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Original Article

# HYDROGEOLOGY AND CHEMICAL QUALITY OF GROUNDWATER IN SOUTHWESTERN PART OF MINNA, NIGER STATE, NIGERIA.

*Amadi, A. N[1].,Olasehinde, P. I[1].Egharevba N. A[2].,Idris-Nda, A[1].,Goki, N. G[3]. and Uruevho, C. I[1].

[1]Department of Geology, Federal University of Technology, Minna.
[2]Department of Agricultural and Bio-Resources Engineering, Federal University of Technology, Minna.

[3]Department of Geology, Nasarawa State University, Keffi

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## ABSTRACT

The pastoral community of Minna, capital of Niger state, Nigeria, is rapidly growing and water needs for domestic and agriculturally purposes consequently has increased. Groundwater samples were collected from different parts of Minna and their physico-chemical properties analysed. The concentrations of most parameters analysed met the standards for safe drinking water, except $NO_3^-$, $HCO_3^-$, Mg, Ca, Fe, Pb, and Cd whose concentrations in some locations were above the recommended maximum permissible limits. The envisaged high concentration of these elements is primarily anthropogenic, through fertilizer and pesticides application, leaching from dumpsites, cemetery and possibly mechanic workshops. Water from the area is predominantly hard. The dominant water type in the area as shown in Piper diagram is $Mg\text{-}SO_4^{2-}$ type. Boreholes and Hand-dug wells in Abatoir area, northeast of the study area may not be useful for domestic and agricultural purposes due to the high Cd and Pb contents with the attendant public health implications. Proper waste disposal system and controlled application of fertilizer must be implemented in the area in order to address groundwater contamination via human activities.

Keywords: Anthropogenic, Evaluation, Groundwater Samples.
***Corresponding Author:** akoamadi @ yahoo.com. Mobile Tel. 08037729977

## INTRODUCTION

Groundwater 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 decrease in mineral content as it migrates. As it 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 water in terms of its fairly constant temperature and ionic exchange as well as been turbidity free. The progressive degradation of the water quality via human activities, if unchecked, will greatly affect its usability. Similarly, bacteriological and chemical pollution of groundwater has an immediate impact on human health as evidenced in transmission of water-borne diseases such as typhoid, cholera and dysentery (Amadi, 2007).

Minna, like most state capitals in Nigeria, has witnessed rapid demographic growth and spatial expansion. The peaceful nature of Minna and its proximity to the Federal Capital Territory, Abuja may have contributed to this. The aim of this study was to evaluate the quality of groundwater in Minna area in order to ascertain its fitness for domestic, agricultural and industrial purposes.

## MATERIALS AND METHODS

### Description of the Study Area

The study area lies between longitudes 6°30′E and 6°38′E of the Greenwich meridian and latitudes 9°31′N to 9°42′N of the equator. It covers a total area of about 295km$^2$. The area is accessible through Suleja road, Bida road, Zungeru road and Kuta road. The area is drained by river Chanchaga and its tributeries (Fig.1).

