Variability of Nitrate in Groundwater in Some Parts of Southwestern Nigeria.

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ABSTRACT

This study analyzed the nitrate-nitrogen content and variability in the groundwater of the basement complex and sedimentary geologic terrains located in Abeokuta and Ewekoro, Southwestern Nigeria, using the Bricine-sulfamilic method. The results indicated that the groundwater in the Cretaceous sedimentary rocks of Ewekoro and environs contained fairly high nitrate concentrations (14.93 – 44.37 mg/l) when compared with the relatively low values (0.5 – 10.1 mg/l) obtained in the aquifers of the Precambrian basement complex rocks of Abeokuta and its environ. Similarly, the produced geochemical maps of groundwater nitrate confirmed a large spatial variability in its distribution across the diverse sampling locations while the hazard indicator maps indicated that more than 50% residents of Ewekoro and its environs are at the risk of groundwater nitrate-nitrogen contamination. The discrepancy in the nitrate concentration can be attributed to the settlement pattern, soil nitrate-nitrogen content and the use of inorganic fertilizer in the farming system of the study area. Proper sewage disposal and the adoption of organic farming in the study area will keep the nitrate concentration of the groundwater resources in the study area to the barest minimum.

(Keywords: nitrate distribution, groundwater resources, Abeokuta, geological formations, Nigeria)

INTRODUCTION

In Nigeria, domestic wells and boreholes are constructed to serve as alternatives to the existing but unreliable public water supply. Well water is expected to bring some measure of relief to the problem of irregular public water supply in some quarters, if only its safety for consumption by the teeming population is ensured. This is due to the fact that the wells are often opened to quite a number of contaminants in soils. These include break down of decaying plants, manures or other organic residues by microbes in soils which serve as natural in-roads to nitrate contamination in some groundwater. However, in most cases, higher levels of groundwater nitrate pollution results from human activities such as the use of inorganic fertilizers, manure, animal feedlots, municipal wastewater, sludge, and septic systems.

Since the recommended limit of nitrate in drinking water is 10 mg/L nitrate-nitrogen (NO_3-N) (WHO, 1993) which is equivalent of 44.3 mg/L nitrate (NO_3-), its concentration in ground water with low velocity requires attention because of the health hazard of this compound especially for infants and pregnant women and also the costly socio-economic implication of groundwater pollution. It has been inferred that high nitrate concentration in potable water is capable of causing cyanosis (or methemoglobinemia); a condition in infants under two years old which could be fatal (Onugba et al., 1992). In addition to cyanosis, nitrate in drinking water is also a probable factor in stomach cancer development (Forslund, 1986). Organic nitrate concentration in solution could probably contribute to high infant mortality rate (De Rooy, 1986). Although there is no enforceable drinking water standard for livestock, it has been advised that animals especially the young ones should not be allowed to drink water with more than 100 mg/l NO_3-N (Soltanpour and Raley, 1993).

Nitrate can be removed from drinking water by three methods: distillation, reverse osmosis, and ion exchange. Mere boiling of water will increase, rather than decrease the nitrate concentration (Gibson et al., 1973; Self and Waskom, 2008; Wisconsin Department of Natural Resources, 2003; Jennings and Sneed, 1996). There is therefore the need to pay more attention to the exploitation and management policy of groundwater resources, which is a major component of any building structure in Nigeria today.

From the foregoing, nitrate is a significant problem in many parts of the world. Analysis of the ground waters from the northern part of old Gongola state revealed that over 40% of the bore holes in Ga'anda and Jada district in the Precambrian rocks were found to contain excessive nitrate-nitrogen concentrations (greater than 100 mg/l) (Onugba et al., 1992) while nitrate-nitrogen concentration in groundwater within the basement complex of central Nigeria, was found to range between 0.02 – 1.80 mg/l (Olarewaju et al., 1997). The high nitrate contents reported in some borehole water in the Precambrian rocks were attributed to shallow rock weathered profiles and fractures in the bedrock aquifer; which serve as water channels for rapid recharge. Incidentally, several hand-dug wells and boreholes in the study area for this work are not being subjected to routine chemical quality assessments. Some hand dug wells and boreholes in parts of Nigeria have been found to contain an appreciable amount of nitrate-nitrogen in excess of the recommended limit of 10 mg/l. This paper therefore aimed primarily at ascertaining the presence, occurrence, concentration, distribution and variability of nitrate-nitrogen content in the ground water resources of two distinct geologic formations in a part of south western Nigeria.

MATERIALS AND METHODS

The Study Area

The study area includes Abeokuta metropolis - an urban area, and Ewekoro environs – a rural area, all in Ogun State, southwestern Nigeria. The areas are situated within two distinct geologic formations; the former is located on basement complex of igneous and metamorphic origin while the latter is on the sedimentary geologic formation comprising essentially of limestone and shale (Jones and Hockey, 1964). The detailed description of the geology of the area can be found in (Kehinde-Phillips, 1992). In both terrains, water tables fluctuate with the season, but a majority of wells are productive in both seasons.

The basement complex segment of the study area in which Abeokuta is geographically located can be described by latitudes 7° $7'$ N to 7° $11'$ N and longitudes 3° $11'$E to 3° $22'$ E. (Figure 1a) and enjoys a tropical climate with distinct wet and dry seasons with dry period of about 130 days (Koppen, 1918). The mean annual rainfall and temperature are about 1,270 mm and 28 $^{\circ}$C respectively while the estimated mean annual potential evaporation is 1,100 mm. Actual Water Availability (AWA) of this area is 2314mm (AWA = Available Precipitation + Regional Evapotranspiration) (Bello, 2009).

