ANALYTICAL STUDIES ON SURFACE AND GROUNDWATER IN ZUNGERU, NIGER STATE, NORTH-CENTRAL NIGERIA

A. N. Amadi*[1], A. A. Soliu[1], S. C. Agwuncha[2], H. O. Nwankwoala[3], C. N. Nwakife[4], Isah Shaibu[5]

[1]Department of Geology, Federal University of Technology, Minna, Niger State
[2]Department of Chemistry, Ibrahim Badamasi Babangida University, Lapai, Niger tate
[3]Department of Geology, University of Port Harcourt, Rivers State
[4]Department of Chemistry, Federal University of Technology, Minna, Niger State
[5]Department of Geology, Federal University, Gusau, Zamfara State
*Corresponding Author's email: an.amadi@futminna.edu.ng, Phone No.+234-80377-29977

Abstract
The physical, chemical and bacteriological characteristics of water in an area is a function of the geogenic and anthropogenic activities domiciled in the area and this in turn determines its suitability for either domestic, industrial or agricultural application. The quality of surface and groundwater from Zungeru area of Niger State, north-central Nigeria was investigated in this study from the point view of suitability for drinking and domestic purposes. A total of 10 surface water and 25 hand-dug wells were used assess the water quality in the area. Physical parameters were determined in the field before sampling while chemical and microbial parameters were determined in laboratory. The results of the analyses revealed that the water in the area is good from physical and chemical standpoint and very poor bacteriologically, due to high concentration of total coliform (38.0-800 cfu/100ml), faecal coliform (0.0-160.0 cfu/100ml) and faecal streptococci (0.0-180.0 cfu/100ml), an indication of faecal contamination of the water sources in the area. The high content of faecal bacteria in the water from the area may responsible for observed wide variation in the concentration of total hardness (19.2-1480.0 mg/l), total dissolved solids (35.05-2800.4 mg/l) and electrical conductivity (52.03-4170.55 mg/l). Boiling of water before consumption is advocated. Sensitization campaign on the implication of water pollution should be carried out in the area to enable the people to be aware of some of their actions.

Keywords: Quality Assessment, Surface Water, Groundwater, Zungeru, Niger State, North-central Nigeria

1.0. Introduction

Water which is a vital resource of life is increasingly being polluted in the wake of modern civilization, industrialization, urbanization, high population growth, poor sanitation and agricultural activities. Water is indispensible for human existence and this explains why people settle near it. Water quality denotes the physical, chemical, biological and sometimes radiological composition of water. The chemistry of surface and groundwater is largely controlled by the nature of host and associated rocks, the discharge-recharge pattern as well as the anthropogenic activities (Amadi *et al.*, 2015). Geochemical processes occurring within the surface and groundwater have a profound effect on water quality. Close relationship exists between water quality and land use as various land use activities results in surface and groundwater contamination (Amadi *et al.*, 2014; Yisa *et al.*, 2012; Ranjana, 2009). Groundwater accounts for greater percentage of the world's fresh water and it is fairly distributed throughout the world. It is the world's greatest essential factor for sustainable development. Surface is not evenly distributed by nature as groundwater and where available are sometimes seasonal and prone to contamination either as a result of various human activities. Hence, the need to qualitatively evaluate the potability of surface and groundwater in Zungeru area of Niger State, north-central Nigeria cannot be overemphasized.

2.0. Materials and Methods

Description of Study Area

Zungeru is one of the ancient city and former Capital of Nigeria. The town Zungeru was very popular during the era of railway in Nigeria as it has one of the best railway stations in Nigeria. The study area is part of Zungeru Sheet 163 and it lies between latitudes 9°46'N to 9°52'N of the Equator and Longitudes 6°07'E to 6°13'E of the Greenwich Meridian (Fig. 1). It has an area extent of approximately 155 km^2 and it is accessible through Minna-Zungeru road, Zungeru-Wushishi road and Zungeru-Kontagora road as well as the Lagos-Minna-Zungeru - Kano railway line.