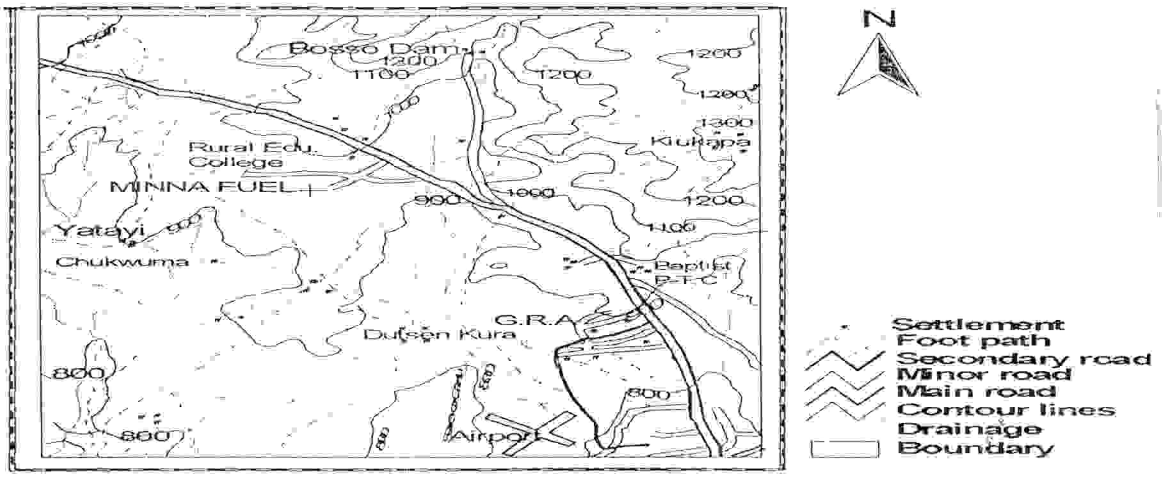


Fig. 1: Map of Southwestern part of the study area showing the sampling locations

### Hydrogeological Mapping of the Area

The Static Water Levels (SWL) of the perched aquifer in hand-dug wells was determined with the aid of a measuring tape. The longitude, latitude and elevation of the area were obtained using a Global Positioning System (GPS). The value of the Static Water Levels (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 in the area using Surfer-8 software. The groundwater in the area flows from the North West to South East and North East to South West directions away from the high topographic area and converge towards the central and southern part of the city (Fig. 2). These directions are parallel to the joint directions. The convergence of the groundwater in these areas is therefore fracture-controlled (Amadi,2007).

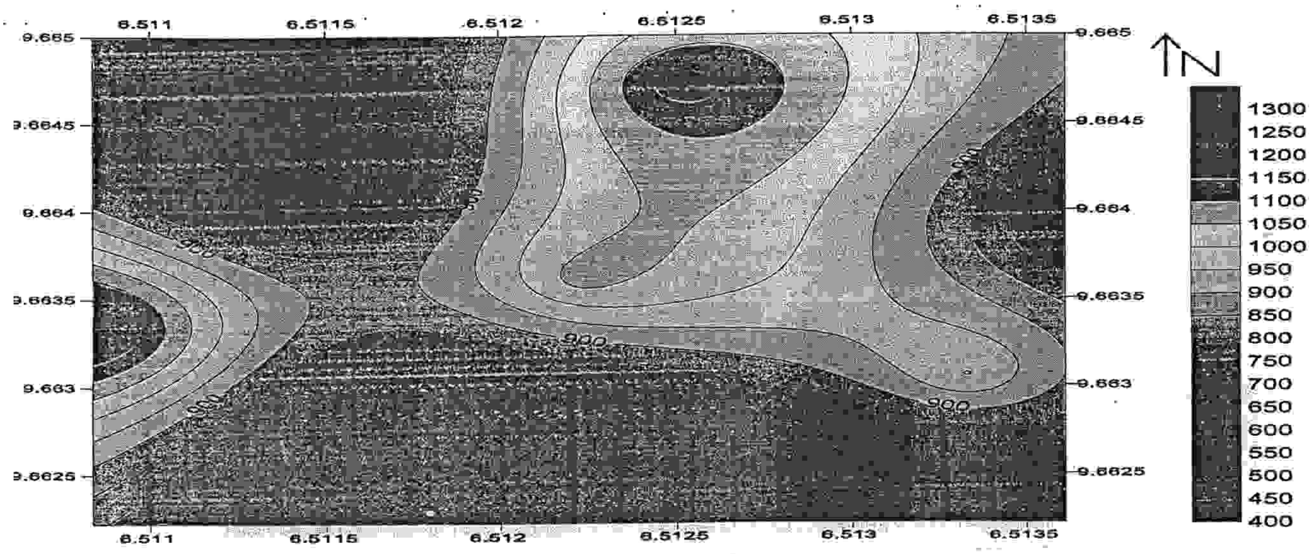


Fig. 2: An Overlay of Groundwater flownet in the Southwestern part of the study Area. (Source: Amadi, 2007)

### Sample Collection

A total of 20 hand-dug well samples were collected and sent to the laboratory for relevant chemical and physical analyses. At every location, a glass container was used to collect water sample for the anion analysis while a plastic container were used for the cation analysis. The samples in the plastic containers (for metal analysis) were sealed with a drop of trioxonitrate (v) acid ($HNO_3$) to ward off atmospheric interference, homogenize the water samples and prevent the growth of algae or microbial organisms as well as, to prevent the metallic ions from adhering to the walls of containers. Samples were properly covered and put into a box containing ice while in the field and finally preserved in a refrigerator at a $10^0$cbefore the determination of metal ions using Atomic Absorption Spectrometry (AAS). The physical parameters namely pH, conductivity, temperature and turbidity were determined on the field using a calibrated pH metre, conductivity meter, thermometer and turbidometer respectively.

