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Evaluation of Groundwater Quality in Diko and Environs, Niger State, North Central Nigeria

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Abstract

A total of 45 water samples were collected from hand-dug wells in Diko and immediate environs and send to the laboratory for relevant physical, chemical and microbial analyses. The results of the analyses were compared with the guideline for a safe drinking water stipulated by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). The physical and chemical parameters analyzed compete favourably with the WHO and NSDWQ guideline values. In some locations, the microbial analysis shows values higher the maximum permissible limit recommended by WHO and NSDWQ which is an indication of faecal contamination. They wells that contained total coliform and Escherichia coli were located close the toilet system. The study has shown that the level of faecal contamination in the wells is a function of the distance of the well from the pit-latrine or soakaway system. Future hand-dug wells should be sited away from the toilet system as this will reduce the level of contamination in the area. Since most infectious diseases are transmitted primarily through human and animal excreta, particularly faeces, boiling of water before drinking is advocated because pathogens do not survive under high temperatures.

Introduction

In the last decade, there has been an increase in the exploration and exploitation of groundwater for the water supply needs of many communities in Nigeria especially in the northern part of Nigeria where portable water is not readily accessible. To meet the present and future challenges of population expansion in line with the millennium development goals (MDGs), it has become necessary to assess the groundwater resources in order to manage it efficiently and utilize it sustainably (Amadi, 2009). Unlike surface water, groundwater accumulates and flows underground in both unconsolidated sediments and crystalline rocks. The Hydrochemical facies of the groundwater changes in response to its flow path history as well as anthropogenic interference in the area (Olasehinde and Amadi, 2008).

This paper evaluates the groundwater quality in Diko area of Niger State and its suitability for drinking and house-hold application. This is necessary because the area hosts the NNPC underground petroleum product storage tanks and the tendency of these products leaking into water-table cannot be completely rolled out. Also water intended for drinking and house hold-hold purposes must not contain water-borne pathogens and poisonous inorganic elements (Amadi, 2009). Hence, groundwater is the only realistic water supply option for meeting the growing demand of a safe drinking source.

Accessibility and location of the study area

The study area is along Lambata-Suleja road. It lies between longitudes 7°01'E to 7°13'E of the

Greenwich Meridian and latitudes $9^{o}10^{I}$N to $9^{o}21^{I}$N of the Equator (Fig.1), covering an area of about $442km^2$. The area is drained by Gurara River and its tributarires.

Climate and Physiography of the area

The study area lies within the north-central part of Nigeria which is characterized by Guinea savannah. The Vegetation is made up of trees, shrubs and grasses. The climate comprises of rainy season (April to October) and dry season (November to March). The temperature in the area is generally high with a mean value of 30^{o}C while the average rainfall is about 240mm (Minna airport, 2004).

Geology of the area

The area is part of the Nigeria Basement Complex rocks, which consist of a suite of Precambrian migmatites-gneiss, low grade meta-sediment schist-belt and the older granites (Ajibade and Woakes, 1976). The gneisses and the low grade meta-sediment schist constitute the host rocks to the granitoids and are found mostly as flat-lying outcrops are often well exposed except along river channels and road cuttings. The rock types in the area were dominated by Granites, Schist and gneiss respectively (Fig. 1). Granite and gneiss weather into medium to coarse grained sand while the schist weather to clays.

