QUALITY ASSESSMENT OF GROUNDWATER FROM SHALLOW AQUIFERS IN HONG AREA, ADAMAWA STATE, NORTHEASTERN NIGERIA

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ABSTRACT

The present study evaluates the quality of groundwater in shallow aquifers in Hong area of Adamawa State, Northeastern Nigeria. Groundwater samples, soil samples and rock samples were collected during dry and wet seasons and subjected to laboratory analysis to determine their physico-chemical characteristics. The study revealed that the concentration of the major cations (calcium, magnesium, sodium and potassium) and anions (sulphate, chloride, bicarbonate, nitrate and phosphate) were below the respective permissible limit recommended by WHO and NSDWQ. The hydrochemical facies analysis indicates the groundwater in the area is Ca-HCO_3 type. The observed wide variation in the concentration of the electrical conductivity (10.00-1320.00 mg/L) and total dissolved solid (70.00-2690.00 mg/L) is an indication that the groundwater in the area contained dissolved ions. The slightly acidic water (5.50-6.94) in the area encourages the dissolution of iron and fluoride mineral into the groundwater system. High iron content (0.03-0.93 mg/L) in water as against the recommended value of (0.30 mg/L) does not pose any health threat but deteriorates the colour, odour and taste of water while the high fluoride concentration (0.06-2.58 mg/L) in the groundwater system as against the permissible limit of (1.50 mg/L) has resulted in dental fluorosis in the area especially in children between the ages of 10 to 20 years. The high fluoride in the groundwater in Hong area is clearly geogenic and due to chemical weathering and subsequent decomposition, dissociation and dissolution of fluoride bearing minerals (nacaphite) within the porphyritic granite portion. The high content of fluoride and iron in the groundwater may have contributed to the high EC and TDS especially during the rainy season when the rate of leaching and infiltration is high.

Keywords: Quality Assessment, Groundwater, Shallow Aquifer, Hong, Northeastern Nigeria

INTRODUCTION

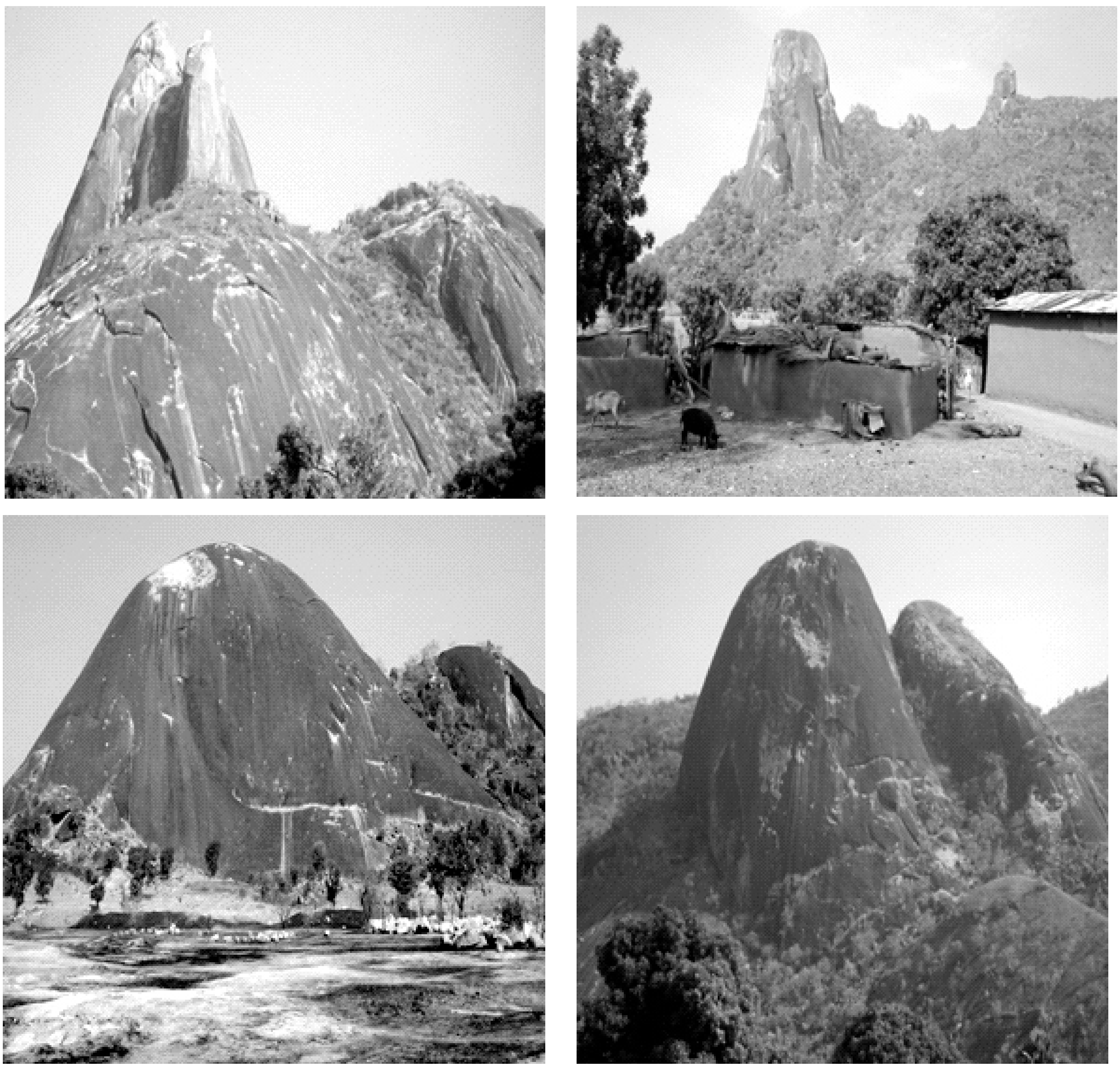
About 80% of all communicable diseases affecting human beings are either water borne or water related according to the World Health Organisation (WHO, 2006). Diseases such as typhoid, dysentery, cholera, meningitis and diarrhoea are signatures of drinking unsafe water. The quality of water is assessed by its physical, chemical and bacteriological characteristics and is usually compared with the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) among others.

Water is one of the basic needs of human beings and all living things. This vital resource is vulnerable to contamination and pollution emanating from natural and anthropogenic activities (Amadi *et al*., 2012, DanHassan *et al*., 2012). The major factors controlling the geochemical evolution and quality of groundwater are chemical composition of rain-water, soil types, soil-water interaction and mineralogy of rock formations (Amadi *et al*., 2014). The chemical composition of groundwater provides information about the environment through which water has circulated (Appelo and Postman, 1993). The initial composition or background chemistry of groundwater may be altered through anthropogenic influences which are now prevalent because of increase in level of urbanization, industrialization and large scale agricultural activities (Amadi *et al.*, 2013). An estimated 62 million people globally suffer from fluorosis due to consumption of water with high fluoride concentration and Nigeria is among the 23 nations in the world with health problems arising from high fluoride concentration in water (UNICEF, 2000).

Description of the Project Environment

Geographic Description, Climate, Vegetation and Physiography

The study area lies within longitudes 12°50'E to 13°00'E and latitude 10°05'N to 10°22'N. The area falls within Hong Local Government Area of Adamawa State, North-eastern Nigeria and is accessible through Gombi-Mubi road, Hong-Garaha road and Hong-Gaya road (Figure 1). Hong and environs are drained by Kilanye and Shashau Rivers (Bassey *et al.*, 2006). The area is characterized by dry season (October to March) and wet season (April to September). The area falls within the Sudan Savannah vegetation type which consists of shrubs, grasses and trees especially along the river channels (Dada, 2006). Physiographically, the area falls within the Adamawa highlands with rugged hills and heights of between 800 and 1500 m above sea level that forms inselbergs and whalebacks (Plates 1-4).