## RESULTS

### Physical Parameters

The results of the physico-chemical parameters are summarized in Table 1. The pH ranged from 6.40 to 7.60 with a mean value of 6.80, which indicate that the groundwater in the area is slightly acidic. Electrical conductivity (EC) varied from 0.28µS/cm to 1.46µS/cm ($\bar{x}$ 0.52µS/cm). The electrical conductivity values are far below the permissible limits of 1000µS/cm recommended by WHO (2006) and NSDWQ (2007). Similarly, the values of total dissolved solid (TDS) were of the order 0.14mg/l to 0.74mg/l (mean 0.26mg/l). The value is much lower compared with the maximum allowable value of 500mg/l (WHO, 2006; NSDWQ, 20007). Turbidity varied from 0–14(NTU) with an average value of 1.67NTU. The values of turbidity in most locations were below the WHO and NSDWQ guideline of 5NTU for safe drinking water except location 15(Tungan-goro). The color value increased from 0–550 (pt.co) with a mean value of 41pt.co, as against 15pt.co recommended by WHO (2006) and NSDWQ (2007). The temperature was of the order of $21^0$C to $23^0$C with an average value of $21.25^0$C. This range of temperature is within the WHO and NSDWQ guideline values for safe drinking water.

Table 1: Mean and Range of the Physico-chemical parameters of Groundwater samples in Minna

| Parameters (mg/l) | Mean | Range |
|---|---|---|
| Electrical Conductivity (µs/cm) | 0.52 | 0.28 -1.46 |
| TDS | 0.26 | 0.14 -0.74 |
| Suspended Solid | 23.2 | 0 – 362 |
| Colour (pt.co) | 41 | 0 – 550 |
| $Fe^{3+}$ | 0.17 | 0 – 1.3 |
| $NO_2^-$ | 11.78 | 1.4 – 35.8 |
| $NO_3^-$ | 51.81 | 6.16 -157.5 |
| $PO_4^{3-}$ | 1.24 | 0 – 6.2 |
| $Cu^{2+}$ | 0.03 | 0 – 0.58 |
| $Mg^{2+}$ | 93.97 | 26.4 – 240 |
| $Ca^{2+}$ | 63.02 | 17.6 – 160 |
| $HCO_3^-$ | 91 | 20 – 230 |
| $SO_4^{2-}$ | 29.55 | 11 – 44 |
| $Pb^{2+}$ | 1.4 | 0 – 2.8 |
| $Zn^{2+}$ | 0.01 | 0- 0.17 |
| Cd | 0.6 | 0 – 2.1 |
| $Cl^-$ | 0.03 | 0 – 0.15 |
| Mn | 0.049 | 0 – 0.3 |
| $K^+$ | 0.072 | 0 – 0.347 |
| $Na^+$ | 9.44 | 4.27-31.03 |
| pH | 6.86 | 6.4 – 7.6 |
| Temp. $^0$C | 21.25 | 21.0 -23.0 |
| Turbidity (NTU) | 1.67 | 0.0-14 |

### Chemical Parameters

#### Cations

The value of magnesium ion ($Mg^{2+}$) varied from 26.4mg/l to 240mg/l with a mean value of 93.97mg/l while calcium ($Ca^{2+}$) ranges from 17.6mg/l to 160mg/l ($\bar{x}$, 63.03mg/l. These values comply with the maximum permissible limits of 200mg/l for magnesium and 150mg/l for calcium (WHO, 2006; NSDWQ, 2007). The concentration of Sodium ($Na^+$) ranged from 4.27mg/l to 31.03mg/l ($\bar{x}$, 9.44mg/l while potassium ion ($K^+$) varied from 0.00 to 0.347mg/l with a mean of 0.075mg/l. The WHO (2006) and NSDWQ (2007) maximum permissible values for Sodium and Potassium are 200mg/l and 150mg/l, respectively. Their measured values are comfortable with the two standards. Nitrate values ranged from1.4mg/l to 35.8mg/l with an average concentration of 11.78mg/l while phosphate varies from 0–6.2mg/l and a mean value of 1.24mg/l. Their presence in groundwater could be partly through application of fertilizer (N-P-K). The fertilizer weakens the soil cohesiveness thereby making the soil more porous and permeable. These elements get to the water-table via infiltration processes.

