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Research Article

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An Evaluation of Aquifer Lithostratigraphy and groundwater quality in Ikwerre Local Government Area in the Niger Delta, Nigeria

Morrison, T., Esonanjor, E.E[2], Mangewosa, S.[3]

Department of Geology, Faculty of Science, Rivers State University
Email Address*: erefama.esonanjor@ust.edu.ng

Abstract The Stratigraphy of the aquifer and hydrochemical properties of groundwater in Ikwerre Local Government Area were assessed. This was to determine the aquifer location, composition and type, and also to ascertain the groundwater suitability for domestic use. Six boreholes in six communities were used.iStrata log was used for the stratigraphic studies while water samples were analysed for iron, chloride, salinity, pH, conductivity and Alkalinity. Two aquifers were delineated at varying depths. Sample analysis in the laboratory was done using the standard method of ASTM and APHA. From the analysis, it was indicated that all parameters investigated are within the WHO (1997) except for iron and pH. ron is excessive at Isiokpo, Omagwa, and Omerelu.iAlso pH values are below the permissible range of 6-8.5 in all the locations except Ubima and Omerelu. The acidic nature of the groundwater is attributed to anthropogenic activities or leaching of organic vegetable materials. There is therefore need to treat the groundwater in these locations to reduce the iron content and bring the pH to normal. Further studies is recommended to identify the real source of the iron.

Keywords Aquifer Stratigraphy, physiochemical parameters, groundwater, strata logs

1. Introduction

The issue of sustainable potable water supply has become a major water world issue due to rapid urbanization and industrialization, with an attendant rapid increase in population, leading to an astronomical demand for water. Safe and accessible drinking is now a major global challenge to humanity. The issue is the availability and accessibility of good quality water throughout the world [14].

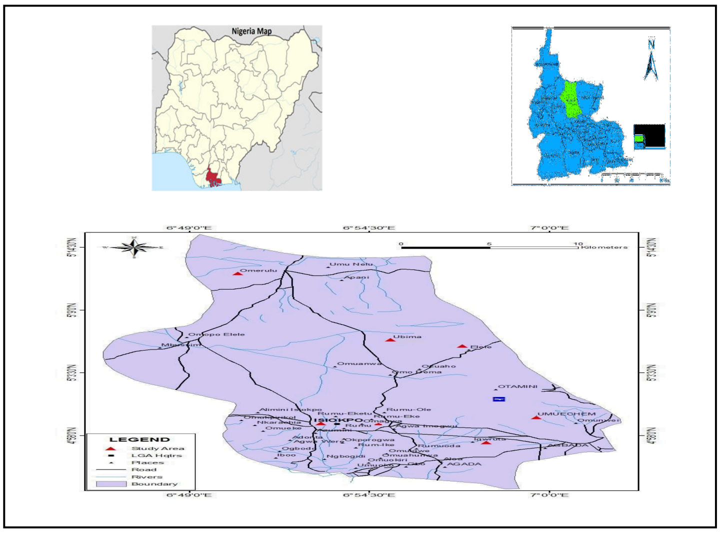
Groundwater has become a good source of potable water for domestic and industrial uses. A large percentage of the globe depends on groundwater for various uses. This is because it is readily available, especially in the sedimentary terrain. [3] It is also not easily contaminated, unlike surface waters, which could easily be polluted with infectious agents and toxic chemicals due to human activities. Groundwater is stored in tiny pores between rocks, soils, gravels and/or a combination of these in various proportions. Such geologic structures, (aquifers) which have good inter-connectivity and can easily transmit water (and other fluids), are said to be permeable. The volume of subsurface materials, as well as the size and number of pores and fractures, determine how much water an aquifer can hold [12].

Groundwater pollution can occur in a variety of ways. One possible way is through the recharge of an aquifer by polluted surface water. Also, hazardous substances from human activities can infiltrate into subsurface aquifers, causing contamination. Contaminants dissolved in groundwater can potentially flow into wells used for domestic and industrial purposes. This poses serious health risks [13].

The use that water is put into depends on its quality, which is determined by its chemistry. Therefore, knowing the hydrogeochemistry of groundwater becomes as important as its availability [2] [14]. Water that is polluted is unfit for domestic use without going through various treatment processes because of the health risk it poses. Water treatment, in most cases, is quite an expensive and cannot be afforded especially in rural communities. It is with the above view in mind that this study was carried out, to examine the lithostratigraphy from ground level to the aquifer-bearing formation of the area as well as determine the hydrogeochemistry of the groundwater. [7][9] These are expected to aid practitioners in the water industry in providing high-quality, portable water to the communities in the area.

1.1 Study Location

The study area (Ikwerre local government area of Rivers State, Nigeria) is in the Niger Delta, the southern part of Nigeria. It has geographic coordinates of latitude 4°.50'N to 5°.15N and longitude 6°.30E to 7°.15'N (See Fig. 1). The area is generally low-lying with an average elevation of 13 m above sea level.



