Effects of Solid Waste Disposal on the Groundwater Resources of Okene and Environs, Kogi State, North Central Nigeria

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Abstract
Evaluation of the solid waste disposal on the groundwater resources of Okene metropolis was carried out with the view of assessing the hydrochemical quality of the shallow groundwater system. The research methods applied involved field sampling and in situ measurements of physico-chemical parameters followed by hydrochemical analyses of the water samples. In situ measurements revealed Electrical conductivity (EC) value ranging from 2.00 to 1717.00µS/cm (average 688.04µS/cm) and the pH value ranged from 7.00 to 9.00 (average 7.37). Results of the study show that the cationic and anionic concentration varies as follows: Mg^{2+} ranges from 1.90 to 1532.29mg/l, (average 538.44 mg/l). Ca^{2+} ranges from 70.50 to 1540.00mg/l, (average 410.23mg/l) K^{+} ranges from 0.40 to 122.10mg/l, (average 20.9mg/l). Na^{+} ranges from 0.20 to 2.10mg/l, (average 0.76mg/l). Fe ranges from 0.00 to 0.35mg/l, (average 0.07mg/l). HCO3- ranges from 30.30 to 2010.00mg/l, (average 798.29mg/l) Cl^{-} ranges from 3.00 to 176.40mg/l, (average 98.14mg/l). $SO4^{2-}$ ranges from 0.80 to 42.10mg/l, (average 19.89mg/l). The study also reveals that the groundwater in areas where solid wastes are being dump, in most cases, is slightly alkaline (pH ranges from 7.00 to 9.00), slightly saline (TDS varies from 124.00 to 7839.00mg/l), and belongs to the following hydrochemical facies; Mg-Ca-HCO_3, Mg – HCO_3, Ca-Mg-HCO_3, Ca-HCO_3 and Ca-HCO_3-Cl in order of increasing dominance. The abundance of chemical concentrations in groundwater within the study area is in order of Mg > Ca > K > Na for the major cations and HCO_3^- > Cl > SO_4^{2-} for the major anions. Statistical correlation reveals positive correlation between most of the parameters. Heavy metal parameters such as Cu, Pb, and others such as Cl, NO_3, H_2S in most of the sampled areas are above World Health Organisation, Nigeria Standard for Drinking Water Quality and European Union Standards for drinking water. Conclusively, Shallow Groundwater resources in the study area is considered to be unsafe for drinking purposes but can be considered excellent for irrigation with respect to Percentage sodium (Na%), sodium Adsorption ratio (SAR) and bicarbonate hazard.

Keywords: Groundwater, Hydrochemical Quality, Hydrochemical Facies, Solid Waste, Drinking Water

INTRODUCTION

Groundwater resources evaluation and re-evaluation plays a significant role in the sustainability of groundwater resources and management globally. Factors mitigating the quality of groundwater include; Increase in rate of population, rural urban migration, high rate of industrialization, increased urbanization, poor drainage system, environmental hazards such as indiscriminate disposal of refuse and sewages. Okene in Kogi State is one of the fast-developing commercial cities in the state, it is a highly densely populated town surrounded with very massive high hills and mountains. Groundwater (dug wells and boreholes) is a reliable alternative to the epileptic public pipe-borne water supply and its quality makes it the safest source of water for drinking and allied purposes as a result of the natural filtration effect of earth materials through which it infiltrates and percolates (Musa *et al.*, 2014; Adabanija *et al.*, 2015). Groundwater constitute the most abundant source of freshwater on earth, it is less susceptible to pollution just as it is cheaper to access compared to surface sources (Jha *et al.,* 2007; Ahmed II *et al.*, 2013). However, with the growth in population and its resultant pressure on groundwater usage, the quality of this critical resource is no longer guaranteed as many cases of health problems may result from its consumption (Jasrotia *et al.,* 2012; Ahmed II *et al.,* 2016).

The quality of groundwater all over the world is deteriorating at a fast rate due to industrialization, urbanization, indiscriminate disposal of refuse, sewage and agricultural activities (Akankpo *et al.,* 2012). Many shallow aquifers are now potentially vulnerable to pollution from agricultural (fertilizers), domestic (waste dumps, latrines) and industrial sources, except where surface layers afford some protection of the underlying aquifers.

Determination of groundwater quality for consumption has been the subject of many researches. Musa and Akuh, (2020) found high pH and high concentration of total dissolved solids (TDS) in groundwater from wells and boreholes closely located to refuse dumps in Lokoja metropolis. Similarly, Adabanija *et al.* (2015) in their water quality studies of part of Ogbomoso found high electrical conductivity (EC) which was strongly correlated with high TDS and chloride concentrations in groundwater close to a waste dump site. Indiscriminate dumping of abattoir wastes was also found to affect the concentration of TDS, EC, chloride and nitrate in groundwater around abattoir areas (Magaji and Chup, 2012; Ahmed II *et al.*, 2016).

