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Physico-Chemical Characterization and Ground Water Quality Assessment in Selected Area of Uvwie Local Government in Delta State, Nigeria

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ABSTRACT: The status of the ground water in Uvwie local Government Area and its surrounding environment was evaluated in this study. The aim of the research was to evaluate the physico-chemical composition and quality profile of the ground water. A total of twenty samples were collected from boreholes and hand dug wells and analysed. Iron chromatography and titrimetric method were employed for the analysis. The results shows that almost all the physico-chemical parameter such as PH (5.11 -8.46), temperature (24.5oC - 26.8oC) EC (12.87µs/cm -34µs/cm) TDS (6.44mg/l-440mg/l) fall within the limit recommended by WHO and Nigeria Industrial Standard. Chemical parameters has the following results: Cl-(8mg/l - 250mg/l), Na+ (2.13mg/l - 957mg/l) K+ (0.192mg/l - 15.86mg/l) Ca2+ (0.173mg/l - 88.34mg/l), Mn (0.02mg/l-0.43mg/l), Fe2+(0.01mg/l - 1.65mg/l). The concentration of Pb2+ was 0.009mg/l in all locations. All major Ions revealed that concentration is within limits of both standards. The study concludes that the water is save for drinking and domestic purposes. However, bacteriological and radiological test should be researched.

Keywords: Ground water, boreholes, dug wells, iron chromatography, titrimetric method, WHO, NIS

INTRODUCTION

In Nigeria, the rate of urbanization characterized by high population concentration, increasing industrial and agricultural activities coupled with environmental pollution degradation and indiscriminate disposal of all kind of waste are perceived to pose serious pollution treat with all its health hazard on ground water quality especially in urban areas (Kehinde, 1998; Adelana et all 2003; Adelana et al., 2004).

Fresh water is considered to be the most important earth natural resources that is essential for human existence yet fresh water is just a finite resource which requires careful management if human existence is required to survive. The global water resources is about 97.2% of salt water mainly found in oceans and only 2.8% is available as fresh water (Raghunath, 2006). Out of the 2.8% of fresh water, only 0.6% is found as ground water with about 0.25% that can be economically extracted with the present drilling techniques (Raghunath, 2006).

Due to the ever growing population growth on earth and the level of industrialization, the anthropogenic impact on the environment has led to changes in the biophysical environment, ecosystem and natural resources (Wikipedia, 2019). This has resulted in global warming and increase in the pollution of the environment, which in turn has affected the quality of ground water. The quality of ground water depends on the quality of recharged water, atmospheric precipitation, inland surface water, and sub-surface geochemical processes (Binu et al, 2014). The availability of good quality water is an indispensable feature for preventing disease and improving quality of life (Oluduru and Aderiye, 2007). The quality of ground water in some African countries are still below acceptable limit as stipulated by the World Health Organisation (WHO) as many sources of ground water pollution can still be found in most African countries.

The sources of ground water pollution include open dumpsites, poorly constructed or unmaintained landfill, latrines and other waste sites (Asadu, 2016). The ground water can also be polluted by infiltration of acidic rain to the ground water aquifer which is one of the major source of ground water pollution in regions that engage in gas flaring. Another major source can be from the overuse of pesticide and fertilizer for agricultural purposes, as

harmful chemical can migrate toward the ground water aquifer.

The water quality is determined by the physico-chemical parameter of the water and the water quality index. The physico-chemical parameter shows the physical and chemical constituents of the ground water which can be determined by standard procedures such as the America Public Health Association (APHA) Standards, thereafter the level will be compared with acceptable limit stipulated by the WHO. The Water Quality Index is a value that enable one to know at a glance the level of quality of the water without looking at the individual physical or chemical constituent of the water. The water quality index was introduced by National Sanitation Foundation (1970).