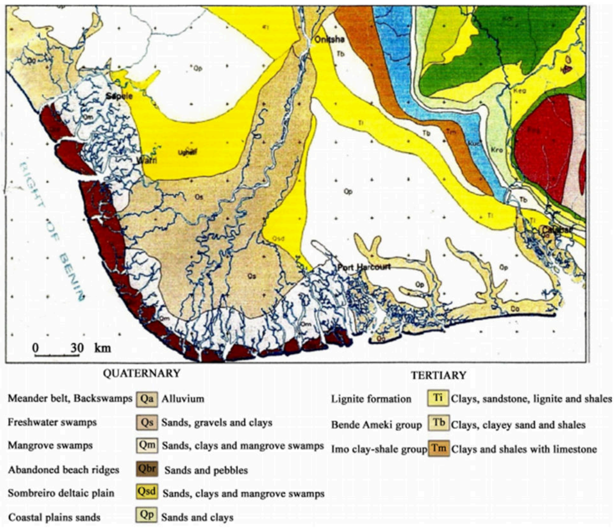


Figure 1: Map showing Ikwerre Local Government Rivers State *Figure 2: Geology Map of the Niger Delta [2]*

1.2 Geology

The geology of the area is associated with that of the Niger Delta, which was formed in the Holocene by a process of erosion and sedimentation [1]. It is located in the southern part of Nigeria, on the continental shelf of West Africa. Three major litho-stratigraphic units have been identified in the Niger Delta. [2].

These are the lower Akata, the middle Agbada and the top Benin Formations. The Akata Formation is mainly marine shale with leases of siltstones and fine-grained sandstone. It is approximately 4000 m thick [13]. Its age range is from the Paleocene to Recent [9]. Below the

Akata formation is the Agba Formation, made up of alternating beds of sand, sandstones, and shale. The poorly sorted and highly porous sands and sandstone range in grain size from fine to coarse. The thickness of the Agbada Formation is between 10000 km and 12, 000 km and is of Eocene to Recent age. [2]

The top formation, the Benin Formation, covers the whole of the Niger Delta and southward beyond the coastline. It consists of coastal plain sands and is overlain by Quaternary deltaic deposits. The Benin Formation is mainly sand with some localized shale interrelations. Its thickness is between and 30 m. It is the main aquifer in the Niger Delta [11] [10]. The Akata Formation is the source rock, while the highly porous Agbada Formation is the reservoir rock of the Niger Delta petroleum system [3].

1.3. Hydrogeology

The deltaic plain sands and the Benin Formation, with a thickness of about 1892 m, are the main aquifers in the Niger Delta. The Benin formation consists of mainly sands (90%) and sandstone with about 10% clay and lignite beds [4]. It is recharged mainly by infiltration from rainfall with interflow and baseflow to the river discharge sources and also by abstraction through boreholes.

Several aquifers have been discovered in the Niger Delta [8] [1], with the top shallow unconfined aquifer ranging in depth from 0 to 40 m depending on location. In some coastal surface aquifers, there is the problem of saline water intrusion into the unconfined aquifer, thereby making the water unfit for various human uses [10] [12]. Different units within the multi-layered aquifer system of the Niger Delta have been delineated using aquifer frequencies [6] [10] [9]. The variation of aquifer frequencies with depth shows that all the aquifers are generally overlain by a sandy/silty clay or clay at the surface, except in most of the coastal beach islands. Ngah [8] delineated three aquifer zones in the Delta within a depth range of 0 to 250 mm, with the possibility of a deeper aquifer as one goes down. The aquifers are of continental deposit. Some hydrogeological parameters recorded in the area are given in Table 1 below.

Table 1: Some hydrogeological parameters of the Niger Delta

Parameter	Range of Values
Transmissivity	$(1.05 - 8.58) \times 10^{-2}$ m^2/sec
Hydraulic conductivity	0.03 – 65 m/d
Storativity	$(1.07 + 3.53) \times 10^{-4}$
Specific capacity	4.13 – 98.52 $m^3/hr/m$

The water table is generally affected by the climate, rainfall, and drainage conditions. Rain falls almost continuously throughout the year, for about nine months (March to November). The dry season between November and March is not without rainfall. The water table increases during the rainy season and falls in the dry season in the unconfined shallow aquifer [2] [12] [15] [11].

2. Materials and Methods

The study involved field sampling of soil and water samples and laboratory analysis and interpretation of analyzed results. Six sampling communities were selected based on spread, accessibility, and human activities (population). Soil samples collected and analyzed during drilling (drillers log were used). Samples were obtained at a regular interval of about 1.0 m and at a depth where there was an observed change in soil type.

The collected samples were washed and first inspected for field description and classification before being bagged for further analysis.Six borehole litho-stratigraphic logs were used to access aquifer lithology. The lithology-stratigraphic analysis gives an indication of the aquifer thickness, position, depth, and composition of the aquifer. The hydrogeochemical study included the sampling and analysis of six (6) wells, which were drilled mainly for domestic purposes. All the wells were fully screened and samples were taken at about half of the maximum well depth. Water samples from the study boreholes were collected and preserved according to standard procedures [5].