Information on the status and changing trends in water quality is important to formulate suitable guidelines for quality assessment, monitoring and enforcement of prescribed limits. This work is therefore aimed at re-appraising the effect of solid waste disposal on the physicochemical quality of groundwater resources within Okene metropolis in Kogi State.

Determination of water quality for consumption has been the subject of many researches (Ayuba *et al.,* 2019; Oyelami *et al.,* 2013; Talabi and Tijani, 2013; Musa *et al.,* 2013; Egbunike, 2007; Omada *et al.,* 2011)

GEOLOGICAL SETTING

The geology of Okene and its environs is localized within the gneiss - migmatite - quartzite unit of the Nigeria Basement Complex (Akinrinsola and Adekeye, 1993). Adegbuyi (1981) reported that migmatite gneiss series is exposed almost throughout the whole of the area. Some parts of the exposures are represented by a uniform measure of migmatite biotitic gneisses and migmatites with thin horizons and intercalations of amphibolites. These exposures are located between Okene and Lokoja (Figure 1).

Olade, (1978) noted that the dominant lithological units in the area are the granodiorite – tonalite gneiss, overlain by a sequence of low-grade metasediments and intruded by granodiorites and granitic rocks. The main rock types identified in the area include granite gneiss, amphibolites, quartzites, schists, granites and pegmatites. The quartzites in the area are ferruginous and non - ferruginous with the ferruginous quartzites occurring as magnetite - rich and hematite - rich bands and lenses of 10m - 60m wide in alternation with gneisses. The three main ore bodies delineated in the area comprise of a group of ferruginous quartzite bands or lenses. The ore deposits have been folded and faulted and affected by regional metamorphism.

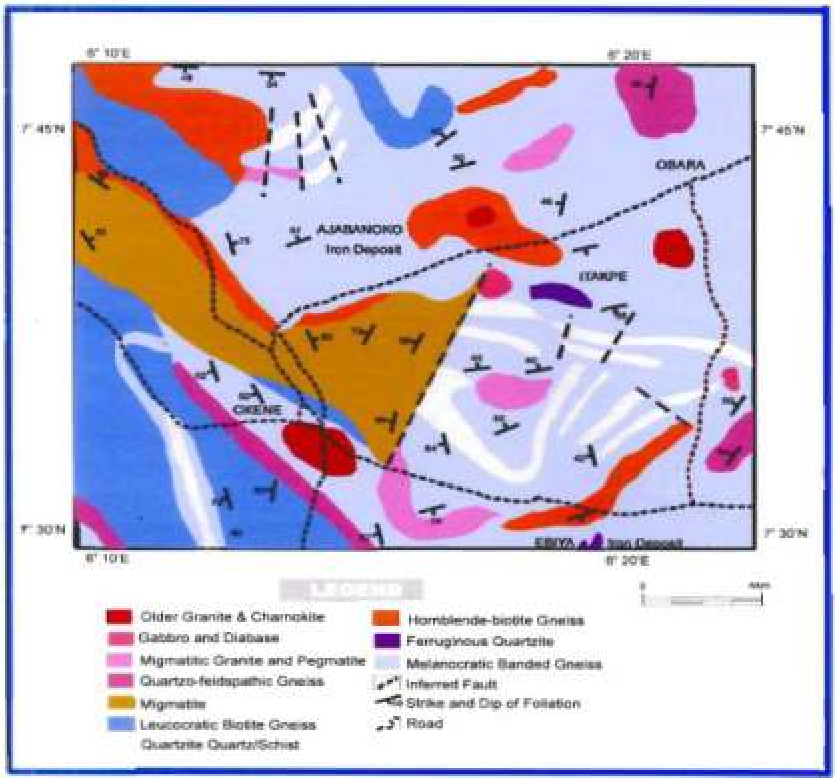

Figure 1: Geologic map of Okene area (modified from Adegbuyi, 1981)

MATERIALS AND METHODS

Twenty-seven (27) water samples from twenty-seven locations close to refuse dumps were collected within Okene Metropolis. Sampling was restricted to groundwater from hand dug wells and boreholes. Sixty (60) ml of water samples was collected from each of the twenty-seven locations. The water samples for cationic analysis were acidified to pH 2 with concentrated nitric acid at the point of collection. The samples were adequately labelled and refrigerated prior to analysis.

The temperature, pH, total dissolved solids (DS) and electrical conductivity (EC) were measured in the field and compared with the analyzed physical parameters of the water sample. Analysis of collected samples was done at the Multi User's laboratory, Ahmadu Bello University Zaria, Kaduna State using ICP – OES method.

RESULT AND DISCUSSION

Table 1 presents results of the physical and chemical characteristics of the groundwater sampled from twenty-seven locations within the Okene metropolis. Table 2 is the summary of their characteristics and the mean values in comparison with the World Health Organization (WHO) standards, Nigeria Standard for Drinking Water Quality (NSDWQ) and European Union (EU) standards for drinking water.

