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Assessment of Spatio-Temporal Variation of Groundwater Quality in Udi-Ezeagu Watershed, Enugu Area Southeastern Nigeria

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Abstract: This study was carried out to assess the spatio-temporal variation of groundwater quality in Udi-Ezeagu Watershed, Enugu Area, Southeastern Nigeria. The specific objectives were to determine the physical, chemical and microbiological characteristics of groundwater samples in space and time and to ascertain the quality of groundwater using the parameter in comparison with WHO permissible limits. A total of five (5) groundwater samples were collected in triplicates from boreholes located at Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo at two different time scales. The samples were collected in April (before the onset of rainy season) and September (before the cessation of rainy season), in 2014. The groundwater samples were analyzed in the laboratory for their physical, chemical and microbiological characteristics. On comparing the results with standard values recommended by World Health Organization (WHO), it was discovered that most of the groundwater samples were within permissible limits with slight variation across the locations and in seasons. However, pH of the groundwater samples were not within the permissible limit of 6.50mg/l – 8.50mg/l in four different locations which are Ninth Mile Corner, Umuase, Abor and Akama-Amankwo with pH values of 5.60, 6.20, 5.00 and 5.00. Total hardness of the groundwater samples with values of 12.00mg/l, 58.50mg/l, 45.00mg/l, 15.50mg/l and 11.70mg/l in the dry season and 8.00mg/l, 59.00mg/l, 43.00mg/l, 12.00mg/l and 7.00mg/l respectively in the rainy season were not within the permissible limit of 100.00mg/l – 200.00mg/l in all the locations and in the seasons for Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo respectively. Magnesium hardness of the groundwater samples with values ranging from 1.50mg/l - 1.65 in the dry season and 5.60mg/l - 6.80mg/l respectively in the rainy season were slightly above the permissible limit of 1.00mg/l in all the locations and in seasons. Total coliform were absent in all the locations during the dry season and was slightly in excess during the rainy season at 9th Mile Corner and Abor with a value of 4.00 per 100ml against the permissible limit 3.00. The study found out that minimal treatment is required in the study area and recommends continuous monitoring of the groundwater supply to keep the quality in check.

Keywords: Groundwater Quality, Spatio-Temporal Variation, Udi-EzeaguWatershed, SE Nigeria

1. Introduction

Groundwater is the most important source of domestic, industrial and agricultural water supply in the world. Many countries in the Africa depend heavily on groundwater. Exploitation of surface water has reduced, ensuring an increasing reliance on groundwater abstraction due to increasing pollution with the concomitant rise in the cost of water treatment (Kortatsi, 2007). Groundwater is usually of excellent quality. Being naturally filtered in their passage through the ground, they are usually clear, colourless and free from microbial contamination and required minimal treatment (Ebrahim, 2011). Unfortunately, these valuable resources are now posed by an ever-increasing number of soluble chemicals from urban and industrial activities and from modern agricultural practices. The quality of groundwater depends on several factors, including climate, soil characteristics, manner of circulation of groundwater through the rock type and topography of the area (Onwuka *et al.*, 2010). The chemical composition of groundwater

depends not only on natural factors such as lithology of aquifer, the quality of recharge waters and types of interactions between water aquifer, but also on anthropogenic activities, which can alter fragile groundwater systems polluting them or by changing hydrological cycle (Helena *et al.,* 2002). The quality of groundwater is constantly changing in response to daily, seasonal and climatic factors. Continuous monitoring of water quality parameters is highly crucial because changes in the quality of water have far reaching consequences in terms of its effects on man and biota (Sarukkalige, 2012). Enugu metropolis Nigeria, largely depends on ground water from Udi/Ezeagu watershed as alternative source of potable water supply. The increasing groundwater usage is based on the assumption that groundwater is less polluted since water is filtered and percolated down the ground. However, numerous studies have shown otherwise. According to Ngaje *et al* (2010) problem of acid mine drainage have been reported in some areas, especially the coal mining areas in Enugu. Fetter, (1993) pointed out that groundwater contamination may cause various disease and other problems. Hence, there is need to assess the sustainability of water used for domestic purposes and need to assess the groundwater quality based on location and time. The main objective of this work is to assess the spatio-temporal variation of groundwater quality in Udi/Ezeagu watershed, Enugu Area Southeastern Nigeria.