The area is drained mainly by River Ogun which passes through and divides the city into two, and the drainage pattern is dendritic. The metropolis which covers a geographical area of 78.57 square kilometers has a human population of about 605, 461 whose main occupations are farming, trading in fabrics with local designs (Adire), pottery, and fishing (Oyawoye, 1964). The principal geologic features in this sector of the study area consist of crystalline basement complex rocks, which cover one-quarter of the entire state. The basement rocks are overlain by various sedimentary rocks. There is a high degree of homogeneity in the basement complex terrain. The proliferation of hand-dug wells (over 2000) all over the metropolis is a reflection of the unreliable nature of public water supply and the ease of excavation to water level. The land-use types in the city also reveals that large portion of undeveloped land parcels spaces between buildings are either cultivated or used as a dumpsite, and are typically littered with human and animal wastes.

The sedimentary terrain subdivision of the study area is essentially rural. It lies within latitudes 6° $51'$ N and 7° $2'$ N and longitudes 3° $5'$ E and 3° $20'$ E (Figure 1b). The area is mainly drained by river Ewekoro, its tributaries and other seasonal streams. Rainfall here is also tropical occurring from February to July which coincides with the first peak of the raining season and from September through November forming the second peak of the raining season. The mean annual rainfall is 2100mm with the recharge of the aquifers probably occurring throughout this period.

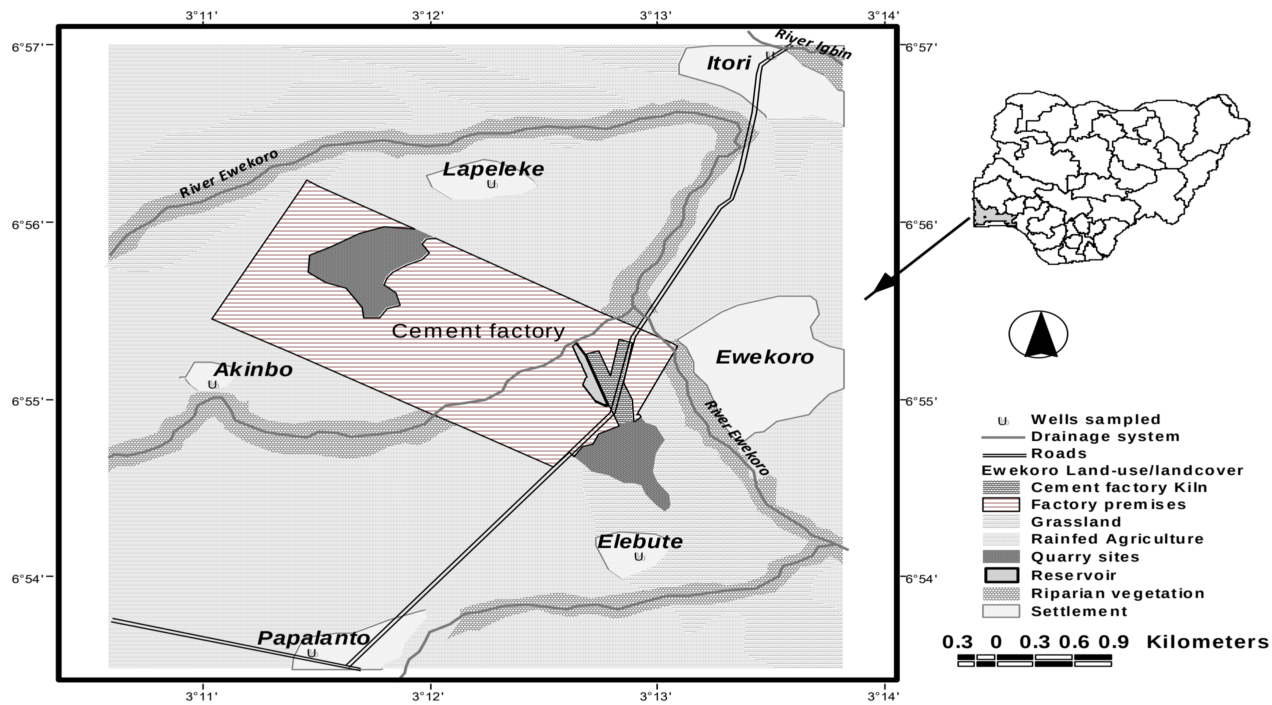

Figure 1a: Land-Use Map of Abeokuta Metrpolis (Basement Complex Terrain Section of the Study Area. Inset Location in Nigeria).

