EFFECTS OF SOLID WASTE DISPOSAL ON THE GROUNDWATER RESOURCES OF LOKOJA METROPOLIS, KOGI STATE, NORTH CENTRAL, NIGERIA

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Abstract
Assessment of Groundwater quality is very vital for a sustainable groundwater resources management. The quality of groundwater all over the world is deteriorating at a fast rate due to industrialization, urbanization, indiscriminate disposal of refuse and sewages. Assessment of the effect of solid waste disposal on the groundwater resources of Lokoja metropolis was undertaken with emphasis on the hydrochemical quality of the shallow groundwater system. The study approach 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 ranges from 214.00 to 1703.00 µS/cm (av 734.93 µS/cm) and The pH value ranges from 6.00 to 8.80 (av 7.70). Results of the analysis shows that the cationic and anionic concentration varies as follows: Mg^{2+} ranges from 22.00 to 775.50 mg/l, (av 314.70 mg/l). Ca^{2+} ranges from 1.50 to 106.00 mg/l, (av 33.20 mg/l) K^{+} ranges from 9.40 to 134.00 mg/l, (av 23.83 mg/l). Na^{+} ranges from 18.60 to 4789.00 mg/l, (av 0.65 mg/l). Fe ranges from 0.02 to 5.70 mg/l, (av 0.04 mg/l). HCO_3^- ranges from 126.00 – 3111.00 mg/l, (av 720.20 mg/l). Cl^- ranges from 5.0 to 2625.00 mg/l, (av 63.36 mg/l). $SO4^{2-}$ ranges from 12.50 to 16.90 mg/ l, (av 19.06 mg/l). The study also reveals that the groundwater in areas where solid wastes are being dump, in most cases, is slightly alkaline (pH ranging from 6.01 to 8.77), slightly saline (TDS ranging from 98.60 to 816.00 mg/l), and belongs to seven hydrochemical facies, namely: Ca-Mg-Cl-HCO_3, Ca-Mg-HCO_3, Mg-Ca, Mg-Ca-Cl-HCO_3, Mg-Ca-HCO_3, Mg-Ca-HCO_3-Cl and Mg-HCO_3. The dominant hydrochemical facies are Mg–HCO_3 and Mg-Ca-HCO_3 while Ca–Mg–Cl- HCO_3, Ca-Mg-HCO_3, Mg – Ca and Mg-Ca-Cl-HCO_3 constitute the minor water type. Statistical correlation reveals positive correlation between most of the parameters. With the exception of Na, Fe, Zn, and Cl, all other parameters are mostly above the World Health Organisation (2011) standards for drinking water. Conclusively, the overall hydrochemical facies with TDS values of over 500.00 mg/l in most of the sampled areas reveals that the groundwater is slightly polluted and may be considered not suitable for drinking but very suitable for irrigation purpose due to its low Sodium hazard and low salinity.

Keywords: ***Groundwater, Hydrochemical Quality, Hydrochemical Facies, Solid Waste, Drinking Water, Lokoja, Kogi State***

1.0. Introduction
The quality of groundwater all over the world is deteriorating at a fast rate due to industrialization, urbanization, indiscriminate disposal of refuse and sewage, agricultural activities such as the use of various kinds of fertilizers which eventually results in gradual release or dissolution of organic or inorganic toxic materials that affects the quality of groundwater. Groundwater is the safest source of water for drinking purposes as a result of the natural filtering effect of the earth materials through which it infiltrates and percolates.

According to Vasanthi *et al.* (2008), solid wastes are being dumped on land indiscriminately, without proper sanitary land filling practices. Precipitation that infiltrates the solid wastes disposed on land mixes with the liquids already trapped in the crevices of the waste and leach compounds from the solid waste. The leachate thus formed contains dissolved inorganic and organic solutes. In course of time, the leachate formed diffuses into the soil and changes the physico- chemical characteristics of water. Leachate from a solid waste disposal site is generally found to contain major elements like calcium, magnesium, potassium, nitrogen and ammonia, trace metals like iron, copper, manganese, chromium, nickel, lead and organic compounds like phenols, polyromantic hydrocarbons, acetone, benzene, toluene, chloroform etc. (Freeze and Cherry 1979 *in* Vasanthi *et al.,* 2008). The concentration of these elements in the leachate and water depends on the composition of wastes (Alker *et al.,* 1995 *in* Vasanthi *et al.,* 2008). Some of the pollutants may be adsorbed on to the soil media during the flow of leachate through the soil.