All samples were put in iced-boxes and taken to the laboratory for further tests. The laboratory parameters determined in the laboratory included iron, chloride, alkalinity (TA), and dissolved oxygen

(DO). The sampling bottle was filled to the brim to avoid air bubbles, and 1ml of manganese sulphate was added and mixed. In-situ, parameters such as pH, water temperature, turbidity, total dissolved solids (TDS), and electrical conductivity were determined in-situ using a quality instrument (Ex TECH multi-parameter water instrument DO700). Data obtained from the analysis was compared with both the World Health Organization (WHO) and the Nigerian Industrial Standards.

Table 2: Sample Location

S/N	Community	Borehole Location (Bps) Northing	Easting	Depth (m)
1	Isiokpo	5°58’33”	6°53’21”	70.1
2.	Omagwa	5°33’98”	6°88’72”	70.1
3.	Omujechem	5°54’82”	7°15’70”	132
4.	Elele	5°06’30”	6°48’51”	61
5.	Ubima	5°7’14”	6°54’10”	70.0
6.	Omerelu	5°03’33”	6°88’70”	71

3. Results and Discussion

Lithostratigraphy units within the boreholes were identified based on the soil samples. Soil samples collected and processed gave accurate lithologic well logs (Figure 3). Analysis of the samples gave an indication of the lithologic character and thickness of the aquifer and boundaries.The stratigraphy of the study area, as revealed by the logs, is made up of clay, silt, and gravel combined in various proportions and of variable proportions and variable thickness and texture. The topmost layer is clay, which is followed by a layer of fine to medium sand.

The sands are sharp and unconsolidated but poorly sorted. Below the sand is another layer of confining clay at various depths.

The clays which are kaolinitic are light grey at the top and dark grey below. The thickness of the clay ranges from 2m at Isiokpo to 10.0m at Elele. They are laterally extensive and can be correlated (figure 3). Multiple aquifer systems are observed in the area, the top shallow aquifer at a depth of between 3m and 10m and a more extensive confined aquifer below a capping clay layer. Below this second clay layer is sand of various grades ranging from fine to very coarse and gravel with varying thickness. They are laterally extensive and poorly sorted, porous and permeable. This is the main aquifer in the area. Its depth is location dependent.

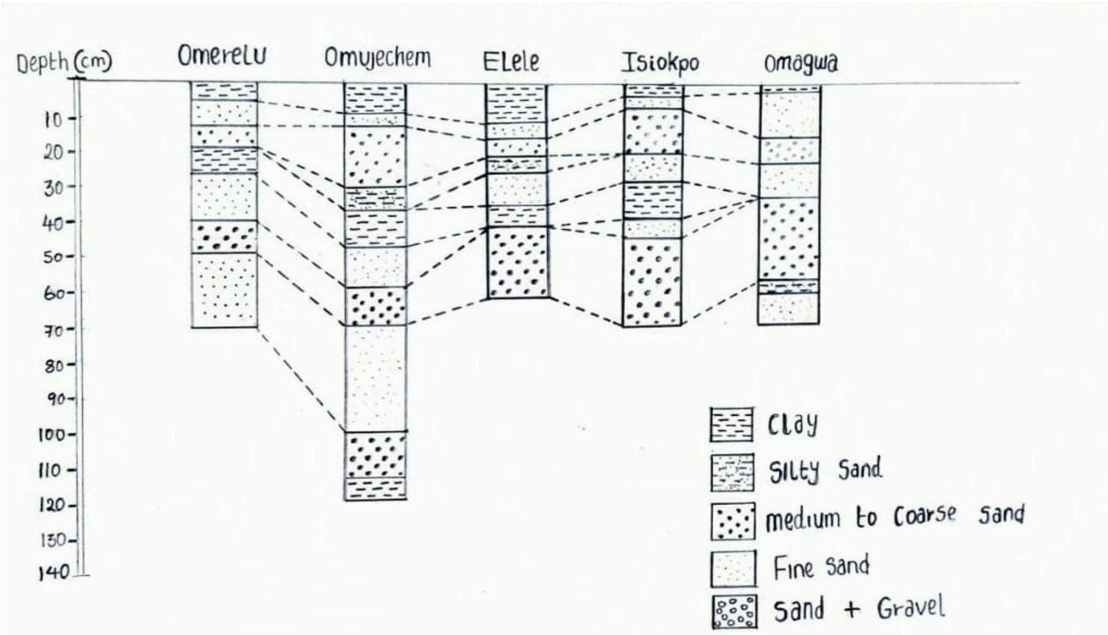


Figure 3: Lithostratigraphic Logs of study Area

3.1 Hydrogeochemical Analysis

The water quality of the area was determined through the analysis and interpretation of the physicochemical constituents of the water samples. The results of the analysis are represented in Table 3. The average well depth is 70.1m. This is the lowest at Elele (61.0m) and the deepest at Omuechem (132m). The chloride, salinity, conductivity, alkalinity, and total hardness values are within the World Health Organization (WHO) and the Nigerian Industrial Standard (NIS) for drinking water.

The iron and pH levels are, however, higher at some locations (Fig. 4). At Omerelu (0.4 mg/l), Omagwa (0.43 mg/l), and Isiokpo (2.0 mg/l), iron concentrations are higher than permissible levels at Omerelu (0.4 mg/l). Also, waters from Isiokpo, Omagwa, Omuechem, and Elele are slightly acidic (below the minimum value of pH 6), while Ubima and Omerelu are within the WHO level. The range of values of salinity is from 20 to 100 mg/l. The highest value of 100mg/l occurs at Omuechem, while the lowest value of 20m/l occurs at Omerelu. The average chloride concentration is 25.5 mg/l in the area. This falls within the range of acceptable limits (250mg/l) set by WHO.