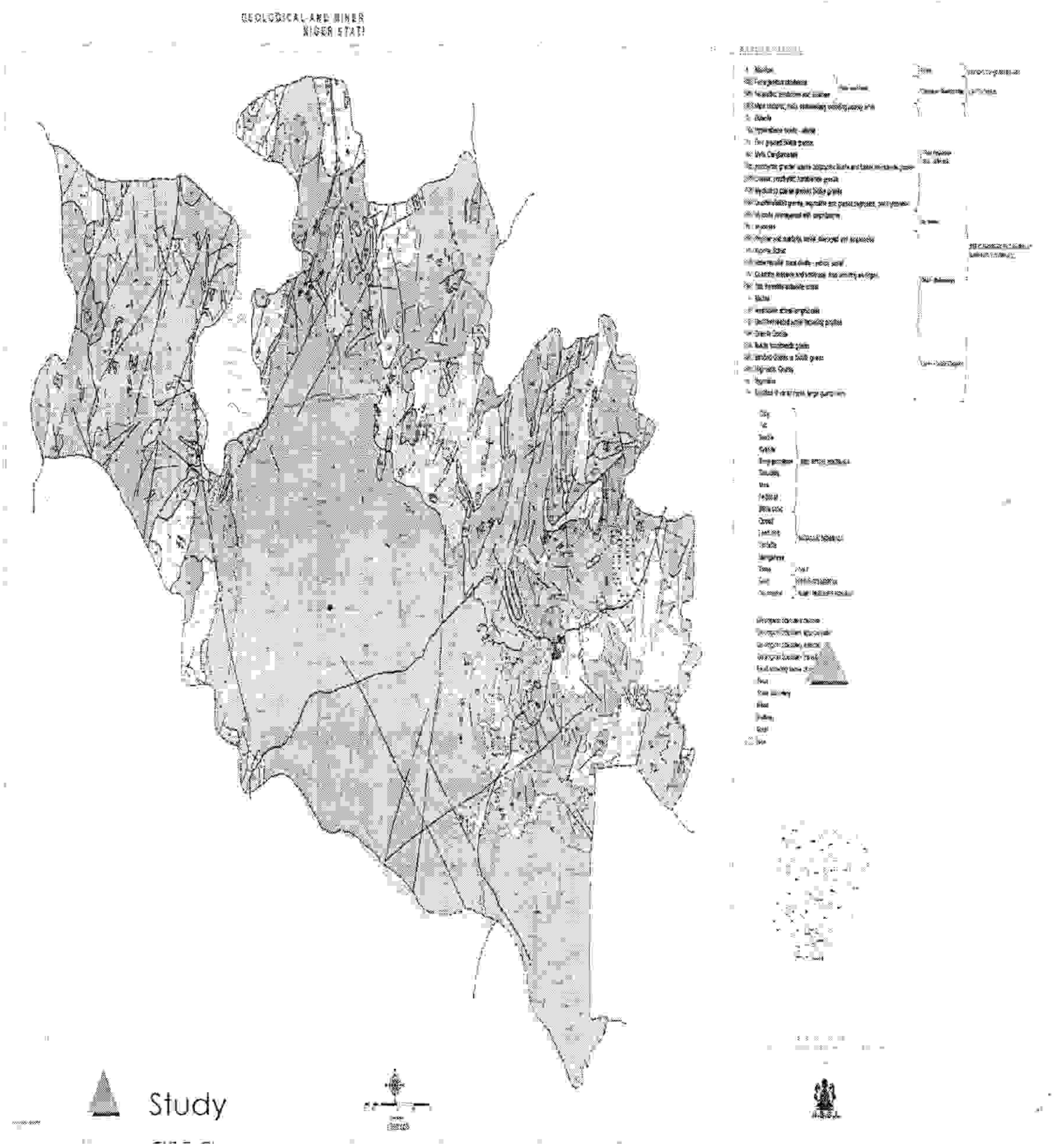


Fig.1 Geology map of Niger State showing the Study area.

Hydrogeology of the Area

The longitude, latitude and elevation of the area were obtained using a Global Positioning System (GPS). The values of the Static Water Levels (SWL) of some hand-dug wells in the area were determined using a measuring tape. The SWL below the ground surface was subtracted from their corresponding elevation values to obtain the Static Water Level (SWL) above sea level. The values of the corresponding longitude, latitude and SWL above sea level were used to generate groundwater flow direction (Fig.2) and groundwater contour map in the area using Surfer-8 software. The groundwater in the area flows in an N-S direction in line with the major fracture pattern in the area.