Most of these inorganic materials are essential to all living things at minimal concentrations but become hazardous at higher concentration. Heavy metals get into the groundwater from many sources such as automobile exhaust, mines, and even natural plants and soil. Their concentrates increase as the animals feed on plants and are consumed in turn by other animals. When they reach high levels in the body, these heavy metals become poisonous, or can result in long-term health problems. Determination of water quality for consumption has been the subject of many researches (Oyelami *et al.,* 2013; Talabi and Tijani, 2013; Musa *et al.*, 2013; Egbubike, 2007; Omada *et al.,* 2011).

Ayuba *et al.* (2019) assessed the suitability of groundwater within Lokoja metropolis and its environs for human consumption using water quality index (WQI) technique based on methods described by Vasanthavigar *et al*. (2010) and WHO (2006) guidelines for drinking water quality. It revealed that 59.0% of the groundwater samples represents "excellent water", 33.3% represents "good water" and 7.7% of "poor water. The poor water quality" recorded in the eastern part of the study area is a reflection of poor hygienic prac-tice in this populated area, and hence the anthropogenic contamination (Ayuba *et al.,* 2019). 69.2% of the groundwater samples within Lokoja were found suitable for irrigation purposes; while 20.8% of the samples were unsuitable. Therefore, this work is aimed at re-appraising the effect of solid waste disposal on the physicochemical quality of groundwater resources within Lokoja metropolis.

2.0. Geological Setting

Lokoja metropolis is predominantly underlain by crystalline rocks which are generally strongly folded rocks, forming part of the Basement Complex of Nigeria. The remaining area is underlain by gently dipping Cretaceous and Tertiary sediments which nonconformably overlie the Basement Complex and forms part of the Southern Bida Basin. Recent alluvium covers a considerable area around the Niger/ Benue confluence in a continuous strip up to 4 km wide along the valley of the lower Niger between Lokoja and Idah (Geological Survey of Nigeria, 1986), (See Figure1).

The Bida Basin is a rift bounded NW-SE trending depression perpendicular to the main axes of the Benue Trough (Omada, 2005). Its development is closely related to the faulting associated with the drifting apart of the African and South American plates during the late Jurassic- Cretaceous (Kogbe *et al*., 1981; Whiteman, 1982; Ojo and Ajakaiye, 1989).

Falconer (1911) named the Cretaceous sedimentary rocks in the southern Bida Basin around Lokoja as the Lokoja Series. Jones (1955) divided these sediments into two formations: The Lokoja Formation and the Patti Formation. The Lokoja Formation nonconformably overlies the Basement Complex. Lithologically, this formation ranges from conglomerates, fine to pebbly sandstone and siltstone to claystone. The rocks are generally poorly sorted and compose mainly of quartz and feldspar, and are therefore texturally and mineralogical immature (Ojo and Akande, 2003).

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The Patti Formation directly overlies the Lokoja Formation and it is the lateral equivalent of the Enagi Siltstone in the central Bida Basin. It is capped by Agbaja Ironstone (Adeleye and Dessauvagie, 1972). The Patti Formation consists predominantly of argillaceous rocks (siltstone, shale, claystone) with minor sandstone. The sandstone unit of this formation is more mineralogically mature compared to the Lokoja Formation in the southern Bida Basin and appears to have been formed under marine conditions (Abimbola *et al*., 1999).

The migmatite- gneiss complex dominates the Basement Complex in the study area consisting of fairly uniform biotitic- hornblende –gneisses with locally intercalated bands of amphibolite and quartzite (Geological Survey of Nigeria, 1986) (Figure 1). The degree of migmatisation varies from one part of the migmatite- gneiss complex to another and majorly, it increases from east to west. The rocks in the Kabba area, for example, appear to have been affected more than those near Lokoja (Geological Survey of Nigeria, 1986). The mineral foliations defined by alternating biotite-rich and quartz-feldspar rich are common in the gneiss (Obaje, 2009). Major foliation and fracture trends are in the NS and NNE, SSW directions markedly exhibited by the flow direction of the River Niger (Obaje, 2009).