Table 3: Max and min mean values of some parameters

	Maximum	Minimum	Mean
Iron	2	0	0.52
Chloride (mg/l)	38.94	18	25.6
Salinity (mg/l)	100	20	57.4
Conductivity (µs/cm)	36	15	21
pH	65	5.1	3.73
Alkalinity (mg/l)	15	0.6	4.8
Total hardness (mg/l)	10	4	6.3

Table 4: Result of Water Analysis [16][5]

Location	Iron (mg/l)	Chloride (mg/l)	Salinity (mg/l)	Conductivity (µs/cm	pH	Alkalinity (mg/l)	Total Hardness
Isiokpo	2	38.94	64.4	20	5.6	15	10
Omagwa	0.4	20	20	20	6.5	0.6	8
Umejechem	0	18	50	18	6	2	4
Elele	0	29.8	49	15	5.2	3	5
Ubima	0.3	26.0	100	36	5.7	3	6
Omerulu	0.43	19.7	0	1.0	5.9	5	5.3
WORLD HEALTH ORGANISATION STANDARD (WHO)							
	0.3	250	500	2000	6-8.5	200	300
NIGERIAN STANDARD FOR DRINKING WATER QUALITY							
	0.3	250	500	1000	6-8.5	200	300

Table 5: Iron (mg/l) concentration

Locations	Isiokpo	Omagwa	Umuejechem	Elele	Ubima	Omerulu	Av
Iron (mg/l)	2	0.4	0	0	0.3	0.4	0.5

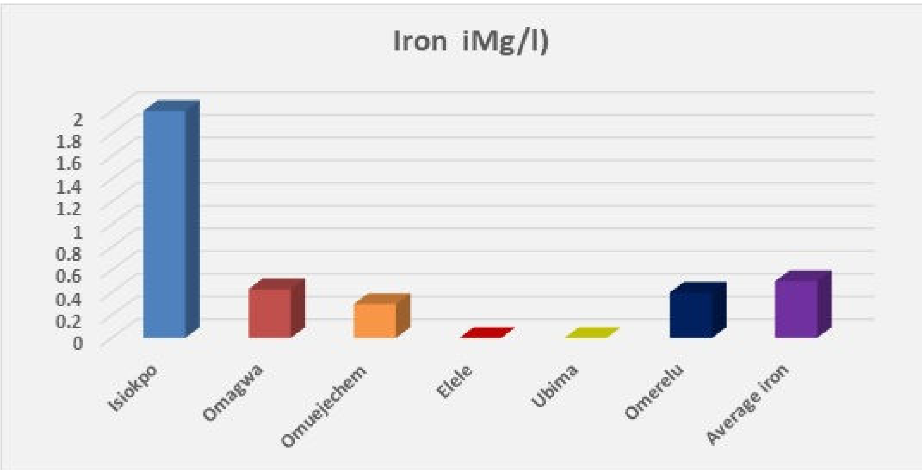


Figure 5: Iron concentration (mg/l) in groundwater from all sampling Communities

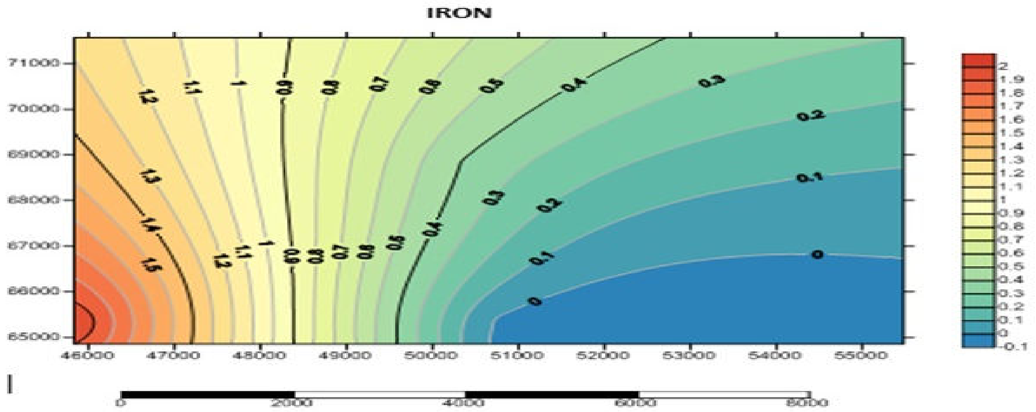


Figure 5: Contour map showing the concentration of iron (mg/l) in groundwater samples from all sampling communities

Table 6: Chloride (mg/l) concentration

Location	**Isiokpo**	**Omagwa**	**Umuje chem**	**Elele**	**Ubima**	**Omerulu**	**Av**
Chloride (mgl)	38.94	20	18	29..8	26.9	19.7	25.5

