International Journal of Chemistry; Vol. 4, No. 3; 2012
ISSN 1916-9698 E-ISSN 1916-9701
Published by Canadian Center of Science and Education

Spatial and Temporal Distribution of Nitrate Pollution in Groundwater of Abuja, Nigeria

M. A. Dan-Hassan[1], P. I. Olasehinde[2], A. N. Amadi[2], J. Yisa[3] & J. O. Jacob[3]

[1] Rural Water Supply and Sanitation Department, FCT Water Board, Garki, Abuja

[2] Department of Geology, Federal University of Technology, Minna, Nigeria

[3] Department of Chemistry, Federal University of Technology, Minna, Nigeria

Correspondence: A. N. Amadi, Department of Geology, Federal University of Technology, Minna, Nigeria. Tel: 234-818-821-8076. E-mail: geoama76@gmail.com

Received: February 22, 2012 Accepted: March 12, 2012 Online Published: May 27, 2012

doi:10.5539/ijc.v4n3p104 URL: http://dx.doi.org/10.5539/ijc.v4n3p104

Abstract

Groundwater has been recognized as playing a very important role in the development of Abuja, Nigeria's Capital as many households, private and government establishments depends solely on hand-dug wells and boreholes for their daily water needs. Exploitation of groundwater is rather delicate because of its potency to contamination and difficulty to remediate when compared to surface water. The purpose of this paper is to present the occurrence of nitrate in groundwater of Abuja and discuss the implication and sources of the nitrate. High nitrate level in drinking water leads to infant methaemoglobinaemia (blue-baby syndrome), gastric cancer, metabolic disorder and livestock poisoning. A simplified map of nitrate occurrences in Abuja indicates that some areas have nitrate concentration above the WHO and NSDWQ guide limit of 50 mg/l and it is dominant in the rainy season than dry season. The number of people drinking water with nitrate concentration above the permissible level cannot be quantified presently. The sources of nitrate in the groundwater were attributed to bedrock dissolution in the course of groundwater migration and more importantly anthropogenic activities such as on-site sanitation, waste dumpsites and agricultural chemicals. Water treatment by bio-denitrification and nitrate pollution control programs should be introduced at local, state and federal levels in order to educate people on the need to protect groundwater from nitrate pollution caused by agricultural activity and indiscriminate disposal of wastes.

Keywords: anthropogenic activity, nitrate pollution, groundwater, Abuja

1. Introduction

The problem of nitrate pollution in groundwater is a common global phenomenon and has been reported by various authors in many parts of Nigeria (Egboka & Ezeonu, 1990; Uma, 1993; Edet, 2000; Adelana & Olasehinde, 2003; Amadi, 2010). The presence of nitrate in groundwater can be derived from natural and/or anthropogenic sources. The soil/rock-water interactions can result to weathering and enrichment of the groundwater with ammonium ions, since groundwater quality is a function of the chemical composition of the soil/rock through which it passes (Amadi, 2010). The chemistry of groundwater is generally conditioned by the nature of the rock formation through which it flows. The sources and distribution of nitrate in groundwater have been studied in some details in Botswana (Staudt, 2003; Vogel et al., 2004; Schiwiede et al., 2005; Stadler, 2005), Namibia (Heaton, 1984; Wrabel, 2005) and South Africa (Tredoux, 2004; Tredoux et al., 2005). These studies have shown that pollution by anthropogenic activities is the main source of high and variable levels in groundwater. Such activities includes inappropriate on-site sanitation and wastewater treatment, improper sewage sludge drying and disposal, livestock concentration at watering points near boreholes and farming activities by application of nitrogenous fertilizers.

Nitrogen is a major constituent of the earth's atmosphere, comprising nearly 80 % of the air we breathe (Berner & Berner, 1987). Gaseous nitrogen can be found in many forms such as N_2, N_2O, NO, NO_2, NH_3 and NH_4 (Comly, 1987; Kross et al., 1993). Although there are many sources of nitrogen (both natural and anthropogenic) that could potentially lead to the pollution of groundwater with nitrates, the anthropogenic sources are really the ones that most often cause the amount of nitrate to rise to a dangerous level (Hallberg & Keeney, 1993). Some major sources of potential nitrate contamination in groundwater includes: sites used for disposal of human and animal sewage, industrial wastes related to food processing and application of nitrogen-rich fertilizers to crops (Burkart et al., 1993). Enrichment of nitrate in groundwater via human activities is largely an environmental issue and needs to be approached as such. Concentration of nitrate above 50 mg/l in drinking water should generate concern due to the health implications (WHO, 2004).

