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THE IMPACT OF DUMPSITES ON GROUNDWATER QUALITY IN MAKURDI METROPOLIS; BENUE STATE

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Abstract
Makurdi, the capital and commercial nerve centre of Benue State lies between latitude 7°40'00"N to 7°50'00"N of the Equator and longitude 8°20'00"E to 8°40'00"E of the Greenwich Meridian. A total of 15 water samples were collected from hand-dug wells within the vicinity of 2 major waste dumpsites within Makurdi Metropolis while another 15 samples were collected far away from the dumpsites. The set of samples were analyzed for relevant physical, chemical and bacteriological parameters using standard analytical method. The results of the analyses were compared to World Health Organisation (WHO), Nigerian Standard for Drinking Water Quality (NSDWQ) and National Agency for Food, Drugs, Administration and Control (NAFDAC) standards. The results of the water samples collected far away from the dumpsites compete favourably with these standards while the samples within the vicinity of the dumpsites show some level of groundwater degradation such as low pH and high concentration of Fe, Mn and Ca respectively. The Ca enrichment of the groundwater is attributed to the dissolution of the host rock through which the water passes while the low pH, high iron and manganese concentration may be due to leachate from the dumpsites. The water in the area is poor bacteriologically as revealed by the high coliform content. Piper and stiff plots show that the water in the area is mainly Ca-SO_4^{2-} type. The use of the existing dumpsites should be discontinued and future dumpsites be sited away from residential areas and landfill and sanitary laws enforced.

Keywords: Environmental impact, Waste dumpsite, Groundwater Quality, Makurdi

Introduction

Waste management and control is of concern to every individual in a society because of its effect directly or indirectly on the health of the people (Amadi, 2008). The disposal of waste accumulated through human activities in urban area of Nigeria has become an urban problem (Abimbola, et al., 2002). Benue state has a population of about 4.2 million people (2006, census). Due to the peaceful nature of Makurdi, the capital of Benue State, its population is increasing and subsequently, the demand for sundry uses of water is increasing progressively. Boreholes and hand dug wells are preferred to surface water by the people and this has lead to uncontrolled abstraction of groundwater resources in the area. Consequently, the upsurge in population and industrialization of Makurdi has resulted to increased waste generation and the existing official dumpsite has been overstretched, leading to indiscriminate dumping of refuse at other undesignated places and this has affected the groundwater system in the area negatively.

Leacheate from dumpsites percolate into groundwater and moves through pore-spaces within rocks and reacts with minerals that make up the rocks. These minerals may be soluble or insoluble and hence, groundwater increases or a decreases in mineral content as it migrates. As groundwater moves, it is filtered naturally until equilibrium of the dissolved substances is achieved (Amadi, 2007). The dissolved minerals in groundwater determine its geochemical characteristics and its suitability for domestic, agricultural and industrial purposes (Oteze, 1991). Groundwater is the most economic source of potable water for urban, semi-urban and rural areas in Nigeria because of its known advantages over surface. The progressive degradation of groundwater quality via human activities particularly from waste dumpsites, if unchecked, will greatly affect its usability. Similarly, bacteriological and chemical pollution of groundwater has an immediate impact on human health as evidenced in water-borne diseases such as typhoid, cholera and dysentery (Amadi, 2007).

Study Objectives.

The need to determine the extent to which groundwater in the area has been contaminated via leachate from dumpsites and unlined soakaway is the focus of this study. The study is also aimed at assessing the environmental impact of selected dumpsites on the quality of groundwater in Makurdi Metropolis, Benue state in order to ascertain its suitability for domestic, industrial and agricultural uses. Water and sanitation are essential for maintaining a healthy life and environment, therefore the need to determine the quality of water in Makurdi metropolis is of paramount importance and hence this study.

Study Area Description.

The study area is Makurdi the Benue State Capital. It lies between latitude 7°40 00 N to 7°50 00 N of the Equator and longitude 8°20 00 E to 8°40 00 E of the Greenwich Meridian, covering a total area of about 670km² (Fig.1). The area is accessible through Nassarawa, Taraba, Obodu, Enugu, and Ankpa roads. It also good road network within Makurdi Metropolis and a railway runs through the town from Enugu to Jos and Kaduna. The area can also be accessible through the Benue River which flows through from the Cameroon Mountain to the Niger-Benue confluence at Lokoja. A local air port is also situated in Makurdi (Fig.1).

Climate and Physiography of the Area

Makurdi lies within the Guinea Savannah vegetation zone with a few patches of forests. The annual rainfall ranges between 1,500mm to 2,000mm, with the peak rainfall in the months of July and September. Temperatures in March and April are 38°C and 48°C respectively, while in December/January, the temperature is 27° (Benue State Water Supply and Sanitation Agency, 2008).

Geology and Hydrogeology of the Area

Makurdi, the Benue State Capital belongs to the Makurdi Formation (Fig.2) of the Lower Benue Trough (Table 1). The Formation overlies the Albian Shale. It consists of thick current bedded coarse grained deposits as described by Jones, 1958. The Makurdi sandstone has a thickness of about 900m (Offodile, 1976). The southern part of the Benue valley is generally gently undulating and punctuated by a few low hills here and there. But toward the northeast, the relief is exaggerated by hills like the Lammuder and Ligri, which rise up to 600m above sea level. The drainage consists of rivers which meander into the River Benue from the north and south direction. Geologically the Benue valley consist of a linear stretch of sedimentary basin running from about the present confluence of the Niger and the Benue rivers to the north east, and bounded roughly by the Basement Complex areas in the north and south of the River Benue (Fig.2). The elongated trough-like basin is continuous with the coastal basin, and in fact, has been correctly described as the long arm of the Nigerian coastal basin (Offodile, 197).