The specific objectives were to determine the physical, chemical and microbiological characteristics of groundwater quality in space and time and to ascertain the quality of groundwater using the parameters in comparison with WHO permissible limits.

2. Materials and Methods

2.1. Study Area

Udi/Ezeagu watershed is a large watershed within Enugu area, southeastern Nigeria. It is situated within longitudes $7^0 9$'E and $7^0 28$'E and latitudes $6^0 12$'N and $6^0 41$'N (Fig.1) in the Southeastern part of Nigeria encompassing an area of about 897 km^2, with an elevation ranging from 231m to 500m above mean sea level. Rainfall is seasonal with a wet rainy season and a dry harmattan season controlled by the north-east and south-west wind. The soils are made up of shallow and stony lithosols found on the steep slopes of the cuesta and often left uncultivated and Ultisols in the lower part (Anikwe et al 2007). The soil erosion is rampant in the area and is as a result of both physical and anthropogenic causes. The study area is underlain by three major geological formation; the Mamu, Ajali and Nsukka formations respectively. (Fig 2)
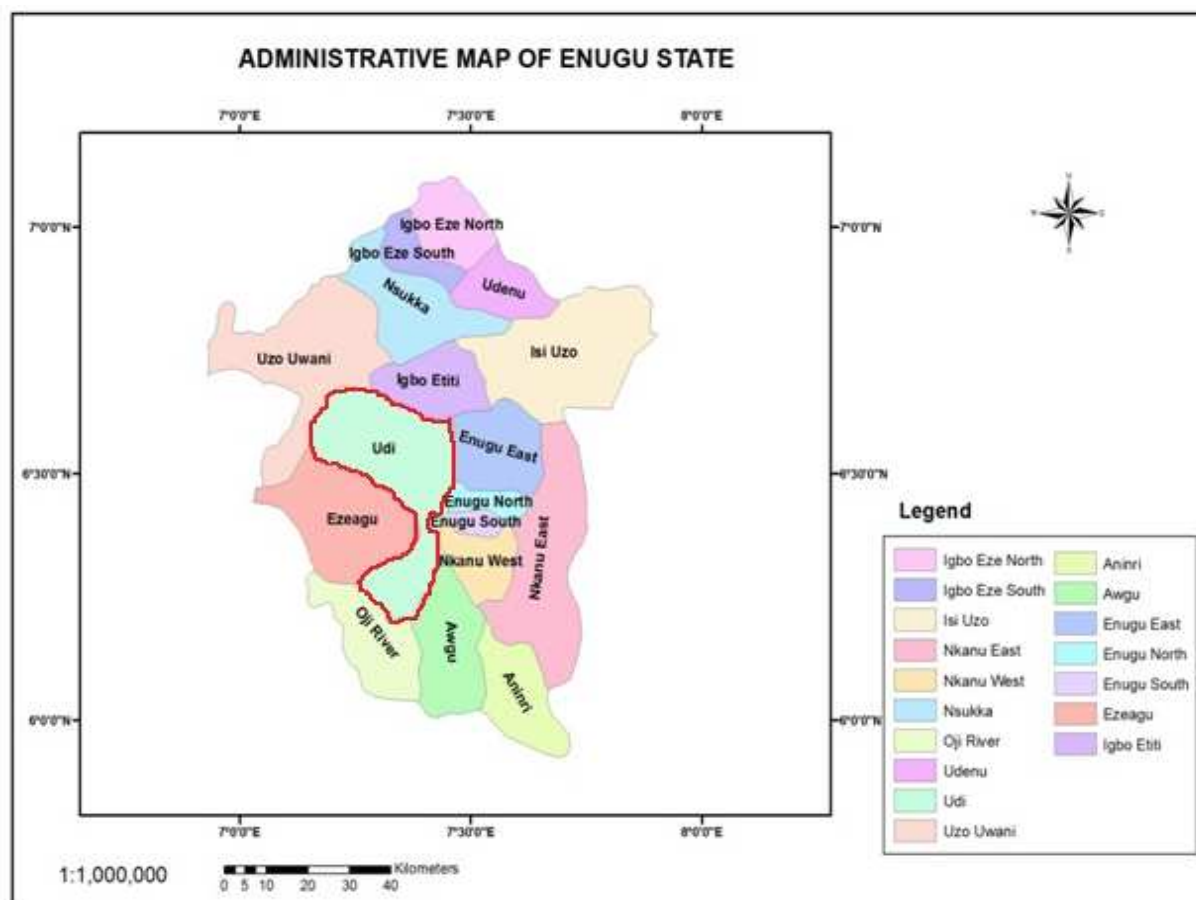