The study is aimed at characterizing the ground water in selected area of Uvwie local government area in Delta state, Nigeria along the line of their physico-chemical constituents

The study area is in Effurun Delta State in Nigeria. Uvwie is located geographically between longitude 5.40' and 5.50' East and between latitude 5.30' and 5.50' North as shown in Figure 1, at an elevation of 8m above mean sea level. The land area is approximately 100 square kilometres and it is bounded by Okpe Kingdom in the North and Udu and Ughievwen in the North-West, Agbarho kingdom in the North East, Agbarho-Ame in the East, Okere Kingdom in the South and Itsekiri in the South .

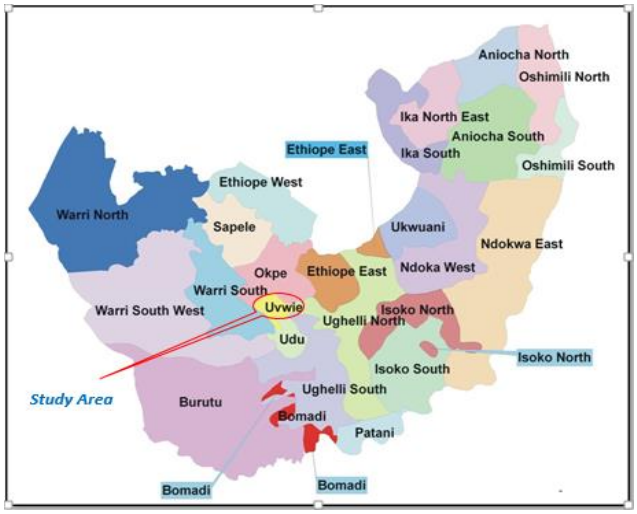

Figure 1. Location Map of Uvwie Local Government Area, in Delta State

The population of the study area is approximately about three hundred thousand (300,000) people. The total water demand required by the community is approximately 36 mega litre per day, taking the average daily consumption per capital to be 120l/d. The people in this area are predominantly occupied with industrial activities which include oil and gas, construction, production etc. which contribute to ground water pollution due to waste discharge from the by-product of their activities.

MATERIAL AND METHODS

Sample Collection

Water sample were collected from nine selected locations (Figure 2) in Uvwie local Government Area, see Table 1 for the geographical coordinate of sampling points. The samples were collected in washed and clean 1.5 litres plastic container with cock tap at laminar flow after the tap was allowed to flow for about five minute to avoid any water retained in the pipe being taken as sample. The collection procedure was done according to prescribed sample collection procedure.

The water samples collected were transported to the laboratory the same day and analyses were done to obtain the physico-chemical parameters of the ground water according to APHA (2001).

Figure 2. Location Map of Sampling points

Table 1. Geographical Coordinate of sampling points

S/N	Sampling Points	Latitude	Longitude
1	Refinery Road	5°34'9.08"N	5°44'60.00"E
2	PTI Road	5°34'4.86"N	5°47'49.02"E
3	Jakpa Road	5°33'44.76"N	5°46'5.19"E
4	Bendel Estate	5°32'32.42"N	5°45'59.22"E
5	Effurun Market	5°33'14.93"N	5°47'8.25"E
6	Okuokoko	5°34'39.68"N	5°49'0.93"E
7	Okorodudu Road	5°33'32.87"N	5°46'19.92"E
8	Ekpan	5°33'49.93"N	5°43'47.33"E
9	NPA Expresswa Ekpan	5°32'53.50"N	5°43'43.17"E

Computing the Water Quality Index

The Water Quality Index is an important tool design to give a numerical value for easy evaluation of the quality of drinking water. The water quality index (WQI) takes into account nine water quality parameters which are dissolved oxygen, faecal coliform, pH, BOD, temperature difference, total phosphate, nitrate, turbidity, and Total solids for computation of the water quality Abbasi et al. (2012). The water quality index is computed by applying equation 1. The Q-value represent the water quality of a particular parameter which is obtained from a chart. Each physico-chemical parameter has a chart where the Q-Value can be obtained, Figure 3 shows the chart for the Q-value of PH. Table 2 shows the weighting factor, which is a value assigned to each of the nine water quality parameter that signify its importance. Table 3 show the water quality rating.