Geology of the Study Area

The rock types encountered in the mapped area include migmatite-gneisses, schists, amphibolites, quartzites and granites (Fig. 1). The gneisses occupy most of the study area and include the granite gneiss and the banded gneiss. Both gneisses intruded the schist and have in turn been intruded by granites. The gneisses occur as hilly, massive and low lying outcrops, where they form contact with the schists. The schist and amphibolites occupy the central part of the study area and are boarded by approximately N-S trending units of the migmatites-gneiss complex. The contact with the gneisses may be tectonic in places and is marked by development of cataclastics and mylonites. The amphibolites occur in association with quartzites and this association suggests that both rocks must have been sediments deposited and later metamorphosed to form amphibolites and quartzites. Two varieties of amphibolites were revealed in the field (Ako, 2014). They are the banded and massive varieties. The banded variety is medium grained, strongly foliated and dark green in colour whereas the massive variety is fine to medium grained, weakly foliated and dark grey in colour. Ajibade *et al.* (1979) have reported large bodies of amphibolite within the study area. They described the contact between the amphibolites and the quartzo-feldsparthic rocks as sharp in some areas while in others the contacts are transitional. The transitional contacts mapped by (Ajibade *et al.*, 2008) made him to conclude that the amphibolites were probably derived from calcareous sediments. The rocks in the area has witnessed serious structural deformation resulting in folding, fracturing (faulting and jointing) leading to the formation of mylonites.

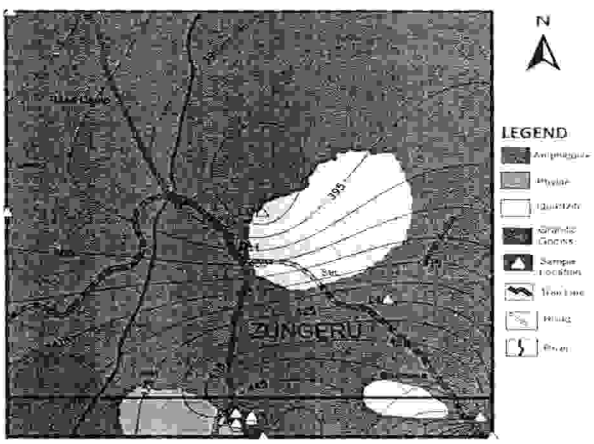

Fig. 1: Geology Map of parts of Zungeru

Sampling

A total of 10 surface water samples and 25 hand-dug wells samples were collected in pairs (plastic and glass bottles) from different parts of Zungeru and send to the laboratory for relevant chemical and bacteriological analysis. To each of these water samples in plastic bottles, two drops of concentrated HNO_3 acid were added for homogenization and prevention of adsorption of the metals to the walls of the plastic container and used for the heavy metal determination while the samples in the glass container were used for the determination of the anions. Prior to the collection of the water samples in the various bottles, the physical parameters such as pH, conductivity, turbidity and temperature were measured in the field using pH meter, conductivity meter, turbidiometer and mercury thermometer respectively while the chemical and microbial parameters were analyzed in Federal Ministry of Water Resources Regional Laboratory, Minna and Central Laboratory of Federal University of Technology, Minna.