Figure 1. Map showing the study area, Udi Local Government Area (Source: ASTAL Uyo, Nigeria).
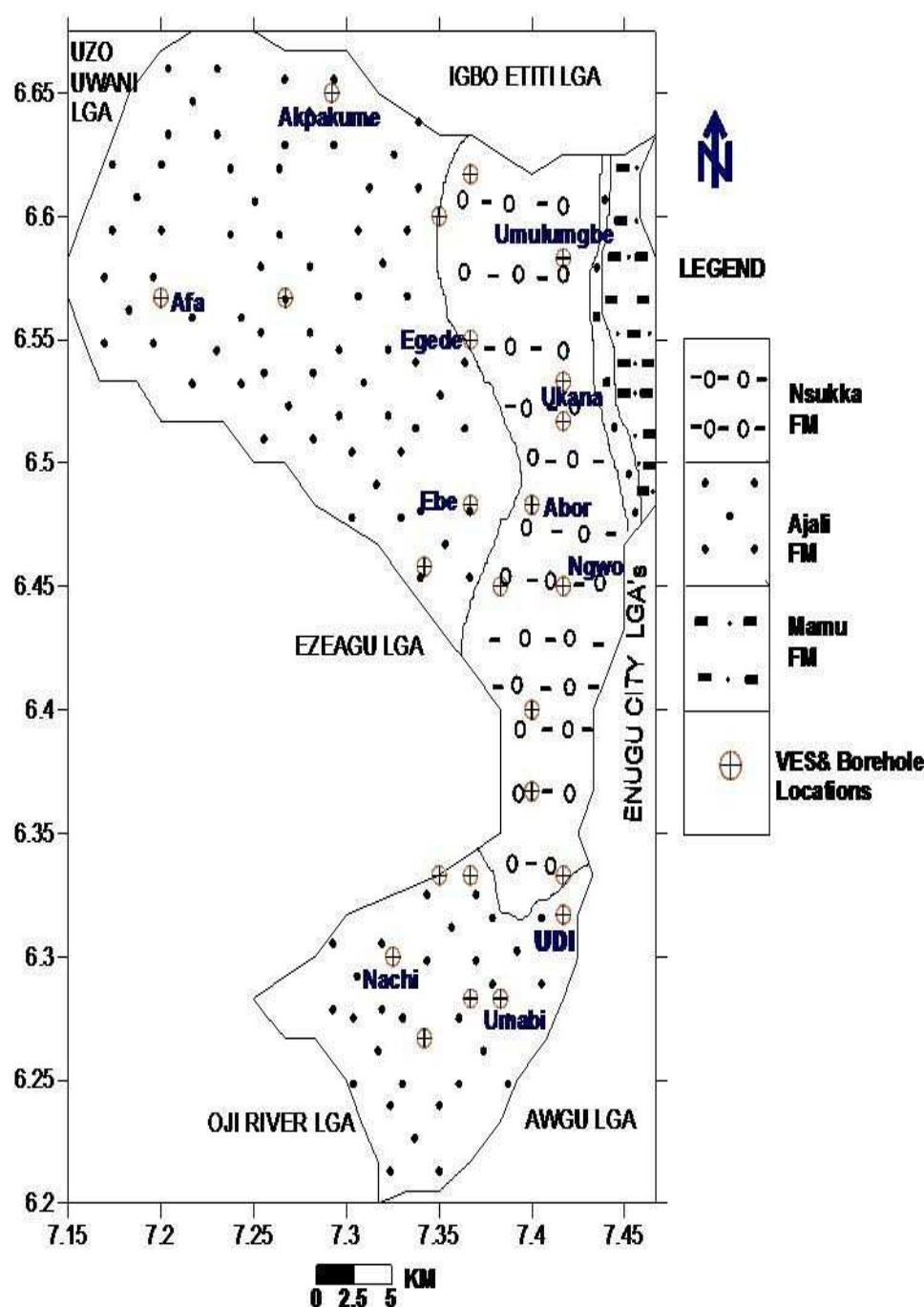
Figure 2. Geologic map of the Udi area (Source: Eze et al, 2013).