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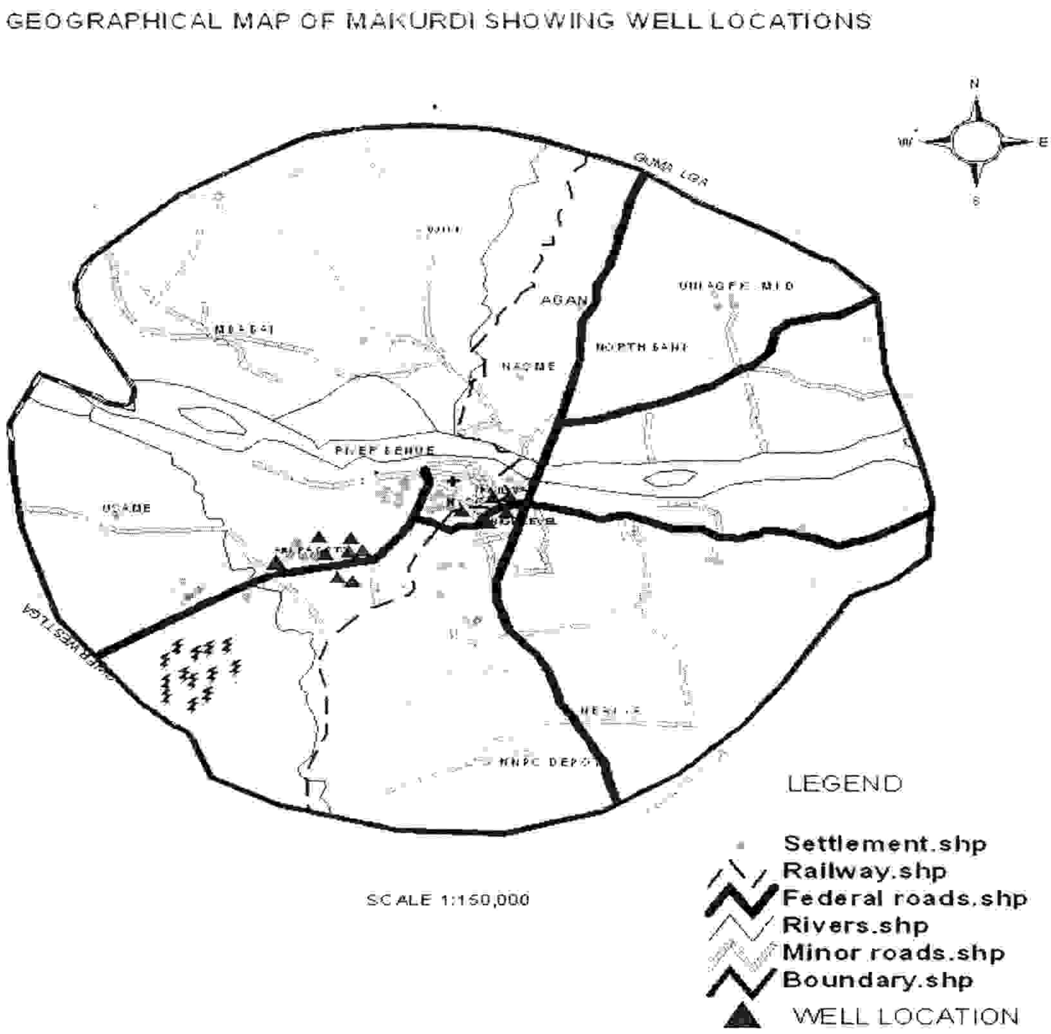

Fig.1: Map of Makurdi showing the road network and drainage pattern.