3.0. Results and Discussion

The physical, chemical and bacteriological parameters analyzed are statistically presented in Table 1. The pH which is the hydrogen ion concentration of a medium ranged from 6.83-7.68 with a mean value of 7.17 (Table 1) and these values falls within the acceptable range of 6.50 to 8.50 postulated by Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). The pH is an important water quality indicator and it shows an extent of pollution in water and soil media. It also influences the mobility metals in rocks, soil and water media (Amadi *et al.*, 2015). The total dissolved solids (TDS) indicate the amount of solutes dissolved in water and a useful parameter in assessing the water quality of an area. The concentration of TDS ranged from 35.05-2800.0 mg/l with an average value 599.53 mg/l (Table 1). The mean value exceeds the maximum permissible limit of 500.00 mg/l stipulated by the World Health Organization (WHO, 2010). The amount of substance that dissolves in water affects the overall quality of the water and makes water conductive (Okunlola *et al.*, 2016). The electrical conductivity (EC) is a valuable indicator of water quality because water in its pure state is none conductive. The dissolution of ions in water makes it conductive and these ions can be beneficial or harmful to animal or plant health (Olasehinde *et al.*, 2015). The determined value of EC in the water sample ranged between 52.03-4170 µs/cm with a mean value 874.02 µs/cm. The mean conductivity value is below the acceptable limit of 1000.00 µs/cm for safe drinking water (NSDWQ, 2007). However, in some locations, the values are far above the maximum permissible limit, which implies deterioration of the water quality in the area either geogenically or anthropogenically (Nwankwoala *et al.*, 2015).

Table 1: Statistical Summary of Parameters Analyzed

Parameters (mg/L)	Range	Mean	NSDWQ, 2007
TDS	35.05 – 2800.40	599.53	500
Conductivity (µS/cm)	52.03 – 4170.55	894.02	1000
Dissolved Oxygen	7.31– 8.50	7.65	10.0
Temperature (^{0}C)	28.60 – 28.70	28.63	Ambient
pH	6.73 – 7.68	7.17	6.5-8.5
Turbidity (NTU)	0.62 – 274.05	33.58	5.0
Chloride	14.40 – 240.80	65.52	250.0
Sulphate	3.00-135.00	46.20	100.0
Total Hardness	19.20 – 1480.00	247.70	150.0
Fluoride	0.00 – 1.03	0.31	1.5
Alkalinity	2.00 – 21.00	8.92	100.0
Phosphate	0.00 – 14.90	2.32	15.0

Bicarbonate	1.00 – 24.00	10.25	100.0
Nitrate	4.64 – 64.00	17.45	50.0
Sodium	4.00 – 155.00	44.08	200.0
Potassium	3.00 – 15.00	6.5	100.0
Calcium	8.97 – 385.00	75.35	250.0
Magnesium	2.44 – 126.80	25.21	200.0
Aluminium	0.28 – 12.00	4.28	0.2
Iron	0.03 – 0.74	0.18	0.3
Arsenic	0.00-0.00	0.00	0.00
Copper	0.02 – 1.40	0.33	1.0
Zinc	0.00 –5.81	0.93	3.0
Total Coliforms (cfu/100mL)	38.00 –800.00	258.08	10.0
E. Coliforms (cfu/100mL)	0.00 –160.00	56.00	0.0
Faecal Strep. (cfu/100mL)	0.00 –180.00	59.00	0.0

Temperature is a measure of the degree of hotness or coldness of a substance. The water temperature was measured varied from 28.60-28.70°C with a mean value of 28.63°C (Table 1). Many biological processes in water are known to be influenced by changes in environmental temperature and chemical substances dissolve more readily as temperature increases, unlike most gases which become less soluble as temperature rises (Amadi, *et al.*, 2012). The amount of suspended substances in water makes the water turbid. The measured turbidity in the various water sources in the area ranged between 0.62-274.05 NTU with a mean value of 33.58 NTU as against the permissible value of 5.00 NTU recommended by (NSDWQ, 2007). Surface water is generally more turbid than groundwater due to surface run off. Dissolved oxygen (DO) represents the amount of oxygen required to oxidize the organic matter content in the water samples to carbon dioxide and water (Yisa and Jimoh, 2010). The value of DO in the water samples ranged from 7.31-8.50 mg/l with an average value of 7.65 mg/l (Table 1).