Plates (1-4): Inselbergs and whalebacks in Hong Area, Northeastern Nigeria

Geology and Hydrogeology of the Area

The geological mapping undertaken in the study area revealed that the local geology comprises of migmatites and porphyritic granite of Pan African age. The migmatites are composed of weak bands of fine grained rocks with granitic composition, cut by numerous pegmatitic and aplitic veins. The porphyritic granite form elongated dome to sub-dome cluster of inselberg (Plates 1-4). Field observation on the migmatitic and granitic outcrops show moderate weathering and presence of structural elements such as joints and faults. Hydrogeologically, the hand-dug wells in the area derived their water source from regolith aquifer while secondary porosity and permeability initiated via fractures account for the groundwater storage and yield.

MATERIALS AND METHODS OF STUDY

Sample Collection and Laboratory Analysis

Sixty five groundwater samples were collected from hand-dug wells in the study area (Fig. 1). Ten soil samples and five rock samples were also collected and sent to the laboratory for the chemical analysis. At each water sampling point, two set of samples were collected using glass and plastic containers and 2 drops of HNO_3 ($pH < 2$) were added to the plastic containers for cation analyses in order to prevent loss of metals, bacterial and fungal growth and then stored in a cooler before transporting them to the laboratory for the analyses of the following elements: calcium, magnesium, sodium, potassium, chloride, nitrate, sulphate, bicarbonate, fluoride, phosphate and iron. Physical parameters such as temperature, pH and colour were determined in the field using portable HACH meters. All the samples were analysed at the National Geosciences Research Laboratory of NGSA, Kaduna. The sampling and analytical procedures met the APHA (2008) standard.

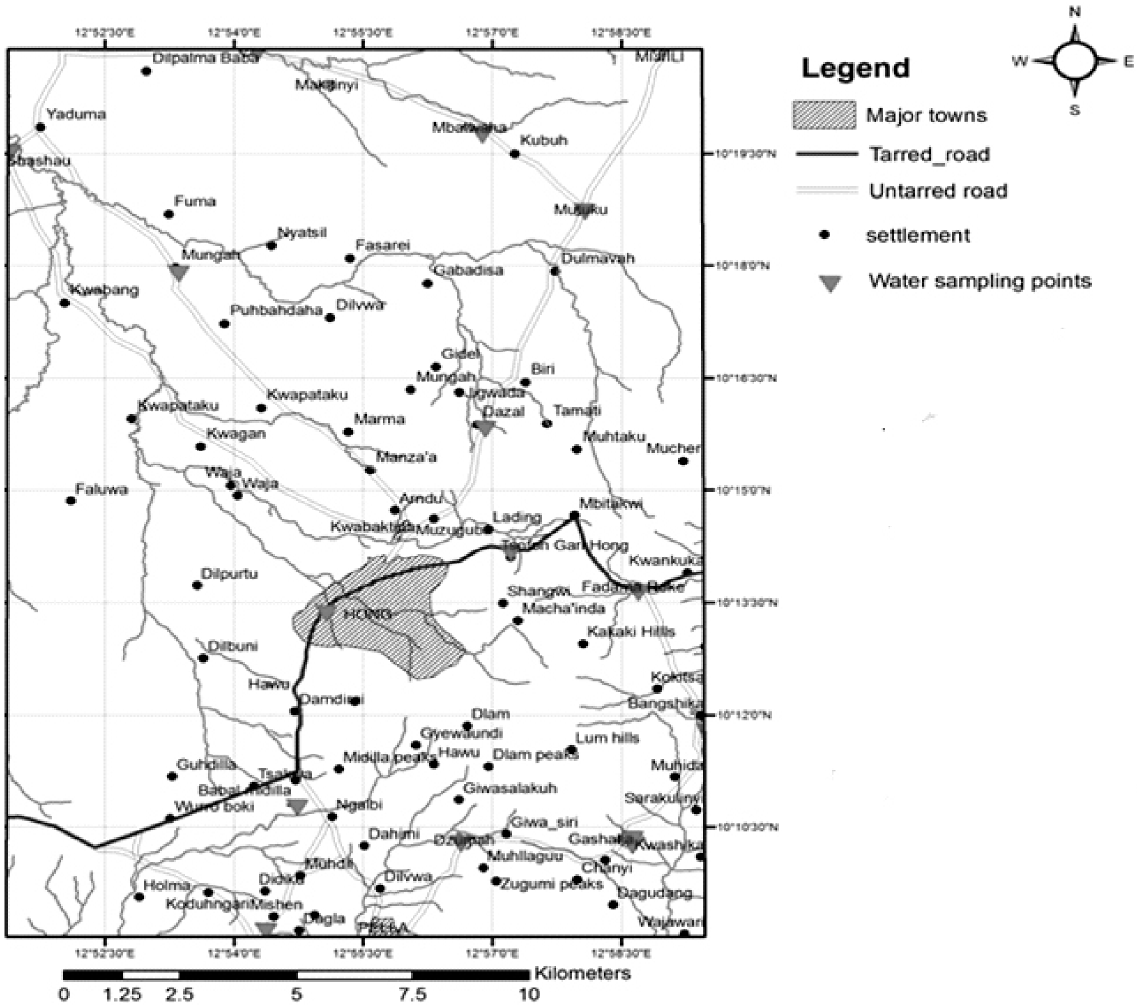


Fig. 1: Map of the Study Area Location Showing the Sampled Points

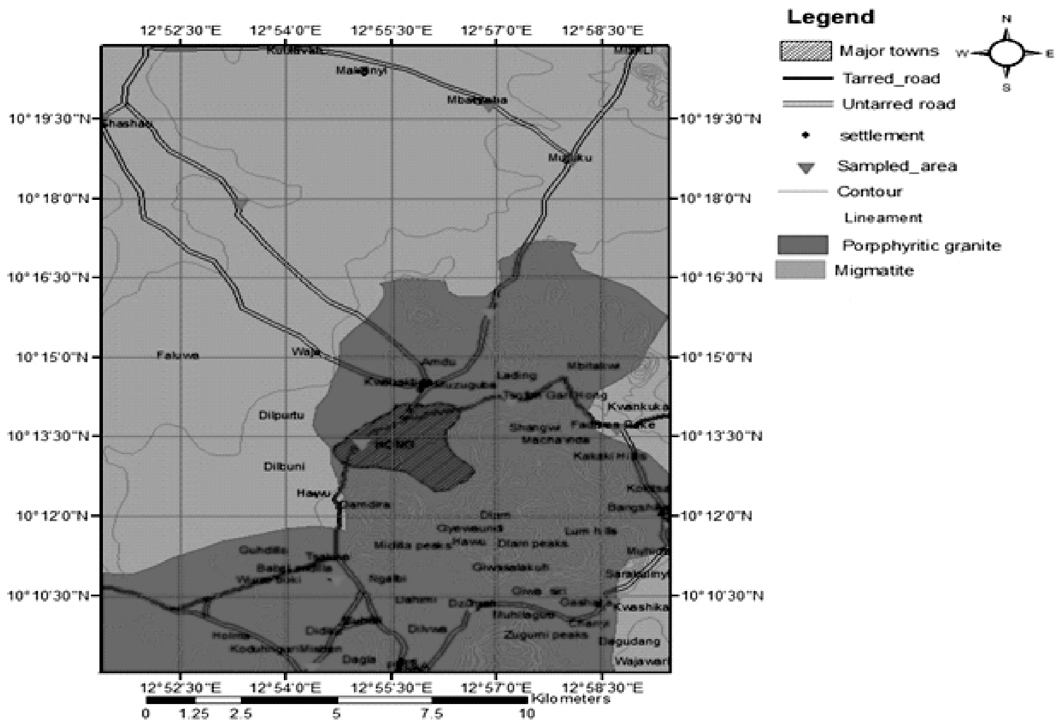


Fig. 2: Geology of Hong Area

RESULTS AND DISCUSSION

The statistical summary of the physico-chemical parameters analysed for dry and wet seasons are contained in Tables 1 and 2 respectively. Temperature values ranged from 29.60°C to 30.50°C with a mean value of 29.50°C for dry season and 25.20°C to 27.93°C with an average value of 27.93°C. High temperature enhances the solubility and mobility of metals (Amadi *et al.*, 2015). The pH value ranged between 5.50 to 6.94 with a mean value of 6.55 for the dry season and 6.72 to 7.38 with an average value of 7.03 for the wet season as against the range of 6.50 to 8.50 recommended by World Health Organization (WHO, 2006) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) for potable water.