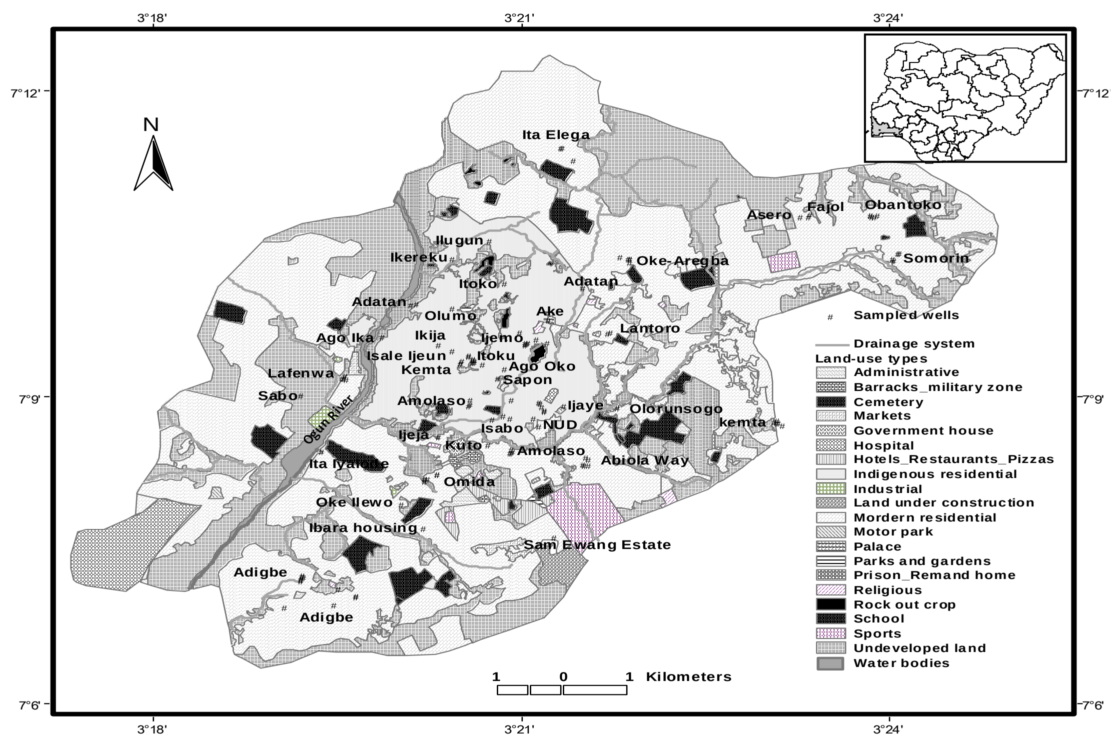

Figure 1b: Land-Use Map of Ewekoro Village and Environs (Sedimentary Terrain Section of the Study Area.)

The vegetation is forest characterized by shrubs and trees although a high level of succession have taken place in this area over the years converting the once high forest to a derived savannah.

The area has quite an expanse of limestone deposits geologically belonging to Ewekoro Formation which is dated Paleocene to Eocene in age. The formation is not folded but has minor depositional structures all of which serve as potential sources of artesian wells in some areas. The general succession of the rock units comprising of the Ewekoro Formation has been described by several authors (Kogbe, 1976 and Adegoke, 1972). However, erratic variability of rock conditions (especially within the overburden/regolith zones) in the sedimentary terrain even within a distance of less than 10 m may result in variability in the metal contents including nitrate in the ground water resources of these zones.

In terms of the land-use pattern, the inhabitants of Ewekoro area are predominantly farmers and the area is known for large scale cultivation of sugarcane the consumptive water requirement of which is put at 1200mm (Penman, 1948). Poor hygiene such as improper human waste disposal as a evident from the building architecture (either pit latrine or no toilet system) coupled with the use of fertilizers in farms which often are in close proximity, can be sources of increase in nitrate content of the groundwater.

Methodology

Well Inventory and Sample Size: This study conducted an inventory of wells (hand-dug) in the study areas and over 2,063 wells were recorded in Abeokuta metropolis (Basement complex terrain) while, 38 hand dug wells were randomly selected for water sample collection. Similarly, out of the 7 functioning wells in Ewekoro area (Sedimentary terrain) 5 wells were selected for water sampling. The coordinates of the selected wells were obtained using Garmin 12 Global Positioning System (GPS) hand-held receivers. The decision on the proportion of wells in the two areas was guided by the number of wells available and the human population density.

Sample collection and Water Quality Analysis: A total of 43 samples (i.e., 38 from Abeokuta metropolis and 5 from Ewekoro and its environs were used for this study. The water samples used for water quality analysis were collected in 100ml plastic containers after rigorous agitation using the bailer in order to ensure thorough mixing of the water samples before collection. Refrigeration of the water samples while in transit to the laboratory was achieved by placing them in coolers containing ice. The water samples were left un-acidified and were used for the determination of the nitrate ion using Brucine-Sulfanilic acid method. Accuracy of the chemical data was ensured through replication of analysis and the use of blank samples.

Soil Sampling and NO_3-N Determination: Forty (40) soil samples from the surface (0-10cm) and subsurface (10-20cm) were collected from 20 locations (i.e., 15 from Abeokuta metropolis and 5 from Ewekoro and its environs) from the study area. 50g of each soil sample were mixed with 100ml of 0.025 mol/l calcium chloride solution in a glass bottle. A spatula-tip full of charcoal activated for soil test was added and the closed bottle was placed on a shaking machine for 1 hour. The suspension was allowed to settle then filtered with Whatman No. 42 filter paper. The filtrate was used for nitrate-nitrogen analysis using Brucine sulfamilic method.

Spatial Database Development and Spatial Analysis in GIS: Land-use maps of the two segments of the study area were captured by 'on-screen' digitizing technique from a geo-referenced high resolution satellite image of the two areas. The land-use maps served as the base map on which the sampled wells would be overlaid. The results of the chemical analyses of water samples from each well were tabulated in a spreadsheet against their respective geographical coordinates obtained using GPS. The data (in spreadsheet) was converted to database file format and the information imported into ArcInfo 9.2®. The GIS database was imported as route event theme and overlaid on the digitized base maps.