The Mamu formation, previously known as lower coal measures (Reyment, 1965), underlies the eastern part of the study area. It consists of fine-medium grained white to grey sandstones, shaly sandstones, sandy shales, grey mudstones, shales and coal seams. The sandstone consists of thick friable, poorly sorted arkosic sandstones typically white in colour but sometimes iron stained. The Nsukka formation, previously known as the upper coal measures (Reyment, 1965), lies comfortably on Ajali sandstone. The lithology is very similar to that of Mamu formation and consists of an alternating succession of sandstone, dark shale and sandy shale, within coal seams at various horizons. The Ajali

sandstone ranks the second most prolific aquifer in Nigeria after the coastal plain sands. Its permeability and high storage capacity enables it to absorb all the run-off resulting from rainfall. It comprises mainly a water table aquifer, and also has semi-confined aquifer where fingers of clays occur in appreciable thicknesses (Offodile, 2002).

2.2. Field Study

A total of five groundwater samples were collected during the dry season (April) and rainy season (September) respectively at five different sampling sites in the study Area. Groundwater samples were collected in triplicates

from Ninth Mile Corner ($6^0$43'2.94' N; $7^0$40'6.27'E), Obioma ($6°$35'8.54'N;$7°$39'3.53'E),Umuase ($6°$41'46.58'N;$7°$25'13.78'E), Abor ($6°$47'4.37'N; $7°$41'4.66'E) and Akama-Amankwo ($6°$44'3. 41' N;$7°$42'7. 29'E) in April, 2014 representing dry and rainy season respectively. The parameters analyzed were twenty-four (24) in number which include: Temperature, pH, Electrical conductivity, Total solids, Turbidity, Colour, Total dissolved solids, Total suspended solids, Total hardness, Magnesium hardness, Chlorides, Chlorides as Nacl, Sulphates, Nitrate, Silica, Total alkalinity, Calcium hardness, Iron, Calcium ion, Magnesium ion, Manganese, Total plate count, Total coliform and E-coli. An *in situ* test was carried out using potable digital meter for Temperature, pH, Total dissolved solids and Electrical conductivity. The instruments used for measuring the Temperature was thermometer and HANNA instrument with models, pHep was used in measuring pH and H196301 used in measuring Electrical conductivity and Total dissolved solids. The co-ordinates and elevations of the sampling pointes were recorded using Global Positioning System (GPS). The groundwater samples were collected in a clean 1.5 litre plastic jar with screw caps and packed in a cooler and transported to the laboratory immediately. The groundwater samples were stored in the refrigerator at 4^0C until analysis was completed. The twenty-four parameters were analyzed according to the standard methods of APHA-AWWA-WEF (2012).

3. Results

3.1. Spatial Distribution of Groundwater Samples in the Study Area During the Dry Season

Table 3.1 showed that the mean temperature values of groundwater samples obtained from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 21.00^0C, 19.50^0C, 21.50^0C, 18.50^0C and 19.00^0C. The results showed variation in temperature in the various sites. The mean pH values of groundwater samples obtained from 9th Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 7.02, 7.30, 7.50, 7.50 and 8.11. The results showed variation in space as shown in Table 3.1. The mean values of electrical conductivity of groundwater samples obtained from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo respectively were 50.70μs/cm, 198.80μs/cm, 175.80μs/cm, 80.35μs/cm and 20.70μs/cm as shown in Table 3.1 . Table 3.1 also shows the mean values of Total Solids from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 52.28mg/L, 154.20mg/L, 132.08mg/L, 73.12mg/L and 29.00mg/L. These results showed variation from location to location.