The groundwater in the area is therefore slightly acidic and tends towards neutral. Electrical conductivity (EC) of the groundwater ranged from 100.00 µS/cm to 870.00 µS/cm with an average value of 382.00 µS/cm for the dry season and10.00 µS/cm to 1320.00 µS/cm with a mean value of 498.00 µS/cm for the wet season (Tables 1 and 2).

Table 1: Statistical Summary of the Analyzed Physico-chemical Parameters in Dry Season

Parameters (mg/L)	Minimum	Maximum	Mean	Median
pH	5.50	6.94	6. 55	5.53
EC	100.00	870.00	382.00	320.00
TDS	90.00	680.00	219.30	150.00
Temp. (°C)	28.20	30.50	29.46	29.50
Calcium	23.42	164.30	58.92	12.96
Magnesium	5.29	49.72	15.02	40.93
Sodium	3.44	63.92	25.05	15.56
Potassium	1.26	10.61	3.65	18.34
Chloride	1.12	6.93	4.10	6.23
Nitrate	0.19	5.86	4.06	1.12
Sulphate	3.40	18.10	11.24	0.60
Bicarbonate	30.50	122.30	60.16	18.34
Fluoride	0.08	2.58	1.33	1.58
Phosphate	0.01	0.98	0.12	0.04
Iron	0.03	0.93	0.23	0.15

Table 2: Statistical Summary of the Analyzed Physico-chemical Parameters in Wet Season

Parameters (mg/L)	Minimum	Maximum	Mean	Median
pH	6.72	7.38	7.03	6.78
Conductivity (µs/cm)	10.00	1320.00	498.00	270.00
TDS	70.00	2690.00	776.00	490.00
Temp. (°C)	25.20	27.93	27.93	26.50
Calcium	16.46	135.10	46.52	11.34
Magnesium	3.18	45.78	13.75	31.00
Sodium	2.97	60.51	22.87	20.32
Potassium	0.76	8.76	3.20	2.78
Chloride	0.98	6.54	3.65	3.61
Nitrate	1.54	5.80	4.27	0.98
Sulphate	2.29	15.60	9.25	9.20
Bicarbonate	21.5	113.20	56.30	57.40
Fluoride	0.06	2.45	1.32	0.98
Phosphate	0.001	0.42	0.10	0.01
Iron	0.03	0.93	0.23	0.15

The EC values during the dry season falls within the maximum permissible limit of 1000.00 μS/cm recommended by (WHO, 2006 and NSDWQ, 2007) while during the wet period, the concentration of EC in some locations exceeded the allowable limit and this is an indication of possible groundwater pollution.

The total dissolved solid (TDS) varied from 90.00 mg/L to 680.00 mg/L with an average value of 219.3 mg/L for the dry season and 70.00 mg/L to 2690.00 mg/L with a mean value of 776.00 mg/L for the wet season as against the maximum allowable limit of 500.00 mg/L (WHO, 2006; NSDWQ, 2007). Similarly, the values of TDS in most locations during the wet season far exceeded the maximum permissible limit and this further confirms that the groundwater system in the area is polluted. The relatively high values of the pH, EC and TDS during in the wet season compared to dry season (Figs. 3-5) could be attributed to increased infiltration, dissolution, weathering and surface runoff due to rainfall.

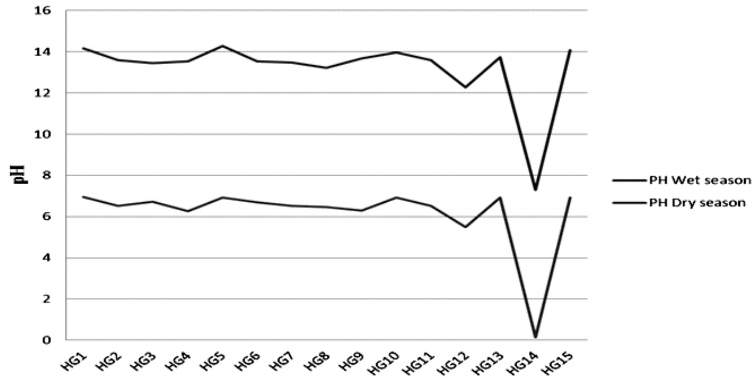


Figure 3: Graph of pH in Dry and Wet Seasons in Study Area

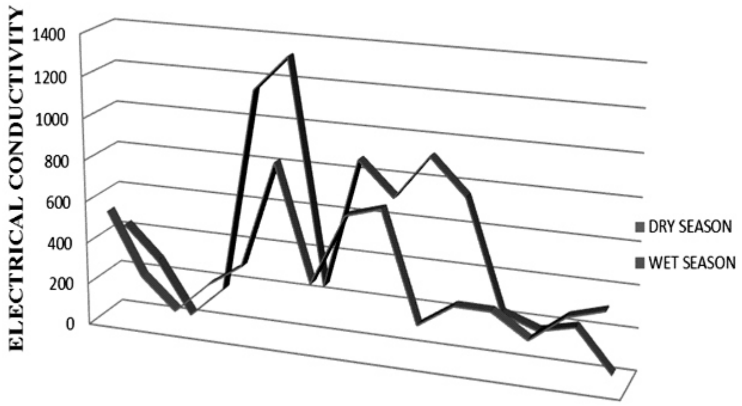


Figure 4: Graph of Electrical Conductivity for Dry and Wet Seasons in the Study Area

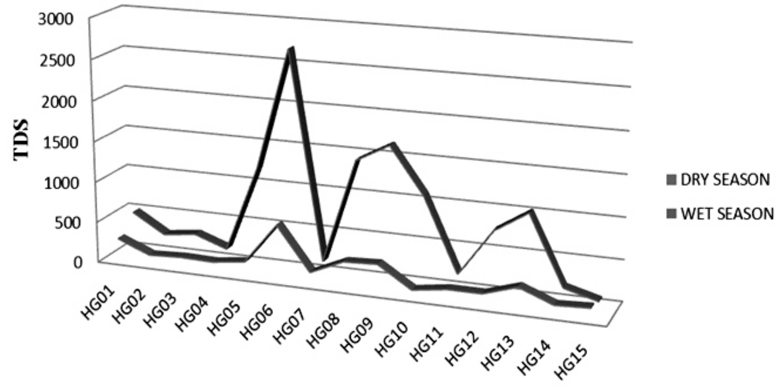


Figure 5: Graph of Total Dissolved Solid for Dry and Wet Seasons in the Study Area

The concentration of calcium ranged from 23.42 mg/L to 164.30 mg/L with a mean value of 58.90 mg/L for the dry season and between 16.46 mg/L and 135.10 mg/L with an average value of 46.52 mg/L for the wet season. The concentration of calcium in both season are below the permissible limit of 200.00 mg/L postulated by WHO (2006) and NSDWQ (2007). Calcium is beneficial element with respect to strong teeth and bone formation and its high concentration in water does not constitute any health hazard (Amadi *et al.*, 2014). Magnesium concentration varied from 5.29 mg/L to 49.72 mg/L with an average value of 15.02 mg/L for the dry season and 3.18 mg/L to 45.78 mg/L with a mean value of 13.75 mg/L for the wet season (Tables 1 and 2). The presence of calcium and magnesium ions in water is responsible for hardness of water. The concentration of sodium ranged between 3.44mg/L and 63.92mg/L with a mean value of 25.05mg/L for the dry season and 2.97 mg/L to 60.51 mg/L with an average value of 22.87 mg/L for the wet season as against the recommended value of 200.00 mg/L (WHO, 2006; NSDWQ, 2007).

Sodium is a dietary mineral for animals and people suffering from diarrhea require a higher dietary amount of sodium for quick recovery. It regulates extra cellular fluids, acid-base balance and membrane potential. High concentration of sodium however lead to increased blood pressure, arteriosclerosis and oedema while low amount of sodium lead to dehydration, convulsion, muscle paralysis and decreased growth. The concentration of potassium ranged from 1.26 mg/L to 10.61 mg/L with a mean value of 3.65 mg/L for the dry season and between 0.76 mg/L and 8.76 mg/L with an average value of 3.20 mg/L for the wet season. The concentrations of the major cations (calcium, magnesium, sodium and potassium) during the dry and wet seasons were found to be within the acceptable limits indicating that the groundwaters in the area are not contaminated by these elements. The concentration map of calcium and sodium in groundwater in the study area are shown in Figures 6 and 7 respectively.