The total dissolved solid (TDS) values range between 124.00mg/l to 7839.00mg/l with an average of 744.37mg/l; these in most cases were generally less than 1000 mg/l, which indicate fresh and brackish water class according to the Classification of water based on total concentration of dissolved solids (Van der Aa, 2003). The pH values range between 7.00 and 9.00 with an average of 7.37. All samples with the exception of sample SL 6 (Felele), fall within the permissible pH limit of 6.5 to 8.5 for drinking water standard WHO, NSDWQ, and EU. This shows possible presence of free CO_3 meaning that the dissolved anions exist almost entirely in Bicarbonate (HCO_3) ion (Freeze and Cherry, 1979). Electrical conductivity (EC) values range between 2.00 to 1717.00µS/cm with an average of 688.04mg/l. Total dissolved solids (TDS) concentration ranges from 124.00 to 7839.00 mg/l (average 744.37mg/l). Magnesium is the dominant cation with its values ranging from 1.90 and 1532.30 mg/l (average 538.44mg/l) while the concentration of Calcium ranges from 70.50 to 1540.00 mg/l (average 410.23mg/l). Potassium ranges from 0.40 to 122.10mg/l (average 20.98mg/l). The concentrations of Sodium ranged from 0.20 to 2.10mg/l (average 0.76mg/l).

Bicarbonate is the dominant anion with concentration ranging from 30.30 to 2010.00mg/l (average 789.29mg/l). This is followed by Nitrate concentrations ranging from 4.50 to 489.00mg/l (average 102.87mg/l). About 44% of the samples analyzed which represent groundwater from Obangede Junction 1, Iruvucheba 1, Iruvucheba 2, Orietesu Okene 1, Idoji, Ipaku 2, Uhucheba, Ebogogo 1, Ebogogo 2, Inike and Enyinurawa have nitrate concentration above the World health standard WHO, (2011), NSDWQ (2007), and EU (2020) (Table 1).

Chloride concentration in groundwater within the studied area ranges from 3.00 to 176.40mg/l with an average of 98.14mg/l. by World health organization WHO, NSDWQ, and EU maximum permissible limit of 250.00mg/l. Sulphate has concentrations in the range of 0.80 to 42.10mg/l (average 19.89mg/l), while Oxygen (O_2) concentrations ranged between 1.70 and 7.40mg/l (average 6.45 mg/l). The presence of sulphate in drinking-water can cause noticeable taste and very high concentration might cause laxative effect to unaccustomed consumers WHO, 2011 NSDWQ 2007, and EU 2020. All samples analyzed had sulphate concentration below maximum permissible limit of 100mg/l WHO (2011). The concentration of Hydrogen Sulphide (H_2S) ranged between 38.40 and 92.00mg/l (average 41.08mg/l). All samples analyzed have H_2S concentration above the WHO (2011), NSDWQ (2007), and EU (2020) maximum permissible limit of 0.05mg/l and 0.05 – 1 mg/l respectively. Water containing hydrogen sulfide does not pose any direct health risk but impacts a “rotten egg” smell and taste. Hydrogen sulfide formed by bacteria that may occur naturally in water and use sulfur in decaying plants, rocks or soil as their food or energy source and produce hydrogen sulfide as a byproduct. For the Heavy Metals, Copper is dominant with concentration ranging between 14.90 and 45.20mg/l (average 26.41mg/l). The concentration of Lead ranged between 0.00 and 8.00mg/l (average 0.99mg/l). The concentration of Zinc ranged between 0.10 and 0.30mg/l (average 0.15mg/l). The concentration of Iron ranged between 0.00 and 0.35mg/l (average 0.07mg/l).

The concentration of Copper ranges from 14.9 to 45.2mg/l (average 26.41mg/l). High concentration of Copper in the groundwater usually arises from the corrosive action of water leaching into the soil. This corrosive action of water is often accelerated by high levels of dissolved oxygen in water. The analysis reveals concentration of 1.70 to 7.40mg/l with an average of 6.45mg/l for samples analyzed. At concentration above 5 mg/l copper affects the colour and adds an undesirable bitter taste to the water. Maximum permissible limit of copper concentration in water for drinking and domestic uses is set at 1.00mg/l; consumption of water with concentration above this value causes gastrointestinal disorder. All samples analyzed have iron concentration far above the 1 mg/l and 2 mg/l guidelines WHO, NSDWQ, and EU. The concentration of iron in groundwater within the study area ranges from 0.00 to 0.35mg/l (average 0.07mg/l). The concentration of Zinc ranges from 0.10 to 0.30mg/l (average 0.15mg/l). This falls below the permissible limit of 3.00 mg/l. Zinc in drinking water has no direct health impact but creates an undesirable astringent taste to water at a taste threshold concentration of about 4mg/l. Water containing zinc at concentrations in excess of 3.00 to 5.00mg/l may appear opalescent and develop a greasy film on boiling WHO, NSDWQ and EU. Zinc in groundwater results from zinc leaks from zinc pipes and rain pipes, Car tires containing zinc and motor oil from zinc tanks which releases zinc compounds on roads, zinc compounds present in fungicides and insecticides and from solid waste refuse dumps, chemical waste dumps and landfill. The concentration of lead ranges from 0.00 to 8.00 mg/l (average 0.99mg/l).