Table 3.1. *Spatio-Temporal Variation of Physical Properties of Groundwater Quality Characteristics in the Study Area.*

S/no	Parameters	Units	Who std	sample result										
	Sample identification / location			A Ninth Mile Corner		B Obioma		C Umuase Ngwo		D Ubiekpo Abor		E Akama Amankwo Ngwo-uno	
				Seasons		Seasons		Seasons		Seasons		Seasons	
				Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
1.	Physical Analysis												
	Temperature	°Celsius	°Celsius	21.00	29.50	19.50	29.00	21.50	26.00	18.50	26.00	19.00	26.50
	pH		6.50-08.50	7.02	5.60	7.30	6.80	7.50	6.20	7.30	5.00	8.11	5.50
	Electrical conductivity	Microh ms/cm	1000.00	50.70	71.30	198.50	233.00	175.80	201.00	80.35	105.70	20.70	41.60
	Total Solids	mg/L	1000.00	48.49	46.38	155.29	151.50	133.19	130.69	70.42	68.74	28.12	27.07
	Turbidity	NTU	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Colour	TCU	50.00	2.45	4.00	2.10	4.00	2.65	5.00	2.00	4.00	2.05	4.00
	Total Dissolved Solids	mg/L	500.00	48.48	46.35	155.25	151.45	133.15	130.65	70.40	68.71	28.10	27.04
	Total Suspended solids	mg/L		0.01	0.03	0.04	0.05	0.04	0.04	0.015	0.03	0.018	0.03

Table 3.2 showed that the mean values of Total Hardness of the groundwater samples in the sites viz. Ninth Mile Corner, Obioma, Umuase, Abor and Akam-Amankwo were 12.00mg/L, 58.50mg/L, 45.00mg/L, 15.50mg/L and 11.70mg/L respectively and mean values of Total Alkalinity of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 20.00mg/L, 78.50mg/L, 60.00mg/L, 32.40mg/L and 28.14mg/L, respectively. The mean values of Calcium Hardness of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 10.50mg/L, 54.50mg/L, 42.00mg/L, 13.90mg/L and 10.05mg/L respectively whereas mean values of Magnesium Hardness as shown on Table 3.1 from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 1.50mg/L, 4.00mg/L, 3.00mg/L,1.60mg/L, 1.65mg/L. These results also showed variation in space.

As shown in Table 3.2, the mean values of Iron of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 0.05mg/L,

0.03mg/L, 0.05mg/L, 0.04mg/L and 0.03mg/L respectively and the mean values of Calcium ion of the groundwater samples from Ninth Mile Corner, Obioma , Umuase, Abor and Akama-Amankwo were 5.60mg/L, 44.75mg/L, 31.28mg/L, 9.05mg/L and 4.50mg/L respectively. Table 3.2 also showed that the mean values of Magnesium ion of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 0.15mg/L, 0.46mg/L, 0.28mg/L, 0.14mg/L and 0.15mg/L respectively. However, as shown in Table 3.3, Total Coliform and E.coli showed zero mean values in the study sites.

Table 3.2. *Spatio-Temporal Variation of Chemical Properties of Groundwater Quality Characteristics in the Study Area.*