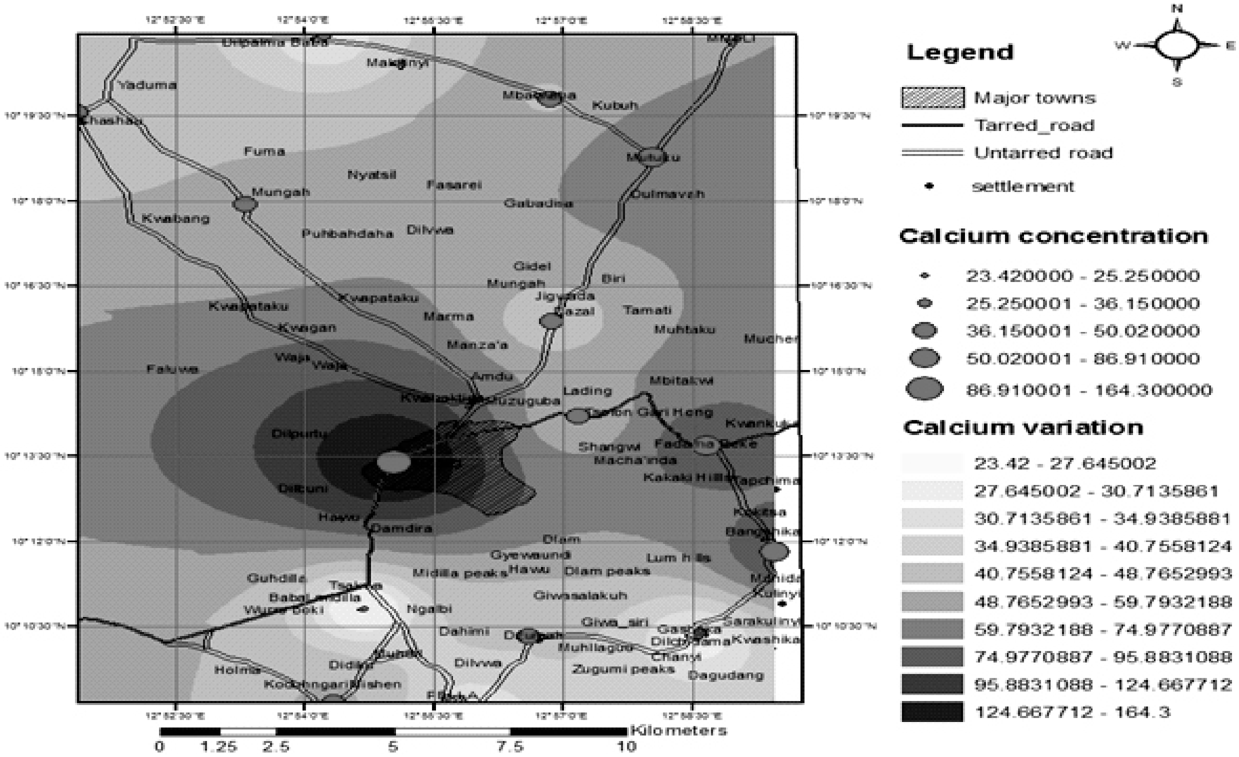


Figure 6: Concentration Map of Calcium in Groundwater in Hong Area during the Dry Season

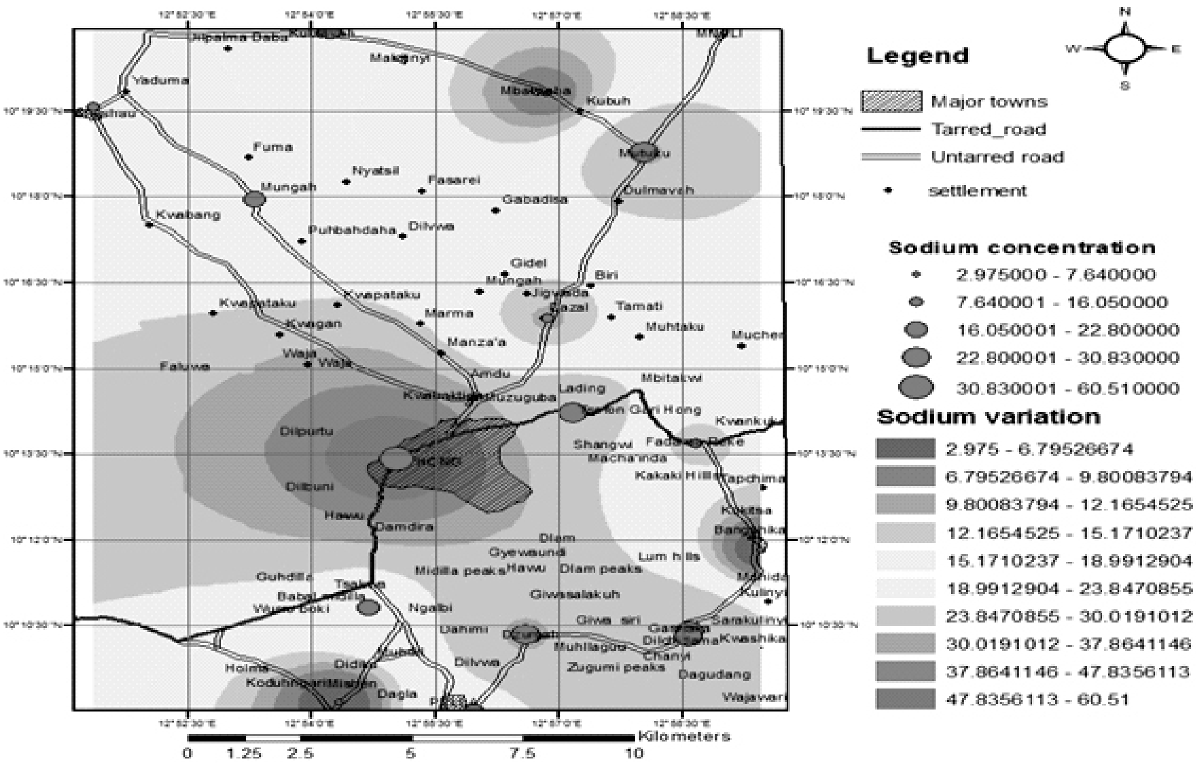


Figure 7: Concentration Map of Sodium in Groundwater in Hong Area during the Dry Season

The concentration of iron ranged from 0.001 mg/L to 0.109 mg/L with a mean value of 0.053 mg/L for the dry season and 0.02 mg/L to 0.98 mg/L with a mean value of 0.145 mg/L for the wet season as against the maximum permissible limit of 0.30 mg/L (WHO, 2006; NSDWQ, 2007). High iron content in groundwater during the wet season does not constitute any health problem except impairment of the colour, odour and taste (Olasehinde *et al.*, 2004; Amadi *et al.*, 2013; Okunlola *et al.*, 2014). The concentration of sulphate lies between 3.4 mg/L and 18.1 mg/L with an average value of 11.24 mg/L for the dry season and 2.29 mg/L to 15.6 mg/L with a mean value of 9.25 mg/L while the concentration of nitrate varied from 1.54 mg/L to 5.8 mg/L with an average value of 4.06 mg/L for the dry season and 0.19 mg/L to 5.86 mg/L with a mean value of 4.27 mg/L for the wet season. The chloride concentration in both season are very low (1.12mg/l to 6.93mg/l) for the dry season and (0.98 mg/L to 6.54 mg/L) for the wet season while phosphate concentration varied from 0.01mg/l to 0/.98 mg/L with a mean value of 0.12 mg/L in the dry season and 0.00 mg/L to 0.42 mg/L with an average value of 0.10 mg/L for the wet season (Tables 1 and 2).