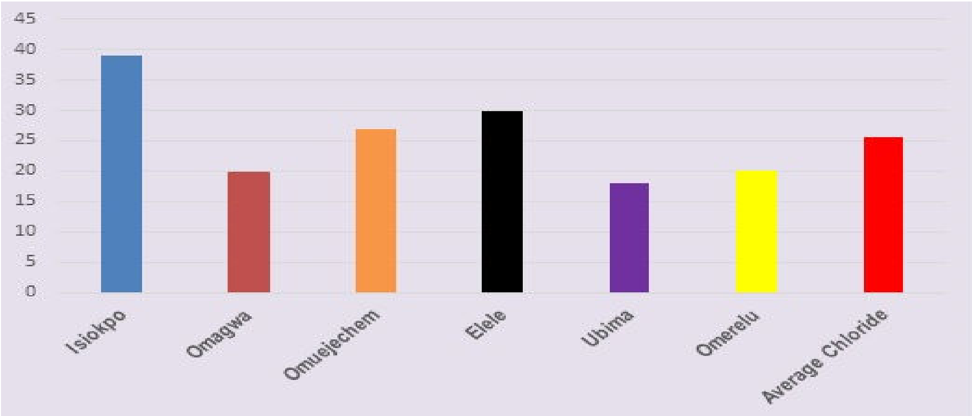


Figure 6: Chloride concentration (mg/l) in groundwater from all sampling Communities

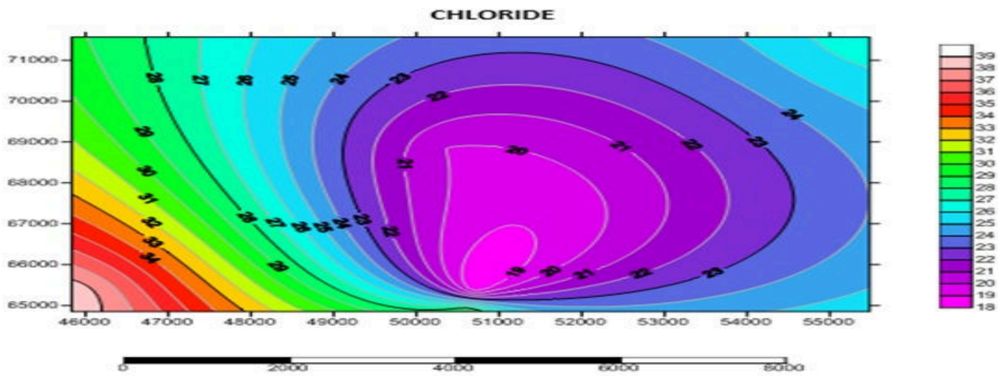


Figure 7: Contour map showing the concentration of Chloride (mg/l) in groundwater samples from all sampling communities

Table 7: Salinity (mg/l) concentration

Location	**Isiokpo**	**Omagwa**	**Umuje chem**	**Elele**	**Ubima**	**Omerulu**	**Av**
Salinity (mg/l)	64.4	20	50	49	100	0	57.4

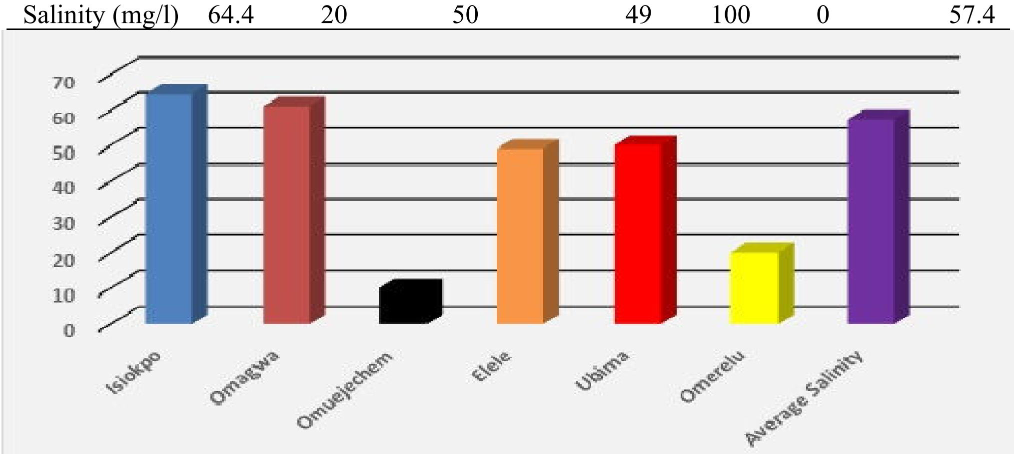


Figure 8: Salinity concentration (mg/l) in groundwater from all sampling Communities