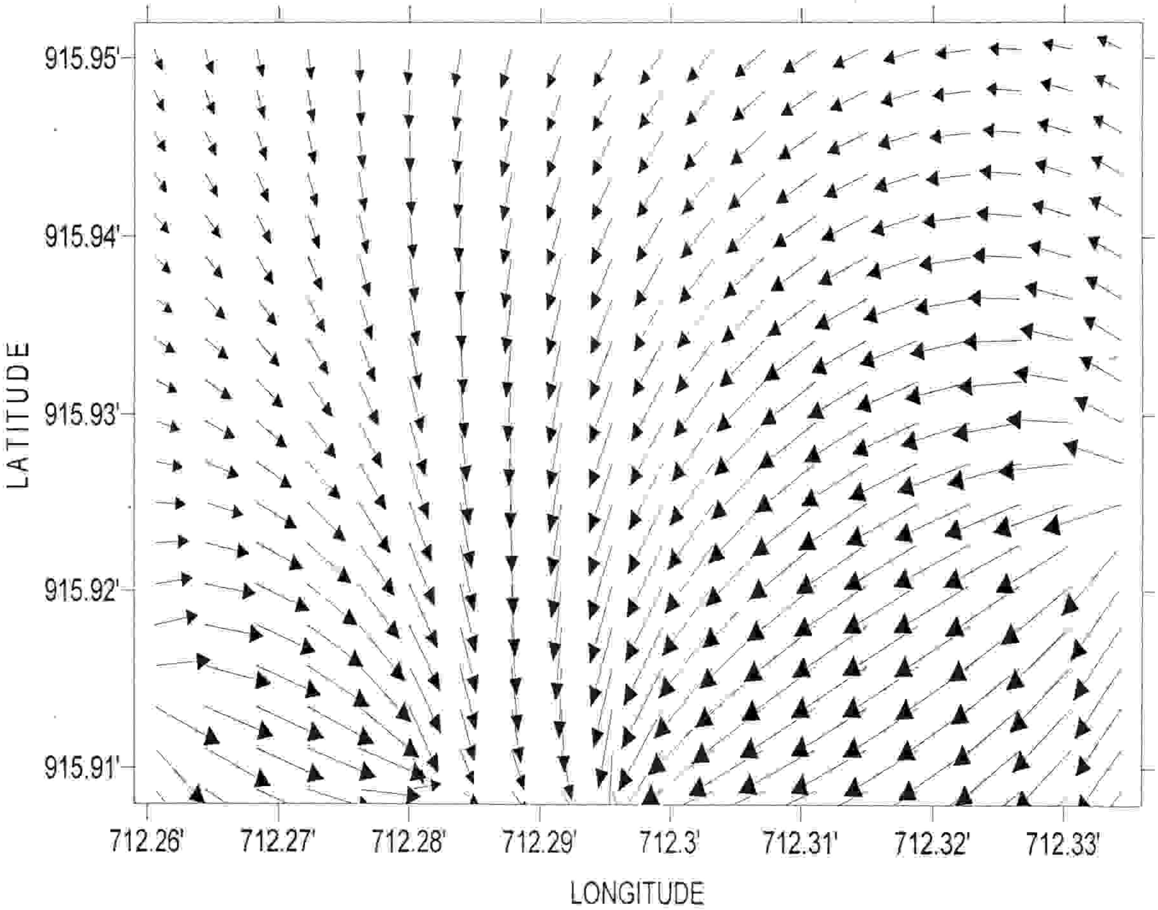


Fig. 2 Groundwater flow direction for the area.