$$WQI = \frac{\sum_{i=1}^{n}(Q-value \times weighting\ factor)}{\sum weighting\ factor} \quad 1$$

Table 2. Weighting factor for computing Water Quality Index

Factor	Weighting Factor (W)
DO (% Saturation)	0.17
Faecal Coliform nos./100ml	0.16
pH	0.11
BOD (mg/L)	0.11
Temperature change (^oC)	0.1
Total phosphate-P (mg/L)	0.1
Nitrate (mg/L)	0.1
Turbidity (NTU)	0.08
Total Solids (mg/L)	0.07

Table 3. Water Quality Rating

Water Quality Index	Water Quality
>90-100	Excellent
>70-90	Good
>50-70	Medium
>25-50	Bad
0-25	Very Bad

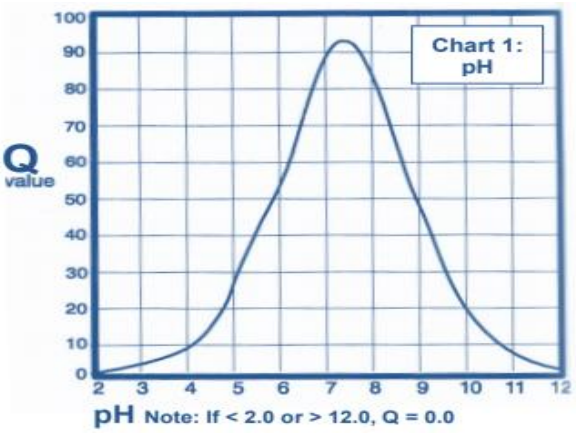

Figure 3. Q-Value chart for pH

Statistical Analysis

Agglomerative hierarchy clustering (AHC) was used to analyse the water quality parameters test result. AHC explore the data set and try to cluster groups of observation that have similarity. This statistical method was employed in other to enable one know which groups of location in Uvwie LGA have similar concentration of a particular physico-chemical parameters. The Microsoft Xlstat software was used in performing the statistical analysis.

RESULTS AND DISCUSSION

The result from the test carried out in the laboratory to determine the pyhsico-chemical constituent of the water is shown in Table 4 and Table 5. Table 4 shows the physical quality of the ground water, while Table 5 shows the chemical quality of the ground water in Uvwie LGA.

Table 4. Test result showing the physical parameter of the ground water

Sampling Points	pH	Temperature	Conductivity	TDS	DO	BOD_5	Total Hardness	Turbidity	Coliform
Refinery Road	6.58	24.5	98.5	49.02	8.56	0.04	25.51	9.6	0
PTI Road	8.46	25	214	111	4.15	0.04	28.12	13.99	0
Jakpa Road	6.59	24.44	111	55.52	3.25	0.04	61.57	9.6	0
Bendel Estate	5.11	24.8	145	75	6.87	0.04	21.08	0.26	0
Effurun Market	6.11	24.76	142	440	5.39	0.04	12.76	1.93	25
Okuokoko	5.83	26.8	12.87	6.44	5.83	0.04	0.75	24	0
Okorodudu Road	7.14	25.4	288.9	144.5	3.98	0.04	131.05	2.39	0
Ekpan	7.04	25.5	341	163	8.53	0.04	2.1	6.44	0
NPA Expressway Ekpan	5.38	25	118	8.47	6.76	0.04	41.54	0.6	0
WHO Standards	6.5-8.5	NA	1400	1000	NA	4.0	NA	5	
Nigeria Industrial Standard (NIS 554)	6.5-8.5	Ambient	1000	500	NA	N/A	150	5	10