The iso-concentration map(s) of nitrate-nitrogen concentrations were produced using kriging technique in GIS (Navas and and Machin, 2002) since this will assist in the prediction of the radial distribution and variability of the contaminants in groundwater especially in areas of non availability of hand-dug wells. Since one of the objectives of this study is to estimate the distribution of nitrate-nitrogen content of groundwater resources across the study area rather than a simple estimate of expected value at some location, both Ordinary Kriging (OK) and Indicator Kriging (IK) with semivariogram method were used in the spatial analysis. The choice of IK along sides OK – a linear Kriging was also because IK is more reliable method of interpolation recommended [Journel, 1982) for environmental mapping of this kind where it is essential to have an indication of the proportion and location of the area of groundwater resources exceeding the permissible limit of NO_3-N as a pollutant.

RESULTS AND DISCUSSION

The results of well inventory in both the basement complex and sedimentary terrain are shown in Table 1. In Abeokuta basement complex a total of 2063 wells which are generally shallow with average depth of 4.48m relative to a total of 7 wells in Ewekoro (sedimentary terrain) area with an average depth of 7m were recorded. Septic tank system of sewage disposal (74%) compared to the pit latrine system (26%) is more regular in Abeokuta. The average distance of the sewage tank from the wells is 11.98m. This is due to the compact nature of the city stemming from the dense population and the rather compact housing patterns especially in the indigenous part of the city which also forms the core and accounts for about 15 % of spatial extent of the city land area. However, human sewage disposal is 100% pit latrine in Ewekoro.

In Tables 2 and 3 the results of the nitrate concentrations, alkalinity and electrical conductivity in water and soil samples are presented. The electrical conductivity and the alkalinity values ranged from 150.0 to 805.0 µS/cm and 14.0 to 93.0 mg/l, respectively, in the groundwater samples from the basement complex area. Values of electrical conductivity and alkalinity ranged from 334.0 to 686 µS/cm and 28.9 to 36.9 mg/l in the groundwater from the sedimentary terrain. Similarly, the mean electrical conductivities of the surface and subsurface soils developed on the basement complex rocks of Abeokuta and the limestone rocks of Ewekoro ranges from 101.0 – 156.5 µS/cm and 189.0 – 266.0 µS/cm; 100.2 – 145.8 µS/cm and 182.0 – 213.0 µS/cm, respectively.

Table 1: Summary of Well Inventory within Abeokuta (Basement Complex) and Ewekoro (Sedimentary Terrain).

Districts	No of wells	Average Well Depth (m)	Avg. Dist. to Septic Tank	Covered Wells	Open Wells
Obantoko/asero	380	5.7	13.8	277	102
Abiola Way/Olorunsogo	115	5.8	13.4	96	19
Oke Lantoro/kemta/idiaba/ elite road	237	6.6	13.5	180	57
Ewang/Okemosan/Okeilewo/GRA	187	3.7	11.2	127	60
Oke-Aregba/Adatan/Isale abetu/Lantoro	120	2.4	12.8	69	18
Kugba/Saje Area/Elega/ Bode olude	82	2.6	9.9	63	19
Mokola/Itoko Adedotun/Iberekodo	77	4.6	8.0	45	32
Okejigbo/Ake/Ijemo/Sapon	62	3.4	11.6	17	45
IsaleAke/Ago-Ijesa	36	3.1	8.5	9	27
NUD/Kuto/Amolaso/Isabo/Isale-oja	117	3.9	12.5	73	44
Oke Ijeun/Isale Igbein/Grammar sch	47	3.0	12.1	16	31
Ago Oko	9	3.2	9.0	6	3
Erunbe	45	4.0	12.0	21	23
Ilogbo	15	4.0	10.2	7	8
Oke Itoku/Itoku/Igbore/Owu Area	85	2.6	11.2	13	72
Itamerin	12	2.6	13.7	7	5
Idi Ape	8	2.6	9.2	0	8
Isale Ijeun	12	2.6	11.6	5	7
Ita Eko/Adigbe/Panseke/Onikolobo/omida	121	4.0	14.0	107	14
Sabo/Lafenwa	87	2.0	14.9	82	3
Quarry/Olomore/Brewery/Ita Oshin/Pepsi	132	4.9	16.8	111	21
Ita Iyalode/Totoro/Ogbe	77	4.1	13.7	56	21
Ewekoro*	7	7.5	8.0	2	5

* Sedimentary Terrain

Table 2: Nitrate Values in the Groundwater Samples from Basement Complex and Sedimentary Terrains.