Seventeen of the samples analyzed have elevated lead concentration above the 0.30mg/l maximum permissible limit (WHO, NSDWQ and EU). These includes water samples from Obangede Junction 1, Obangede Junction 2, Orietesu Okene 1, Orietesu Okene 2, Idoji, Ipaku 2, Uhucheba, Ebogogo 1, Kuroko, Ahache, Agassa, Enyinare 2, Obehira Uvete, Okengwe, Nagazi Eba, Nagazi, Eika Adayu and F.C.E. areas of Okene Metropolis (Table 1). Lead can get into water from lead pipes and solder in older water systems, children exposed to lead in water can suffer mental retardation. Lead poisoning also results when water with high lead concentration is consumed or when plants and animals that have taken up high concentration of lead are consumed by humans.

Hydrochemical facies

The major ions concentrations were used in plotting the Piper trilinear diagram (Piper 1944) Schoeller diagram (Schoeller 1964) and Wilcox diagram where the ions in milliequivalent per litre are expressed in percentages of cations and anions (Figures. 2, 3 and 4). Plots of hydrochemical parameters of the groundwater show that 90% of the water falls within the high-alkaline proportion type, predominantly bicarbonate and sodium, and 10% belongs to the normal earth alkaline water proportion. The abundance of chemical concentrations in groundwater within the study area is in order of Mg > Ca > K > Na for the major cations and HCO_3^- > Cl > SO_4^2 for the major anions (Table 3). The water characterization shown in the diagrams (Figures. 2 and 3) presents five main hydrochemical facies namely: Mg-Ca-HCO_3, Mg-HCO_3, Ca-Mg-HCO_3, Ca-HCO_3 and Ca-HCO_3-Cl in order of increasing dominance.

TABLE 1: RESULTS OF WATER ANALYSIS FROM OKENE METROPOLIS

Location	Sample ID	Ph	TDS	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	Fe	Cl^-	HCO_3	NO_3	SO_4	Cu	Zn	Pb	D.O	H_2S
Obangede Junction 1	SL 1	7.0	358.0	734.0	0.7	23.0	474.3	1.9	0.0	3.0	676.7	78.8	0.8	34.1	0.2	0.7	7.4	39.0
Obangede Junction 2	SL 2	8.0	254.0	526.0	0.3	9.8	431.8	2.8	0.2	162.2	646.4	10.9	7.0	41.6	0.1	0.6	4.5	38.8
Idanhuha	SL 3	8.0	301.0	632.0	0.4	12.1	482.4	110.3	0.0	66.9	676.7	9.3	5.6	17.2	0.2	0.1	6.8	39.4
Iruvucheba 1	SL 4	7.0	450.0	942.0	0.5	1.5	514.7	72.1	0.0	87.2	929.2	98.0	40.4	22.4	0.1	0.0	7.4	39.6
Iruvucheba 2	SL 5	7.0	345.0	721.0	0.7	17.6	512.7	540.6	0.1	74.4	686.8	89.9	35.3	19.1	0.1	0.0	7.4	39.2
Orietesu Okene 1	SL 6	7.0	1015.0	2.0	1.9	77.6	262.2	578.4	0.1	87.2	1090.8	258.4	28.0	22.4	0.3	8.0	5.6	39.6
Orietesu Okene 2	SL 7	8.0	785.0	1558.0	1.5	55.6	72.4	533.1	0.0	159.2	848.4	39.2	29.5	40.8	0.1	0.4	6.7	39.0
Ikpaku	SL 8	7.0	835.0	1717.0	1.8	57.2	254.2	583.1	0.2	77.8	868.6	42.7	41.3	20.0	0.1	0.1	1.7	39.2
Idoji	SL 9	7.0	1123.0	2.0	0.2	72.6	70.5	554.5	0.0	67.7	868.6	489.0	11.7	17.4	0.1	0.7	7.0	39.0
Karaworo	SL 10	7.0	339.0	7.0	0.5	8.5	540.6	34.1	0.0	58.1	727.2	44.2	13.5	14.9	0.1	0.0	7.3	39.2
Ipaku 2	SL 11	7.0	611.0	1255.0	0.6	0.4	533.1	1157.1	0.0	120.5	1404.0	329.0	16.5	30.9	0.1	1.0	6.9	39.2
Uhucheba	SL 12	8.0	600.0	1234.0	0.8	4.3	532.9	1108.7	0.0	129.1	1282.8	235.9	24.6	33.1	0.2	0.7	7.1	39.6
Ebogogo 1	SL 13	7.0	596.0	1547.0	1.4	1.2	532.3	854.0	0.0	94.7	1060.5	202.3	25.2	24.3	0.2	0.5	7.3	39.0
Ebogogo 2	Sl 14	7.0	535.0	1083.0	0.7	15.8	537.4	1045.9	0.0	140.5	1252.4	261.1	18.0	36.0	0.1	0.2	7.2	38.8
Kuroko	SL 15	7.0	434.0	920.0	0.7	4.5	1374.5	761.2	0.1	169.5	919.1	25.0	20.1	43.5	0.1	0.6	4.8	39.2
Ahache	SL 16	8.0	164.0	337.0	0.4	4.3	954.3	382.6	0.0	80.7	525.2	32.2	42.1	20.7	0.1	0.6	6.8	92.0
Agassa	SL 17	9.0	127.0	272.0	0.4	10.7	578.8	549.2	0.1	131.6	373.7	32.5	40.1	33.7	0.1	0.9	6.5	38.4
Agassa Uvete	SL 18	7.0	166.0	357.0	0.4	4.5	1540.0	407.8	0.1	91.2	545.4	18.0	14.6	23.4	0.2	0.0	7.2	39.8
Ekuku	SL 19	8.0	7839.0	175.0	0.2	0.7	110.3	377.5	0.2	64.3	474.7	5.5	13.4	16.5	0.1	0.0	7.4	39.2
Enyinare 1	SL 20	7.0	137.0	295.0	0.4	5.5	72.6	238.2	0.1	66.7	343.4	36.1	13.7	17.1	0.1	0.0	6.6	39.4
Enyinare 2	SL 21	7.0	498.0	1050.0	1.0	32.1	86.6	253.1	0.1	76.8	30.3	24.0	11.7	19.7	0.3	1.9	4.8	39.2
Inike	SL 22	7.0	368.0	780.0	0.5	1.9	105.0	846.2	0.0	76.9	939.3	124.9	14.4	19.7	0.2	0.1	7.0	38.6
Enyinurawa Obehira Uvete	SL 23	8.0	1206.0	252.0	2.1	122.1	101.1	1532.3	0.1	176.4	2010.0	184.9	12.4	45.2	0.2	6.2	7.3	39.0
Okengwe	SL 24	7.0	124.0	268.0	0.3	6.1	99.7	403.8	0.35	114.9	484.8	9.8	11.9	29.5	0.2	0.8	4.0	38.4
Nagazi Eba	SL 25	7.0	403.0	854.0	0.8	3.8	105.1	696.7	0.1	118.7	777.7	46.2	14.5	30.4	0.1	1.5	6.7	39.2
Nagazi	SL 26	8.0	321.0	703.0	0.9	7.4	97.9	565.4	0.0	87.5	686.8	4.5	14.3	22.4	0.2	0.6	7.3	39.2
EikaAdayu F.C.E.	SL 27	7.0	164.0	354.0	0.4	5.6	98.9	347.3	0.1	66.2	424.2	45.1	16.4	17.0	0.2	0.7	7.4	39.0