Groundwater in the Lokoja area occurs in weathered/and or weathered/fractured basement rocks and is recharged by precipitation and by river Niger (Omali, 2014). Two aquifer types have been delineated in the area: weathered layer aquifer and weathered/fractured aquifer (Musa *et al*., 2014). The Lokoja area is generally drained by rivers Niger, Benue and Meme. Aquifer parameter data of the study area are relatively sparse (Ibrahim, *et al*., 2014). Based on aquifer test data, the static water level varies between 1.5 metres and 7.6 metres; well depth is between 8.2 metre and 21.8 metre; and yield is between 70 M^3/day and 130 M^3/day (Ibrahim, *et al*., 2014).

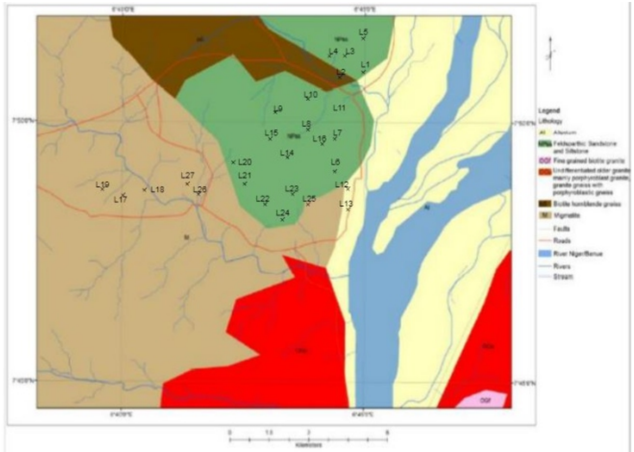

Figure 1: Geological map of Lokoja and Environs (modified after: Omali, 2014)

3.0. Materials and Methods

Twenty-seven (27) water samples were collected from twenty-seven locations close to refuse dump within Lokoja 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 (TDS) 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

4.0 Results and Discussion

Table 1 present result of the physical and chemical characteristics of the groundwater sampled from twenty-seven locations within the Lokoja metropolis. Table 2 is the summary of their characteristics and the mean values in comparison with the World Health Organization (WHO) standards (WHO, 2011) standards for drinking water.

The total dissolved solid (TDS) values ranges from 98.60 mg/l to 816.00 mg/l with an average of 388.70 mg/l; these in most cases were generally less than 1000.00 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). pH values ranges from 6.01 and 8.77 with an average of 7.67. All samples with the exception of sample SL 6 (See Table 1) fall within the permissible pH guideline values of 6.50 to 8.50 for drinking water standard by World health organization (WHO, 2011). This shows possible presence of free CO3 meaning that the dissolved anions exist almost entirely in HCO3 ion (Freeze and Cherry, 1979). Electrical conductivity (EC) values ranges from 214.00 to 1703.00 uS/cm with an average of 734.90 mg/l. Total dissolved solids (TDS) concentration ranges from 98.60 to 816.00 mg/l (av 388.73 mg/l). Magnesium is the dominant cation with its values ranging from 22.00 and 775.53 mg/l (av 314.68) mg/l) while the concentration of calcium ranges from 41.30 to 236.80 mg/l (av 85.94 mg/l). Potassium ranges from 1.50 to 74.60 mg/l (av 23.83 mg/l). The concentrations of Na ranges from 0.10 to 1.70 mg/l (av 0.65 mg/l).

Bicarbonate is the dominant anion with concentration of 40.40 to 7,547.00 mg/l (av 720.19 mg/l). This is followed by nitrate concentrations ranging from 1.19 to 360.24 mg/l (85.42 mg/l). About 63% of the samples analyzed which represent groundwater from Natako, Sarki Noma, Felele, Kogi SUBEB Office, Fegge, Old market; Rimi Street, Elphinestone Street, Otokiti Village, Mami Barracks, Lokongoma and Adankolo have nitrate concentration above The World Health Organization (WHO, 2011) permissible limit (Table 1).

Chloride concentration in groundwater within the studied area ranges from 14.80 mg/l to 184.00 mg/l with an average of 63.32 mg/l. All samples analyzed have chloride concentration which falls below The World Health Organization (WHO, 2011) maximum permissible limit of 250.00 mg/l. Sulphate has concentrations in the range of 7.00 to 54.00 mg/l (av 19.06 mg/L), while O2 concentrations ranges from 2.33 and 7.64 mg/l (av 5.78 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). All samples analyzed had sulphate concentration below maximum permissible limit of 100.00 mg/l WHO (2011).

