total Hardness	44	94	186	800	22	1,360	48.00	326.40	104	204
				Heavy metals and Cations (mg/l)						
Fe^{2+}	2.37	0.29	0.29	0.34	2.35	0.92	ND	ND	0.80	0.75
Fe^{3+}	0.04	ND	0.03	0.10	0.12	0.11	ND	54.87	0.08	0.06
Ca^{2+}	9.6	31.2	46.4	32	8.8	534.4	1.601	23.54	128	65.6
Mg^{2+}	4.88	3.91	17.09	8.79	4.4	5.86	0.320	1.921	20.51	9.77
Na^{2+}	21	12	24	130	12	220	6.002	2.998	55	27
Pb^{2+}	0.10	0.07	0.03	0.19	0.20	0.34	-0.029	ND	0.267	0.24
Mn^{2+}	0.39	0.99	0.73	1.05	0.14	0.05	0.012	0.098	0.17	0.06
K^{+}	6	1	8	9	ND	34	2.530	2.998	10	11
					Anions (mg/l)					
SO_4^{2-}	29	15	66	27	31	19	4.13	42	23	34
NO_3^-	2.64	4.84	0.44	16.72	6.16	20.29	1.56	0.19	1.7	15.40
Cl^-	24.99	26.66	13.3	46.65	1.67	1945	16.00	12.2	1298	1993
HCO_3^-	28	74	174	80	20	344	ND	280	110	60

**** HDW (hand dug well), BH (borehole) LW (lake water) and SW (surface water)**

3.2 Water quality

The results of the water quality were compared to that of the World Health Organization (WHO), 2017 standard, the hardness classification of water by Sawyer and McCarty 1993, and TDS water classification table by Todd 1980.

Table 2: Standards for water quality analysis by World Health Organization (WHO), 2017.

Constituent	Recommended Concentration limit-mg/l
Total dissolved solid	≤1000
Colour	15
PH	6.5-8.5
Hardness	≤500
Nitrate	≤10
Sulphate	≤250
Sodium	≤200
Chloride	≤250
Coliform count	0 per 100 ml

From the analysis, the pH values are within the recommended concentration, the TDS generally shows that samples are of fresh water except for Locations **LW1 and LW2**, indicating source from saline water.

Table 3: Standards for hardness classification of water by Sawyer and McCarty, 1993

Hardness (mg/l as $CaCO_3$)	Description
0-75	Soft
75-150	Moderately hard
150-300	Hard
>300	Very hard

Table 4: TDS water classification by Todd, 1980.

Category	TDS (mg/L)
Fresh water	0-1000
Brackish water	1000-10,000
Saline water	10,000-100,000
Brine water	>100,000

The total hardness and nitrate concentration in the water samples tells also that they are within the WHO recommendation, except for Locations **LW1,**

LW2 and HDW3, which is as a result of the salt intrusion, anthropogenic activities and particles carried by wind to the water. The chlorides are generally high for Location **LW2 and HDW3** due to salt intrusion making the water toxic and not good for human consumption. The number of coliform bacteria counted ranges from 13MPN to 84 MPN, and this shows high coliform count as recommended by the W.H.O. This high count may be attributed vigorously to so many indicative causes like, pollution in the area, such as in sewage effluents, pit latrines and solid wastes disposal. Non-sterilization of the borehole causing pipes before usage and the shallowness of more of the water wells could help improve the high count of the coliform bacteria.

3.3 Stiff diagram

From the Stiff diagram, four parallel horizontal axes extending on each side of a vertical zero axes respectively are used seen in (Fig 5). Concentrations are in meq/l. The size of the pattern is approximately equal to the total ionic content (Hounslow, 1995).