Geology and Age	Location	X Coordinates	Y Coordinates	Well Depth (m)	Electrical Conductivity (μS/cm)	Alkalinity (mg/l)	Nitrate conc. (mg/l)
Precambrian Crystalline Basement Complex Terrain	Adatan	7.1692	3.3586	2.40	450.0	41.0	4.33
	Ago Egun	7.1480	3.3520	4.55	463.0	48.0	3.39
	Ago Ika	7.1613	3.3313	1.50	476.0	64.0	1.74
	Ago Oko	7.1560	3.3480	3.20	546.0	79.0	2.99
	Ake	7.1640	3.3540	2.72	438.0	93.0	2.64
	Amolaso	7.1430	3.3490	3.90	640.0	30.0	3.65
	Ibara housing	7.1300	3.3370	3.74	732.0	14.0	6.34
	Ijaye	7.1500	3.3560	2.71	374.0	40.0	2.05
	Ijeja	7.1450	3.3390	5.48	393.0	26.0	4.68
	Ijemo	7.1620	3.3500	2.71	385.0	67.0	1.65
	Ikereku	7.1740	3.3410	3.65	373.0	50.0	3.18
	Ikija	7.1600	3.3390	2.55	236.0	34.0	2.73
	Ilugun	7.1770	3.3460	1.58	321.0	45.0	2.65
	Isabo	7.1479	3.3488	3.88	190.2	14.0	1.96
	Isale Ijeun	7.1590	3.3410	2.69	543.0	54.0	4.10
	Ita Iyalode	7.1439	3.1439	4.07	638.0	38.0	4.13
	Itoko	7.1700	3.3480	4.70	418.0	50.0	2.96
	Itoku	7.1570	3.3420	2.36	513.0	57.0	3.86
	Kemta	7.1570	3.3420	1.64	417.0	76.0	1.04
	Nepa road	7.1484	3.3479	3.45	640.0	16.0	1.57
	NUD	7.1467	3.3526	4.20	688.0	24.0	5.60
	Oke bode	7.1510	3.3490	2.96	805.0	18.0	2.30
	Oke Ilewo	7.1340	3.3340	6.62	770.0	22.0	5.70
	Olorunsogo	7.1496	3.3634	3.55	190.0	31.0	0.59
	Olumo	7.1660	3.3410	0.53	298.0	53.0	1.38
	Sapon	7.1545	3.3470	2.58	150.0	40.1	1.91
	Car wash	7.1740	3.3650	1.80	725.0	30.5	9.50
	Oke-Aregba	7.1740	3.3650	3.50	529.0	60.1	10.10
	Omida	7.1380	3.3376	4.25	800.0	69.2	9.98
	Lafenwa	7.1549	3.3264	4.30	603.0	50.9	8.10
	Brewry	7.1543	3.3264	3.20	727.0	70.1	7.89
	Sabo	7.1545	3.3259	2.50	537.0	72.1	7.60
	Lantoro	7.1619	3.3620	3.60	425.0	68.9	6.55
	Oke-Itoku	7.1567	3.3450	3.80	785.0	72.1	7.60
	Totoro	7.1575	3.3437	4.00	665.0	59.1	9.34
	Sam Ewang	7.1796	3.2209	3.20	268.0	68.8	4.10
	Elega	7.1921	3.3557	3.10	432.0	70.2	6.56
Cretaceous Sedimentary Terrain	Akinbo	6.9178	3.1852	7.60	686.0	36.9	28.86
	Elebute	6.9026	3.2147	6.40	334.0	20.4	14.93
	Itori	6.9470	3.2238	7.70	650.0	28.9	44.37
	Lapeleke	6.9356	3.2045	8.30	341.0	32.8	37.19
	Papalanto	6.8940	3.1921	7.60	394.0	38.5	16.35

Table 3: Nitrate and Electrical Conductivity Concentration in Soils of Abeokuta and Ewekoro Areas.

Geology and Age	Location	Lat	Lon	NO_3-N (*surfaces)	NO_3-N (*sub-surfaces)	EC surface (μS/cm)	EC sub-surface (μS/cm)
Precambrian Crystalline Basement Complex Terrain	Adatan	7.1693	3.3585	45.1	36.2	135.4	133.0
	Ago Ika	7.1614	3.3314	41.7	34.1	138.5	136.4
	Ake	7.1641	3.3540	42.8	34.4	133.4	132.1
	Amolaso	7.1431	3.3490	44.6	35.9	140.3	139.8
	Ibara housing	7.1300	3.3371	46.2	38.8	156.3	145.3
	Ijeja	7.1450	3.3390	45.4	36.4	125.6	125.0
	Ikereku	7.1740	3.3410	44.3	35.8	122.0	121.2
	Ilugun	7.1770	3.3460	42.9	34.5	118.3	117.4
	Ita Iyalode	7.1439	3.1439	44.9	36.0	142.3	141.8
	Itoko	7.1700	3.3480	43.2	34.8	131.3	128.1
	NUD	7.1467	3.3526	45.6	37.1	148.2	137.6
	Oke Ilewo	7.1340	3.3340	45.8	37.2	156.5	145.8
	Olorunsogo	7.1496	3.3634	40.8	33.6	109.3	107.1
	Olumo	7.1660	3.3410	41.4	34.1	110.5	110.2
	Sapon	7.1545	3.3470	41.8	34.1	101.0	100.2
Cretaceous Sedimentary Terrain	Akinbo	6.9178	3.1852	72.1	65.5	266.0	213
	Elebute	6.9026	3.2147	70.1	63.4	189.0	182
	Itori	6.9470	3.2238	84.2	75.3	256.0	205
	Lapeleke	6.9356	3.2045	80.4	73.8	192.0	183
	Papalanto	6.8940	3.1921	73.1	63.2	195.0	205

*Surfaces = 0 – 10 cm depth, subsurface = 10 – 20 cm depth)

The electrical conductivity and alkalinity were observed to vary widely in their distribution when compared with the nitrate values in the well water from the wells of Abeokuta metropolis. This pattern does not strictly hold for groundwater from the Ewekoro and its environs where the nitrate-nitrogen concentration is high (NO_3-N > 40 mg/l).

The nitrate concentrations in the groundwater from the Ewekoro wells are higher (14.90 to 44.40 mg/l) than those of groundwater from Abeokuta metropolis (0.59 to 6.34 mg/l). The frequency distribution pattern of nitrate concentration in the groundwater from both the basement complex areas of Abeokuta and the sedimentary terrain of Ewekoro is shown in the histogram (Figure 2). Nitrate-nitrogen contents of water from dug wells within the basement complex terrain generally falls below the recommended limit relative to the ones in the sedimentary terrain all of which falls above the recommended limit of nitrate in drinking water. Thus water from these wells are obviously not safe from drinking but may also not be too safe as irrigation water for the off season vegetable production that is common in these areas.