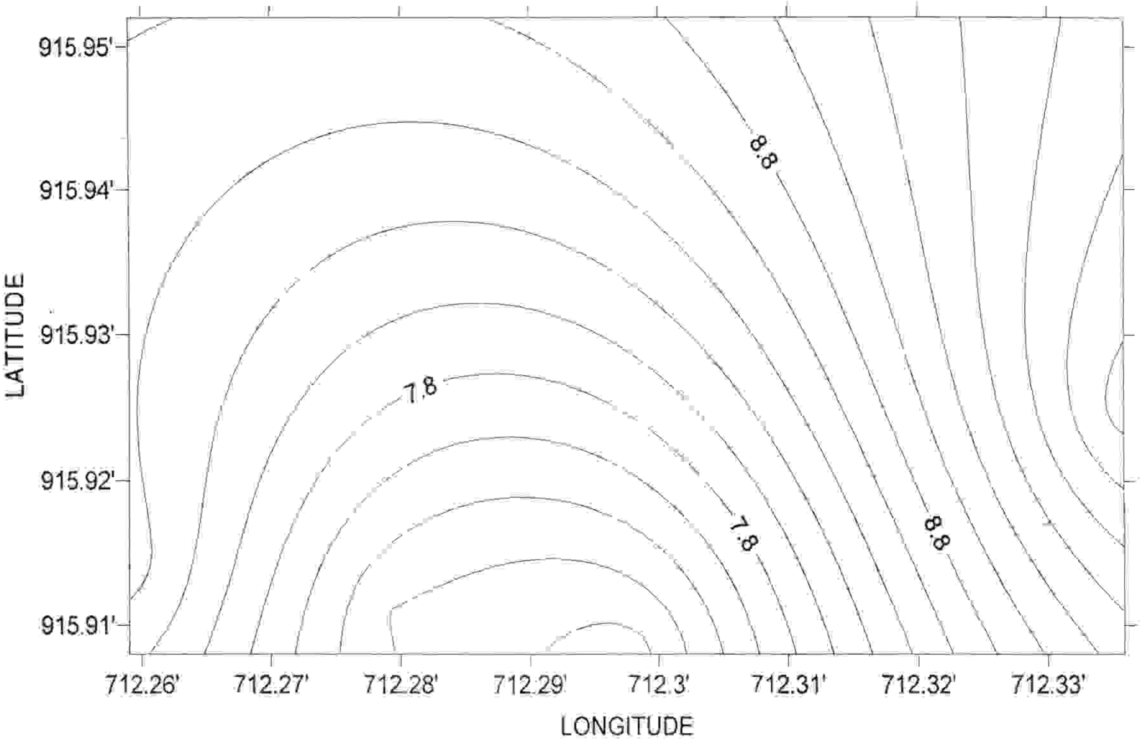


Fig. 3 Groundwater contour lines of the study area.