High concentration of nitrate in drinking water causes infant methaemoglobinaemia, a disease commonly known as 'blue baby' syndrome and at higher levels, livestock poisoning (Canter, 1996). Records have shown that infants are exposed to unsafe levels of nitrate in drinking water when it is used to mix formula milk or other type of baby food, where children are not breast-fed and the risk is aggravated by bacteria pollution and malnutrition (Colvin, 1999). Although there is no accurate statistics on infant methaemoglobinaemia in Abuja, several cases have been reported elsewhere (WHO, 2004). The overall lack of data on the morbidity and mortality of infant methaemoglobinaemia gave rise to this study, which is aimed at providing baseline information on the occurrence and aerial extend of nitrate in Abuja groundwater system.

Groundwater contamination in Nigeria is of great concern as most aquifers are used for domestic water supply purposes and in some cases, marketed as sachet or bottled water. Groundwater in major cities of Nigeria is exposed to active pollution arising from urbanization and indiscriminate waste disposal, since these cities are without organized sanitary waste disposal system while existing landfills are poorly planned and maintained.

2. Materials and Methods

2.1 Study Area Location

Abuja is Nigeria's Federal Capital Territory and lies approximately between longitudes 6°46′E to 7°37′E and Latitudes 8°21′N to 9°18′N (Figure 1). It is bounded in the east by Nasarawa State, north by Kaduna State, west by Niger State and south by Kogi State.

2.2 Relief and Drainage

The topography of the Abuja is varied with the lowest elevations in the extreme southwest at the floodplains of the River Gurara, about 76 m above sea level and it rises irregularly northwestwards to a height of 760 m above sea level. There are numerous hills that occur in the area but the Zuma rock stands out clearly on its own as the most conspicuous Inselberg at the boundary of the Abuja with Niger State. The Inselberg, landscape and extensive plains found between hills, dominate the study area. The rivers take their source from the hills in the northeast and flows to the southwestern. The two major rivers are the River Gurara and River Usman, which join at Nyimbo village to form a tributary of River Niger in the south (Figure 2).

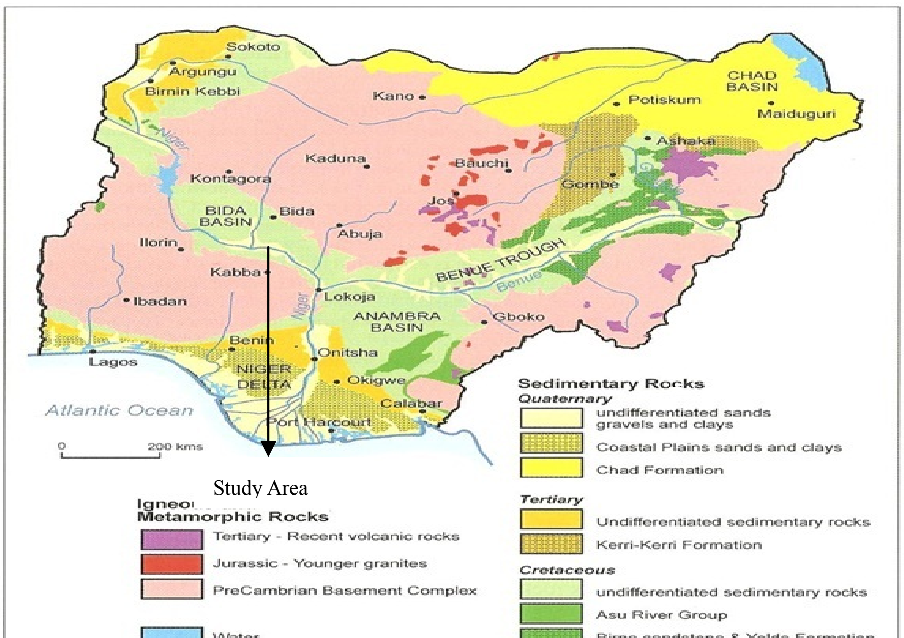


Figure 1. Geological map of Nigeria showing the study area (After MacDonald et al., 2005)