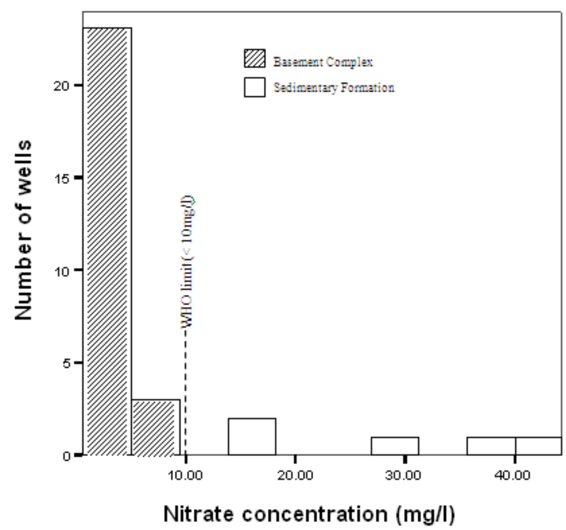

Figure 2: Histogram of Distribution of Nitrate Concentration in Hand Dug Wells.

Figure 3 a & b, identifies areas of high and low nitrate concentrations in the study areas. In the basement complex area, Omida and Oke-Aregba, have the highest concentration slightly above the values for Ibara housing estate and Oke Ilewo. Olorunsogo, Ago-Ika and Ijemo areas have the lowest concentration. Similarly, nitrate distribution in dug wells of the sedimentary terrain, reveals that villages around the cement plant – Akinbo, Quarry, Itori and Lapeleke show very high nitrate contents as shown by the colour density on map of the interpolated nitrate-nitrogen contents of the sampled wells while areas like Papalanto and Elebute have lowest concentration of nitrates. The prediction of the radial distribution and spatial variability of nitrate-nitrogen concentrations in groundwater resources of the study areas are also presented in Figures 3a and 3b.

The highest concentrations of 10.1 mg/l (NO_3-N) were recorded in Oke-Aregba and Omida. This is expected since as indicated in the land-use map, the sampled well in Oke-Aregba is in close proximity with a community cemetery while Omida is a food item market; where improper municipal waste disposal is a likely source of increase in nitrate-nitrogen content. In the sedimentary terrain however, the contents of the groundwater in Itori, Akinbo, Papalanto, and a significant part of Ewekoro villages has Nitrate-nitrogen content greater than 10mg/L. The wells here are all close to the quarry site of the cement factory and generally close to areas of intensive sugarcane farming. The effect of constant use of fertilizer (Urea) on sugarcane is a major source of nitrate-nitrogen increase in the groundwater.

Comparison of the results with the standard indicated that nitrate-nitrogen is generally below 10mg/l level recommended by World Health Organization [WHO, 1993] in the basement complex areas while it is generally above this value in all the sampled sedimentary wells. The discrepancy in the variability of nitrate distribution in the two geological environments as observed in the study may be attributed to a number of factors such as soil nitrate concentration, historical settlement patterns, methods of sewage disposal and agricultural practices. Other factors include host rock chemistry, leaching effects, and chemical reactions within the aquifers. In addition to anthropogenic sources, most parent rocks have their own concentration of nitrogen compound(s) which during chemical reaction are capable of being oxidized into nitrate by aquifer microbes. However, concentrations in excess of 10mg/l renders the water non-potable. Furthermore, presence of ammonia in groundwater is an indication of possible bacteriological pollution which may be a threat to human health (Oladejo, 2003).

The nitrate-nitrogen values in the surface and sub-surface soils in the study area ranged from 35.8 to 44.3 mg/l and 68.0 to 71.5 mg/l respectively. Similarly, the observed dense population in most quarters of the Abeokuta metropolis and typical rural life style of the residents of houses in Ewekoro villages encourages the use of pit latrines and backyard sewers, locations of which are relatively close to the wells in most houses. Hence un-sewered sanitations in few cases especially among the residents of Ewekoro cannot be ruled out as a nitrate-nitrogen source. In addition, domestic animal wastes and other solid wastes, the use of organic and inorganic fertilizers in the farms and garden cultivated around the houses in the studied locations are possible sources of nitrate-nitrogen in the sampled groundwater. It is therefore likely that agricultural activities and high water recharge rate of the Ewekoro sedimentary watershed might be responsible for the high level of nitrate-nitrogen in the groundwater of Ewekoro villages. Since nitrate is highly mobile in soils of the aquifers in Ewekoro villages it perhaps moves freely within flowing groundwater. The nitrates from these sources might have added up as part of leachates in the groundwater (Sridhar, 2000). This probably explains the difference in the nitrate-nitrogen contents in the soils around the aquifers in the two locations in the study area.

The low nitrate level recorded in the soil samples of Ewekoro is an indication that these soils have higher potential for nitrate leaching through runoff and therefore constitute a source of potential degradation of groundwater especially in low land area like Ewekoro. This kind of elevated concentration of nitrate-nitrogen from the groundwater of rural setting due to application of agricultural fertilizers have been widely reported by several authors (Nelson and Lee, 1987; Power, 1987; Wai-Osogu, 1990; Burkart and Kolpin, 1993; Demissie and Keefer, 1998; Amalu, 1998; Ishaq and Alassar, 1999). Ewekoro being a sedimentary geological terrain has soil types with possible greater water infiltration capacity than the soils of Abeokuta which are essentially underlain by crystalline rocks.