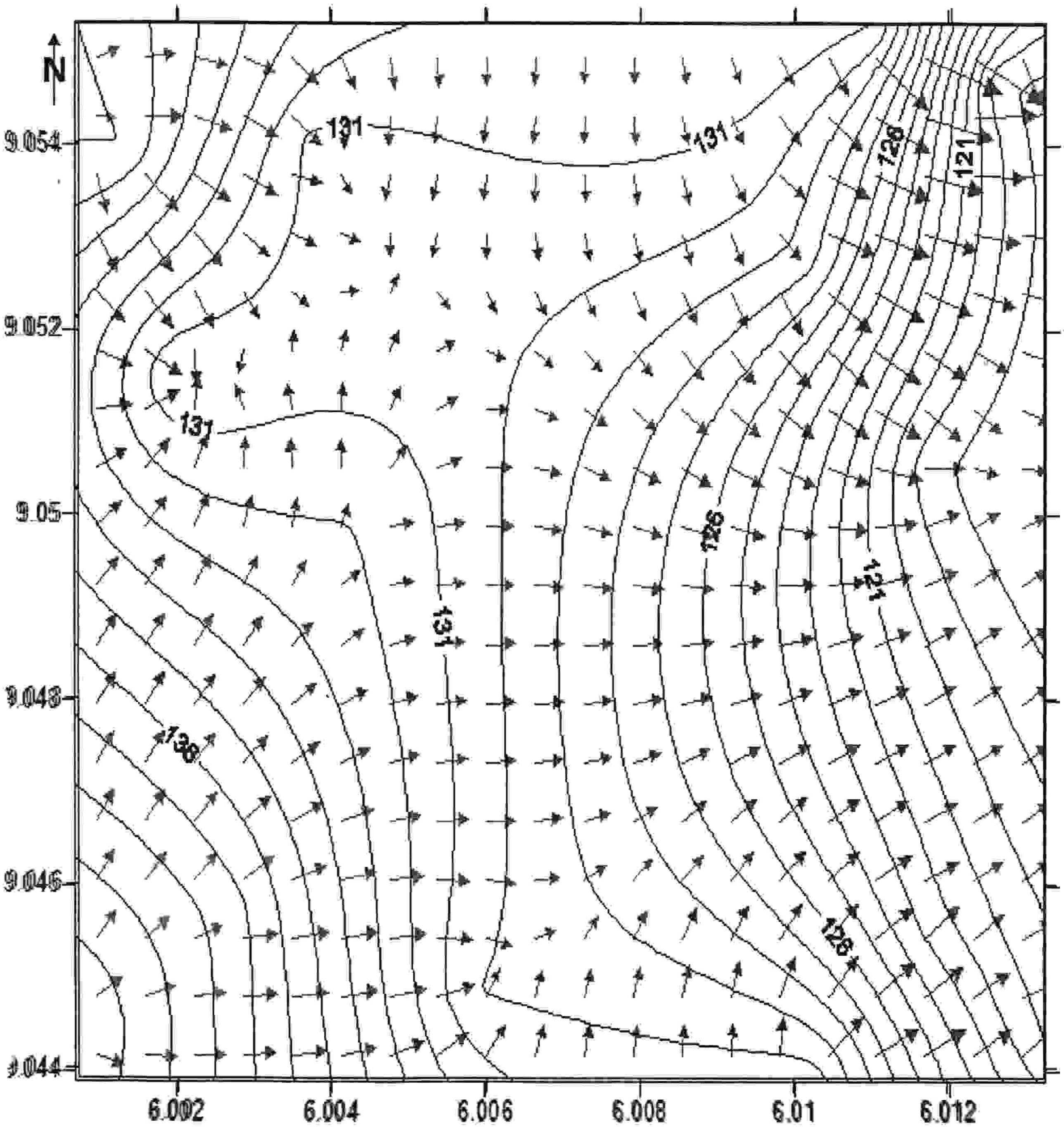
Methodology

A detailed geological and hydro-geological mapping of the area was undertaken to determine the rock types and static water level in the area. A total of 45 water samples were collected in pairs using a glass and plastic container from hand-dug wells (shallow wells) in the area and send to the laboratory for physio-chemical and microbial analyses. The physical parameters (pH, conductivity, temperature and turbidity) were determined on the field using a calibrated pH metre, conductivity meter, thermometer and turbidometer respectively. The chemical parameters (cations, anions and trace elements) were analyzed using Atomic Absorption Spectrometer (AAS) and Flame Spectrometer while Bacteriological determination of (total coliform count, Escherichia coli and Salmonella spp.) was carried out using presumptive count and differential count. These parameters were determined according to standard specification prescribed by the World Health Organization (WHO, 1999) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007).

Results and Discussion

Fieldwork

The mapping carried out enabled the generation of Digital Terrain Model (DTM) of the using Surfer 8.0 software as shown in Figure 4. The highland is at the north while the area slopes southward. The highlands are occupied by granite in the north while the lowlands are occupied by gneiss and schist in southern part. The groundwater flow from north to south obeying topographic gradient and the fracture attern in the area.