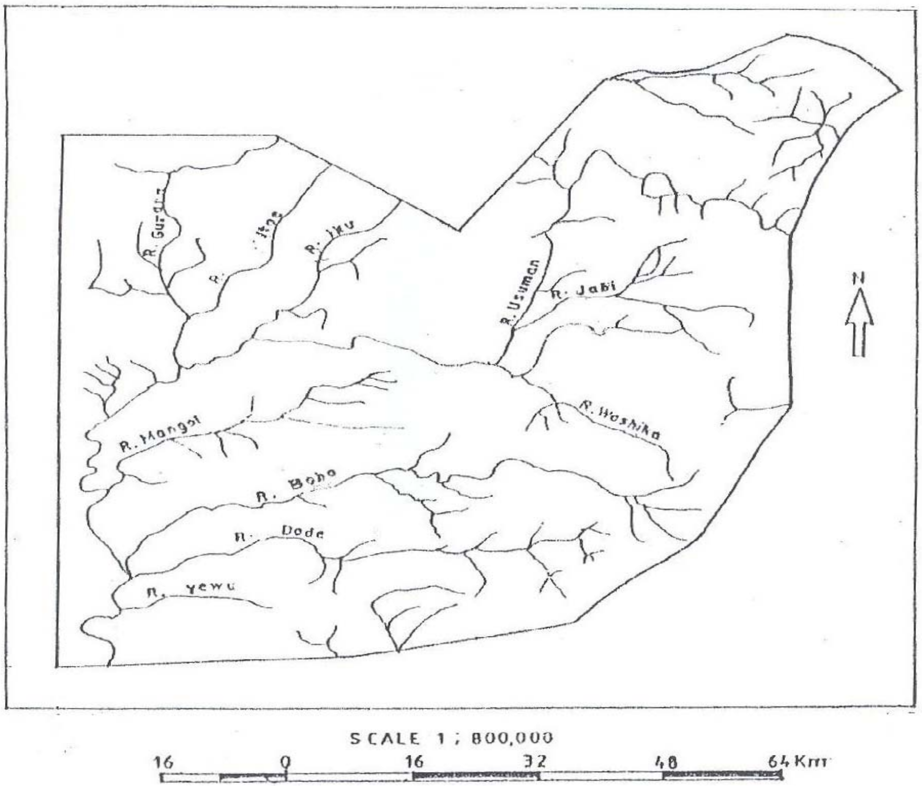


Figure 2. Drainage map of the study area

2.3 Climate, Rainfall and Vegetation

The area records its highest temperature of about 34 ℃ during the dry season, which occurs from November to March. During the rainy season April to October, the maximum temperature drops to about 24 ℃ due to the dense cloud cover (McCurry, 1985). Human sensibility to these temperatures is greatly affected by the relative humidity. During the dry season, relative humidity falls in the afternoon. The annual total rainfall is in the range of 1100mm to 1600mm (Ajibade & Wright, 1988). Two major types of vegetation, namely, forest and savanna, are found within Abuja. The forest is predominantly of woody plants, in which grasses are virtually absent.

2.4 Geology and Hydrogeology of the Area

The geology and hydrogeology of the study area has been described by many workers, including Ajibade (1976), Grant (1978), McCurry (1985) and Ajibade and Woakes (1983). The study area is underlain by Precambrian rocks of the Nigerian Basement Complex which cover about 85 % of the land surface and cretaceous sedimentary rocks belonging to the Bida Basin which cover the remaining 15 % (Figure 3). From the geological mapping carried out, the major lithologic units found are: migmatite-gneiss; older granites; Meta-sediments (mainly schist, phyllite and quartzite) and Bida sandstones.

2.5 Sampling

A total of 60 groundwater samples were collected (Figure 3) in two regimes (dry and rainy season). Forty samples were collected at various locations during the dry season (April) while twenty samples were collected in the rainy season (September) at different sampling points in 2009. Collected water samples were stored in sealed polythene bags and transported to the laboratory for pre-treatment and analyses while physical parameters were determined in the field according to APHA (1995) analytical standard. The cations were determined using ICP-OES Spectro Cirros while anions were analyzed with ion chromatography (Dionex DX-120) at Activation Laboratory (Actlabs), Canada.