Table 5. Test result showing the chemical parameter of the ground water

Sampling Points	Na	NO_3	PO_4^{3}	K	Ca^{2+}	Mg^{2+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	Pb^{2+}	Fe^{2+}	Mn^{2+}	Zn^{2+}
Refinery Road	15.78	0.0009	1.39	11.86	8.23	1.2	25.6	8	2	0.009	1.23	0.13	0.009
PTI Road	16.23	0.95	12.23	15.86	3.6	1.529	1.6	19.85	5	0.009	1.65	0.08	0.009
Jakpa Road	15.48	5.5	0.67	6.98	20.8	2.24	14.8	18	1	0.009	0.08	0.05	0.009
Bendel Estate	957	23	0.1	11.87	3.69	2.88	0.01	13.5	2	0.009	0.02	0.12	0.009
Effurun Market	835	170	3.01	9.88	3	20.67	190	70.18	1.99	0.009	0.01	0.34	0.009
Okuokoko	1.013	0.0009	0.02	0.192	0.173	0.076	1.2	2	1	0.009	0.01	0.06	0.009
Okorodudu Road	8.23	12.2	1.38	8.16	41.67	6.53	60	20.32	2	0.009	0.19	0.43	0.009
Ekpan	11.45	15.2	1.87	7.68	88.34	34.98	68.5	19	1.11	0.009	0.05	0.08	0.009
NPA Expressway Ekpan	2.13	0.52	0.05	1.11	12.5	2.5	0.5	14.59	2.2	0.009	0.02	0.02	0.009
WHO Standards	200	50	NA	NA	75	0.2	NA	250	250	0.01	0.3	0.4	3.0
Nigeria Industrial Standard (NIS 554)	200	50	NA	NA	NA	0.2	NA	250	100	0.01	0.3	0.2	3.0

Physico-Chemical Parameters

The result of the physico-chemical parameters of ground water in Uvwie LGA are presented in Table 4 and 5, it can be observed that the pH ranged from 5.11-8.46. The pH values for most of the sampling points were lower than the acceptable limit of 6.5-8.5 specified by WHO, this observation where also noted in studies done by Asadu (2016) and Olobaniyi et al (2007). Even though there is no scientific base that the pH of drinking water has an impact on human health, some believe that consumption of drinking water with low pH value causes acidosis and skin irritation. Sampling points such has Bendel Estate, Okuokoko, NPA Expressway Ekpan and Effurun Market with very low pH value can have challenges due to corrosion of water mains and pipes in their water distribution system. The possible reason of low-pH value in ground water in Uvwie community is due to the presence of the refining activities taking place in the community and the poor practice of burning of natural gases found in petroleum through gas flaring which led to release of harmful gases like nitrogen oxide and sulphur oxide to the atmosphere thereby mixing with precipitation which result to acid rain that infiltrate to the ground water aquifer. The conductivity of the ground water ranged from 12.87 – 341 μS/cm, the value were within acceptable limit for both the WHO and NIS Standards. The electrical conductivity determine the ground water capability to pass an electrical charge. The total dissolved solute (TDS) gives indication about the amount of inorganic salt and also indication of the clarity of the ground water. The TDS ranged from 6.44 – 440mg/l which was below the acceptable limit by both Standards. Ground water in Okuokoko may have an unacceptable taste because of it flat and insipid taste due to the very low TDS found in the ground water. About 56% of the sampling points had turbidity value greater than the acceptable limit of both standard. Turbidity is caused by particulate matter that maybe present from the ground water aquifer due to poor filtration of the water by the sand bed above the aquifer or due to resuspension of sediment from the water distribution system. Incident with elevated level of turbidity have been associated with several outbreak of disease (Hudey, 2004; Mann et al., 2007).

The concentration of sodium in ground water in Uvwie LGA ranged from 2.13 – 957 mg/l. Concentration of sodium in the ground water in Bendel Estate and Effurun market excessed that acceptable limit set by WHO. Increase consumption of sodium in ground water can possibly lead to occurrence of hypertension, but no firm conclusion had been made concerning the association. High level of sodium in ground water can react with the soil and reduce the level of permeability of the soil (Todd, 1980). The nitrate concentration in Uvwie ranged from 0.0009 – 170 mg/l. Concentration of nitrate at Effurun market far excessed WHO acceptable limit of 50 mg/l. The high level of nitrate in Effurun market ground water can result in methaemoglobinaemia (blue-baby syndrome) in infants.. Possible treatment method of excessive nitrate in the ground water at Effurun market can be achieved by ion exchange. The level of concentration of potassium ranged from 0.192 - 15.86 mg/l and there was no acceptable limit stipulated by WHO and NIS. The calcium concentration ranged from 0.173 – 88.34 mg/l. Majority of the sampling point where within acceptable limit stipulated by WHO with the exception of Ekpan with had calcium concentration of 88.34 mg/l. Calcium is needed in human body at a reasonable quantity as it help in bone formation and repairs. The manganese concentration for the study