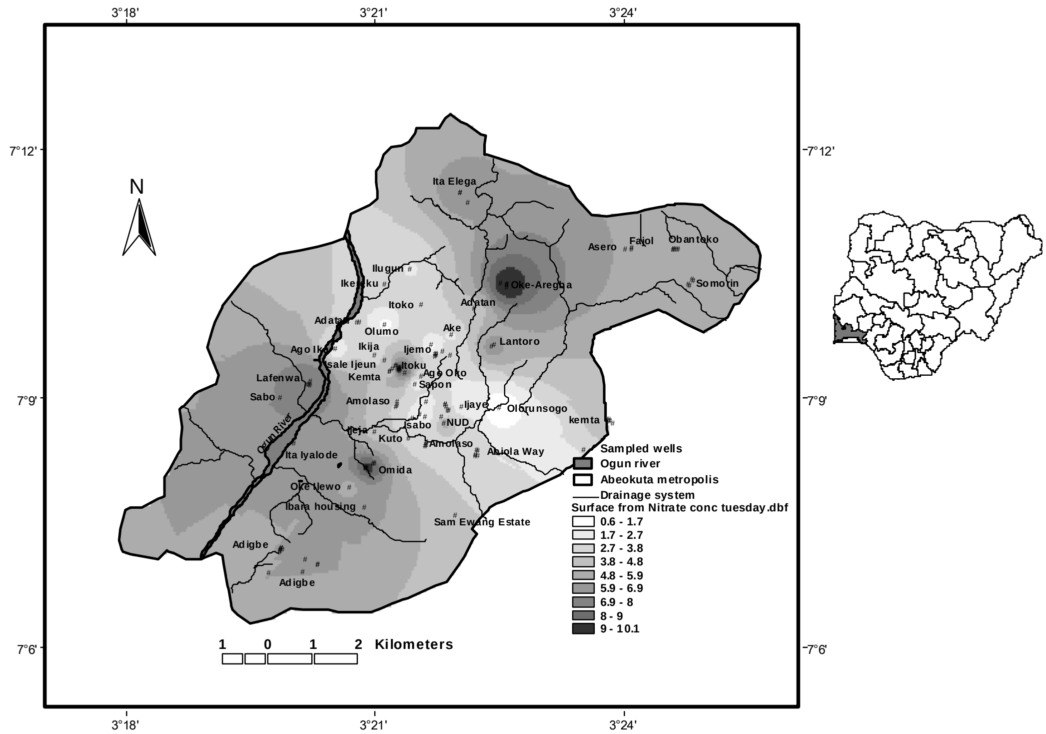

Figure 3a: Map Showing the Distribution Pattern of Nitrate Concentration in the Groundwater from Abeokuta Metropolis.

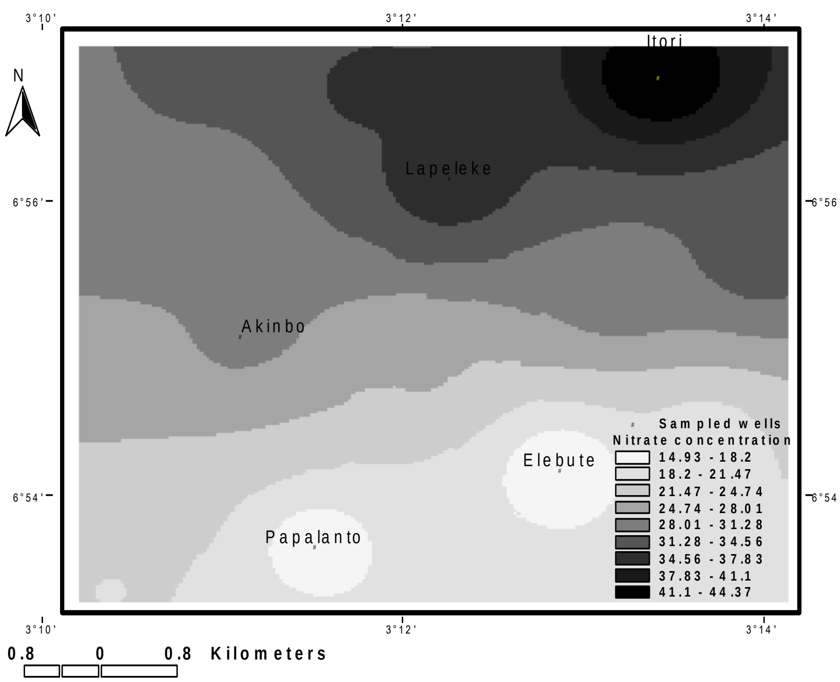

Figure 3b: Map Showing the Distribution Pattern of Nitrate Concentration in the Groundwater from Ewekoro and Environs.

The soils of Ewekoro may enhance rapid surface water penetration and recharge of groundwater through the widespread interconnectivity of the pores compared to localized fracturing nature of the basement rocks. Furthermore, the observed variation in the nitrate-nitrogen concentration in groundwater of Ewekoro may be attributed to the relatively inactive nature of soil aquifer microbes. These microbes have been found to be less active in the breaking down of the soil organic matter in soil that is obtained in the flat lying watershed areas like that of Ewekoro. Since nitrate is highly mobile in tropical soils, it might have therefore percolated into the groundwater resources of Ewekoro and therefore portends contamination in the area.