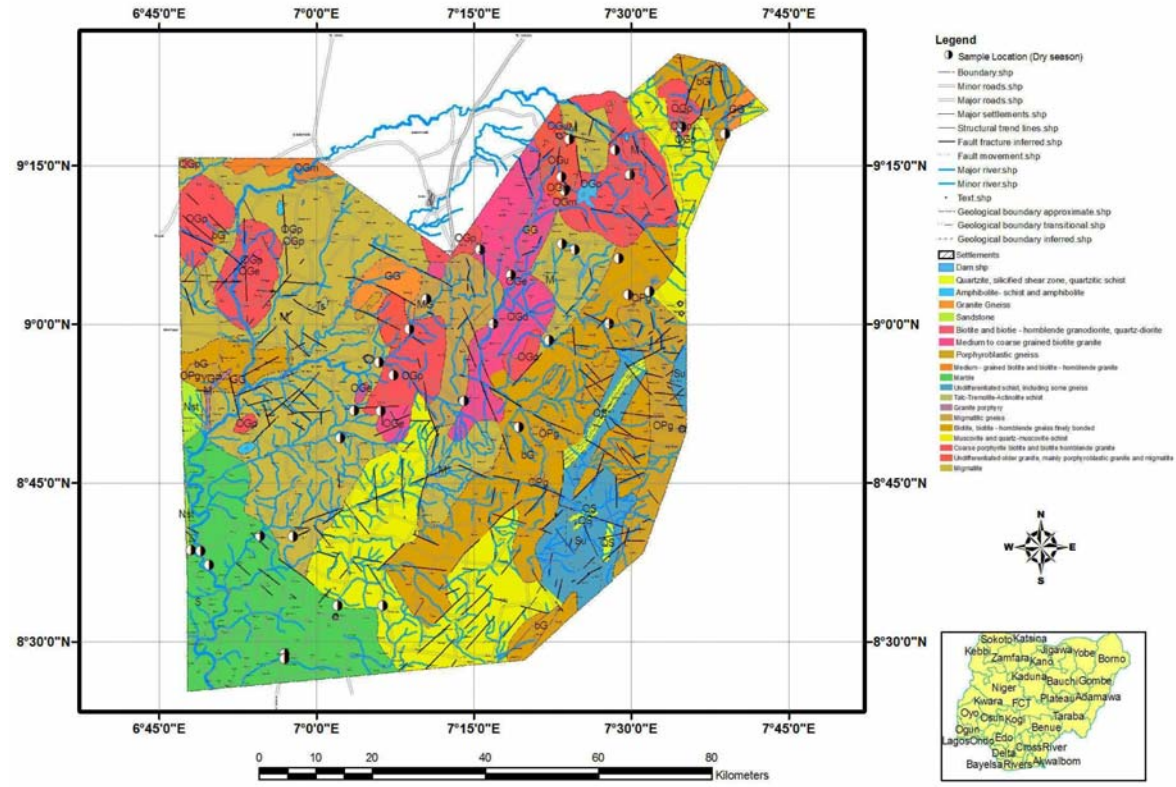


Figure 3. Geological map of Abuja showing the rock types and sampling points (Modified after NGSA, 2004)

3. Results and Discussion

The pH values ranges from 4.42 to 7.54 with a mean value of 6.11 for the dry season and 4.50 to 6.70 with an average value of 6.44 for the rainy season. The pH values indicate a slightly acidic to neutral condition. The concentration of nitrate varies from 0.30 mg/l to 33.90 mg/l with an average value of 5.14 mg/l for the dry season and 0.40 mg/l to 63.90 mg/l with a mean value of 14.40 mg/l in the rainy season. It can be observed from the results that the mean concentration of nitrate and other parameters are lower in dry season compared to the rainy season. This can be attributed to the heavy municipal run-off and high rate of infiltration of leachate through the overburden into the perched shallow aquifers in the area that are recorded during the rainy season. The mean concentration of total dissolved solids (TDS) and electrical conductivity (EC) were also higher in rainy season compared to the dry season as observed earlier, which is also attributed to municipal run-off and or dissolution of bedrock in the course of groundwater migration. A strong positive correlation (< 0.01 level) exist between NO_3 and other parameters (EC, TDS, Ca, K, Cl and SO_4) as illustrated in Table 1.

The relationship between NO_3 and Cl during both seasons is relatively strong with a value of $r = 0.94$, which is a clear indication of common anthropogenic sources. Piskin, (1973) as well as Ritter and Chimside, (1984) pointed out that in any analysis, if the correlation coefficient of NO_3 and Cl is greater than 0.35, it implies that municipal waste is likely the source of pollution. This is true for samples collected from locations with poor on-site sanitation as demonstrated in plates 1 and 2. It suggests a common origin or source which can either be natural via weathering/dissolution of bedrock or artificial through human activities. The influence of bedrock dissolution in groundwater quality is illustrated in (figures 4a and 4b), where nitrate concentration vary with lithology. This lead to the determination of nitrate concentration maps for both dry and rainy season for the area as shown in figures 5a and 5b.

Many epidemiological studies have shown strong positive correlation between exposure to nitrate and cancer risk. Nitrate in drinking water has been correlated with gastric cancer risk in Colombia and England while exposure to nitrate-containing fertilizers is linked to gastric cancer mortality in Chile (Canter, 1996). Nitrate itself is not directly carcinogenic but when converted to nitrite in the human body, it reacts with secondary and tertiary amines to form nitrosamines which have been identified as a potent carcinogen (Staudt, 2003). Other human effects caused by high nitrate intake are hypertension, the 'hot-dog' headache, congenital malformation and spontaneous abortion (Spalding & Exner, 1993). It has also been confirmed that chronic exposure to high level of nitrate in drinking water have adverse effects on the cardiovascular system and blood disorder (Bowman, 1994) as well as reduction in metabolic activities and thyroid malfunction (WHO, 2006).