ranged from 0.02 – 0.43 mg/l, manganese concentration level for most of the sampling points were within acceptable limit of 0.4mg/l as stipulated by WHO and NIS. Okorodudu Road was the only sampling point that had concentration above the stipulated guideline value by WHO. Manganese can result to adverse health effect from deficiency or overexposure. Consumption of ground water with high manganese concentration can result to neurological effects (e.g., tremor, gait disorders). The level of concentration of chloride found in the ground water for the various sampling points were all within acceptable guideline value stipulated by WHO. The level of the concentration of chloride were in-line with the study done by Olobaniyi et al. (2007). The level of chloride in ground water can be increased by the sea water intrusion into the ground water aquifer, urban runoff containing de-icing salt and industrial effluents. High level of chloride can result in the ground water having a bitter taste and can also lead to corrosion in distribution system. Lead concentration limit found in all sampling locations were below the WHO guideline value. The lead concentration in all sampling location was 0.009 mg/l. The level of concentration of iron ranged from 0.01 – 1.65 mg/l, with PTI road having the highest concentration of iron content. Increased level of iron content in water can result from leaching of Fe^{2+} into groundwater from iron-bearing minerals such as hematite, limonite and goethite (Olobaniyi et al, 2007) and also from the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Water from PTI road and Refinery Road will give a brownish stain to clothes when used for laundry and this is as the result of the oxidation of iron from Fe^{2+} to Fe^{3+}. The concentration of zinc for all sampling points was 0.009 mg/l, this value was far below the acceptable limit stipulate by WHO for the amount of zinc present in water that would be suitable for consumption. The sulphate concentration level was far below acceptable limit by WHO, however high concentration of sulphate in water can result to gastrointestinal health effects.

Water Quality Index

The water quality index computed for the sampling points are presented in Table 6. From Figure 4, it can be seen that the water quality for most of the sampling points where between medium and good with the exception of Effurun market which had a water quality index of 49.38 thereby giving it a rating of Bad. The bad water found in Effurun market is as a result of the high faecal Coliform as shown in Table 4 found in the ground water in Effurun market. Water quality for NPA Expressway Ekpan was found to be the best, these was as a result of the low physico-Chemical parameters found in the ground water in that sampling point.

Agglomerative Hierarchy Clustering (AHC)

Agglomerative Hierarchy Clustering (AHC) help clusters or group observations with similar profile, these statistical approach was employed to see samplings points with similar physico-chemical parameter. The analysis was ran for both pyhsico-chemical parameters in Table 4 and 5. Results from the statistical analysis are presented from Figure 5-8. Figure 5 show the grouping of the sampling points for Table 1, it can be observed that the cutting plane cut the dendrogram into five groups. Group 1 comprises of Refinery Road, Bendel Estate and NPA Expressway Ekpan, Group 2 comprises of PTI Road, Jakpa Road and Okorodudu Road, Effurun Market was grouped as group 3, Okuokoko was grouped as group 4 while Ekpan was grouped as group 5. The parallel plot as shown in Figure 6, shows the relationship between the groups and the physico-chemical parameters.