S/no	Parameters	Units	Who std	sample result									
				A Ninth Mile Corner Seasons		B Obioma Seasons		C Umuase Ngwo Seasons		D Ubiekpo Abor Seasons		E Akama Amankwo Ngwo-uno Seasons	
	Sample identification/ location			Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
2.	Chemical Analysis Total Hardness	mg/LCaCo$_3$	100.00-200.00	12.00	8.00	58.50	59.00	45.00	43.00	15.50	12.00	11.70	7.00
	Chlorides	mg/L	200.00	7.40	2.13	8.62	3.55	8.00	2.84	7.39	2.13	7.94	2.84
	Chlorides as Sodium Chloride	mg/L		9.15	3.51	11.00	5.86	9.35	4.69	9.115	3.51	10.10	4.69
	Sulphates	mg/L	200.00	18.19	9.21	47.30	23.19	25.10	12.05	18.20	9.21	24.15	12.05
	Nitrate	mg/L	50.00	1.04	0.24	1.15	0.29	1.05	0.25	1.01	0.17	1.00	0.15
	Silica			7.80	8.02	8.50	10.90	8.00	10.50	5.00	6.07	4.50	5.82
	Total Alkalinity	mg/LCaCo$_3$	100.00	20.00	5.00	78.50	54.00	60.00	36.00	32.40	12.00	28.14	7.00
	Calcium Hardness	mg/LCaCo$_3$	200.00	10.50	7.00	54.50	56.00	42.00	41.00	13.90	11.00	10.05	6.00
	Magnesium Hardness	mg/LCaCo$_3$	1.00	1.50	1.00	4.00	3.00	3.00	2.00	1.60	1.00	1.65	1.00
	Iron	mg/L	0.05-00.30	0.05	0.25	0.03	0.15	0.05	0.25	0.04	0.20	0.03	0.15
	Calcium Ion	mg/L	50.00	05.60	2.80	44.75	22.40	31.28	16.40	9.05	4.40	4.50	2.40
	Magnesium ion	mg/L	50.00	0.15	0.30	0.46	0.90	0.28	0.60	0.14	0.30	0.15	0.30
	Manganese			NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Table 3.3. *Spatio-Temporal Variation of Microbiological Properties of Groundwater Quality Characteristics in the Study Area.*

S/no	Parameters	Units	Who rec.	sample result									
				A Ninth mile corner Seasons		B Obioma Seasons		C Umuase Ngwo Seasons		D Ubiekpo Abor Seasons		E Akama Amankwo Ngwo-uno Seasons	
	Sample identification/ location			Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
3.	Bacteriological Analysis Total Plate count at 35 ºC after 24hrs	Per ml	100.00	35.00	29.00	52.00	41.00	48.00	33.00	60.00	40.00	70.00	56.00
	Total Coliform	Per 100ml	3.00	NIL	4.00	NIL	Nil	NIL	3.00	NIL	4.00	NIL	2.00
	E. coli	Per 100ml	0.00	NIL	Nil	NIL	Nil	NIL	Nil	NIL	Nil	NIL	Nil

3.2. Spatial Distribution of Groundwater Samples in the Study Area During the Rainy Season

Table 3.2 showed the mean values of temperature for the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo respectively were 29.50ºC, 29.00ºC, 26.00ºC, 26.00⁰C and 26.50ºC. The results showed variations in temperature in the various sites. As shown in Table 3.2, the mean values of pH for the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 5.60, 6.80, 6.20, 5.00 and 5.00 whereas the mean values of electrical conductivity for the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor, and Akama-Amankwo were 71.30 µs/cm, 233.60 µs/cm, 201.00 µs/cm, 105.00 µs/cm and 41.60 µs/cm as shown in Table 3.2. These results showed

variation in space.

The mean values of Total Solids for the groundwater samples from 9th Mile Corner, Umuase, Obioma, Abor and Akama-Amankwo were 46.38mg/L, 151.50 mg/L, 130.69mg/L, 68.74mg/L and 27.07mg/L as shown in Table 3.2. while the mean values of Total Hardness of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor, and Akama-Amankwo were 8.00mg/L, 59.00mg/L, 43.00mg/L, 12.00mg/L and 7.00mg/L respectively. Results also show that the mean values of Total Alkalinity as shown in Table 3.2 of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 5.00mg/L, 54.00mg/L, 36.00mg/L, 12.00mg/L and 7.00mg/L respectively.

The mean values of Calcium Hardness of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 7.00mg/L, 56.00mg/L, 41.00mg/L, 11.00mg/L and 06.00mg/L whereas, the mean values of magnesium Hardness of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 5.60mg/L, 6.80mg/L, 6.20mg/L, 5.00mg/L and 5.50mg/L. Results showed that the mean values of Iron of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 0.25mg/L, 0.15mg/L, 0.25mg/L, 0.20mg/L and 0.15mg/L and as shown in Table 3.2, the mean values of Calcium ion of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 2.80mg/L, 22.40mg/L, 16.40mg/L, 4.40mg/L and 2.40mg/L.