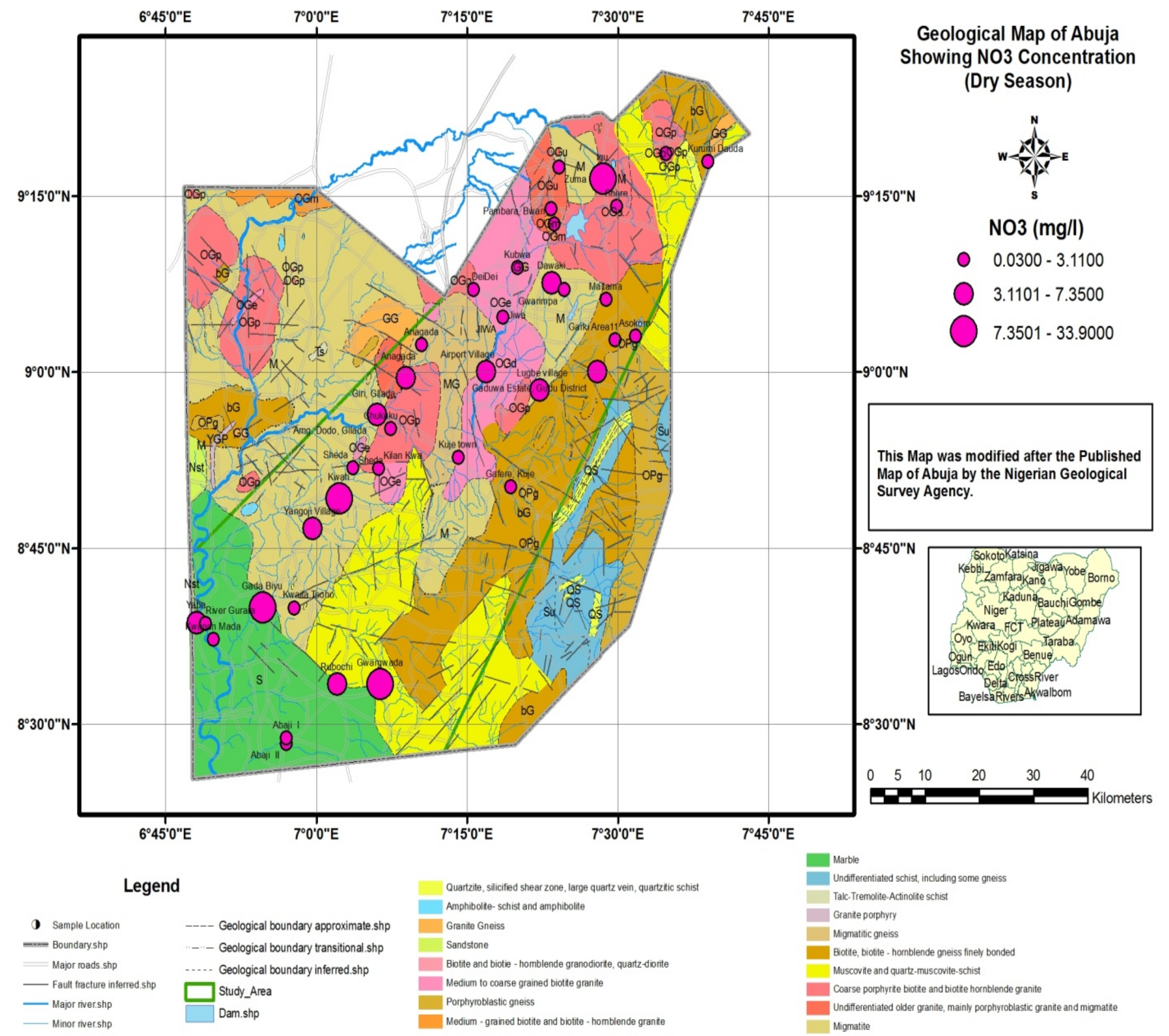


Figure 4a. Geological map of Abuja showing nitrate concentration in the dry season