The risk hazard maps of the two geologic terrains (Figure 4a and 4b) reveal that the groundwater resources of the basement complex area as at the time of the study appears safe for drinking when compared to that of the sedimentary terrain. The risk hazard indicator map of nitrate-nitrogen content of groundwater of the sedimentary area shows that more than 50% of the settlers are exposed to the threat of consuming groundwater with excessive high values of nitrate-nitrogen. Only the groundwater samples from Elebute and Papalanto, at the southern part of the study area have low NO_3-N concentration.

Generally elevated nitrate-nitrogen is capable of constituting a major health risk to the consumers of groundwater supplies due to its wide spread distribution via domestic and agricultural sources (Food and Agriculture Organization, 1997). In high concentrations, it can be metabolized to a nitrosamine, a potential carcinogen. Excessive concentration of nitrate-nitrogen in drinking water has been implicated in infants-methaemoglobinaemia (or blue baby syndrome) (Groen, 1988).

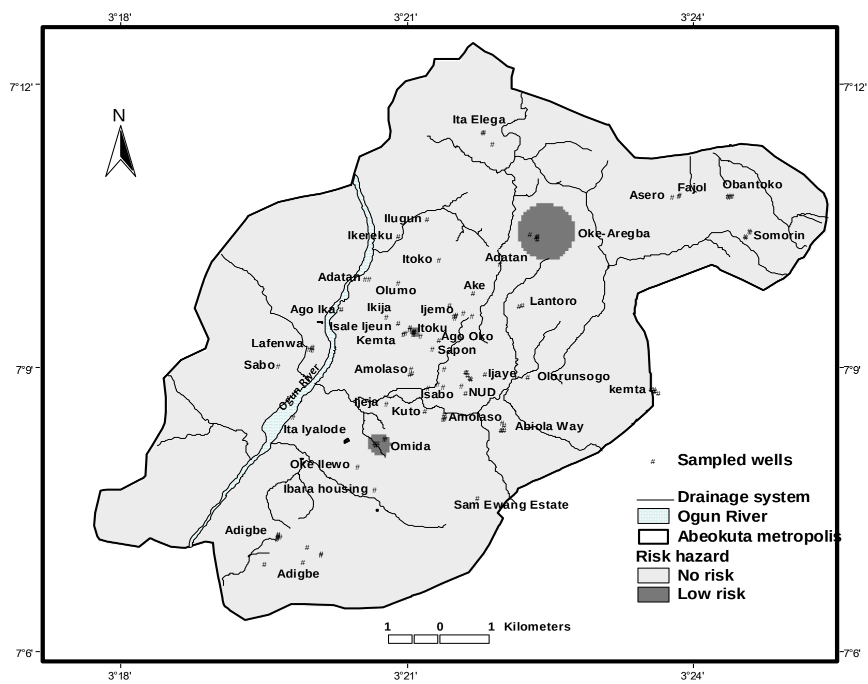

Figure 4a: Map Showing the Area of NO_3-N Risk in Groundwater Resources of Abeokuta Metropolis.

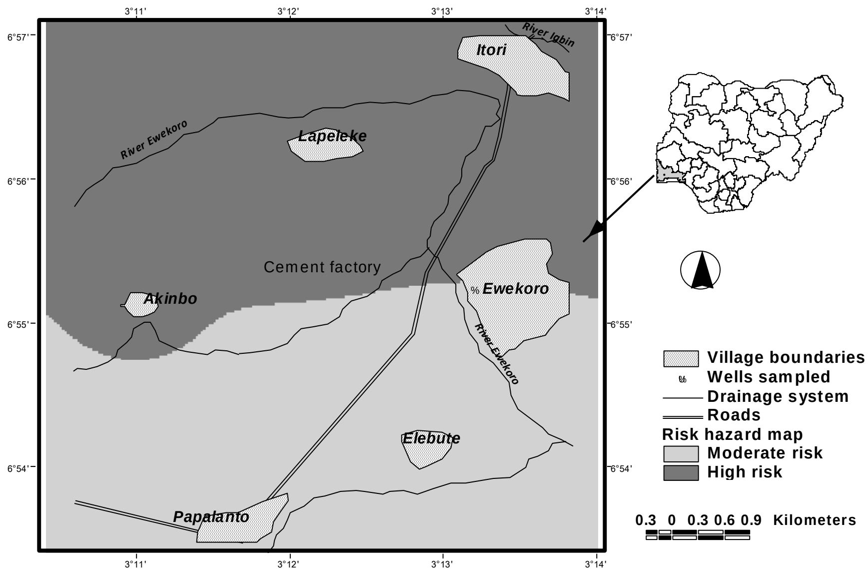

Figure 4b: Map Showing Area of NO_3-N Risk in Groundwater Resources of Ewekoro and Environs.

CONCLUSION

The result of this study reveals that people living within Abeokuta metropolis may be at low risk of nitrate-nitrogen pollution in drinking water abstracted from the basement complex aquifer. Nitrate-nitrogen concentrations are below the WHO recommended limit. In contrast, residents of communities within Ewekoro area are experiencing nitrate-nitrogen pollution problems as concentrations far exceed the WHO recommended limit.

In the light of the above, there is urgent need to reduce the use of inorganic fertilizers while educating the citizenry especially of Ewekoro area on proper method of sewage disposal. Similarly, assessment studies need to be conducted in order to examine the trend of nitrate-nitrogen level of the groundwater of the study area over time. Proper site selection for the location of domestic water wells and proper well construction will also reduce potential nitrate-nitrogen contamination of drinking water source in this area.

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