The mean concentrations of total coliform, Escherichia coli and faecal Streptococci are 258.08 cfu/100ml, 56.0 cfu/100ml and 59.0 cfu/100ml as against their respective maximum allowable limits of 10.0 cfu/100ml, 0.0 cfu/100ml and 0.0 cfu/100ml (Table 1; WHO, 2010). Their presence in water in the area at a very high concentration is a proof that the water sample is in contact with animal and human faeces. Siting of hand-dug wells very close to dumpsites, unlined pit-latrine and soakaway may as well as defecating on surface water or river channels introduce these bacteria into the water system. Faecal contamination of water sources causes water-borne diseases such as cholera, typhoid, meningitis and diarrhea as well as morbidity and mortality among children. It also causes acute renal failure and hemolytic in adults (Amimu and Amadi, 2014). The concentration of chloride ranged from 14.4-240.8 mg/l with a mean value of 65.52 mg/l (Table 1). The values are below the maximum permissible limit of 250.00 mg/l (NSDWQ, 2007). High chloride content in water may be an indication of pollution by sewage, industrial waste or saline water intrusion (Bertram and Balance, 1998). High chloride values may not constitute health hazard to human beings, but it does produce salty taste, corrode metal pipe and may harm non-halophytic plants (Amadi *et al.*, 2013). The concentration of sulphate varied from 3.0-135.0 mg/l and an average value of 46.2 mg/l. The value in few locations especially the surface water and hand-dug wells were found to be higher than the maximum allowable limit of 100.00 mg/l as recommended by (WHO, 2010) and their enrichment in the water system may be attributed to bedrock dissolution due to rock water interaction as well as urban pollution (Amadi *et al.*, 2012).

The concentration of nitrate in the water samples collected lied between 4.64-64.0 mg/l with a mean value 17.45 mg/l (Table 1) as against the maximum permissible limit of 50.00 mg/l by (NSDWQ, 2007). High nitrate level in drinking water causes infant methaemoglobinaemia (blue-baby syndrome), gastric cancer, metabolic disorder and livestock poisoning. The sources of nitrate in the groundwater can be attributed to anthropogenic activities such as on-site sanitation, waste dumpsites and fertilizer application (Dan-Hassan *et al.,* 2012). This concentration of sodium ranged from 4.0-155.0 mg/l with a mean value of 44.08 mg/l and it is within the allowable limit of 200.00 mg/l (WHO, 2010). In epidermiological studies, a direct correlation between hypertension and sodium level in drinking water has been observed while the noxious effects of sodium on blood vessels have been known for years (Dyckner and Wester, 1983). Though high sodium content in water may not be harmful to living matter due to the non-toxic nature of the metal, balance among other nutrient elements may affect the soil used for agricultural purposes (Wardener and MacGregor, 1983). Calcium concentration ranged from 8.97-384 mg/l with a mean value of 75.35 mg/l as against the permissible limit of 250.00 mg/l based on (NSDWQ, 2007). Calcium is necessary in animals for the formation of strong tooth and bone and its high concentration in water does not have any negative impact on health.

The magnesium concentration varied from 2.44-126.8 mg/l with a mean value of 25.21 mg/l (Table 1). The values are within the recommended value of 200.00 mg/l on (WHO, 2010). The importance of Magnesium in water is both quantitative and qualitative. Studies have shown that magnesium in water is better and more quickly absorbed than dietary magnesium (Amadi *et al.,* 2014). Epidemiological data in man and experimental data in rats have demonstrated that the intake of water containing sufficient amount magnesium can prevent arterial hypertension and correlated ionic and nervous disturbances (Durlach *et al.*, 1985). The concentration of potassium ranged from 3.0-15.0 mg/l and a mean value of 6.5 mg/l while the concentration of fluoride concentration 0.0-1.05 mg/l with a mean value of 0.31 mg/l. Their concentration falls within the permissible limit. High concentration of fluoride in water causes a disease known fluorosis which affects the teeth and bones of man and animals (Okunlola *et al.*, 2016). The mean concentration of alkalinity, phosphate and bicarbonate varied in the order of 8.92 mg/l, 2.31 mg/l and 14.25 mg/l (Table 1) and are found to be within the acceptable limit for a safe drinking water. The concentration of aluminum ranged from 0.28-12.0 mg/l with mean value of 0.18mg/l while the concentration of total hardness varied from 19.20-1480.0 mg/l with an average value of 247.7mg/l (Table 1). The mean values of both aluminum and total hardness were found to be higher the maximum permissible limit of 0.2 mg/l and 150.0 mg/l respectively, thereby indicating possible contamination. The average concentration of arsenic, iron, zinc and copper are in the order of 0.0 mg/l, 0.18 mg/l, 0.33 mg/l and 0.92 mg/l and these values falls within their respective permissible limits (Table 1). Iron is an essential nutrient that is vital to the processes by which cells generate energy. This implies that the water system in study area presently is free from heavy metal pollution.