The concentration of Hydrogen Sulphide ranges from 38.60 and 39.4 mg/l (av 39.16 mg/l). All samples analyzed have H2S concentration above the WHO (2011) maximum permissible limit of 0.05 mg/l to 1 mg/l. Water containing H2S 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, Cupper is dominant with concentration ranging from 15.60 and 50.10 mg/l (av 38.72 mg/l). The concentration of Lead ranges from 0.00 and 5.80 mg/l (av 0.28 mg/l). The concentration of zinc ranges from 0.02 and 0.29 mg/l (av 0.12 mg/l). The concentration of Iron ranges from 0.01 and 0.09 mg/l (av 0.04 mg/l).

The concentration of Cupper ranges from 15.60 to 50.10 mg/l (av 38.72 mg/l). High concentration of Cupper in the groundwater usually arises from the corrosive action of water leaching into the soil (WHO, 2011). This corrosive action of water is often accelerated by high levels of dissolved oxygen in water. The analysis reveals concentration of 15.60 mg/l to 50.1 mg/l with an average of 38.72 mg/l for samples analyzed. At concentration above 5

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mg/l cupper affects the colour and adds an undesirable bitter taste to the water (WHO, 2011). Maximum permissible limit of cupper concentration in water for drinking and domestic uses by by World Health Organization (WHO, 2011) is set at 1.00 mg/l; consumption of water with concentration above this value causes gastrointestinal disorder. All samples analyzed have iron concentration far above the 1.00 mg/l and 2.00 mg/l guidelines set by World Health Organization (WHO, 2011) respectively. The concentration of iron in groundwater within the study area ranges from 0.01 to 0.09 mg/l (av 0.04 mg/l).

The concentration of Zinc ranges from 0.02 mg/l to 0.29 mg/l (av 0.119 mg/l). This falls below the World Health Organization (WHO, 2011) 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 4 mg/l. Water containing zinc at concentrations in excess of 3.00 mg/l to 5.00 mg/l may appear opalescent and develop a greasy film on boiling (WHO, 2011). 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 mg/l to 5.80 mg/l (av 0.28 mg/l). Ten of the samples analyzed have elevated lead concentration above the 0.01 mg/l maximum permissible limit (WHO, 2011). These includes water samples from Natako, Sarki Noma, Felele, Otokiti Village, Angwa kura, Mami Barracks, Adankolo and Ganaja areas of Lokoja 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.