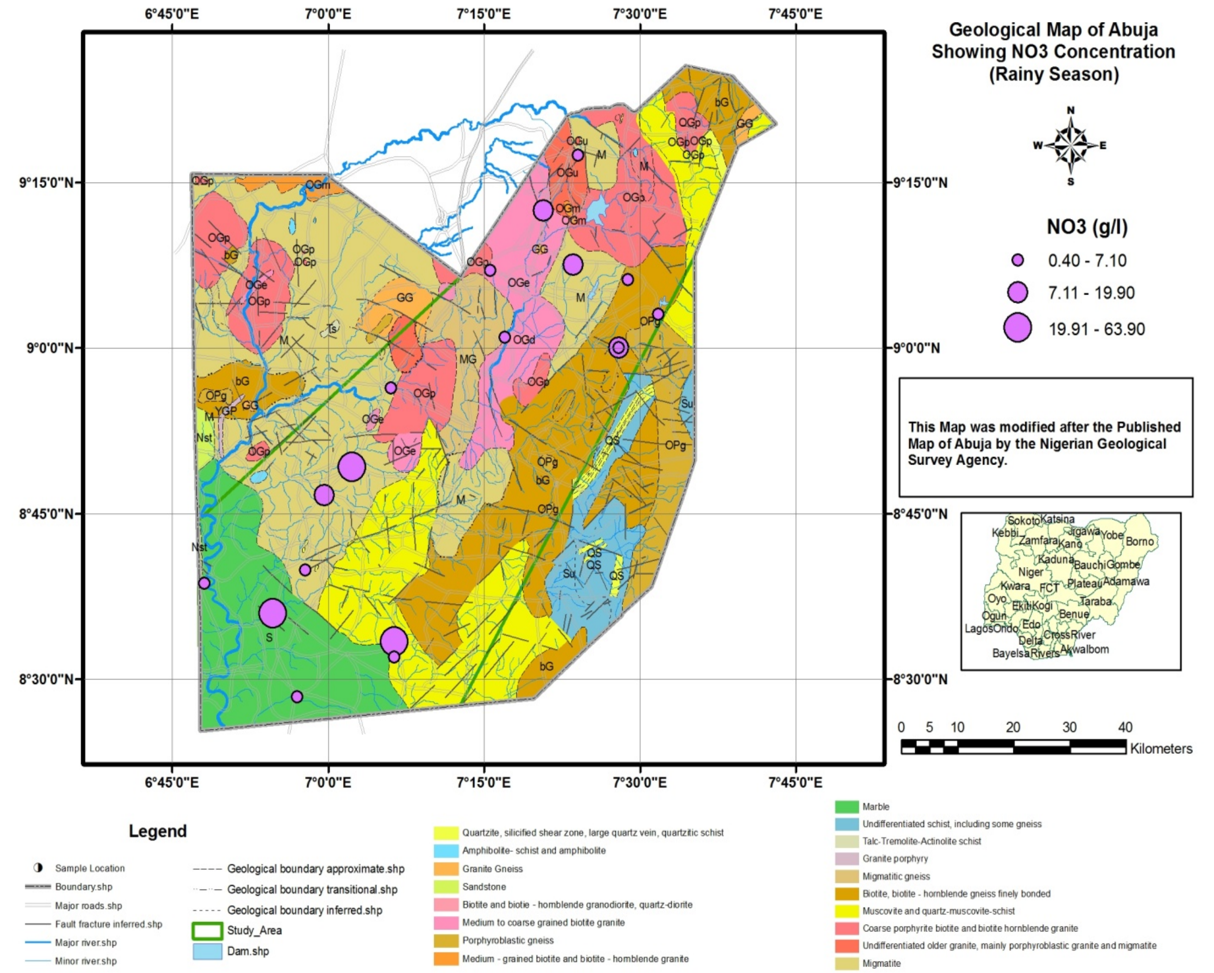
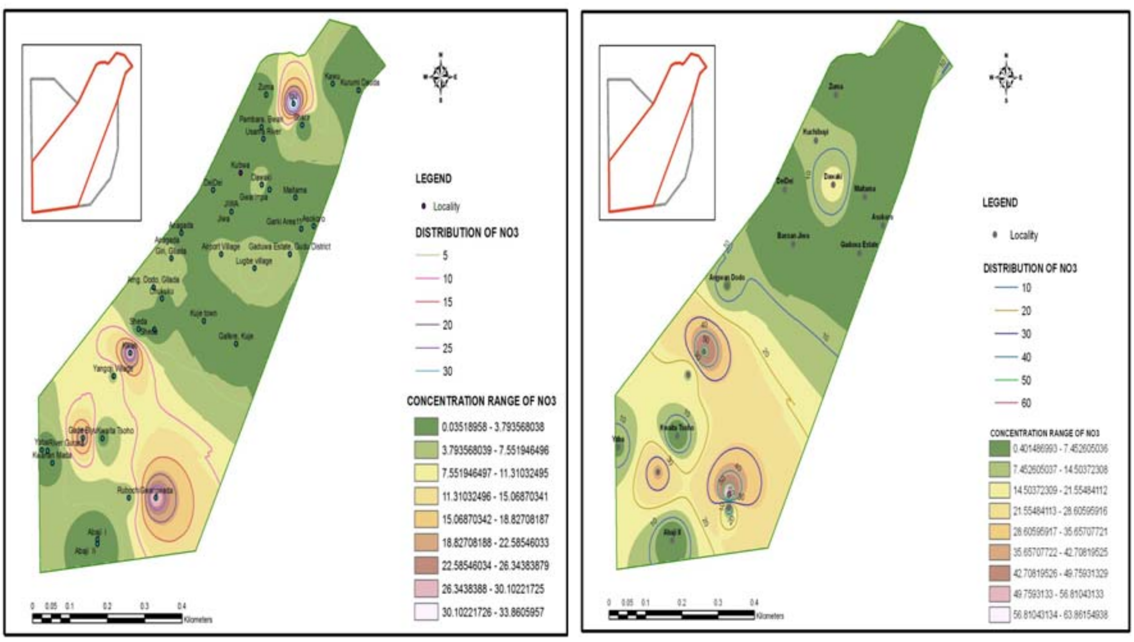


Figure 4b. Geological map of Abuja showing nitrate concentration in the rainy season