Hydrochemical Facies Analysis using Piper and Durov Diagrams

This method was devised by Piper and Durov to outline certain fundamental principles in a graphic procedure which appears to be an effective tool in grouping geochemical data for critical study with respect to sources of the dissolved constituents in water. The concentration of 8 major ions (Na^+ , K^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^-, HCO_3^- and SO_4^-) are represented in the trilinear diagrams by grouping the (K^+ with Na^+) and the (CO_3^- with HCO_3^-), thus reducing the number of parameters for plotting to 6. On the Piper and Durov diagrams, 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 two diagrams. The Piper and Durov diagrams (Figs. 2 and 3) were used to classify the Hydrochemical facies of the water samples according to their dominant ions into their respective water source and type. It should be noted that physical parameters, bacteriological parameters as well as heavy metals are not used in Hydrochemical facies interpretation as it is limited to the major cations and anions that are always present in any given water sample.

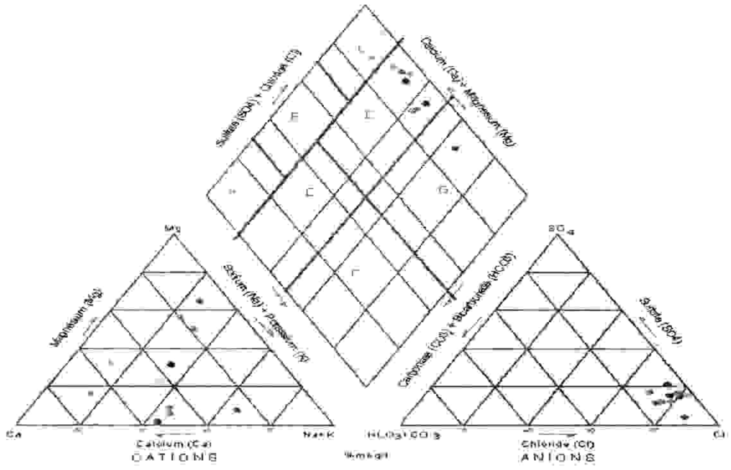

Fig. 2: Piper diagram of water sources in the Study Area

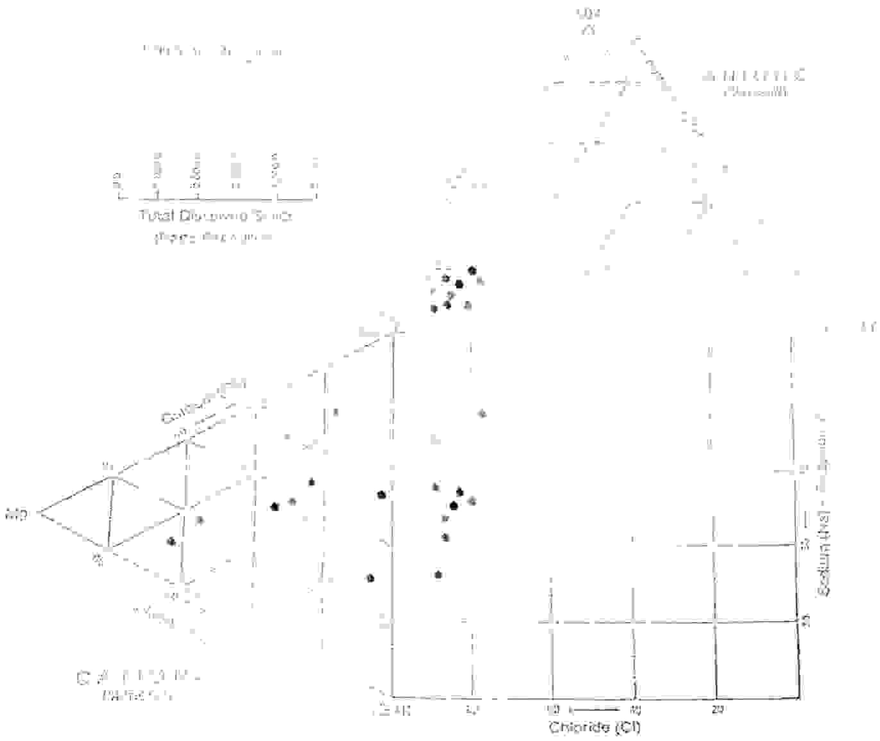

Fig. 3: Durov diagram of water sources in the Study Area

4.0. Conclusions

The work done in Zungeru area of Niger State, northcentral Nigeria comprises of physico-chemical and Bacteriological analyses of surface and groundwater samples. The mean concentrations of the chemical parameters falls within the maximum permissible limit for safe drinking water with recommended by the WHO and NSDWQ. However, the water in the study area is poor bacteriologically as reflected by the high concentration of total coliform (38.0-800 cfu/100ml), faecal coliform (0.0-160.0 cfu/100ml) and faecal streptococci (0.0-180.0 cfu/100ml), an indication of faecal contamination of the water sources in the area. Their presence indicates faecal