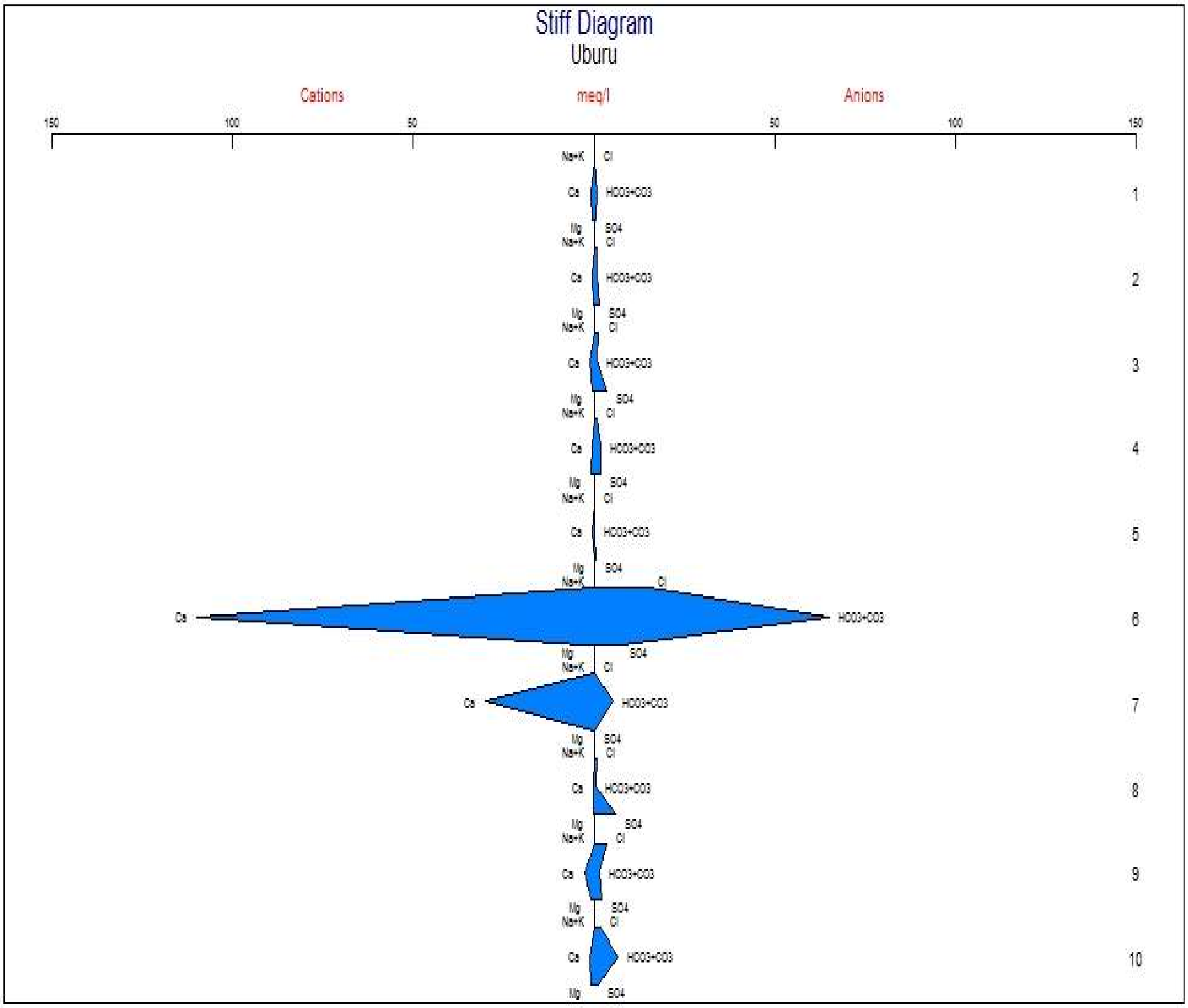


Fig. 5: Stiff Diagram for the ion concentration analysis.

From Fig. 5, it can be seen that there are variations in the ionic content of the different samples, though a few can be correlated. All the samples can be said to have the same shapes and can be thus be said to contain relatively the same amount of ions except for samples at location. All the samples generally have low Ca and HCO_3^-- CO_3 content, except for samples **LW2 and BH3** indicating saline water and presence of a salt intrustion in the study area.

3.4 Piper diagram

Piper diagram can be used to determine water type, hydrochemical facies and ion exchange (Hounslow 1996; Freeze and Cherry 1979). The diamond part of piper diagram may be characterize waters of different types (Hounslow 1995) seen in (Fig 6).