Figsure 5a & 5b. Nitrate concentration for dry and rainy season respectively

Table 1. Pearson correlation coefficient matrix for groundwater in the study area

	pH	EC	TDS	Ca	Mg	Na	K	Cl	SO_4	NO_3	F	Al
pH	1.00											
EC	0.18	1.00										
TDS	0.18	*0.96	1.00									
Ca	0.26	**0.93	*0.93	1.00								
Mg	0.22	**0.89	**0.89	**0.93	1.00							
Na	0.14	*0.56	*0.66	0.43	0.38	1.00						
K	0.19	**0.90	**0.90	**0.90	**0.88	0.47	1.00					
Cl	-0.01	**0.79	**0.80	*0.66	*0.58	*0.62	0.64	1.00				
SO_4	0.18	**0.76	0.75	**0.78	**0.79	0.26	**0.88	**0.82	1.00			
NO_3	0.03	**0.91	**0.91	**0.85	**0.82	0.48	**0.82	**0.94	**0.85	1.00		
F	0.25	0.12	0.11	0.24	-0.22	-0.04	0.04	0.41	-0.16	0.08	1.00	
Al	0.13	0.20	0.21	0.20	-0.11	0.19	0.13	0.06	0.25	0.01	0.21	1.00

******: Correlation is significant at the 0.01 level (2-tailed); *: Correlation is significant at the 0.05 level (2-tailed)

EC-electrical conductivity; TDS-total dissolved solid

The deleterious health and socio- economic effects of nitrate in drinking water sources are generating a serious concern in urban and rural communities. It is therefore imperative to develop groundwater nitrate management strategy, particularly for understanding the pollution processes and the role of the unsaturated zone in groundwater protection. A groundwater protection strategy should comprise a two-fold approach: legislation and enforcement for pollution control and for minimizing nitrogenous inputs to the environment which can be complimented by public mobilization and enlightenment programme.

4. Conclusion

The occurrence and distribution of nitrate in Abuja waters have been described and illustrated in this paper. The elevated nitrate content of the groundwater is partly attributable to geologic factors but more importantly are the anthropogenic sources, particularly indiscriminate waste disposal and agricultural practices. High concentration of nitrate in drinking water constitutes a number of health hazards in humans and livestock. Water treatment by bio-denitrification and nitrate pollution control programs should be introduced at local, state and federal levels in order to create awareness on the need to protect groundwater against nitrate pollution caused by agricultural activity and indiscriminate dumping of domestic and industrial wastes.

Reference

Adelana, S. M. A., & Olasehinde, P. I. (2003). High nitrate in water supply in Nigeria: Implications for human health. *Water resources, 14*(1), 1-11.

Ajibade, A. C. (1976). Proterozoic Crustal Development in the Pan-African Regime of Nigeria. In: C.A. Kogbe (Editor). *Geology of Nigeria*, 57-63. Nigeria: Rock View Ltd.

Ajibade, A. C., & Wright, J. B. (1988). Structural Relationship in Schist Belts of Northwestern Nigeria. In P. O. Oluyide et al. (Ed.), *Precambrian Geology of Nigeria*, 103-109. A Publication of Geological Survey.

Ajibade, A. C., & Woakes, M. (1983). Proterozoic crustal development in the Pan-African Regime of Nigeria. In: C. A. Kogbe (Editor), *Geology of Nigeria*, 57-63. Nigeria: Rock View Ltd.

Amadi, A. N. (2010). Effects of urbanization on groundwater quality: A case study of Port-Harcourt, Southern Nigeria. *Natur. Appl. Sci. J., 11*(2), 143-152. Retrieve from http://www.naasjournal-ng.org

APHA. (1995). *Standards methods for the examination of water and wastewater* (19th ed.). American water works association, water environmental federation, Washington DC.

Berner, E., & Berner, R. (1987). *The Global Water Cycle*, 102-119. New Jersey: Prentice Hall.

Bowman, J. (1994). Water is best: World Pinder still think so? In B. Cartledge (Eds.), *Health and the environment: The Linacre lectures, 1992-3,* 85-125. Oxford: Oxford University Press.

Burkart, M. R., & Kolpin, D. W. (1993). Hydrologic and Land-Use Factors Associated with Herbicides and Nitrate in Near-Surface Aquifers. *Journal of Environmental Quality, 22,* 646-656. http://dx.doi.org/10.2134/jeq1993.00472425002200040002x

Canter, L. W. (1996). Nitrates in groundwater. New York: Lewis Publishers, Chelsea, MI, USA.

Colvin, C. (1999). Increased risk of methaemoglobinaemia as a result of bottle–feeding by HIV positive mothers in South Africa. Paper presented at IAH Congress, Bratislava, Slovakia.

Comly, H. H. (1987). Cyanosis in infants caused by nitrates in well water. *Journal of the American Medical Association, 257,* 2788-2792. http://dx.doi.org/10.1001/jama.1987.03390200128027

Edet, A. E. (2000). Water pollution by nitrate near some waste disposal sites in Calaber, Nigeria. *Groundwater 2000*. Proc. Int. Conf. Groundwater research, Copenhagen, 6-8 June.

Egboka, B. C. E., & Ezeonu, F. C. (1990). Nitrate and nitrite pollution and contamination in parts of Southeastern Nigeria. *Water Resources, 2*(2), 101-110.