contamination and signals a potential health risk in term of water borne and water related diseases in the nearby future if not controlled now. This pollution is basically from animal and human faeces. The far reaching microbial contamination of the water sources in the area is responsible the anomalous concentrations and wide range observed in total hardness (19.2-1480.0 mg/l), total dissolved solids (35.0-2800.40 mg/l) and conductivity (52.03-4170.55 mg/l) as against the recommended values of 150.0 mg/l, 500.0 mg/l and 1000.0 mg/l respectively. Human and animal faeces are the chief sources of pathogens, bacteria, viruses, protozoa and helminthes and their contact in water body contaminates the water. Due to the high faecal coliform content in the water, boiling of the water before drinking is advocated. Most bacteria cannot withstand elevated temperature and boiling will kill such bacteria. Groundwater quality monitoring should be adopted in the area. Siting of hand dug wells close to soakaways, dumpsites and pit-toilets should discontinue. Open defecation and along the river course should be checked. Federal Ministries of Water Resources and Niger State Water Board 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 adjoining tributaries.

References

Ajibade, A. C., Anyanwu. N. P. C. and Okoro, A. U., (2008). The Geology of Minna Area 1:250,000 Sheet 142 Minna. Nigeria Geological. Survey. Agency, Bull. No. 43, 112p.

Ajibde, A. C., Fitches, W. R. and Wright, J. B., (1979). The Zungeru Mylonites, Nigeria: recognition of a major tectonic unit. Rev. Geol. Dyn. Geog. Phys., 21(5), 359-363.

Ako, T. A., (2014). Geology and Geochemistry of Zungeru Amphibolites, Noth-central Nigeria. Universal Journal of Geosciences, 2(4), 116-122.

Amadi, A. N., Olasehinde, P. I., Yisa, J., Okosun, E. A., Nwankwoala, H. O. and Alkali, Y.B., (2012). Geostatistical assessment of groundwater quality from coastal aquifers of Eastern Niger Delta, Nigeria. Geosciences, 2(3), 51–59, doi: 10.5923/j.geo.20120203.03.