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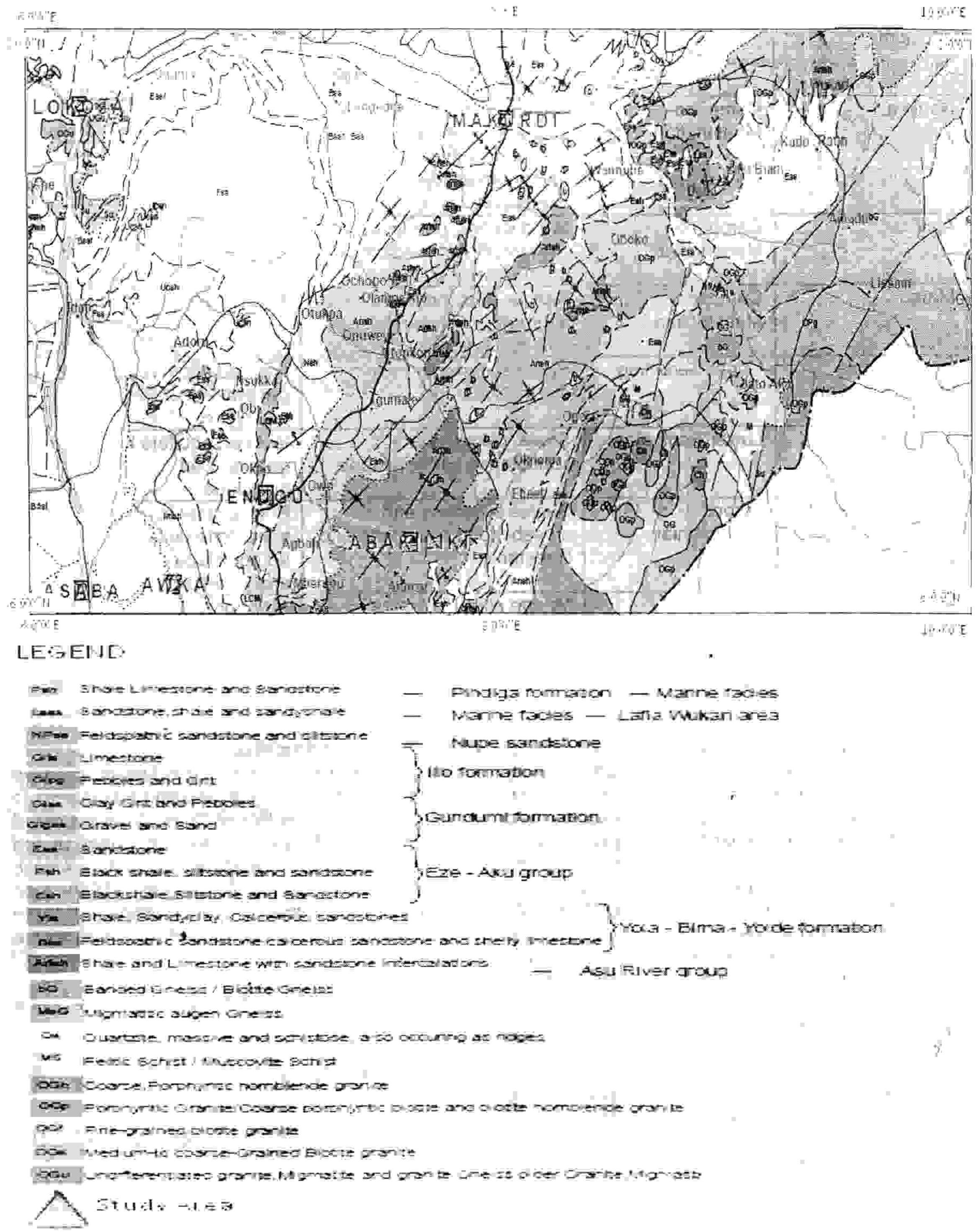

Fig.2: Geological map of the study Area (Modified after NGSA, 2004)

Table 1: Summary of Stratigraphic Succession in the Lower Benue Valley. (After Okurumeh and Oteze, 1996

Formation	Age	Lithology	Hydrologic Significance
Alluvium	Recent	Coarse grain, poorly consolidated to semi-consolidated stand	Aquifer
Nsukka	Campano-Maastrictian	Shales, with alternating succession of clays, siltstones and lenses of coal and fine-medium grained sandstone	Aquiclude
Ajali	Campano-Maestrictian	Sand stones, poorly cemented, fine-medium grained white coloured.	Good aquifer
Mamu	Campano-Maestrictian	Shales, carbonaceous, alternating with sandstones and coal seams.	Aquiclude
Nkporo shale upper Senonian	Upper Senonian	Shale and sandstones	Isolated aquifers but generally an aquiclude
Agwu Shale	Lower Seniqnian	Shale, calcareous sandstones and limestone.	Isolated aquifers but generally an aquiclude
Eze-Aku/Makurdi Formation	Turonian-Cenomanian	Shales siltstones and crossbedded sandstone and limestone	Poor aquifer in sandstone units, but an aquiclude in shaly portion.
Asu River Group	Albian	Marine shale, calcareous shales, sandstones, limestones and contact metamorphosed shales	Aquiclude

Reconnaissance survey of the area was undertaken basically to locate and identify major and active dumpsites in the study area. This was followed by detailed geological and hydrogeological mapping of the area. Prior to the collection of the water samples, the longitude, latitude, elevation, static water level (SWL) and the total drill depth (TDD) of wells were determined using the global positioning system (GPS) device and water level gauge instrument. These values were used for the generation of contour map of the area (Fig.3) and digital terrain model of the area (Fig.4).

Sampling

A total of 30 groundwater samples were collected from the area. Fifteen of the samples were collected in pairs from the vicinity of two major dumpsites in the area while the remaining 15 samples which serve as control were collected about 30m away from the dumpsites. The sampling period lasted for two months (September to October, 2009). The physical parameters: pH, conductivity, turbidity, and temperature were determined in the field using standard equipment.