S/N	Location	Sample ID	PH	TDS	EC	Na	K	Ca	Mg	Cl	SO_4	HCO_3	Fe	Cu	Zn	Pb	NO3	D.O	H2S
1	Natako 1	SL 1	8.1	271	591	0.6	22.6	116	195.6	101.8	12.8	353.5	0.03	26	0.1	5.8	54.9	6.5	38.6
2	Natako 2	SL 2	7	125.2	284	0.2	6.4	96.8	96.7	84.3	13.3	242.4	0.04	22	0.1	0.6	24.6	6.7	39
3	Sarkinoma 1	SL 3	8.3	616	1292	1.2	47.8	115.7	361	61	14.6	636.3	0.1	16	0.1	0	185.4	4.9	39
4	Sarki noma 2	SL 4	8.3	672	1453	1.5	56.4	87.3	514.7	74.2	10.5	717.1	0.1	19	0.1	0.1	205.2	2.33	38.8
5	Sarki noma 3	SL 5	8.4	742	1562	1.7	39.2	115.5	506.5	87.8	12.3	777.7	0.03	23	0.1	0.1	61.2	6.6	39.2
6	Felele 1	SL 6	8.8	816	670	1.0	10.1	104.7	262.2	107.2	14.8	464.6	0.03	28	0.1	0	96.4	5.5	38.6
7	Felele 2	SL 7	7.1	127.2	281	0.3	8.2	102.4	72.41	67.9	11.7	222.2	0.05	17	0.02	0	1.2	6.6	39
8	Felele 3	SL 8	6.0	223	249	0.3	3.5	113.9	113.9	119.5	15.8	424.2	0.03	31	0.1	0.5	137.2	6.9	39.2
9	Kogi SUBEB	SL 9	6.7	98.6	214	0.3	6.1	73.2	70.5	170.4	13.1	171.7	0.08	44	0.02	0	50.5	5.9	39.4
10	Agwan Tiv	SL 10	7.9	158.3	341	0.5	15.8	100.5	34.1	184	14.3	151.5	0.02	47	0.1	0	39.8	5.8	39
11	Fegge	SL 11	7.3	436	925	0.9	37.6	57.8	330.9	14.8	20.4	484.8	0.04	43	0.1	0	126.6	6.6	39.2
12	Old Market 1	SL 12	7.8	346	720	0.7	44.5	93	468.2	23.9	22.1	666.6	0.02	46	0.1	0	82.1	6.5	39.4
13	Old Market 2	SL 13	8.5	384	810	0.8	46.5	112.5	225.8	28.9	12.6	464.6	0.01	41	0.2	0	163.8	7.3	39.4
14	Rimi Street	SL 14	7.4	645	1391	1.4	74.6	72.7	407.19	18.6	25.2	696.9	0.07	42	0.1	0	105.56	3.8	39
15	Elphinestone Str	SL 15	8.4	681	1470	1.4	61.8	75.9	571.28	19.5	15.4	7547.5	0.02	45	0.2	0	155.3	4.1	39.4
16	Agwan Kura	SL 16	7.7	102	222	0.3	10.3	90.6	22	23.2	13.4	131.3	0.07	49	0.15	0.1	31.5	7.6	39.2
17	Otokiti Village 1	SL 17	6.6	806	1703	1.4	70.1	150.2	569.4	48.2	25.2	707	0.06	48	0.29	0.2	360.2	2.5	39.2
18	Otokiti Village 2	SL 18	7.9	278	595	0.4	8.7	236.8	723.1	60.5	7	747.4	0.05	49	0.16	0	4.4	6.8	39.4
19	Mami Barracks	SL 19	7.4	450	953	0.6	4.7	43.7	775.53	23.3	15.4	848.4	0.05	47	0.21	0.1	108	4.6	39.4
20	Lokongoma 1	SL 20	8.4	260	563	0.5	16.2	47.2	292.9	49.3	26.6	313.1	0.04	47	0.12	0	58.0	5.17	39.2
21	Lokongoma 2	SL 21	7.3	791.7	418	0.2	1.5	43.3	272.3	15.8	12.6	474.7	0.03	45	0.12	0	28.5	6.5	39.4
22	Lokongoma 3	SL 22	7.3	305	642	0.3	1.7	45.8	365.2	28.1	32.2	595.9	0.06	43	0.22	0	64.7	6.1	39
23	Adankolo 1	SL 23	7.4	258	555	0.2	15.7	41.3	280.4	121.4	19.6	474.7	0.04	47	0.13	0	94.6	5.7	39.2
24	Adankolo 2	SL 24	7.5	345	727	0.5	17.6	42.1	190.35	32	23.8	40.4	0.09	50	0.26	0.1	11.0	4.1	39.4
25	Adankolo 3	SL 25	7.9	110.1	235	0.2	1.6	44.7	94.66	43	23.8	232.3	0.04	42	0.10	0	8.4	7.5	39.4
26	Ganaja 1	SL 26	7.7	135.7	296	0.1	2.3	46.8	173.4	37	32	323.2	0.04	44	0.06	0.1	34.7	7.2	39.4
27	Ganaja 2	SL 27	8.1	313	681	0.6	11.8	50.1	288.4	65	54	535.3	0.03	47	0.14	0	12.5	6.3	39
SON MPL			6.5 -8.5	500		200			59	250	100		0.3	1	3	0.01	50		0.05
WHO MPL			6.5-8.5	1000		200			150	250	250		0.3	2					0.05-0.1

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Table 2: Statistical summary of measured parameters

Parameter	Min	Max	Average	Recommended (World Health Organisation 2011)	Max permissible (World Health Organisation 2011)
pH	6.0	8.8	7.7	6.5	8.5
TDS	98.6	816.0	388.7	500	1000
Cond	214.0	1703.0	734.9	250	1480
Na	0.1	1.7	0.7	-	200
K	1.5	74.6	23.8	10	15
Ca	41.3	236.8	85.9	75	200
Mg	22.0	775.5	314.7	59	150
Fe	0.01	0.1	0.1	0.3	1.0
Cu	15.6	50.1	38.7	0.5	2.0
Zn	0.02	0.29	0.2	1.0	3.0
Pb	0.0	5.8	0.3	0.4	0.4
Cl	14.8	184.0	63.4	250	600
HCO3	40.4	7547.5	720.2	Variable	Variable
NO3	1.19	360.2	85.4	-	-
SO4	7.0	54.0	19.1	250	500
O2	2.33	7.64	5.8	-	-
H2S	38.6	39.4	39.2	-	-