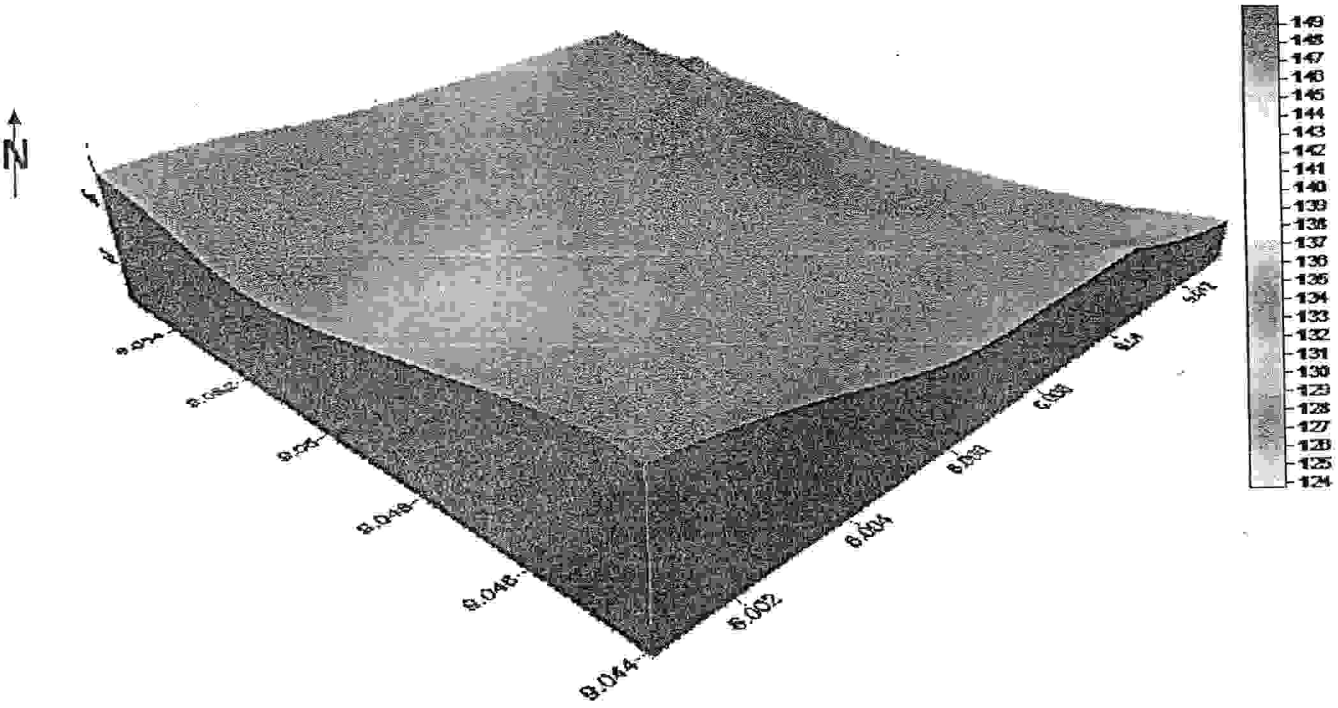


Fig. 4 Digital Terrain model of the area.

Laboratory Analyses Physical Parameters

The results of the physical parameters analyzed were statistically summarized in Table 1. The pH of the water samples ranges from 6.5 to 7.6 with an average value of 6.9. This fall within the pH range value of (6.5-8.5) recommended by the World Health Organization (WHO, 1999) and the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). The temperature varies from 24.8°C to 26.1°C and a mean value of 25.8°C, which falls within the acceptable ambient temperature prescribed by WHO, (1999) and NSDWQ, (2007). Cool water is generally more palatable than warm water. High water temperature enhances the growth of micro-organisms which affects the taste, odour and colour of the water. Colour value of 15TCU (true colour unit) is recommended by WHO, (1999) and NSDWQ, (2007). The minimum, maximum and mean values of both conductivity and total dissolved solids (TDS) are below the maximum permissible limits of 1000mg/l recommended by WHO, (1999) and NSDWQ, (2007).

Bacteriological Parameters

Table 1 summarizes the microbial (bacteriological) parameters analyzed. The value of Escherichia coli varies from 0 to 18cfu/100ml with a mean value of 2.4cfu/100ml. Locations 2, 7 and 10 contain E. coli, which is the major cause of urinary tract infection like meningitis and diarrhea as well as morbidity and mortality among children. It also causes acute renal failure and haemolytic anaemia. Total coliform count was analyzed in water samples from locations 1, 2, 4 and 5, which is an indication of faecal contamination. It is a fact that infectious diseases are transmitted primarily through human and animal excreta, particularly faeces. Such diseases caused by pathogenic bacteria, viruses and protozoa or by parasites are the most common and widespread health risk associated with drinking water. The principal risk associated with water is that of infectious diseases and is related to faecal contamination. Microbial examination of drinking water is a sure way of ascertaining its hygienic quality and should be carried out on a regular basis.