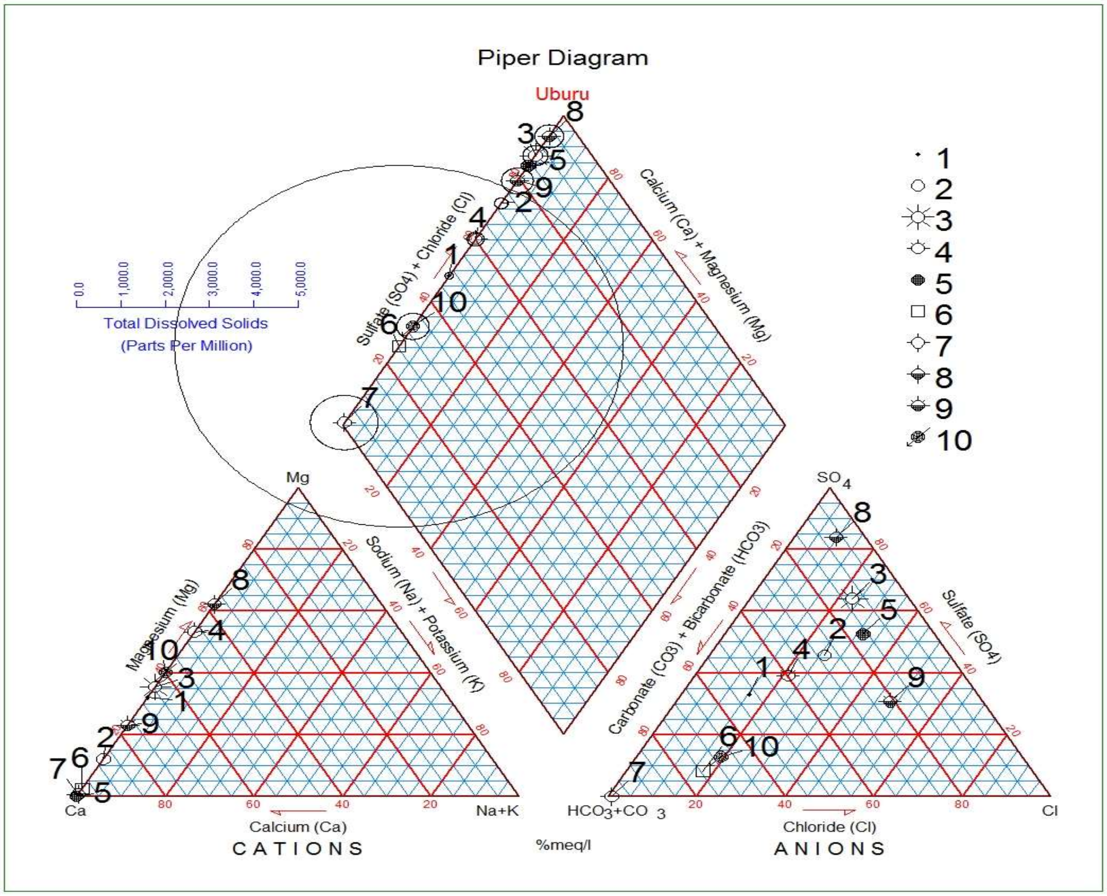


Fig. 6: Piper Diagram used to determine the water type, hydrochemical facies and ion exchange.

Water that plots near the right corner of the diamond is high in SO_4, Cl and Mg+ contents, and may be considered saline. This is typical in samples **BH1**, **SW2, SW3 and HDW2**. In the cations, the samples generally plot at the right side of the triangle, indicating high calcium and magnesium ion, typical for temporal hardness. Samples **SW3,BH1,SW2 ,HDW2 and HDW1** in the anion triangle plots shows high sulphate and chloride with samples **BH3, LW2,HDW3,SW1 and LW1** shows high bicarbonate ions indicating saline waters.

3.5 Multivariate analysis

3.5.1 Cluster analysis for groundwater parameter (Boreholes and hand dug well)

Cluster analysis was used to identify the relationships with the groundwater parameters with regards to possible cluster sources and parameter associations (Badrud-Doza *et al*., 2016;Keita and Zhonghua, 2017). The three cluster extracted accounts for percentage cover of 41.18%, 41.18% and 19.65% respectively (Table 5 and 6)

The first groundwater cluster showed parameter associations for Calcium, Sodium, magnesium, iron (II), bicarbonate, sulfate which was attributed to geogenic contaminations (rock mineral dissolution) and are directly responsible to the groundwater PH. The second cluster shows parameter associations for chloride, potassium lead, and nitrate which was attributed to sewage and agricultural waste contaminations and are directly relationship with electrical conductivity, hardness and total dissolved solids. The third cluster shows that manganese and iron (III) are the major contributor to the groundwater Temperature.