#### Anions

The concentrations of bicarbonate ion ($HCO^{3-}$) ranged from 20mg/l to 230mg/l with an average value of 91.0mg/l. These values fell within the maximum allowable limit of 100mg/l (WHO, 2006; NSDWQ, 2007). The concentration of Sulphate ion ($SO_4^{2-}$) varied from 11.0mg/l to 44.0mg/l with a mean of 29.55mg/l. The value is within the limits of 100mg/l for $SO_4^{2-}$ by WHO (2006) and NSDWQ, (2007). The concentration of Chloride ion ($Cl^-$) is of the order of 0.00 to 0.15mg/l with a mean value of 0.03mg/l. This value is very much lower than the guideline value of 200mg/l (WHO, 2006) and 250mg/l (NSDWQ, 2007). The value of Nitrate ($NO_3^-$) ranged from 6.20mg/l to 157.50mg/l with an average concentration of 51.80mg/l. Nitrate concentration is above the maximum allowable value of 50mg/l (WHO, 2006 and NSDWQ,2007) in some locations, especially in areas with intense farming activities.

#### Trace Elements

The values of ferrous ion ranged from 0.00 to 1.30mg/l with a mean of 0.17mg/l while lead ($Pb^{2+}$) varied from 0.00 to 28mg/l with an average value of 1.4mg/l as against the maximum recommended value of 0.3mg/l and 0.01mg/l for $Fe^{2+}$ and $Pb^{2+}$ respectively (WHO, 2006 and NSDWQ,2007). Out of 20 locations sampled, $Pb^{2+}$ was detected only at location 3 while $Fe^{2+}$ had high concentration in locations 1, 2, 5 and 20 (Fig. 3). The concentration of copper ion ($Cu^{2+}$) varied from 0.00 to 0.58mg/l and a mean value of 0.03mg/l while Zinc ion ($Zn^{2+}$) ranged from 0.00 to 0.17mg/l with an average value of 0.01mg/l. The maximum allowable value for Copper is 2.00mg/l (WHO, 2006) and 1.00mg/l (NSDWQ, 2007) while Zinc is 3.00mg/l (NSDWQ, 2007) and 5.00mg/l (WHO, 2006). The concentration of Copper and Zinc in the area are far below their guideline values as postulated by the two standards. The value of Cadmium (Cd) ranges from 0–12mg/l with an average value of

0.6mg/l while Manganese (Mn) varies 0.00 to 0.30mg/l with a mean value 0.05mg/l. The WHO, (2006) maximum permissible values are 0.40mg/l for Manganese and 0.003mg/l for Cadmium while in NSDWQ, (2007) Manganese and Cadmium are 0.20mg/l and 0.003mg/l, respectively.

**Trilinear Diagram.**

The concentration of eight major ions ($Na^+$, $K^+$, $Mg^{2+}$, $Ca^{2+}$, $Cl^-$, $CO_3^{2-}$, $HCO^-_3$ and $SO_4^{2-}$) are represented on a trilinear diagram by grouping the $K^+$ with $Na^+$ and $CO_3^{2-}$ with $HCO_3$, thus reducing the number of parameters for plotting to six (Fig. 3). On the trilinear 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 trilinear diagram is useful in classifying the hydro-chemical facies of the water samples according to their dominant ions. From the result, the dominant cation and anion in the area are Magnesium and Sulphate respectively; hence, the water in the area is $MgSO_4^{2+}$ type.