Chemical Parameters

The statistical summary of the chemical parameters analyzed are contained in Table 1. The concentration of bicarbonate varies from 30mg/l to 217mg/l and an average value of 87.4mg/l while chloride concentration ranges from 13.5mg/l to 104.5mg/l and a mean value of 36.6mg/l. These values are conformable with the stipulated guideline values for a safe drinking water quality by WHO, (1999) and NSDWQ, (2007). Excessive chloride concentration can give rise to detectable taste in water and also increases the rate of corrosion of metals in the distribution system, depending on the alkalinity of the water. Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. However, their concentration in groundwater increases due to fertilizer application. The concentration of the both nitrate and nitrite are very low compared to the WHO, (1999) and NSDWQ, (2007) guideline values. The concentration of calcium is of the order of 9.2mg/l to 45.3mg/l with a mean value of 25.9mg/l while magnesium has minimum and maximum values of 0mg/l and 18.3mg/l respectively and an average value of 4.7mg/l. The concentrations of both calcium and magnesium were far below the prescribed value of 200mg/l by WHO, (1999) and NSDWQ, (2007). Similarly, the concentration of sodium varies from 2.3mg/l to 77mg/l and a mean value of 17.1mg/l while potassium concentration ranges from 1.4mg/l to 8.6mg/l with an average value of 2.7mg/l. Their determined values are in line with the recommendation by the two standards. Furthermore, manganese and copper have their analyzed values within the acceptable range by WHO, (1999) and NSDWQ, (2007).

Table1: Univariate statistical overview of groundwater chemistry data from Diko and environs

Parameter	Mean	Minimum	Maximum	Standard Deviation	WHO STD	NSDWQ
Temperature	25.79	24.8	26.1	0.37	Ambient	Ambient
Colour	200.80	0	807	275.98	15	15
pH	6.96	6.5	7.6	0.38	6.5-8.5	6.5-8.5
Conductivity	263.10	84	588	187.37	1000	1000
TDS	176.27	66.33	393.96	125.54	500	500
Suspended Solid	26.50	0	79	37.63	1000	1000
Bicarbonate	87.40	30	217	61.82	100	150
Carbonate	0.00	0	0	0.00	100	150
Chloride	36.64	13.5	104.47	30.95	200	250
Hydroxide	0.00	0	0	0.00		
Manganese	0.14	0.031	0.229	0.08	0.1	0.2
Copper	0.38	0	3.2	0.99	2	1
Sulphate	2.62	0	11	3.52	150	100
Nitrite	0.06	0.005	0.265	0.08	0.2	0.2
Total Hardness	84.90	18	173	52.47	200	200
Alkalinity	87.20	29	217	61.53		
Magnesium	4.69	0	18.79	5.69	200	200
Calcium	25.90	9.22	45.29	14.87	200	200
Mg-Hardness	19.20	0	77	23.31		
Ca-Hardness	64.60	16	113	37.07		
Potassium	96.05	1.4	865	270.49	150	100
Phosphorus	0.02	0	0.04	0.02	5	5
Nitrate	10.02	2.4	20.2	6.18	50	50
Sodium	17.08	2.3	77	22.36	200	200
E.coli.	2.40	0	18	5.64	0	0
Total coliform	26.50	0	85	37.63	0	10

Units: Temperature-°C, Conductivity-μS/cm, Colour-TCU, Turbidity-NTU, Total coliform-cfu/mL, Escherichia coli-cfu/100mL, others-mg/L.
WHO-STD: World Health Organization Standard for Drinking Water Quality
NSDWQ: Nigerian Standard for Drinking Water Quality

Piper Diagram.

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 the Piper trilinear diagram 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 concentration 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 (Fig. 5). The Piper diagram was used to classify the hydrochemical facies of the water samples according to their dominant ions. The water in the area is Ca- HCO^-_3 type, which implies that the dominant cation and anion in the groundwater system are calcium and bicarbonate respectively.