The mean values of Magnesium Ion as shown in Table 3.2, of the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 0.30mg/L, 0.90mg/L, 0.60mg/L, 0.30mg/L and 0.30mg/L respectively whereas the mean values of Total Coliform for the groundwater samples showed 4.00per 100ml in Ninth Mile Corner, Nil in Obioma, 3.00 per 100ml in Umuase, 4.00 per 100ml in Abor and 2.00 per 100ml in Akama-Amankwo.

4. Discussion

Table 3.1 showed the mean temperature value from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo ranges from 18.50^0C to 21.00^0C in the dry season. It showed that Abor has the lowest mean temperature 18.50^0C while Ninth Mile Corner has the highest mean temperature 21.00^0C. During the rainy season, Ninth Mile Corner showed the highest mean temperature, 29.50^0C whereas Umuase and Abor showed the lowest mean temperature of 26.00^0C. The result showed that there were variations in temperature in both seasons. Higher groundwater temperature in the rainy season could be because of energy released as water builds up in the reservoirs.

Table 3.1, show spatio-temporal variations in pH of water samples. Ninth Mile Corner, showed the lowest mean value of pH (7.02) and Akama-Amankwo showed the highest mean value of pH (8.11) during the dry season whereas Abor and Akama-Amankwo showed the lowest mean values of pH

(5.00) and Obioma showed the highest mean values of pH (6.80) during the rainy season. The dry season results were tending towards alkalinity while the rainy season results were tending towards acidity. Higher acidity in the rainy season may be as a result of higher concentration of exchangeable cations (Calcium and magnesium) in the water samples (Table 3.2) and this may also be a result of water recharge in the aquifers during the rainy season that brings dissolved nutrients with it. The dry season results in the five locations did not exceed WHO permissible limits whereas some locations in the rainy season exceeded WHO permissible limits such as Ninth Mile Corner, Abor and Akama. This could be as a result of anthropogenic activities in and around the locations (Krauskopt and Bird, 1994).

Table 3.1 showed that the mean values of electrical conductivity from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo were 50.70μs/cm, 198.80μs/cm, 175.80μs/cm, 80.35μs/cm and 20.70μs/cm in the dry season and 71.30μs/cm, 233.00μs/cm, 201.00μs/cm, 105.70μs/cm and 41.60μs/cm in rainy season respectively. From the result, Akama-Amankwo showed the lowest mean value 20.70μs/cm and Obioma showed the highest mean value, 198.50μs/cm during the dry season. During the rainy season, Akama showed the lowest mean value 41.60μs/cm and Obioma showed the highest mean value 233.00μs/cm. The results as well showed variations in both space and time. During aquifer recharge in the rainy season, dissolved salts are brought in with water and as evapotranspiration and deep percolation intensify during the dry season, salts are left behind and its concentration increases within the groundwater. The variations across locations could be associated with the lithological formations composed of halite and gypsum (Tizro *et al,* 2004).

Total Solids range from 29.00 – 154.20mg/L in the dry season and 27.07 – 151.50mg/L in the rainy season as shown in Table 3.1. The lowest mean values of Total Solids are recorded in Akama-Amankwo for the both seasons and the highest means values of Total solids are recorded in Obioma. The results from both seasons were in conformity with WHO permissible limits.

The mean result of Total Hardness as shown in Table 3.2 varies from 11.70mg/L to 58.50mg/L in the dry season and from 7.00mg/L to 59.00mg/L in the rainy season. It was recorded that Akama-Amankwo site showed the lowest mean value in both dry and rainy seasons, 11.70mg/L and 7.00mg/L whereas Obioma showed the highest mean value in the both seasons, 58.50mg/L and 59.00mg/L. The concentration of total hardness of groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo showed, the result were below WHO permissible limits of 100.00mg/L to 200.00mg/l $CaCo_3$ Results also showed that the concentration of magnesium hardness observed in the study area is varied from 1.50 to 4.00mg/L $CaCo_3$ in the dry season and 1.00 to 3.00mg/L $CaCo_3$ in the rainy season as shown in Table 3.2. The result recorded the lowest mean value of magnesium hardness at Ninth Mile Corner and highest mean value at Obioma with the values