The chloride, sulphate, nitrate and phosphate contents in the groundwater in the area are very low and this is an indication that the groundwater system in the area is not under any threat of pollution. High concentration of chloride, sulphate, nitrate and phosphate can be geogenic due to bedrock dissolution and chemical weathering or anthropogenic as a result of urban sewage, unlined soakaway and fertilizer application (DanHassan *et al.*, 2012). Bicarbonate content in the groundwater ranged from 30.50 mg/L to 122.30 mg/L with an average concentration value of 60.16 mg/L during the dry season and 21.50 mg/L to 113.20 mg/L with a mean value of 56.03 mg/L in the wet season. Though calcium and bicarbonate are the dominant cation and anion in the groundwater system from the area, their concentrations in both season are far below their respective maximum permissible limits. The implication is that the groundwater in the area is calcium-bicarbonate type and a confirmation that the groundwater is shallow (Olasheinde and Amadi, 2009; Okunlola *et al.*, 2014). The concentration maps of iron and bicarbonate in Hong area are shown in Figures 8 and 9 respectively.

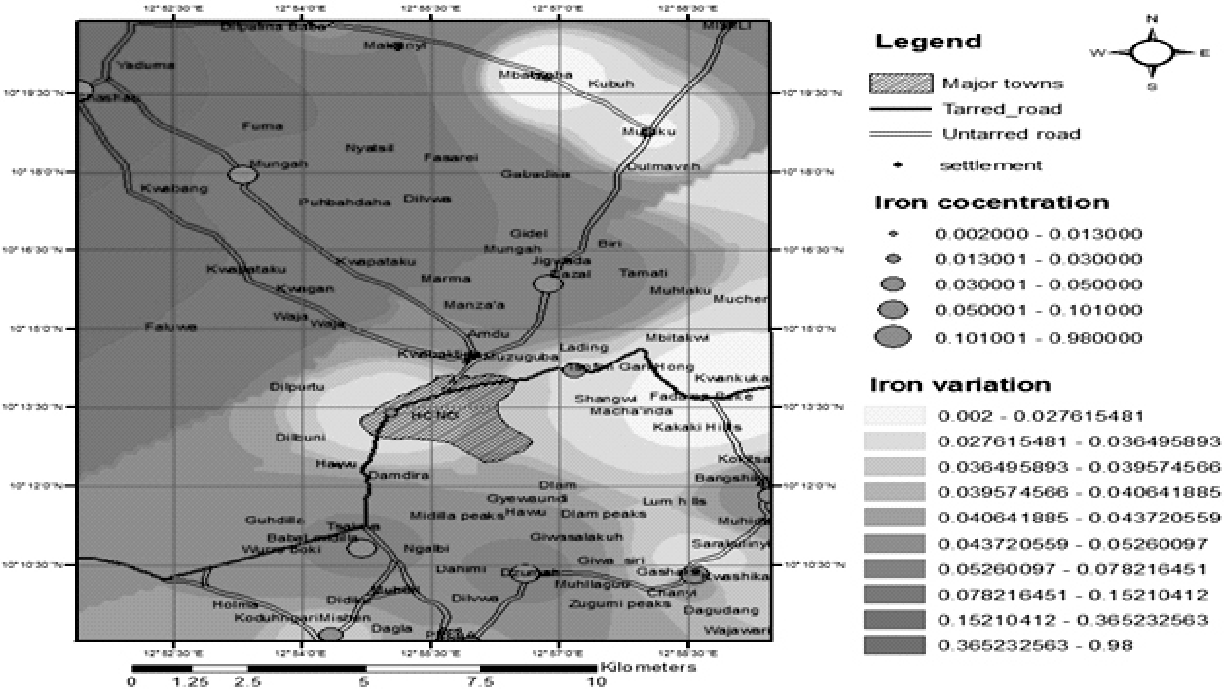


Figure 8: Concentration Map of Iron in Groundwater for Hong Area in Wet Season

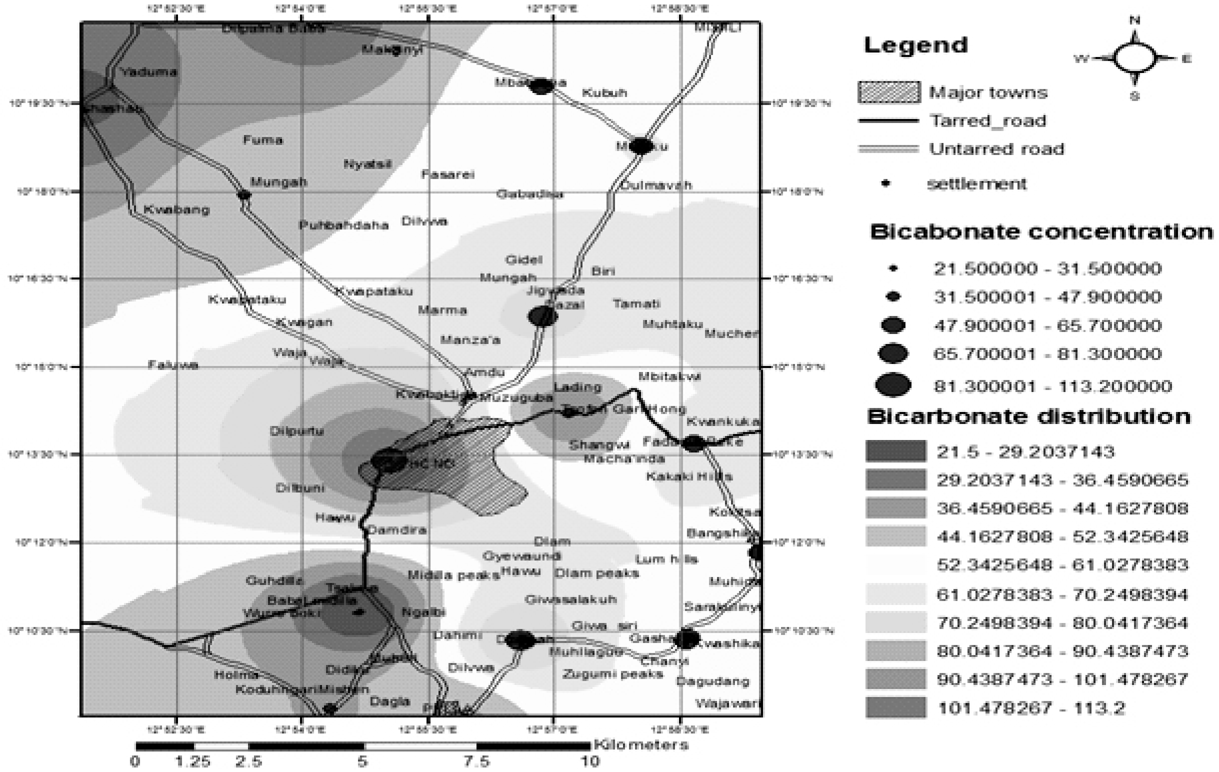


Figure 9: Concentration Map of Bicarbonate in Groundwater for Hong Area in Wet Season

The concentrations of fluoride in dry and wet seasons were found to exceed the maximum permissible limit of 1.50 mg/L (WHO, 2006; NSDWQ, 2007). The value ranged between 0.08 mg/L and 2.58 mg/L for dry season and 0.06 mg/L to 2.45 mg/L for wet season while their respective mean values are 1.33 mg/L and 1.32 mg/L respectively. Fluoride content in water is both beneficial and detrimental to the body depending on the concentration. Fluoride content below 1.50 mg/L helps in the formation of strong bones and tooth while concentrations exceeding

1.50 mg/L cause fluorosis and skeletal paralysis (Aminu and Amadi, 2014). High fluoride content in groundwater can be attributed to either natural means via chemical weathering and rock dissolution processes or anthropogenic interference through the application of fluoride rich fertilizer (Saxema and Ahmed, 2002; Columbus *et al.*, 2003; Nwankwoala *et al.*, 2014). This study revealed that the highest concentration of fluoride in groundwater in the area occurs in the portion underlain by the porphyritic biotite granite while fluoride concentration within the migmatite lithology was found to be generally low, which implies that the high fluoride content in groundwater in the area is by natural release of fluoride rich mineral in the granite dominated portion. The fluoride concentration map for the dry and wet seasons are shown in Figures 10 and 11 respectively while the overlap of the geology map with the fluoride Concentration map is illustrated in Figure 12.