4.1. 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 (Figs. 2, 3 and 4). Plots of hydrochemical parameters of the groundwater show that 96 % of the water falls within the high-alkaline proportion type, predominantly bicarbonate and sodium, and 4 % 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, NO_3, Cl and SO4 for the major anions (Table 3).

The water characterization shown in the diagrams (Figs. 2, 3) presents seven hydrochemical facies namely: Ca-Mg-Cl-HCO_3, Ca-Mg-HCO_3, Mg-Ca, Mg-Ca-Cl-HCO_3, Mg-Ca-HCO_3, Mg-Ca-HCO_3-Cl and Mg-HCO_3. The Mg-HCO_3, hydrochemical facies are about 48 %, the Mg-Ca-HCO_3, facies are about 25 % while Mg-Ca-HCO_3-Cl,Mg-Ca-Cl-HCO_3, Mg-Ca, Ca-Mg-HCO_3,and Ca-Mg-Cl-HCO_3 each constitutes 4% of the entire sample size. An evaluation of the hydrochemistry of groundwater in areas close to refuse dump in Lokoja metropolis was done.

All the water samples fall within the low sodium hazard and low salinity (S1) region as shown in the Wilcox diagram (Fig. 4) and are therefore suitable for irrigation purpose with respect to this parameter. 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 this solid waste. 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.

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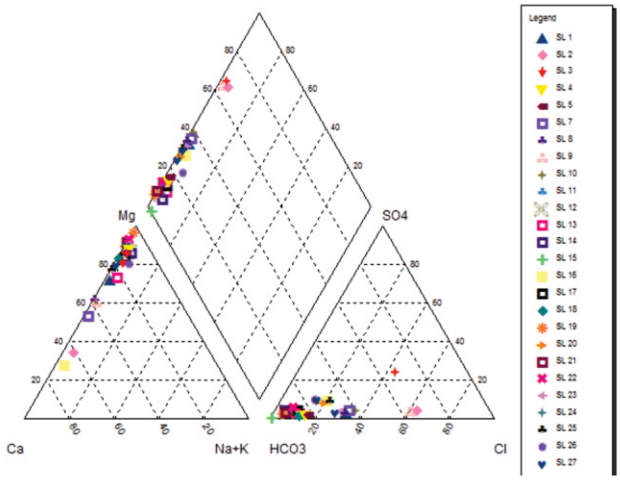