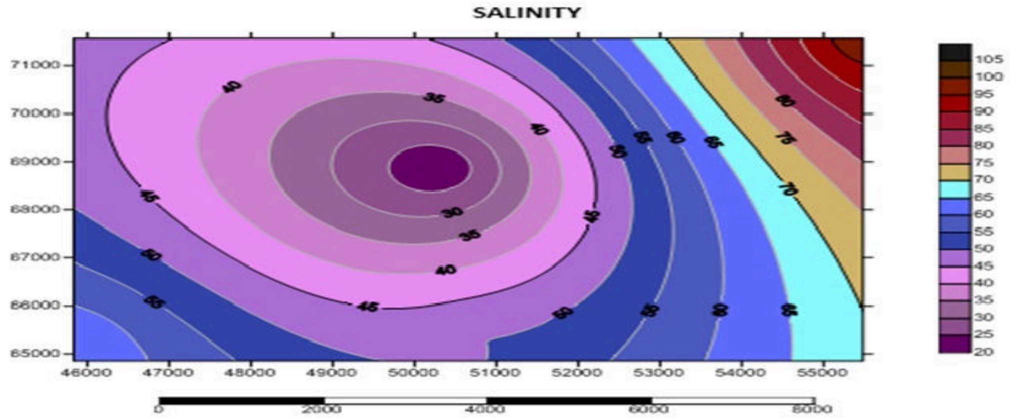


Figure 9: Contour map showing the concentration of Salinity (mg/l) in groundwater samples from all sampling communities

Table 8: Conductivity (µs/cm)

Location	Isiokpo	Omagwa	Umuje chem	Elele	Ubima	Omerulu	Av
Conductivity (µs/cm)	20	20	18	15	36	1.0	21

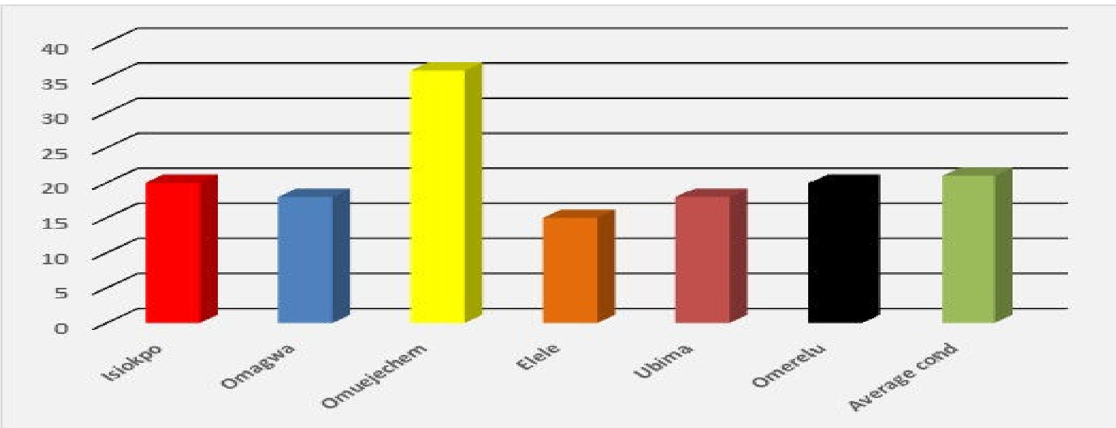


Figure 10: Conductivity analysis (µs/cm) in groundwater from all sampling Communities.

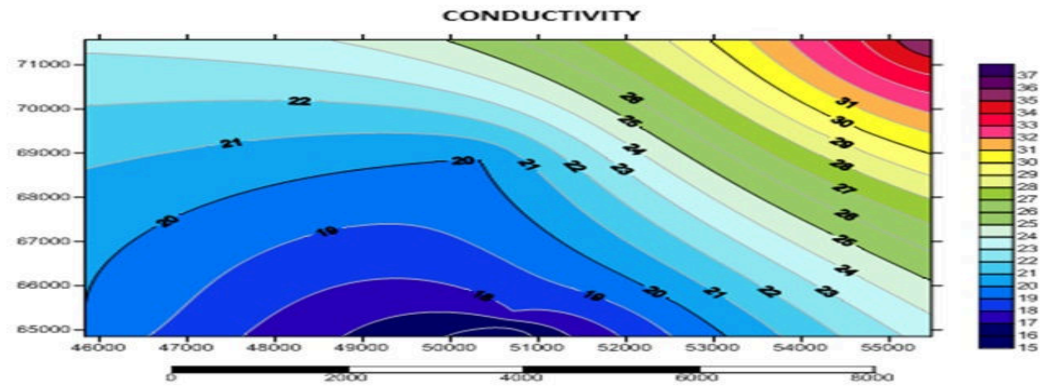


Figure 11: Contour map showing level of conductivity (µs/cm) in groundwater samples from all sampling communities

Table 9: pH (mg/l) concentration

Location	Isiokpo	Omagwa	Umuje chem	Elele	Ubima	Omerulu	Av
pH (mg/l)	5.6	6.5	6	5.2	5.7	5.9	5.7