1.50 and 4.00mg/L in the dry season and in the rainy season, it recorded the lowest mean value of magnesium hardness 9th Mile Corner, Abor and Akama and the highest mean values at Obioma with the values 1.00 and 3.00mg/L respectively. As postulated earlier, during aquifer recharge in the rainy season, dissolved salts are brought in with water and as evapotranspiration and deep percolation intensify during the dry season, salts are left behind and its concentration increases within the groundwater. The variations across locations could be associated with the lithological formations composed of halite and gypsum (Tizro *et al*, 2004). The spatio-temporal differences in total hardness could be due to dissociation of salts on the various locations (WHO, 2011; Narsimha *et al*, 2013). Ong *et al*, (2009) noted that magnesium dissociation mainly comes from the feromagnesium carbonates in sedimentary rocks than the anthropogenic sources (Weiner, 2000; WHO, 2009).

The values of Total Coliform observed in the study area is varied from 2 -4 per 100ml in the rainy season and it showed zero concentration in the groundwater samples from Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo during the dry season. Akama-Amankwo recorded the lowest mean value of 2 per 100ml and Ninth Mile Corner and Abor recorded the highest mean values 4.00 per 100ml in the rainy season. The result showed that groundwater samples from Ninth Mile Corner and Abor with the values 4.00 per 100ml exceeded WHO permissible limits for Total Coliform of 03.00 per 100ml. The high coliform populations are an indication of poor sanitary conditions in the locations and this may be owing to unhygienic practices of the residents (Onianwa *et al*, 2001). That maybe the source of many diseases, the groundwater bacterial contamination will cause typhoid, diarrhea, cramps, nausea and headaches (Harikumar and Kokkal, 2009, Boominathan *et al*, 2012).

5. Conclusions

This study probes the spatio-temporal variation of groundwater quality in 9th Mile Corner, Obioma, Umuase, Abor and Akam-Amankwo in Udi local Government Area of Enugu State. From the study, the physical parameters (Temperature, pH, Electrical Conductivity, Total Solids, Turbidity, Colour, Total Dissolved Solids, Total Suspended Solids), Chemical Parameters(Total Hardness, Chlorides, Chlorides as Sodium Chloride, Magnesium Hardness, Iron, Calcium Ion, Magnesium Ion, Manganese) and Microbiological Parameters (Total Plate Count, Total Coliform, E. Coli) were determined as shown in Table 4.1 and 4.2. The Tables showed that most of the parameters were in consistent with the WHO maximum permissible limits for domestic use except pH which was not in conformity with WHO permissible limit during the rainy season in Ninth mile, Umuase, Abor and Akama-Amankwo in Udi Local Government Area of Enugu State. Total Hardness as well was not in conformity with WHO limits in the five sites, Ninth Mile Corner, Obioma, Umuase, Abor and Akama-Amankwo in both seasons. Magnesium Hardness was not in conformity

with the WHO permissible limits in the five sampling sites during the dry season and in the rainy season only Obioma and Umuase were not in conformity with WHO permissible limits. The result also showed that Total Coliform was not in conformity with WHO limits during the rainy season in Ninth Mile Corner and Abor. These may have negative effect on the quality of groundwater for human consumption in Udi Local Government Area and its environment.

Water, the nectar of life is one of the most important natural resources for all living organisms because it is required for their various activities. From the study, it was concluded that the quality of groundwater in Udi Local Government Area needs little treatment to stabilize the pH especially during the rainy season by the addition of Calcium Carbonate ($CaCo_3$) and also the Total hardness in both season in the study area. Magnesium hardness requires little treatment since excess of it may have laxative effect on human health. It may also cause increased soap consumption and scale deposition in the water distribution system. The Total coliform contamination in Ninth Mile Corner and Abor sites could be attributed to the unhygienic practices of the residence. Total coliform also needs treatment because when found in groundwater supply may cause ill-effect to human health such as cholera, diarrhea and dysentery. Hence, there is need for continuous assessment of the groundwater quality in the study area.

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