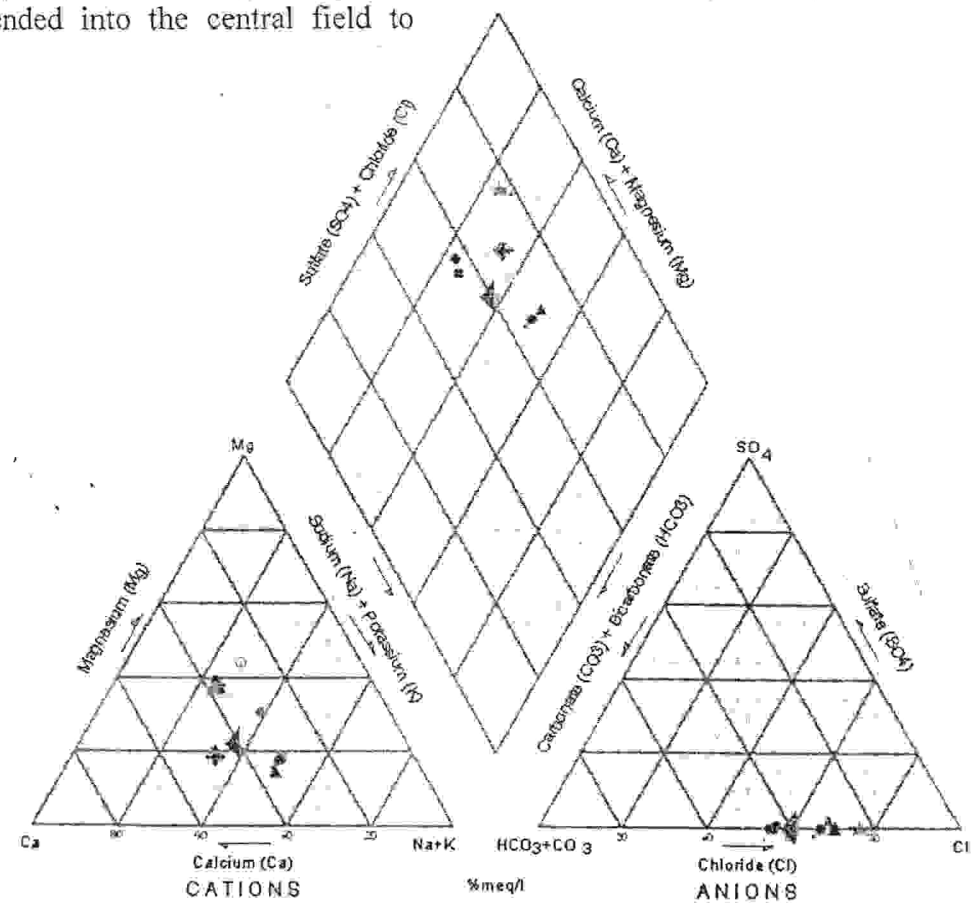


Fig.5 Piper diagram for Groundwater in Diko and environs

Conclusion

The groundwater quality in Diko and environs has been evaluated through hydrogeological mapping and laboratory analyses of physical, chemical and bacteriological parameters. The hydrogeological mapping of the area leads to the construction of groundwater flownet and digital terrain model for the area. The results of the physical and chemical parameters were within the acceptable guideline values stipulated by WHO (1999) and NSDWQ (2007) while the microbial analysis shows anomalous result in some locations with values higher the maximum permissible limit recommended by WHO, (1999) and NSDWQ, (2007). This is an indication of faecal contamination. It was observed that the wells with faecal contamination were sited close the toilet system. The study has also shown that the rate of faecal contamination in the wells is directly proportional to the distance of the well from the toilet system (pit-latrine or soakaway).

Recommendation

Future hand-dug wells should be sited far away from the toilet system, a minimum distance of 20m away from the pit-latrine or soakaway system as this will drastically reduce the level of contamination due the fact that groundwater naturally filter its contaminant as it flows. Boiling of water in the affected location before drinking is advocated because pathogens do not survive under extreme high temperatures. Regular microbial examination of the groundwater in the area is recommended.

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