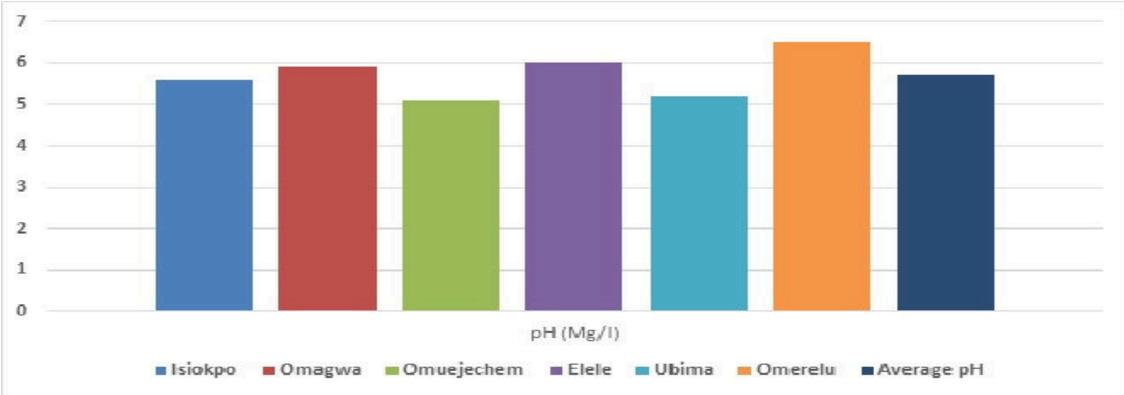


Figure 12: pH (mg/l) concentration in groundwater samples from all Sampling communities

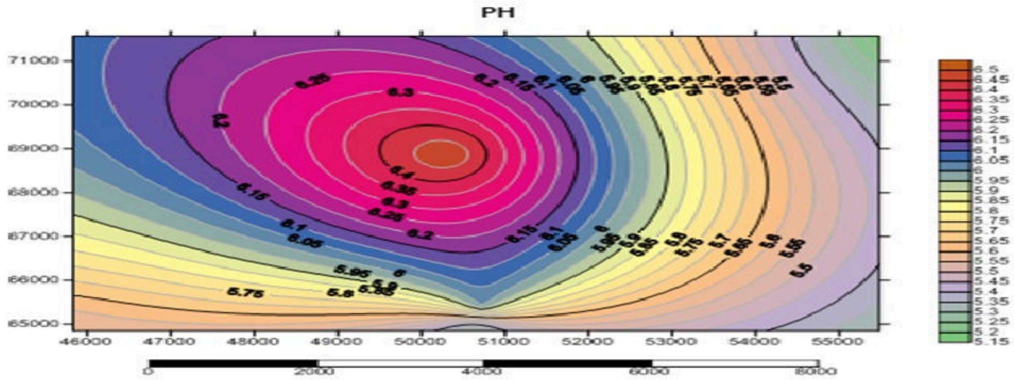


Figure 13: Contour map showing the concentration of pH (mg/l) in groundwater samples from all sampling communities

Table 10: Alkalinity (mg/l) concentration

Location	Isiokpo	Omagwa	Umuje chem	Elele	Ubima	Omerulu	Av
alkalinity (mg/l)	15	0.6	2	3	3	5	4.7

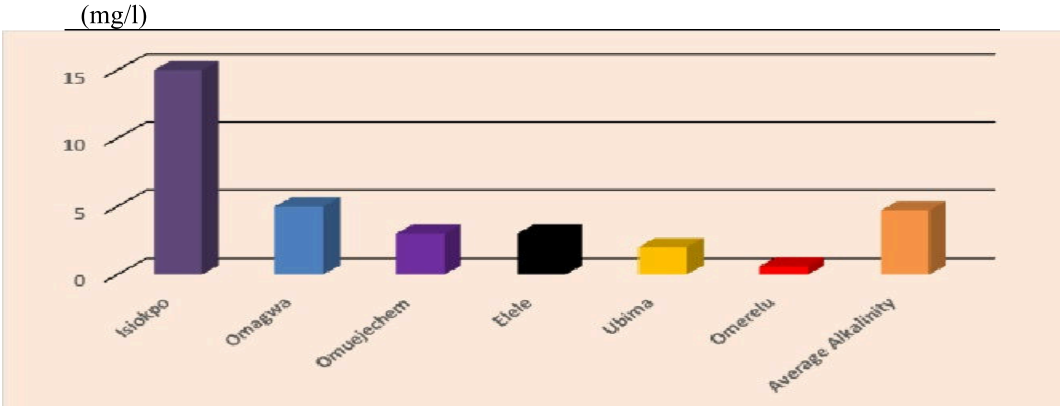


Figure 14: Alkalinity (mg/l) concentration in groundwater samples from all sampling communities.

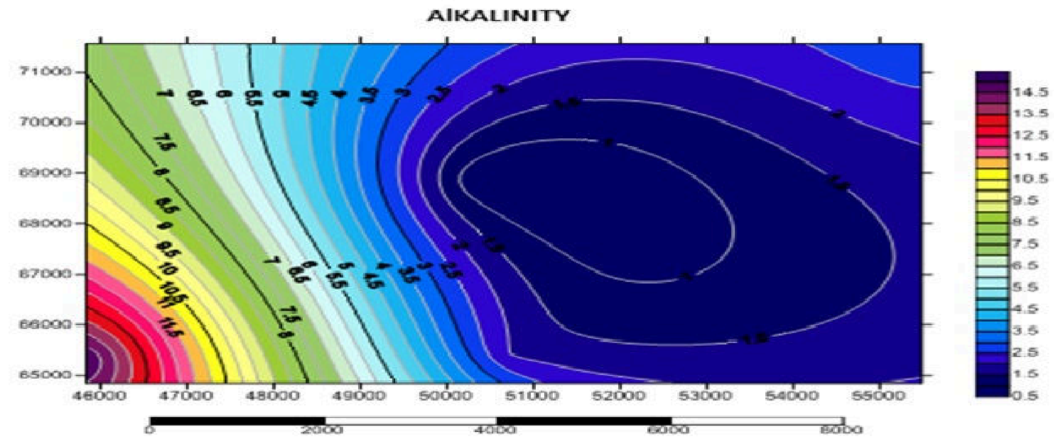


Figure 15: Contour map showing the concentration of Alkalinity (mg/l) in groundwater samples from all sampling communities.