TABLE 2: STATISTICAL SUMMARY OF MEASURED PARAMETERS

Parameter	Min	Max	Average	(WHO, 2011) recommended	(WHO, 2011) max permissible	NSDWQ 2007	EU 2020
pH	7.0	9.0	7.37037	6.5	8.5	6.5 – 8.5	6.5 – 8.5
TDS	124.0	7839.0	744.3704	500	1000	500	-
Cond	2.0	1717.0	688.037	250	1480	1000	250
Na	0.2	2.1	0.759259	-	200	-	-
K	0.4	122.1	20.97778	10	15	-	-
Ca	70.5	1540.0	410.2333	75	200	75	-
Mg	1.9	1532.3	538.4407	50	150	0.20	-
Fe	0.0	0.35	0.072222	0.3	1.0	-	-
Cu	14.9	45.2	26.40741	0.5	2.0	1	2
Zn	0.1	0.3	0.151852	1.0	3.0	3	5
Pb	0.0	8.0	0.996296	0.4	0.4	0.01	0.01
Cl	3.0	176.4	98.14444	250	600	250	-
HCO_3	30.3	2010.0	798.2852	Variable	Variable	-	-
NO_3	4.5	489.0	102.8667	-	50	50	-
SO_4	0.8	42.1	19.88889	250	500	100	-
O_2	1.7	7.4	6.448148	-	-	5.0	-
H_2S	38.4	92.0	41.08148	-	-	-	-

The Mg-Ca-HCO3, hydrochemical facies are about 70 %, while the Mg-HCO_3, Ca-Mg-HCO_3, Ca-HCO_3 and Ca-HCO_3-Cl hydrochemical facies are about 30 %. From the Piper plot (Figure 2) an evaluation of the hydrochemistry of groundwater in areas close to refuse dump in Lokoja metropolis was done. The possible source of the high Mg and Ca in this groundwater from the areas around the refuse dump site could probably be due to the dissolution of plagioclase feldspars. However, the high concentration of HCO_3 and NO_3 might have been generated within the soil zone and infiltrate to the groundwater zone as a result of decomposition of organic matter, which releases carbon dioxide that reacts with water in the soil zone. The reaction suggests weak carbonic acid (H_2CO_3) that aids the breakdown of minerals in the rocks resulting in dissolution and the release of the ions into the groundwater which was responsible for its hydrochemical characteristics.