Laboratory Analysis

After collection, the groundwater samples were stored in a cool box and later taken to the Benue State Water Board Quality Control Laboratory, Makurdi for relevant chemical and bacteriological analyses. The Atomic Absorption Spectrophotometer (AAS) was used for the determination of the concentrations of Ca^{2+} and Mg^{2+} as well as the trace metal; Cr^{6+}, Mn^{2+}, and Fe while Flame analysis was used for the determination of the concentration of Al^{3+}, Na^{+} and K^{+}. The colorimetric method was used to determine SO_4^{2-} and PO_4^{3-} while the concentration of HCO_3^{-} was determined using titrimetric

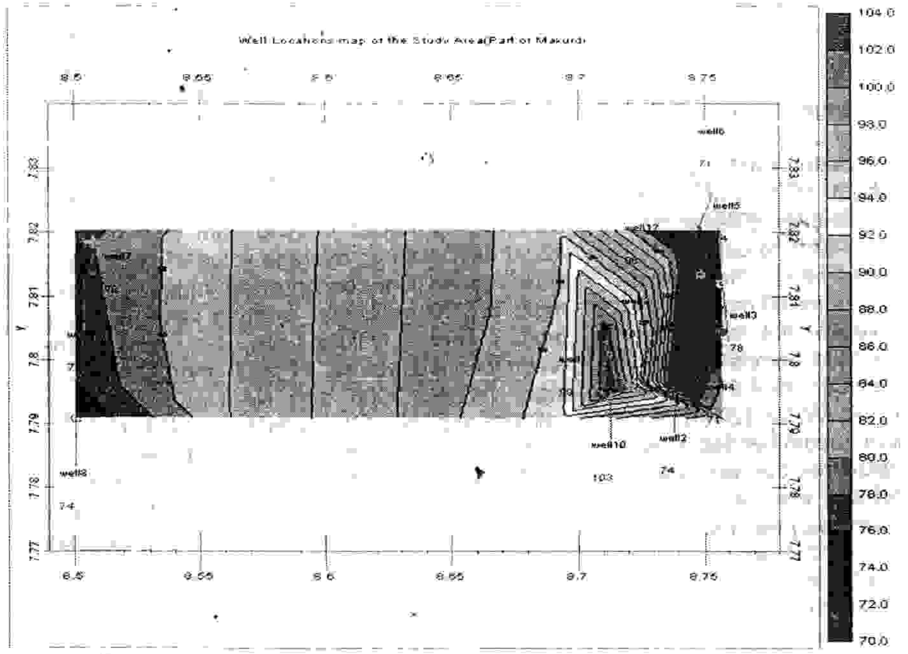

Fig.3: Contour map of the Study Area showing the well locations

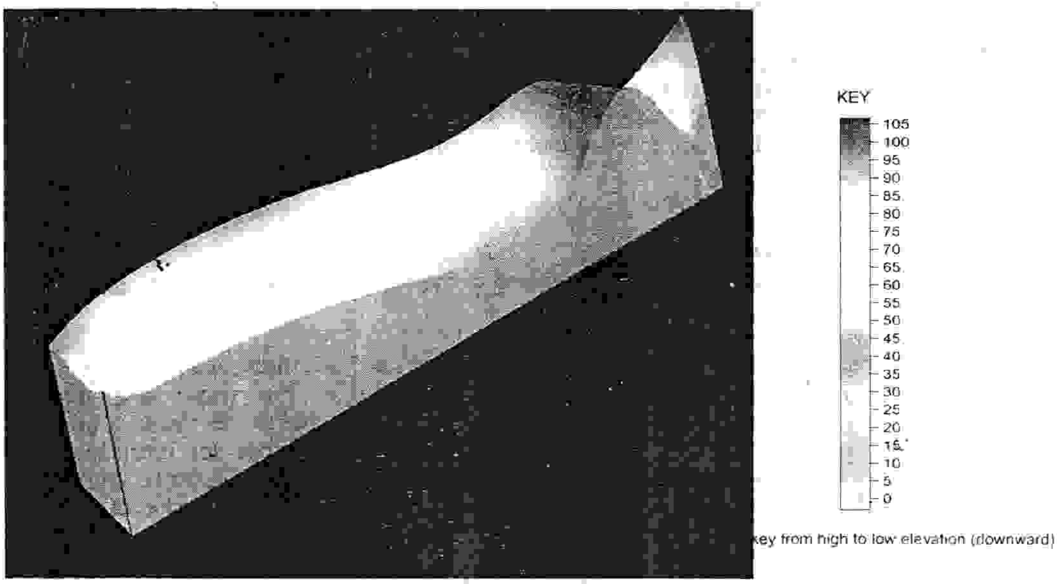

Fig.4: 3-D surface map of the study area

Results and Discussion

The results of the physio-chemical and bacteriological analyses are summarised in Table 2.