Table 11: Total Hardness (mg/l) concentration

Location	Isiokpo	Omagwa	Umuje chem	Elele	Ubima	Omerulu	Av
Hardness (mg/l)	10	8	4	5	6	5.3	6.3

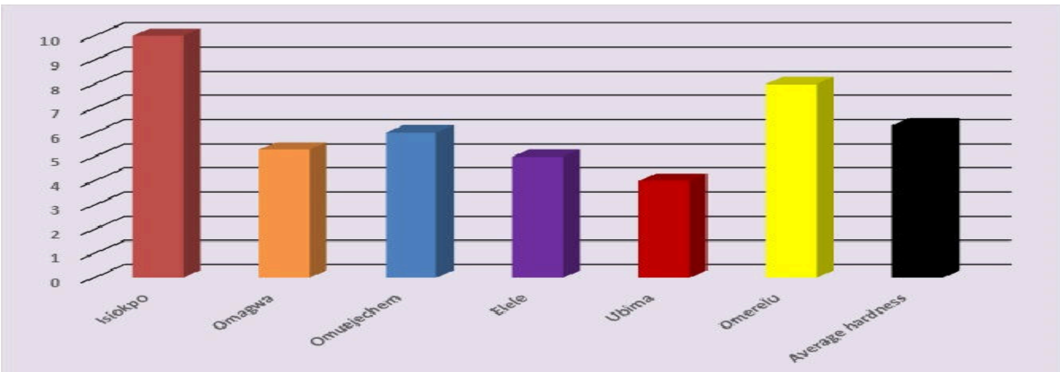


Figure 16: Total Hardness (mg/l) concentration in groundwater samples fro all sampling communities

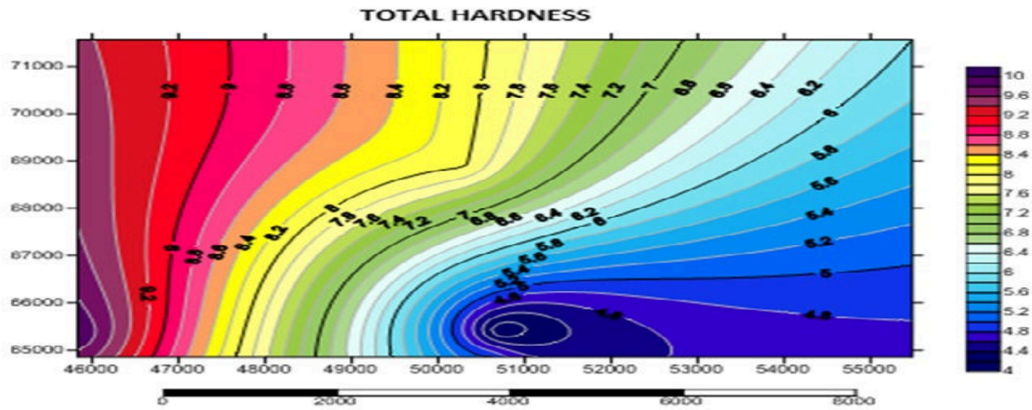


Figure 17: Contour map showing the concentration of Total Hardness (mg/l) in groundwater samples from all sampling communities.

This shows that the chloride concentration in the groundwater is not hazardous to life. The slightly acidic nature of the groundwater at Omerelu, Isiokpo, and Omagwa may be attributed to the presence of organic materials due to the decomposition of organic vegetative materials in a reducing environment. This process generates organic acids which could infiltrate subsurface and groundwater aquifers. It could also be attributed to anthropogenic activities associated with farming and pollution from petroleum exploration activities.

4. Conclusion

Groundwater is a valuable natural resource [7][16][12]. It is the main source of water in the area under study due to the paucity and pollution of most surface waters in the area as a result of petroleum exploration activities. The area (Ikwerre local government area) has enough groundwater for both domestic and industrial uses. The groundwater in the area does not pose a health threat to the people as it meets both the WHO and the NIS standards for domestic water use, except for Omagwa and Omerelu, which have slightly acidic water, for which treatment is recommended for human uses. Regular hydro-chemical studies should be carried out in the area to detect any further deterioration of the groundwater quality. Also, strict measures should be put in place to discourage or minimize the cause (s) of water quality deterioration in the area. The slightly high acidic pH values in Isiokpo, Omagwa, Omuechem, and Elele areas should be treated with sodium bicarbonate, to reduce the acidity and keep the water in the area within the regulatory standards and requirement for the various purposes.

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