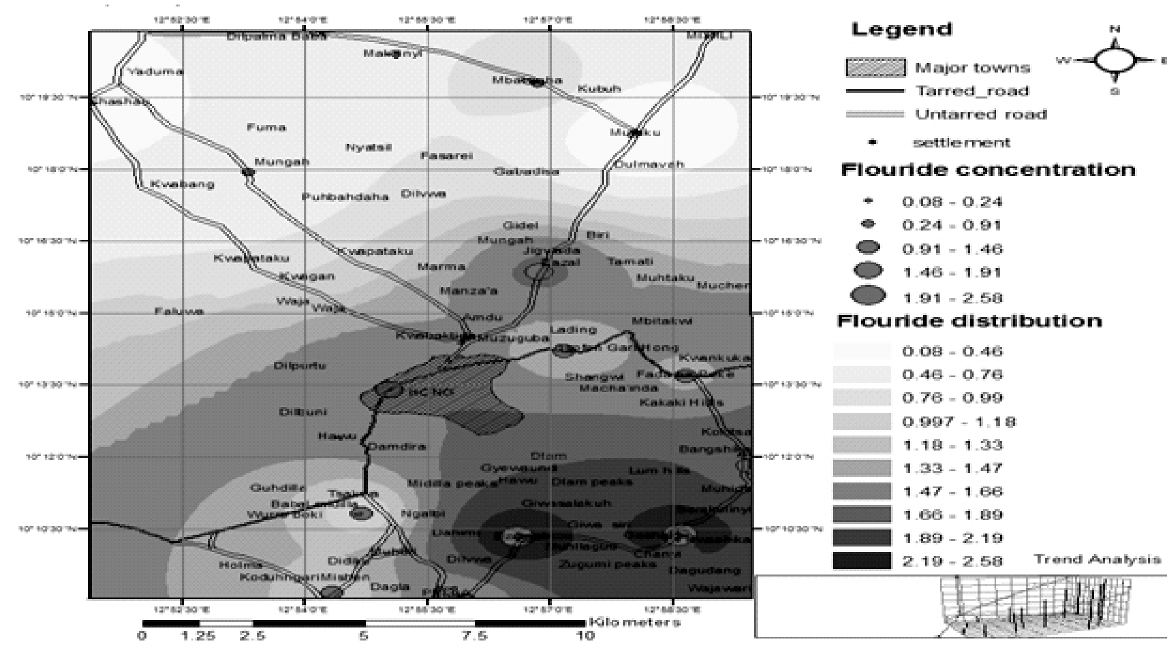


Figure 10: Fluoride Concentration Map for Hong Area in Dry Season

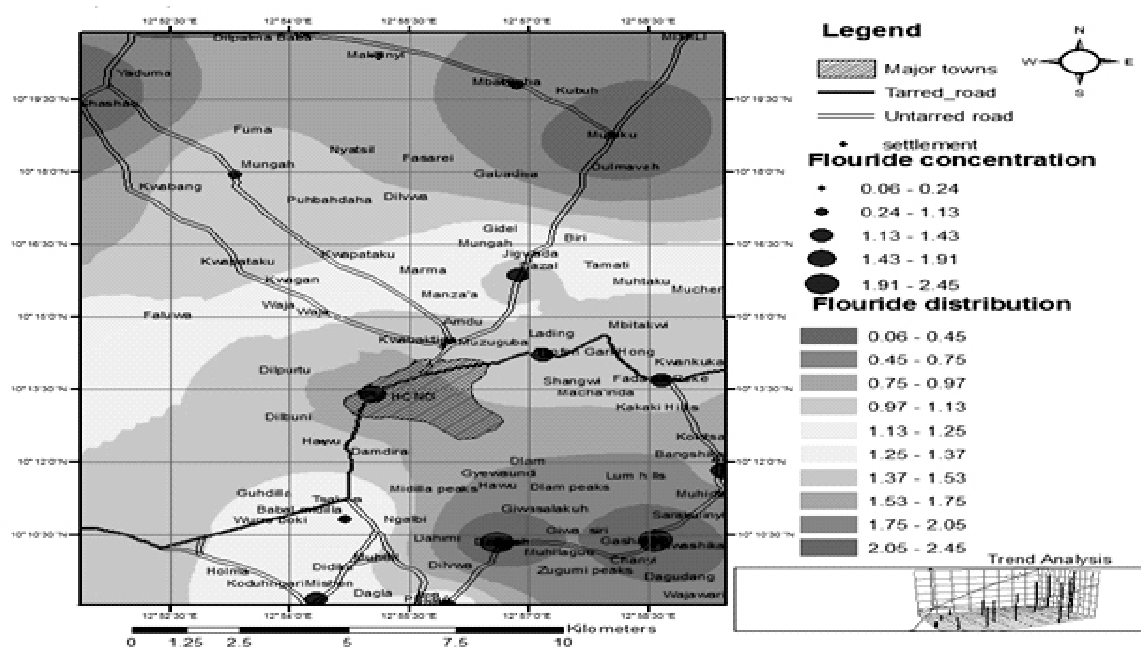


Figure 11: Fluoride Concentration Map for Hong Area in Wet Season

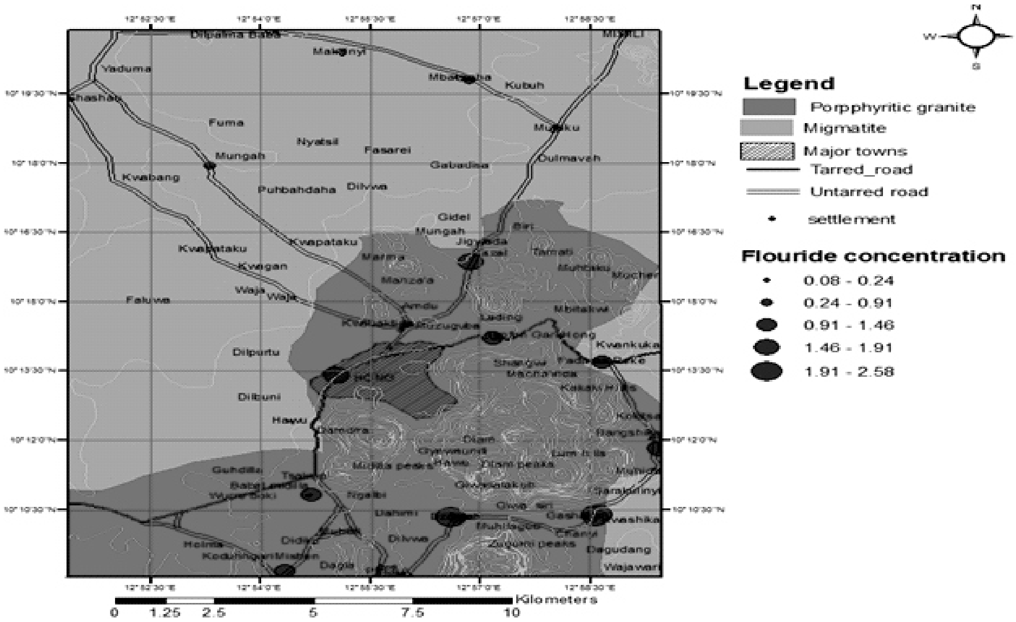


Figure 12: Overlap of the Geological Map with Fluoride Concentration Map for Hong Area

The prevalence of dental fluorosis in the area has been ascertained among teenagers between the ages of 10 to 20 years (Plates 5-8) while no cases of skeletal fluorosis was discovered in the study area as at the time of this study. Rock and soil samples from the area were also analysed in order to unravel the causes of dental fluorosis in the area. Rock and soil samples were taken from porphyritic granite dominated area as well as from the migmatites. The elemental characterization of the soil and rock samples using XRD was attempted to find out the possible primary source of fluoride in groundwater in Hong area. The results from the XRD analysis indicated the presence of sodium calcium phosphate fluoride, a fluoride-rich mineral known as nacaphite from the porphyritic granitic portion (Fig. 13) while soil and rock samples emanating from the Migmatite region were free from necaphite (Fig. 14). This finding is a confirmation that the high fluoride in the area is due to the weathering of the bedrock in the area and possible dissolution and leaching into the shallow groundwater system (Gaciri and Davies, 1993; Fung *et al.*, 1999; Columbus *et al.*, 2003; Shomar *et al.*, 2004). The result of the investigation was used to produce the dental fluorosis prevalence rate map and health-risk map for the area as shown in Figures 15 and 16 respectively.