Physical Parameters

The ambient temperature ranges from 28.0^{0}C to 30.0^{0}C with a mean value of 28.85^{0}C. Water for drinking purposes has a better fresh taste at lower temperature of about 15^{0}C, but higher temperature do not imply impurities (Olasehinde, 1999). Suspended solid is a term to express the muddiness or opaqueness of water. The value of the suspended solid varies from 0.0 mg/l to 44.0 mg/l with an average value of 4.4 mg/l. Apart from location 5 at Ankpa road dumpsite with a value of 44mg/l, other locations have 0.0mg/l as values which is below the WHO (2006) and NSDWQ (2007) maximum recommended value of 500 mg/l. The pH value for the well water ranges from 5.11 to 7.55 with a mean value of 6.98, when compared with the recommended range of 6.5 to 8.5 WHO (2006) and NSDWQ (2007). The water is slightly acidic, the low pH could be as s result of the breakdown of the organic matter derived from vegetation cover and humus buried in sediments at the dumpsites, and subsequent infiltration of rain water (acid rain) through the porous and permeable overburden into the groundwater. The total dissolve solid (TDS) recommended by the WHO (2006) and NSDWQ (2007) for fresh water is between (0-500) mg/l. The well samples have TDS values ranging from 36.0mg/l to 68.0mg/l with an average value of 50.6. These values are within the acceptable limits of the two standards. The value of total hardness varies from 80.0mg/l to 300.0mg/l with a mean value of 192mg/l, which is above the WHO and NSDWQ permissible limit of 100mg/l and 150mg/l respectively. This implies that the water in the area is hard. Hardness is beneficial in drinking water despite the problem it creates for the piping system (Shenge, 2009). People who live in the hard water area suffer less from heart diseases than those who live in soft water area (Shenge, 2009).

Chemical Parameters

Potassium and Sodium are alkali ions; hence they are always examined together. Sodium values from the analyses ranges from 2.21 mg/L to 3.04 mg/L and a mean value of 2.67 mg/L, while potassium varies from 2.0mg/l to 3.8mg/l with average value of 2.54 mg/L. The values of sodium and potassium in the well water samples are generally very low compared to those of WHO, NSDWQ and NAFDAC maximum permissible limits of 150 mg/L for sodium and 75mg/l for potassium respectively. The low concentration of sodium and potassium ions can be attributed to the shallowness of the wells because concentration of sodium and potassium increases with depth due infiltration. It might also be attributed to the low rate of soil reaction, ion exchange, oxidation and or reduction (Awalla and Ezeigbo, 2002), the low concentration might also be caused by the paucity of soluble materials in the bedrock of the formation and the overlying soils (Amadi, 2009).

The alkaline earth metals (calcium and magnesium) are also examined jointly. The calcium has values ranging from 60.0 mg/L to 420.0 mg/L with an average value of 147.7 mg/L while magnesium concentration varies from 20.0 mg/L to 200 mg/L and a mean value of 75.38 mg/L. These values are far above the recommended values of 50.0 mg/L and 75.0 mg/L (WHO, 2006 and NAFDAC, 2004) for calcium and (NSDWQ, WHO and NAFDAC) for magnesium respectively. Both magnesium and calcium ions are responsible for water hardness. Their high concentration implies that the well water is hard and such water does not foam easily with soap. The concentration of iron varies from 0.05 mg/L to 3.3 mg/L with mean value of 1.88 mg/L, except for samples far away from the dumpsite, other samples have values that exceed the maximum permissible limit of 0.3 mg/L for both NSDWQ and WHO.

Iron is widely distributed in the earth's crust occurring in several ferromagnesian minerals. Pyrite is a common form of iron in sedimentary materials, whereas ferric oxides and hydroxides are important iron bearing minerals. The common form of iron in groundwater is the soluble ferrous ion Fe^{2+}. When exposed Fe^{2+} is oxidized to the ferric state Fe^{3+}, which is soluble and precipitates as ferric hydroxide, causing a brown discoloration of the water and the characteristic brown stains in sinks and laundered textiles, metal pipes for reticulation and scaling in pipes (Awalla and Ezeigbo, 2002; Amadi and Olasehinde, 2009). Corrosion of well casing and other pipe may also contribute iron to well water. Bacterial activity can decrease or increase iron concentration in ground water. Concentration of manganese varies from 0.05 mg/L to 0.81 mg/L and an average value of 0.21 mg/L. locations 5, 11, 12 and 13 very close to the dumpsite have concentration of manganese slightly above the WHO and NSDWQ maximum permissible limit of 0.2 mg/L respectively. High concentration of manganese causes neurological and gastrointestinal disorder (NSDWQ, 2007).

The presence of iron, copper and manganese can give undesirable taste (Ezeigbo, 1988; Olarewaju, et. al., 1996; Ibe and Sowa, 2002). The dissolution of carbonate rock in the ground by water molecules leads to the formation of bicarbonate. The concentration of bicarbonate in the well water samples ranges from 7.6 mg/L to 28.9 mg/L with a mean value of 20.58 mg/L. No evidence of carbonate in the groundwater in all the location except for sample 5. These values are far below the WHO and NSDWQ recommended values of 100 mg/L for bicarbonate and 200 mg/L for carbonate respectively. The value of sulphate ranges from 16.0 mg/L to 65.0 mg/L with an average value of 43.5 mg/L and is below the recommended maximum permissible limit of 200 mg/L (NSDWQ, 2007, WHO, 2006 and NAFDAC 2004). The chloride concentration varies from 36.4 mg/L to 64.8 mg/L with a mean value of 44.45 mg/L. This value is below the maximum permissible limit of 150mg/l and 250mg/l (WHO, 2004 and NSDWQ, 2007). The concentration of nitrate ranges from 22.0mg/l to 29.5mg/l and an average value of 24.59 mg/L and are below the recommended permissible limit of 50.0 mg/L by WHO (2006) and NSDWQ (2007). Chromium concentration ranges from 0.01mg/l t0 0.03 mg/L with a mean value of 0.019 mg/L, the values are below those of the NSDWQ, 2007 and WHO, 2006. The concentration of the cations, anions and trace metals in 13 selected locations are reflected in the bar charts shown in Figures 5, 6 and 7 respectively.