Table 5 Cluster Summary for groundwater

Cluster	*Members*	*Percent*
1	7	41.18
2	7	41.18
3	3	17.65

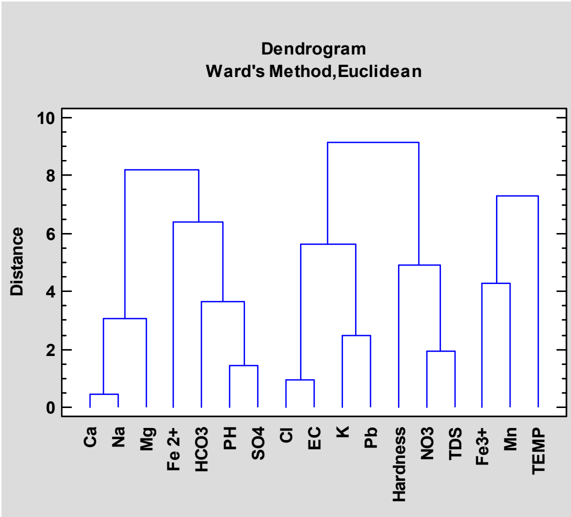
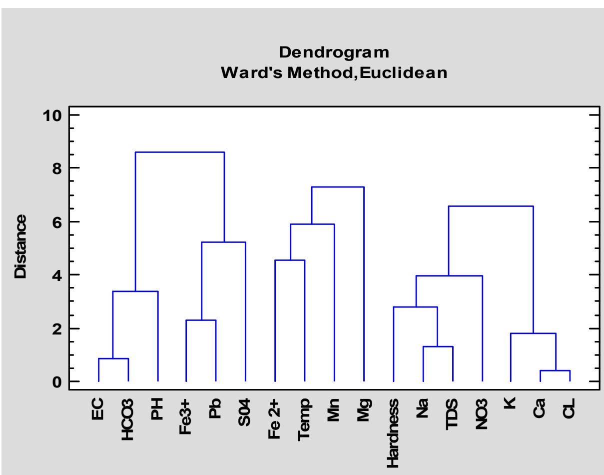


Figure 7:Groundwater cluster diagram.

Table 4 Cluster Summary for surface water

Cluster	*Members*	*Percent*
1	6	35.29
2	4	23.53
3	7	41.18



Fig, 8: Surface water cluster diagram.

The first surface water cluster showed parameter associations for , iron(III),bicarbonate, lead, sulfate which was attributed to geogenic contaminations(rock mineral dissolution) and are directly responsible to the groundwater PH and EC. The second cluster shows parameter associations for iron (II), manganese and magnesium and are the major contributor to the groundwater Temperature

4.0 Conclusion

The study area is a rural settlement bounded within latitudes 6˚ 00' N and 6˚ 05'N, and longitudes 7˚ 40'E and 7˚ 45'E. Water quality in Uburu area of southeastern Nigeria was investigated applying multivariate Statgraphics Centurion XVII, ArcGIS 10.2.2 and Surfer 10 software on hydro chemical and bacteriological data from 10 water samples ranging from boreholes, hand dug wells and surface waters to unravel the major factor controlling water quality in the study area

The study area is underlain by Abakaliki Shale, which comprises bluish grey shales with fine to medium to coarse grained sandstones. Hydrologically, the area is classified under the Anambra-Imo River Basin. Physico-chemical and bacteriological analyses were used to assess the influence of geogenic and anthropogenic processes on the groundwater quality. Results suggest that the groundwater is acidic, hard and salty, due to salt water intrusion in the Uburu area.

The water types are mainly $Na^{+}+K^{+}$ and $S0_4^{2-}$ - Cl^{-} According to the W.H.O (2017) standards, the levels of the physico-chemical parameters in the groundwater indicate that the water is acceptable for domestic use; but the bacteriological analysis shows high counts of Escherichia coliform (E. coli) bacteria, which indicates poor sanitary conditions in the study area. It will be safe, therefore, to suggest that the water be treated before it is used for drinking and preparation of food, in order to avoid incidences of gastro-intestinal diseases caused by the ingestion of water contaminated by faecal matters. The groundwater and surface water cluster analysis unraveled that rock mineral dissolution, sewage and agricultural waste contaminations, are the main factors controlling the water chemistry in the area.

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