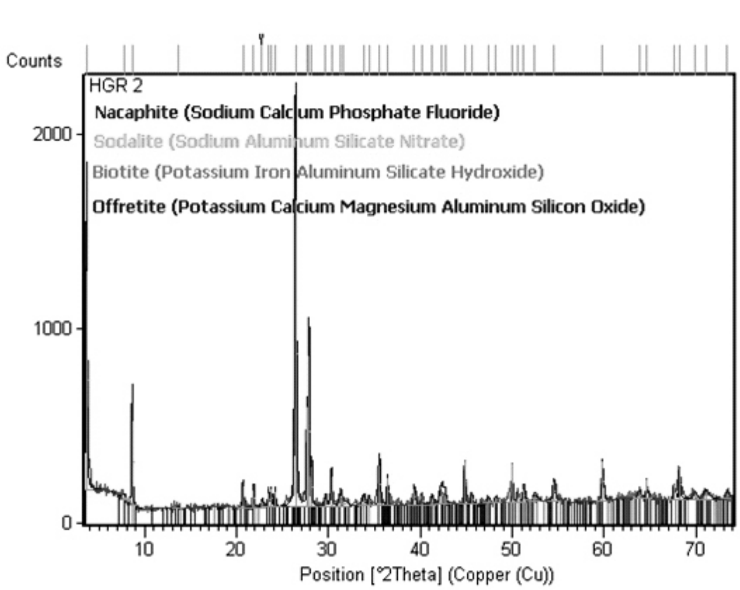


Figure 13: XRD Chart of Rock Samples from Porphyritic Granite Area Showing Nacaphite Mineral