Amadi A. N., Dan-Hassan M. A., Okoye N. O., Ejiofor I. C. and Aminu Tukur, (2013). Studies on Pollution Hazards of Shallow Hand-Dug Wells in Erena and Environs, North-Central Nigeria. Environment and Natural Resources Research, 3(2), 69-77.

Aminu Tukur and Amadi A. N., (2014). Bacteriological Contamination of Groundwater from Zango Local Government Area, Katsina State, Northwestern Nigeria. *Journal of* Geosciences and Geomatics, 2(5), 186 – 195. doi:10.12691/jgg-2-5-2.

Amadi, A. N., Okoye, N. O., Alabi, A. D., Aminu Tukur and Angwa, E. M., (2014). Quality Assessment of soil and groundwater near Kaduna Refinery and Petrochemical Company, Northwest Nigeria. Journal of Scientific Research and Reports, 3(6), 884 – 893.

Amadi A. N., Okunlola I. A., Dan-Hassan M. A., Aminu Tukur, Ola Olubusayo, (2015 Evaluation of Groundwater Quality in Shallow Aquifers in Minna, North-Central Nigeria using Pollution Load Index. Journal of Natural Sciences Research, 5(8), 45 – 56.

Bertram, J. and Balance, R., (1998). Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programmes. (1st Ed.), Taylor and Francis, USA, 400p.

Dan-Hassan, M. A., Olasehinde, P. I., Amadi, A. N., Yisa, J. and Jacob, J. O., (2012). Spatial and Temporal Dstribution of Nitrate Pollution in Groundwater of Abuja, Nigeria. International Journal of Chemistry, 4(3), 104 – 112, doi: 10.5539/ijc.v4n3p104.

Durlach, J., Bara, M. and Guiet-Bara, A., (2008). Magnesium level in drinking water and Cardiovascular risk factor: *Magnesium* 4, 5-15.

Dyckner, T. and Wester, P.O., (1983). Effect of Mg on blood pressure. *British Medical Journal* 286, 1847-1849.

NSDWQ, (2007). Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard, NIS:554, 1-14.

Nwankwoala, H.O., Amadi, A.N., Oborie, E. and Ushie, F.A., (2015). Hydrochemical Factors and Correlation Analysis in Groundwater Quality in Yenagoa, Bayelsa State, Nigeria. Applied Ecology and Environmental Sciences, 2(4), 100 – 105, doi:10.12691/aees-2-4-3.

Okunlola, I. A., Amadi, A. N., Olashinde, P. I., Maspalma, S. S. and Okoye, N. O., (2016). Quality Assessment of Groundwater from Shallow Aquifers in Hong Area, Adamawa State, Northeastern Nigeria. Ife Journal of Science, 18(1), 267 – 283.

Olasehinde P. I., Amadi A. N., Dan-Hassan M. A., Jimoh M. O., (2015). Statistical Assessment of Groundwater Quality in Ogbomosho, Southwest Nigeria. American Journal of Mining and Metallurgy, 3(1), 21 – 28, doi:10.12691/ajmm-3-1-4.

Ranjana, A., (2009). Study of Physico-chemical Parameters of Groundwater quality in Dudu Town in Rajasthan. Rasanya Journal of Chemistry, 2(4), 969-971.

Wardener, H.E. and Mac-Gregor, G.A., (1983). The role of a circulating inhibitor of Na+ K+ATPase in essential hypertension. *American Journal of Nephrology, 3*, 88-91.

World Health Organisation, (2010). Assessment of fresh water quality–Global environmental monitoring system (GEMS). *A report on the related environmental monitoring*, World Health Organization, Geneva, 357-362.
\

Yisa, J. and Jimoh, T., (2010). Analytical studies on water Quality Index of River Lavu, Bida, North-central Nigeria. American Journal of Applied Sciences, 7(4), 453-458.

Yisa, J., Gana, P. J., Jimoh, T.O and Yisa, D., (2012). Underground water Quality Assessment in Doko Community, Niger State, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences, 3(2), 363-366.