Table 6. Water quality index

S/N	Sampling Points	WQI	WQI Rating
1	Refinery Road	79.02	Good
2	PTI Road	63.96	Medium
3	Jakpa Road	70.70	Medium
4	Bendel Estate	74.31	Good
5	Effurun Market	49.38	Bad
6	Okuokoko	73.46	Good
7	Okorodudu Road	66.43	Medium
8	Ekpan	74.78	Good
9	NPA Expressway Ekpan	81.14	Good

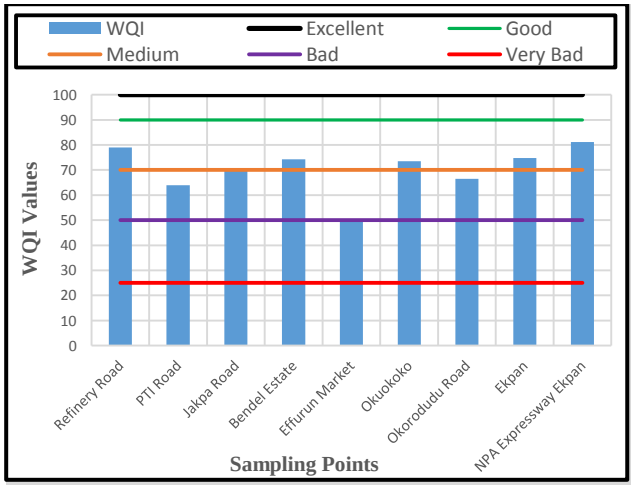

Figure 4. Bar chart showing water quality index with the water quality rating

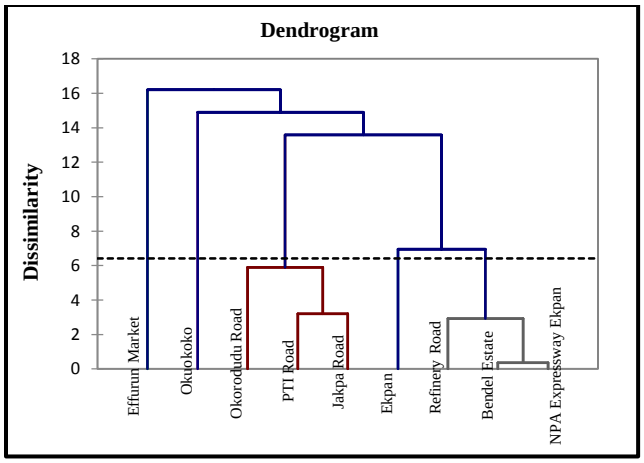

Figure 5. Dendrogram showing result from analysis of pyhsico-chemical parameter from Table 1.

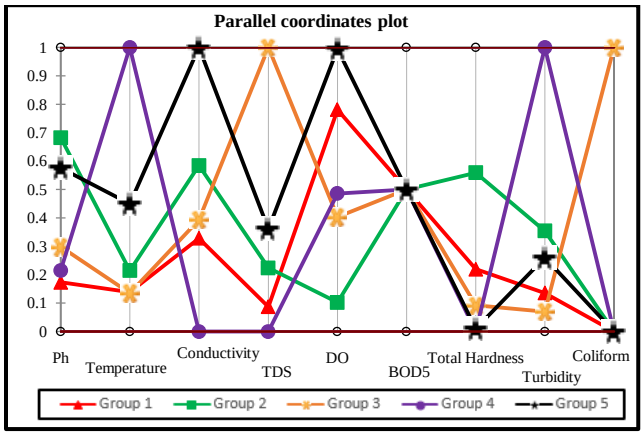

Figure 6. Parallel plot showing the relationship between the groups and the physico-chemical parameter in table 1.

From Figure 6, it can be observed from the parallel plot that group 1 has the lowest pH value, similar treatment method can be applied to these group to stabilize the pH in the ground water to acceptable limit. Group 2 had the highest pH value and the highest total hardness value, frequency monitoring and maintenance should be carried out on the main of the water distribution system as scale in pipes and heat exchanger tend to develop more in these regions. Group 3 had the highest TDS and the highest faecal Coliform, high alert should be taken when drinking water from these region as there are high presence of bacteria in the water which can cause harm to the human body. Government agencies should monitor how human sewage are discharged in this area. The water temperature and turbidity were high in group 4, filtration of drinking water is very important in these region as more suspended particle can be found in water in these regions. Group 5 had the highest conductivity and dissolved oxygen content.