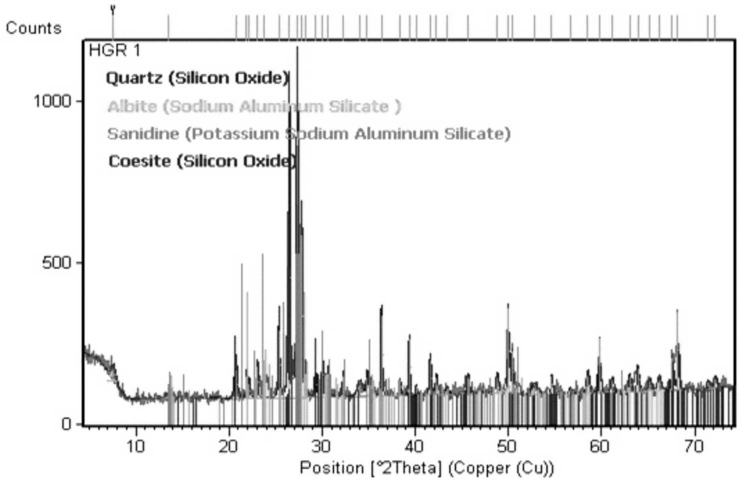


Fig. 14: XRD Chart of Rock Samples from Migmatite Area without Nacaphite Mineral

Plate 5

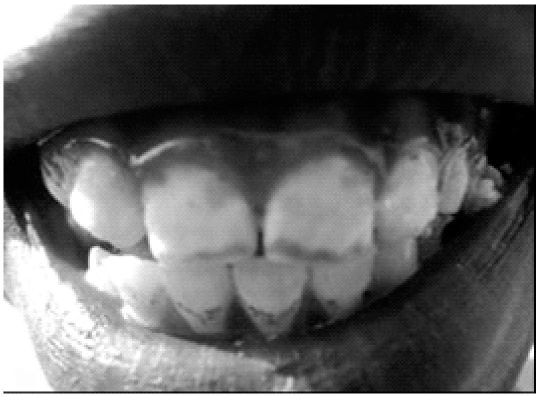


Plate 6

Plate 7

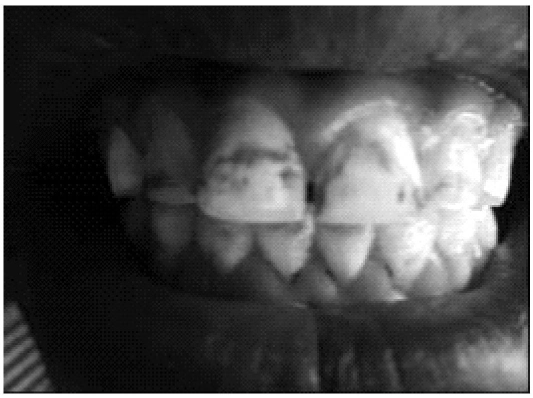


Plate 8

Plates (1-4): Dental Fluorosis in Hong Area, Northeastern Nigeria

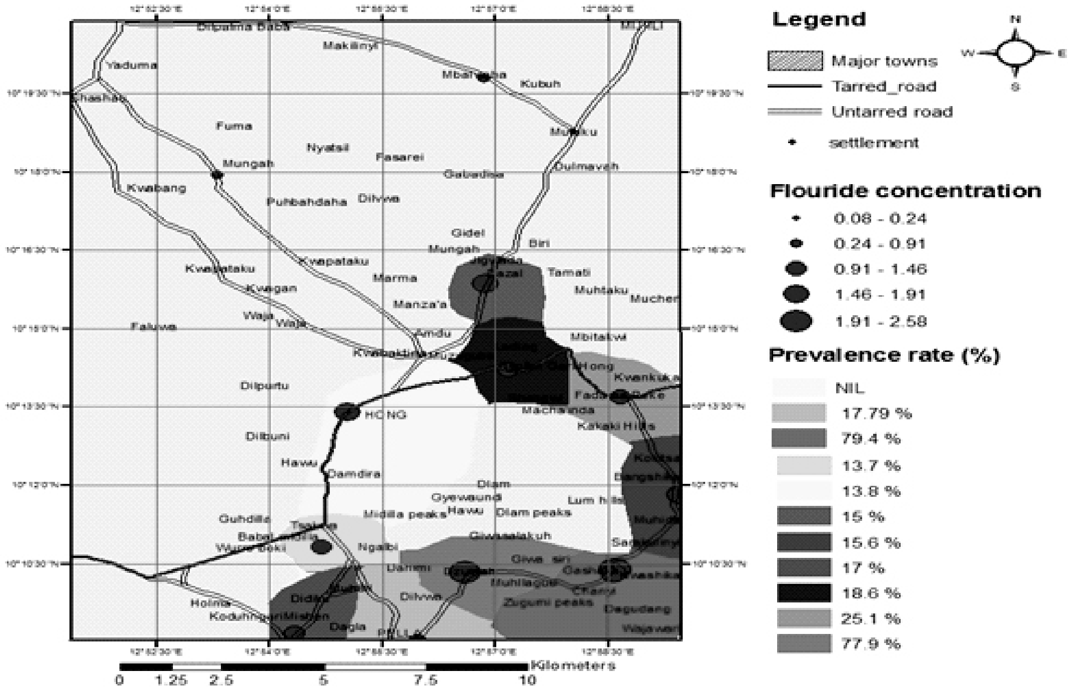


Figure 15: Prevalence Rate Map of Dental Fluorosis in Hong and Environs

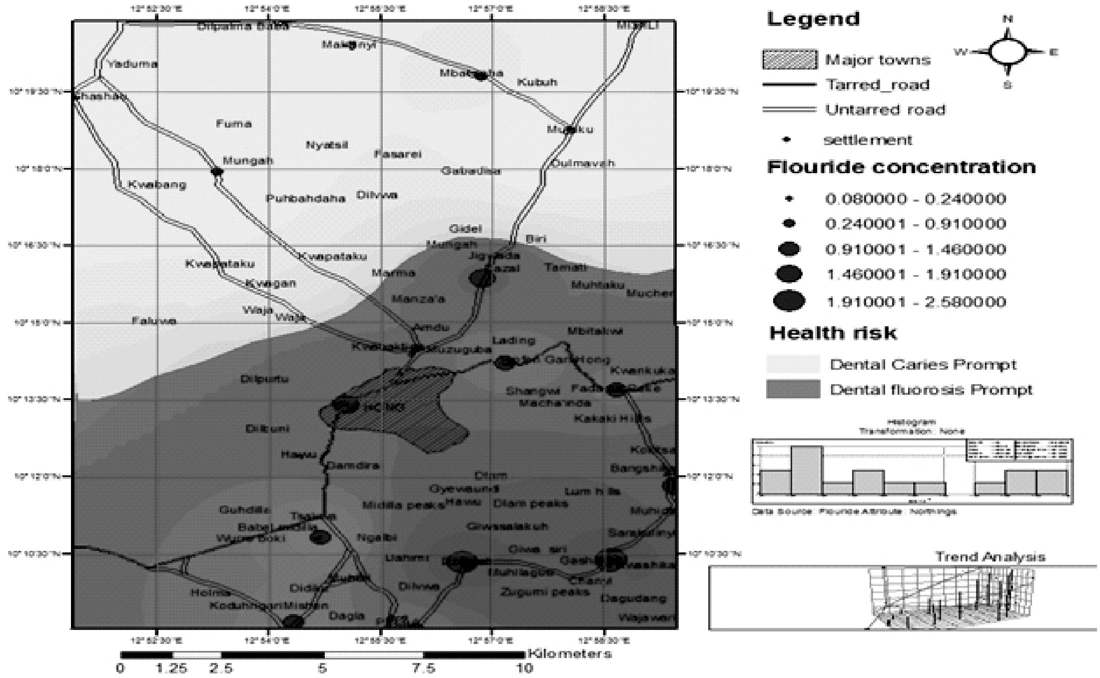


Figure 15: Health-risk Maps Based on Fluoride Concentrations in Groundwater in Hong Area

The concentration of fluoride was considered with pH and depth as shown in Figures 17 and 18 respectively. The concentration of fluoride increases with decrease in pH which implies that more fluoride is released into the groundwater system under lower pH. The decomposition, dissociation and dissolution of fluoride bearing minerals are precipitated under acidic condition (Fig. 17). On the reverse, fluoride content generally increases with depth (Fig. 18). This implies that deeper well or boreholes will be richer in fluoride than shallow wells and this can be explained due to resident time arising from rock-water interaction. The longer the resident time the higher is the fluoride content.

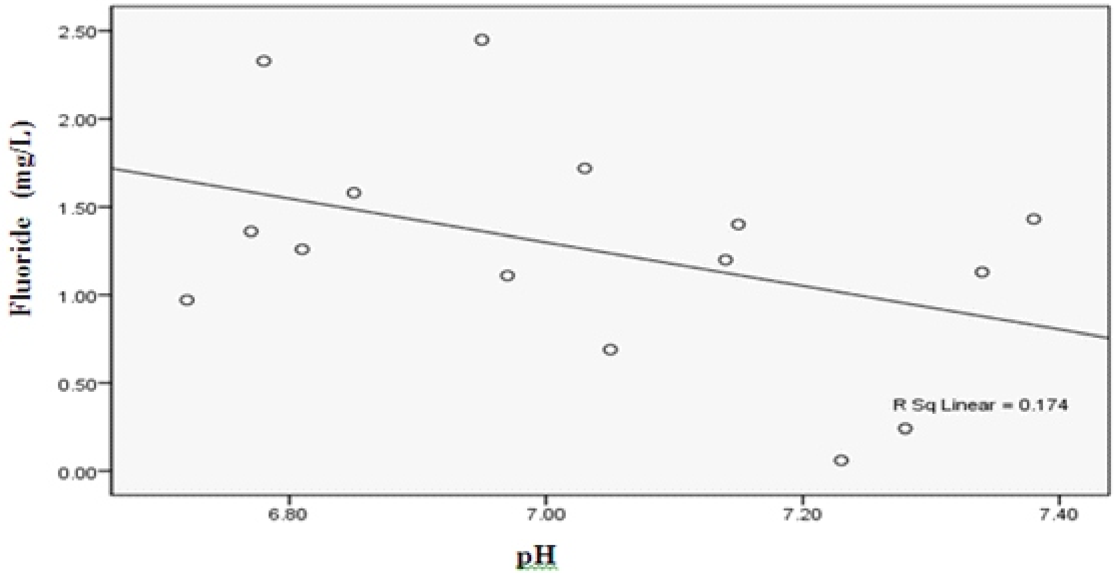


Fig. 17: Plots of Fluoride Content versus pH

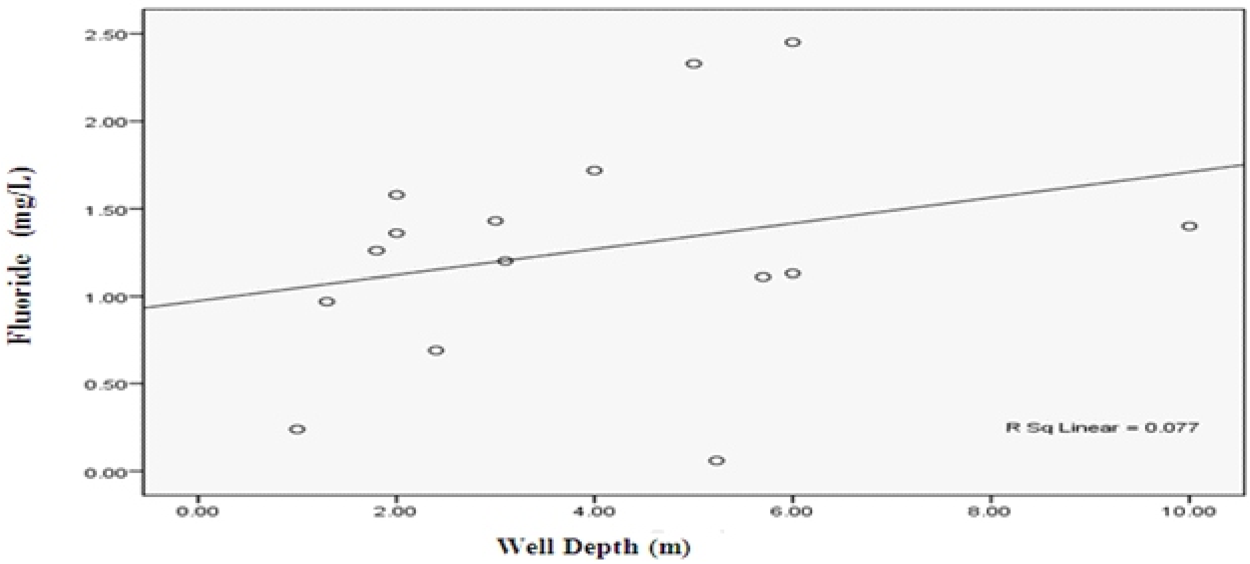


Fig. 17: Plots of Fluoride Content versus Well Depth

CONCLUSION

This study evaluates the quality of groundwater in shallow aquifers in Hong area of Adamawa State, during both dry and wet seasons. The study revealed that the concentration of the major cations (calcium, magnesium, sodium and potassium) and anions (sulphate, chloride, bicarbonate, nitrate and phosphate) were below the respective permissible limit recommended by WHO and NSDWQ. The water type in the area is calcium-bicarbonate type. The values of the electrical conductivity and total dissolved solid fall below the maximum allowable limits during the dry season but some exceed the permissible limit during the rainy season. The groundwater system in the area was found to be contaminated by iron and fluoride. The slightly acidic water in the area encourages the dissolution of the iron and fluoride into the groundwater system. High iron content in water does not pose any health threat while the high fluoride concentration in the shallow groundwater system has resulted to dental fluorosis in the area especially in children between the ages of 10 to 20 years. It was established that the high fluoride in the groundwater in Hong area is clearly geogenic due to chemical weathering and subsequent decomposition, dissociation and dissolution of fluoride bearing minerals (nacaphite) in the porphyritic granite.

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