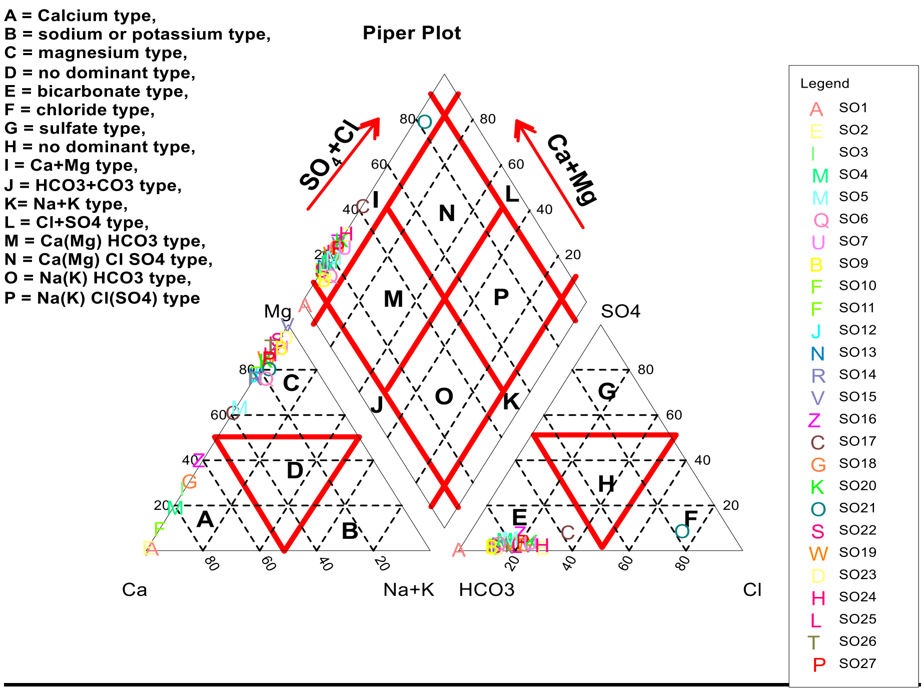

Figure 2: Piper diagram of groundwater in Okene and environs

The Gibb's Plots of hydrochemical parameters of the groundwater $Na^+/(Na^+ + Ca^{2+})$ against TDS show that over 90% of the water falls within the rock dominance, less than 10% belongs to the evaporation dominance while no plot falls within the precipitation dominance (Figure 5).

Correlation analysis

Statistical correlation method explains correlation analysis of some relevant hydrochemical relationships between the following parameters: HCO_3, K, Ca, Mg, Fe, Cl, CO_3, SO_4 and SiO_2 (Table 3). The content of TDS has high positive correlation with Pb (0.56). Na has high positive correlation with K (0.7), Pb (0.63), and HCO_3 (0.54). Mg also shows strong correlation with the contents of Cl (0.56), HCO_3 (0.78) and NO_3 (0.53). Cu and Cl, Zn and Pb, HCO_3 and NO_3 have correlations of 0.73, 0.56 and 0.6 respectively. These positive correlations suggest that these ions could have the same source.