Bacteriological Parameters

There are many different kinds of bacteria that may be present in water supply, some of these bacteria are disease causing (pathogens). The standard water test to determine the microbial quality of water is for total coliform bacteria. The total coliform value ranges from 11.0 cfu/10mL to 1800.0 cfu/10mL with a mean value of 341.0 cfu/10mL. This value is far above the WHO, NSDWQ and NAFDAC maximum permissible limit of 10.0 cfu/10ml and it is an indication of faecal contamination by animals and human being in the area. E.coli was found in all the well water in the area and this could be attributed to the shallowness of the wells and their closeness to a major active dumpsite (solid and liquid waste dump including feaces), Salmonella-typhii were not detected except for locations 1 and 2. The principal risk associated with water is that of infectious diseases and is related faecal contamination. Majority of the water-borne diseases are caused by pathogenic bacteria, viruses and protozoa contained in the human and animal faeces. The water in the area has high microbial pollutant, indicating poor sanitary system in the area.

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Table 2: Summary of the Physio-chemical and Bacteriological Analyses in the area

Parameters	Minimum	Maximum	Average	Stand. Dev.	Variance	WHO Standard	NSDWQ Standard	NAFDAC Standard
	Physical Parameters							
Temperature (°C)	28	30	28.84615	0.618263	0.307692	Ambient	Ambient	Ambient
Turbidity (FTU)	7	103	40.8	32.36618	846.8444	0-5	0-5	-
Conductivity (µs/cm)	64	478	165.8154	135.1493	14076.71	-	1000	-
Suspended Solid (mg/L)	0	44	4.4	16.418	193.6	-	-	-
TDS (mg/L)	36	68	50.6	10.2458	82.71111	1000	500	500
Total Solid (mg/L)	36	112	55	25.02819	446.4444	1000	500	500
pH	5.11	7.55	6.98	0.43685	0.148867	7.0-8.5	6.5-8.5	6.5-8.5
Total Hardness (mg/L)	80	300	192	69.98022	3840	100	150	105
			Chemical Parameters (mg/L)					
Calcium (Ca^{2})	60	420	147.6923	112.4699	9169.231	50	-	75
Magnesium(Mg^{2})	20	200	75.38462	57.97699	2676.923	50	0.2	30
Aluminium(Al^{3})	0.02	0.22	0.132308	0.079873	0.006286	0.5	0.2	-
Iron(Fe)	0.05	3.3	1.880769	1.089233	1.036758	0.0.5-0.3	0.3	-
Sulphate(SO)	16	65	43.5	19.13598	353.1667	200	100	200
Hydrogen Carbonate(HCO)	7.6	28.9	20.58	8.187838	63.16178	100	100	100
Chloride(Cl)	36.4	64.8	44.45385	8.725285	56.04769	150	25	-
Nitrate(NO)	20.4	29.5	24.59	3.193918	8.976556	50	50	-
Chromium (Cr)	0.01	0.03	0.019167	0.007035	4.47E-05	0.05		
Carbonate(CO)	0	0	0	0	0	0.0	0.0	0.0
Potassium(K)	2	3.8	2.544	0.573347	0.234471	1-2	-	1.0
Sodium(Na)	2.21	3.04	2.672	0.261812	0.052707	-		-
Manganese(Mn^{2})	0.05	81	6.381538	27.50588	502.6702	0.05	0.2	-
Phosphate(PO)	0.22	2.77	0.66	0.800483	0.42835	-	-	
Phosphorus(P)	0.1	0.2	0.147	0.032436	0.000846	-	-	
			Microbial Parameter					
Total Coliform (cfu/mL)	11	1800	341	574.6234	232913.7	10	10	-