Figure 7 show the grouping of the sampling points for Table 2, it can be observed that the cutting plane cut the dendrogram into six groups. Group 1 comprises of Refinery Road and Bendel Estate, PTI Road was grouped as group 2, Group 3 comprises of NPA Expressway Ekpan, Jakpa Road and Okuokoko, Effurun Market was grouped as group 4, Okorodudu Road was grouped as group 5 while Ekpan was grouped as group 6. The parallel plot as shown in Figure 8, shows the relationship between the groups and the physico-chemical parameters.

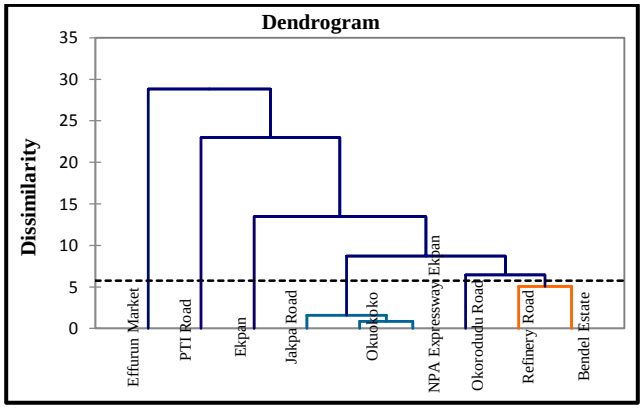

Figure 7. Dendrogram showing result from analysis of pyhsico-chemical parameter from table 2.

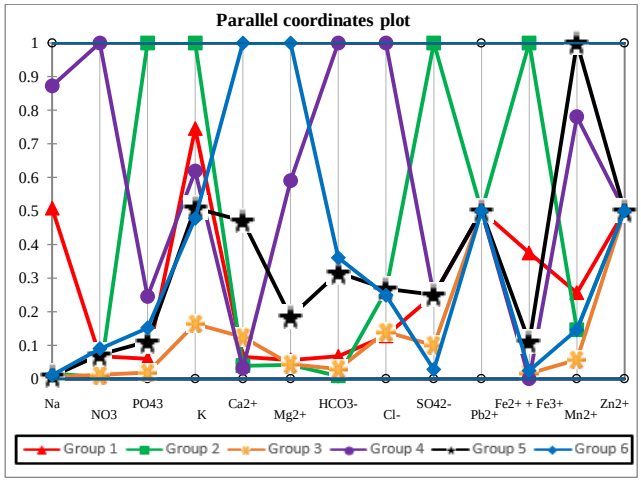

Figure 8. Parallel plot showing the relationship between the groups and the physico-chemical parameter in table 2.

From Figure 8, it can be observed that group 4 had the highest amount of sodium, bicarbonate and Nitrate. Group 2 had the high amount of potassium, sulphate and iron content found in the ground water. Group 6 had the highest concentration of calcium and Magnesium, while group 5 had the highest concentration of Manganese. Clustering of the sampling points enable a similar treatment method to be carried out for sampling points within a group.

CONCLUSION

From the assessment of the physico-chemical parameters and water quality index of ground water in Uvwie LGA, it can be concluded that majority of the sampling points had most of their physico-chemical properties in-line with guideline value stipulated by WHO, with NPA Expressway Ekpan having majority of it physico-chemical properties within acceptable limit while Effurun market have more of its physico-chemical parameter above the stipulated guideline value. The water quality index also showed that NPA Expressway Ekpan had the best water quality with WQI of 81.14 while Effurun market had the least water quality with WQI of 49.38.

Recommendation

It is highly recommended that further research be carried out by scientist and expert in this area especially as it concerns bacteriological test which was not well researched in this study. Also, radiological test has become necessary due to industrial set up around the study area. Open dump site should be discouraged to prevent leachate from infiltrating to join ground water.

DECLARATION

Acknowledgement

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Authors' contributions

The Corresponding author have contributed more to this work than the co-author.

Competing interests

The authors declare that they have no competing interest.

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