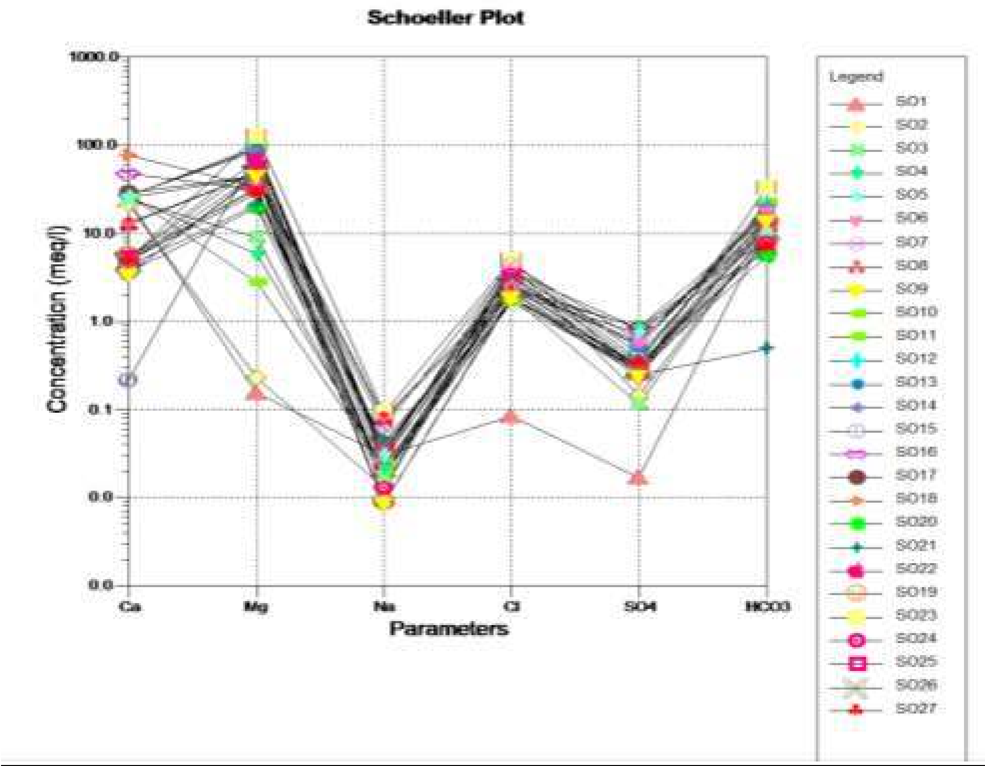

Figure 3: Piper diagram of groundwater in Okene and environs

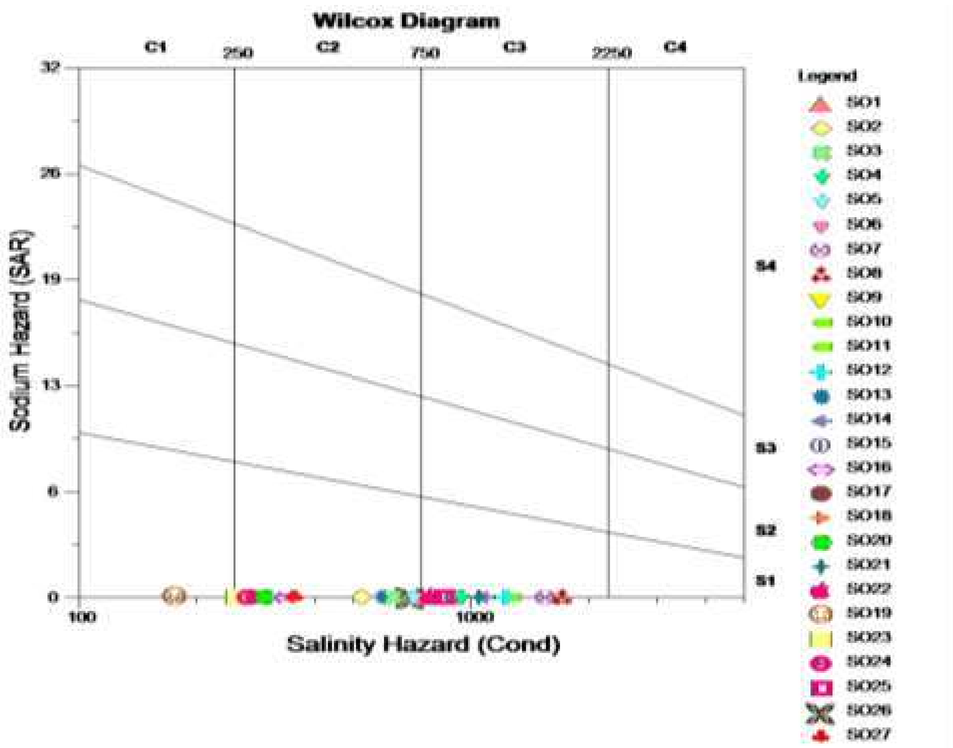

Figure 4: Wilcox diagram of groundwater in Okene and environs

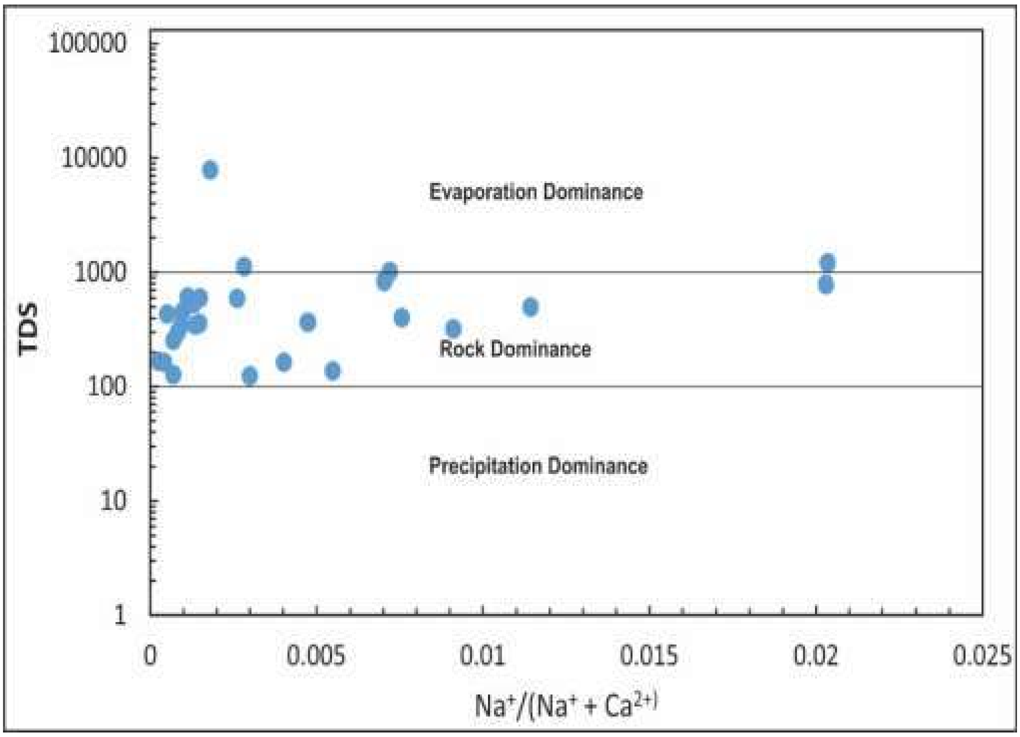

Figure 5: Gibb's diagram for the groundwater samples in Okene and environs

CONCLUSION

Evaluation of the hydrochemical data from this study has reveals the general quality of groundwater within areas close to refuse dump in Okene metropolis. From the interpreted results, the possible source of the high Magnesium (Mg) and Ca in this groundwater from the areas around the refuse dump site could probably be due to the dissolution of these solid wastes. High concentration of bicarbonate and nitrate in the groundwater results from pollution arising from agricultural activities such as excess application of nitrogenous fertilizers and manures, waste water disposal and oxidation of nitrogenous waste products in human and animal excreta. The plot for groundwater TDS(mgl) versus Na(Na+Ca) shows rock dominance. For copper, the concentration ranging from 15.6 to 50.1mg/l with an average of 38.72 mg/l is far higher than 5mg/l recommended maximum permissible limit. This affects the colour and adds bitter taste to the water and can also cause gastrointestinal disorder. The study also reveals that the groundwater in areas where solid wastes are being dump, in most cases, is slightly alkaline pH ranged from 7.00 to 9.00 (average 7.37), slightly saline (TDS) varies from 124.00 to 7839.00 mg/l, and belongs to the following hydrochemical facies; Mg-Ca-HCO_3, Mg-HCO_3, Ca-Mg-HCO_3, Ca-HCO_3 and Ca-HCO_3-Cl in order of increasing dominance. Therefore, this study reveals that the groundwater within the sampled areas of Okene metropolis is slightly polluted and not suitable for drinking purposes, due to the fact that most of the heavy metal parameters such as Cu, Pb, and others such as