Grank, N. K. (1978). Structural distinction between a meta-sedimentary cover and underlaying Basement in the 600MY old Pan Afican domain of Northwestern Nigeria, West Africa. *Bull., Geol. Soc. Amer., 89*, 50-58. http://dx.doi.org/10.1130/0016-7606(1978)89%3C50:SDBAMC%3E2.0.CO;2

Guter, G. A. (1981). *Removal of Nitrate from Contaminated Water Supplies for Public Use.* Environmental Protection Agency, Cincinnati.

Hallberg, G. R., & Keeney, D. R. (1993). In Nitrate. Alley, W. A., (ed.), *Regional Groundwater Quality*, 297-322. New York: Van Nostrand Reinhold.

Heaton, T. H. E. (1984). Sources of nitrate in phreatic groundwater in western Kalahari. *J. Hydro., 67,* 249-259. http://dx.doi.org/10.1016/0022-1694(84)90244-0

Kross, B. C., Hallberg, G. R., Bruner, R., Cherryholmes, K., & Johnson, K. J. (1993). The Nitrate Contamination of Private Well Water in Iowa. *American Journal of Public Health, 83*, 270-272. http://dx.doi.org/10.2105/AJPH.83.2.270

MacDonald, A. M., Davies, J., & Calow, R. C. (2005). African hydrogeology and rural water supply. In: Adelana, S. M. A., & MacDonald, A. M. *Applied Groundwater Studies in Africa.* IAH Selected Papers on Hydrogeology, Volume 13, CRCPress/Balkema, Leiden, Netherlands.

Mc-Curry, P. (1985). The Geology of the Precambrian to Lower Paleozoic Rocks of Northern Nigeria. A review, In C. A. Kogbe (Ed.), *Geology of Nigeria*, 15-39. Lagos: Elizabethan Co..

NGSA. (2004). *Modified Geological map of Abuja,* from Nigerian Geological Survey Agency, 2004.

NSDWQ. (2007). Nigerian Standard for Drinking Water Quality. *Nigerian Industrial Standard,* NIS: 554, 13-14.

Piskin, R. (1973). Evaluation of Nitrate content of groundwater in hall County, Nebraska*. Groundwater, 11*(6), 14-113. http://dx.doi.org/10.1111/j.1745-6584.1973.tb02987.x

Ritter, W. F. & Chimiside, A. E. M. (1984). Impact of land use on groundwater quality in southern Delaware. *Groundwater, 22*(9), 38-47. http://dx.doi.org/10.1111/j.1745-6584.1984.tb01474.x

Schiwiede, M., Duijinisveld, W. H. M., & Bottcher, J. (2005). *Investigation of process leading to nitrate enrichment in soils in Semi-arid environments, Selebi-Phikwe, November 2004*, 103-112. Departmental of Geological Survey, Lobatse.

Spalding, R. F., & Exner, M. E. (1993). Occurrence of nitrate in groundwater-A review. *J. Environ. Qual., 22*, 392-402. http://dx.doi.org/10.2134/jeq1993.00472425002200030002x

Stadler, S. (2005). Investigation of natural processes leading to enrichment in aquifers of semi-arid regions. Ph.D Thesis, University of Karlsruhe, Germany, 262.

Staudt, M. (2003). *Environmental hydrogeology of Ramotswa.* Environmental Geology Division, Department of Geological Survey, Lobatse, Botswana, 65.

Tredoux, G. (2004). Nitrate and associated hazards quantification and strategies for protecting rural water supplies. *Water Research Commission Report* No.1058/1/04, Pretoria. ISSN: 1-77005-173-2.

Tredoux, G., Engelbrecht, J. E. P., & Talma, A. S. (2005). Groundwater nitrate in arid and Semi-arid parts of southern Africa. In: Vogel, H., & Chilume, C. (Eds.), *Environmental Geology in Semi-arid Environment* (pp. 121-131), DGS, Lobatse, Botswana. ISSN: 99912-0-501-2.

Uma, K. O. (1993). Nitrates in shallow (regolith) aquifers around Sokoto Town, Nigeria. *Environ. Geol., 21,* 70-76. http://dx.doi.org/10.1007/BF00775053

Vogel, H., Mokokwe, K., & Setloboko, T. (2004). *Nitrate hotspot and salinity levels in Groundwater in the central District of Botswana.* Environmental Geology Division, Department of Geological Survey, Lobatse, Botswana, 34.

World Health Organisation (WHO). (2006). *International Standards for drinking water* (3rd ed.). Geneva, pp. 346-385.

World Health Organization (WHO). (2002). *Guideline for drinking water quality.* Technical report series, Geneva, pp. 346-385.

Wrabel, J. (2005). Investigation of the processes leading to nitrate enrichment in the Kamtsas quartzite aquifer, Namibia. In: Vogel, H., & Chilume, C. (eds.), *Environmental Geology in Semi-arid Environmental*, 134-139. DGS, Lobaste, Botswana. ISSN: 99912-0-501-2.