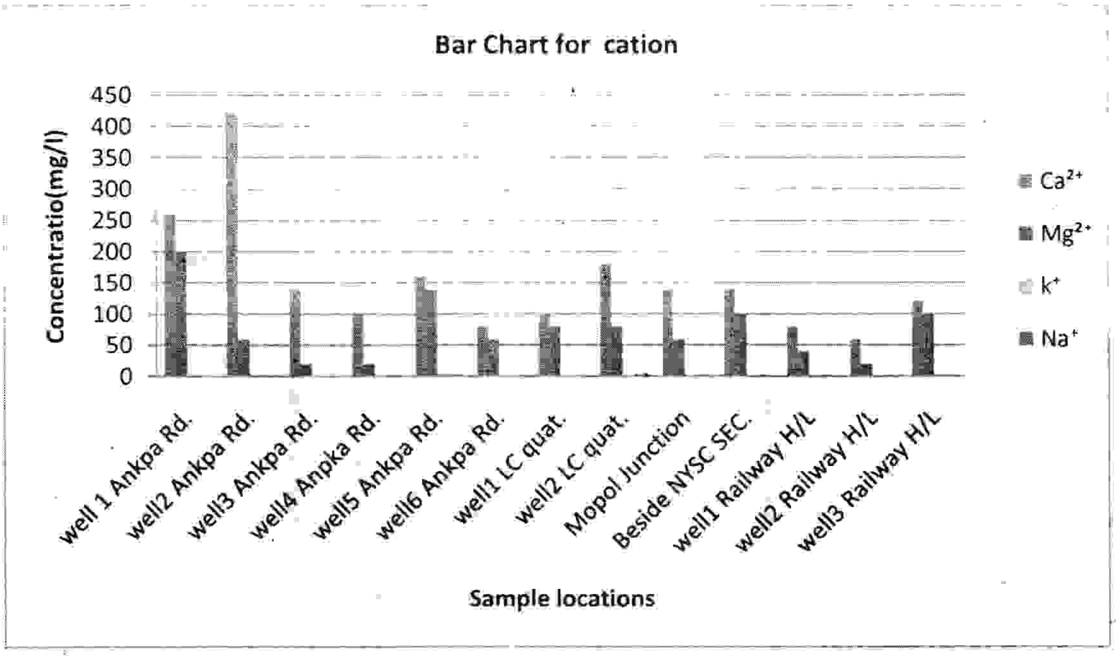

Fig. 5: A bar Chart showing the concentration of the major Cation in the groundwater sample in the area

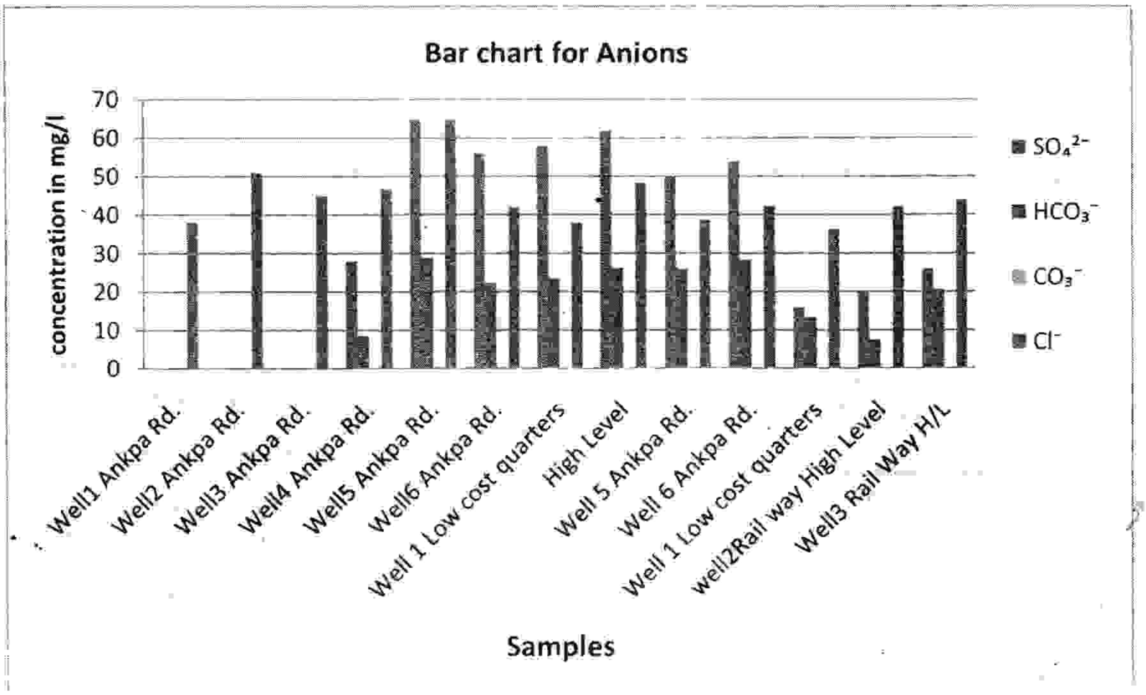

Fig. 6: Bar chart showing the concentration of the major Anion in the groundwater sample in the area