Figure 2: Piper diagram of groundwater in Lokoja metropolis and environs

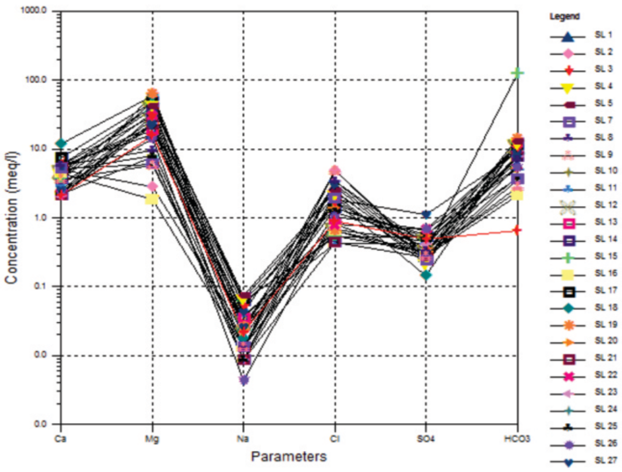

Figure 3: Schoeller plot of groundwater in Lokoja metropolis and environs

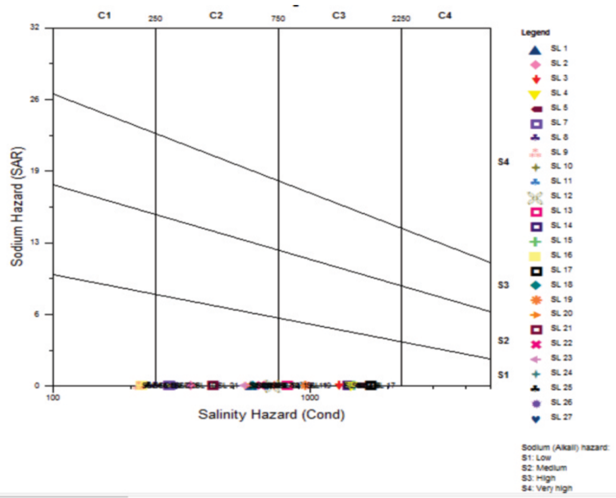

Figure 4: Wilcox diagram of groundwater in Lokoja metropolis and environs

4.2. Correlation Analysis

Statistical correlation method is used for correlation analysis between the following parameters: HCO_3, K, Ca, Mg, Fe, Cl, CO_3, SO_4 and SiO_2 (Table 3). TDS have positive correlation with Na, NO_3 and K with correlation coefficients of 0.78, 0.59 and 0.51 respectively. Na has positive correlation with Mg, K and NO_3 with coefficients of 0.57, 0.7and 0.65, respectively (Table 3).

Table 3: Correlation matrix of measured parameters

	TDS	Na	K	Ca	Mg	Fe	Cu	Zn	Pb	Cl	HCO3	NO3	SO4	O2	H2S
TDS	1.00	0.79	0.51	0.13	0.59	0.07	-0.17	0.36	-0.17	-0.26	0.34	0.59	-0.13	-0.59	-0.19
Na		1.00	0.77	0.25	0.56	0.16	-0.29	0.21	-0.11	-0.14	0.40	0.65	-0.11	-0.63	-0.25
K			1.00	0.15	0.40	0.14	-0.07	0.18	-0.12	-0.31	0.38	0.67	0.05	-0.55	-0.01
Ca				1.00	0.28	-0.02	-0.24	0.03	0.28	0.21	0.00	0.22	-0.48	0.03	-0.13
Mg					1.00	0.07	0.13	0.50	-0.21	-0.39	0.39	0.43	-0.04	-0.50	0.17
Fe						1.00	-0.19	0.11	-0.38	-0.04	-0.22	0.18	-0.06	-0.51	-0.11
Cu							1.00	0.41	-0.31	-0.27	0.09	-0.11	0.39	0.03	0.61
Zn								1.00	-0.24	-0.54	0.26	0.42	0.21	-0.38	0.27
Pb									1.00	0.45	-0.15	-0.16	-0.25	0.21	-0.73
Cl										1.00	-0.24	-0.10	-0.24	0.06	-0.36
HCO3											1.00	0.25	-0.07	-0.29	0.19
NO3												1.00	-0.08	-0.64	-0.09
SO4													1.00	-0.03	0.01
O2														1.00	0.19
H2S															1.00

This positive correlation depicts that the ions in the water were probably derived from the same source. There also. exists positive correlation between Cu and Zn (0.55), H_2S and Cu (0.60) and H_2S and Pb (0.73).

5.0. Conclusion

The analyzed and interpreted data from this study has reveals the general hydrochemistry and quality of groundwater from refuse dump areas within Lokoja metropolis. The study shows that the groundwater in areas where solid wastes are being dump, in most cases, is slightly alkaline (pH ranges from 6.01 to 8.77), slightly saline (TDS varies from 98.6 to 816.0 mg/l), and belongs to seven main hydrochemical facies namely: Ca-Mg-Cl-HCO_3, Ca-Mg-HCO_3, Mg-Ca, Mg-Ca-Cl-HCO_3, Mg-Ca-HCO_3, Mg-Ca-HCO_3-Cl and Mg-HCO_3. The Mg - Ca –HCO_3, hydrochemical facies are about 65 %, while the Ca-Mg-Cl, SO_4, Na- K–HCO_3 and Na - K–Cl-SO_4 hydrochemical facies are about 25%. 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 this solid waste. 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. For Cupper, this affects the color and adds an undesirable bitter taste to the water and causes gastrointestinal disorder. Conclusively, the groundwater within the sampled areas reveals that the groundwater is slightly polluted and not suitable for drinking due to high concentrations of Magnesium, Cupper, Lead, Nitrate and hydrogen Sulphide but their low sodium hazard and low salinity makes the groundwater suitable for irrigation purpose.

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