Cl, NO_3, H_2S in most of the sampled areas are above World Health Organisation, Nigeria Standard for Drinking Water Quality and European Union Standards for drinking water but can be considered excellent for irrigation with respect to percentage sodium (Na %), sodium Adsorption ratio (SAR) and bicarbonate hazard.

TABLE 3: OKENE CORRELATION MATRIX

	pH	*TDS*	*EC*	*Na+*	*K+*	*Ca2+*	*Mg2+*	*Fe*	*Cl-*	*HCO3*	*NO3*	*SO4*	*Cu*	*Zn*	*Pb*	*D.O*	*H2S*
pH	1																
TDS	0.201088	1															
EC	-0.12663	-0.16971	1														
Na+	-0.02477	-0.06264	0.37998	1													
K+	0.063259	0.04115	-0.11927	0.706962	1												
Ca2+	-0.0288	-0.21534	0.030996	-0.2067	-0.33429	1											
Mg2+	0.058569	0.026309	0.293382	0.472084	0.335892	-0.02357	1										
Fe	-0.01718	0.249191	-0.22666	-0.02933	0.046039	-0.15147	-0.14427	1									
Cl-	0.350644	-0.11573	0.228189	0.278405	0.202529	0.147292	0.561505	0.168235	1								
HCO3	-0.01459	-0.01947	0.231167	0.539337	0.473974	0.012463	0.774706	-0.29806	0.470534	1							
NO3	-0.248	-0.01796	0.027425	0.160008	0.386087	-0.12286	0.530001	-0.3941	0.06722	0.601866	1						
SO4	0.177735	-0.0954	0.280245	0.256885	0.02559	0.202379	0.119865	-0.06031	0.145792	0.038809	-0.01256	1					
Cu	0.300259	-0.16624	0.268089	0.295792	0.236017	0.188584	0.431581	0.075501	0.791901	0.483323	0.047935	-0.06496	1				
Zn	-0.12555	-0.13176	-0.0808	0.347099	0.226812	-0.15364	0.047667	0.026424	-0.20622	-0.02227	0.018852	-0.30425	-0.12671	1			
Pb	0.038418	0.015789	-0.29187	0.658458	0.708615	-0.20969	0.36272	0.10864	0.234878	0.445016	0.302607	-0.0115	0.24037	0.529133	1		
D.O	0.120337	0.119454	-0.24258	-0.25365	-0.1736	0.046148	0.114908	-0.64589	-0.19427	0.179892	0.236584	-0.15471	-0.12229	-0.02948	-0.07165	1	
H2S	0.215231	-0.07748	-0.14	-0.13052	-0.11059	0.29498	-0.08541	-0.17281	-0.09348	-0.13574	-0.11518	0.386089	-0.13288	-0.15599	-0.03907	0.056904	1

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