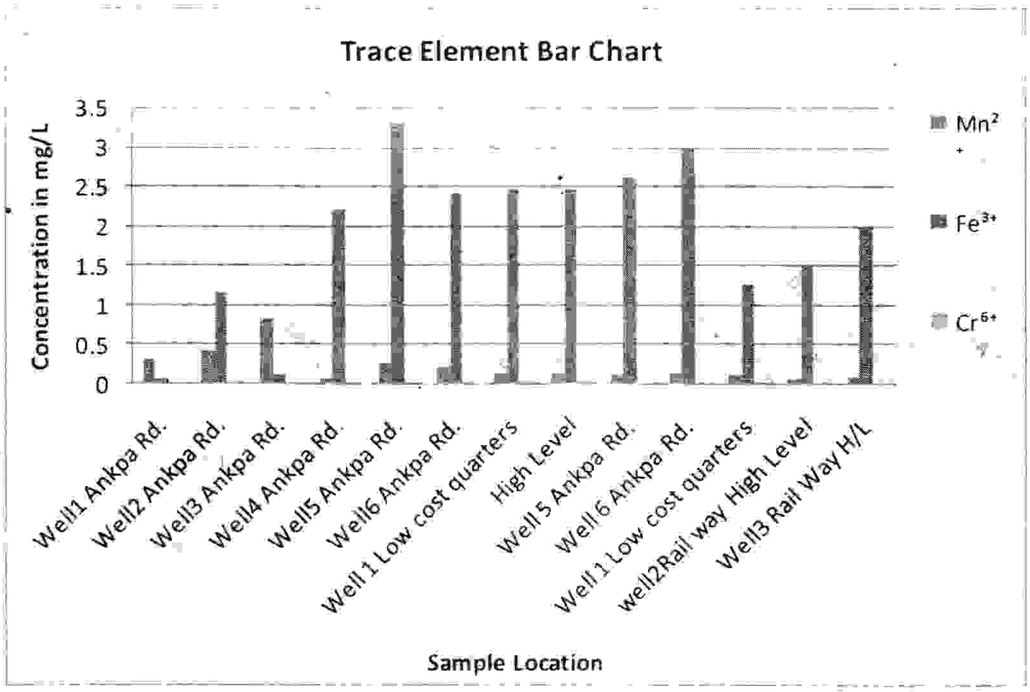

Fig.7: Bar chart showing trace element concentration of the water samples

This method was devised by piper in (1944) to outline certain fundamental principles in a graphic procedure which appears to be an effective tool in separating analytical data for critical study with respect to sources of the dissolved constituents in water (Fig.8). The concentration of 8 major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, HCO^-_3 and SO_4^{2-}) are represented on a trilinear diagrams by grouping the (K^+ with Na^+) and the (CO_3^{2-} with HCO_3), thus reducing the number of parameters for plotting to 6. On the piper diagram, the relative percentages of the cations and anions are plotted in the lower triangles, and the resulting two points are extended into the central field to represent the total ion concentration. The degree of mixing between waters can also be shown on the piper diagram. The Piper diagram (Fig.8) was used to classify the hydro-chemical facies of the water samples according to their dominant ions. The water in the area is of $Ca-SO_4^{2-}$ type.

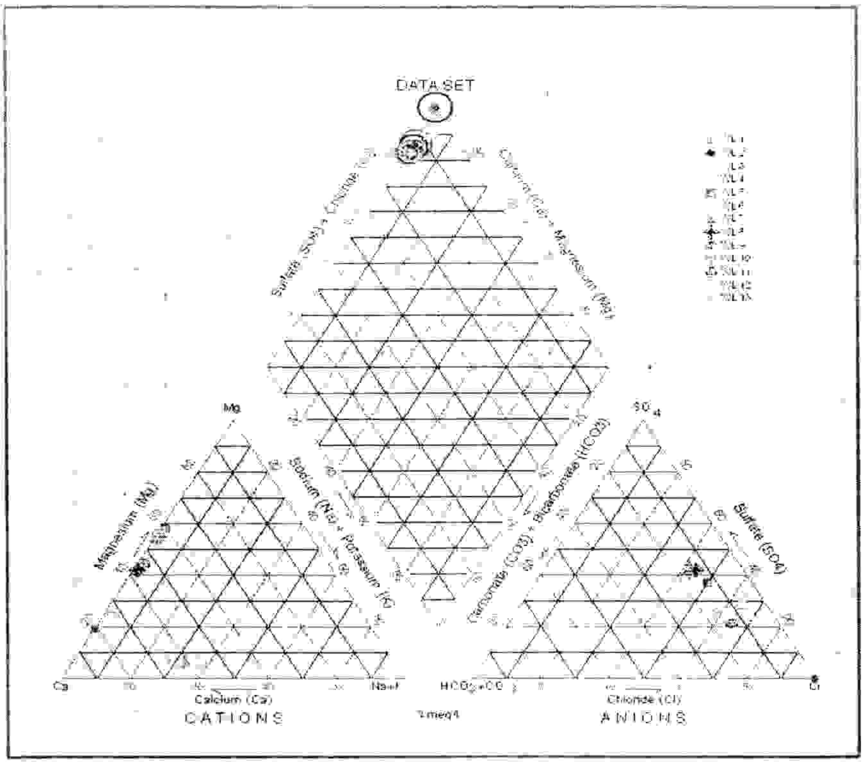

Fig.8: Piper diagram of well samples in Makurdi

Conclusion

The groundwater quality in Makurdi, Benue State capital, Northcentral Nigeria has been investigated and the results compared with NAFDAC, (2004); WHO (2006) and NSDWQ (2007). The physico-chemical parameters compete favourably with these standards except for pH, Mg, Fe and Mn while the bacteriological analysis of groundwater samples show high total coliform count in all the locations. Their presence indicates faecal pollution and signals a potential health hazard in the nearby future. This pollution is basically from animal and human sources due to poor sanitary condition of the area. Groundwater within the vicinity of the dumpsites has higher degree of degradation compared to those outside the vicinity of the dumpsite.

Recommendation

Boreholes should be used in the area instead of hand dug wells as deeper aquifers are less affected by faecal contamination than shallower aquifers. Due to the high coliform content in the groundwater, it is suggested that the water should be boiled before drinking because most bacteria do not withstand heat or high temperature (WHO, 2006). Periodic bacteriological check be carried out on the water in the area. Benue State Environmental Protection Agency should intensify their effort in checkmating random refuse disposal and also to stop the dumping of refuse at the Ankpa quarters and Rail way areas of the town due to their effect on the groundwater in the area. A suitable landfill type that would incorporate a multiple barrier concept to prevent contaminant flow into the aquifer should be adopted.

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