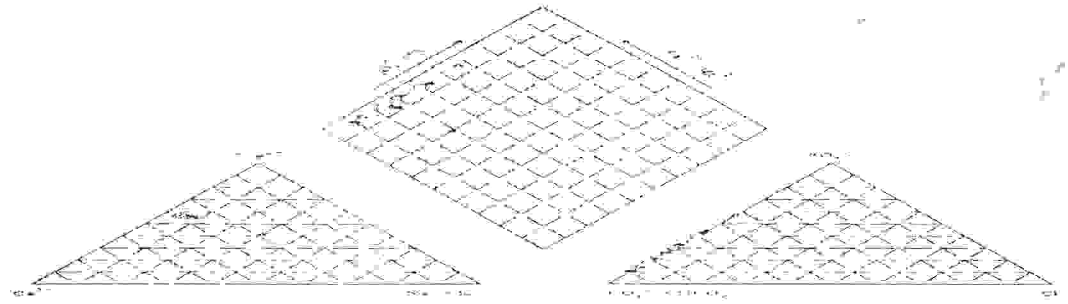

Fig. 3: Piper diagram of the groundwater samples of the study area.

## DISCUSSION

Majority of the physical parameters analyzed have their values below the maximum permissible values of WHO (2006) and NSDWQ (2007), except turbidity in location 15, with a value of 14NTU as against recommended maximum limit of 5NTU. Turbidity has no negative health implication, which implies that physical parameters complied with the guideline values. Similarly, most of the cations and anions have their concentrations below the recommended maximum allowable limits of WHO, (2006) and NSDWQ, (2007) except Magnesium and Calcium in locations 4 and 6, bicarbonate in locations 4, 6, 13 and 17, as well as, Nitrate in locations 4, 9, 11 and 14. Their high concentration may be attributed to primary and or secondary enrichment. The primary enrichment of Magnesium and Calcium ions involves elemental dissolution of host-rock by groundwater as water flows through the rocks. Human activities (dumpsites, cemetery, mechanic workshop, fertilizer application) may contribute to the secondary enrichment. Leachate from these potential pollution point sources could get to the water-table via infiltration thereby contaminating the groundwater with nitrate and bicarbonates.

Furthermore, the trace elements complied with WHO guideline for Drinking Water Quality (WHO, 2006) and the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) except for Cadmium and Lead in location 3 and Iron in locations 2 and 5. High concentration of iron in water is not hazardous as only the colour and taste are affected (WHO, 2007). The body needs iron for efficient metabolic processes, however, high Lead and Cadmium concentrations in water has a serious health implications. High concentrations of cadmium in the body is toxic to the kidney while excess amount of lead causes cancer, interference with vitamin D metabolism, affects mental development in infants and toxic to the central and peripheral nervous system (NSDWQ, 2007).

## CONCLUSION

The groundwater in Minna area has been evaluated using hydrogeological and physico-chemical parameters. The groundwater flow direction has been generated and it has aided the understanding of leachate migration pathways in the area. The water in the area is Mg-$SO_4^{2-}$ type. The analyzed physico-chemical parameters have most of their concentration below the maximum recommended value for safe drinking water, while few parameters have their concentration slightly above the maximum allowable limit. It might be anthropogenically induced via different form of human activities or naturally induced, through the dissolution of bedrock in which the groundwater passes.

## RECOMMENDATION

Due to occurrence of high Nitrate ion in some locations, the use fertilizer in farming should be controlled. The groundwater in location 3 (Abatoir) may not be used for irrigation and domestic purposes due its high concentration of Cadmium and Lead and the associated health risk. Groundwater quality monitoring should be adopted in the area. The Federal Ministry of Water Resources and Niger State Water Cooperation should employ a holistic approach to drinking water supply risk assessment and management. This approach should entail a systematic assessment of drinking water supply from the catchments and its source to the consumer. Other surveillance agencies like Niger State Environmental Protection Agency should be alive to their responsibilities to ensure that random refuse disposal is checked. Drinking water suppliers should provide their consumers with detailed information about the safety of the water supplied to them for domestic purposes through annual water reports. Periodic checks of the chemical and bacteriological quality of selected boreholes and hand-dug wells should be carried out in the area. Groundwater quality management through education of the public on health implications of water pollution and enforcement of necessary law that can help the protection of groundwater system is advocated. The existing (dumpsites and slaughter) in Abatoir area should be abandoned and landfill remediation measures enforced.

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