# Geospatial and Temporal Distribution of Fluoride in Groundwater and Health Impacts in Hong Area, Adamawa State, North-Eastern Nigeria



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## ABSTRACT
A study was carried out on the geospatial and temporal distribution of fluoride in groundwater and health impacts in Hong Area of Adamawa State, North-Eastern Nigeria. Groundwater samples, soil samples and rock samples were collected in both dry and wet seasons and subjected to field and laboratory analysis to determine the physico-chemical characteristics of groundwater with special reference to fluoride. Hanna HI 83200 Multi parameter photometer was used to analyze the fluoride Content. The water samples were analysed for cations and anions, using approved laboratory techniques. Results of analyses were compared with World Health Organisation (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ). The pH ranged between 5.5 to 6.94 with a mean value of 6.55, total dissolved solids varied from 70.00 mg/l to 2690.0 mg/l with an average value of 776.0 mg/l while electrical conductivity ranged between 10.0 mg/l to 1320.0 mg/l with a mean value of 498.0 mg/l. The concentrations of the major cations and anions fall within the acceptable limits recommended by WHO and NSDWQ. The Hydrochemical facies analyses indicate the water in the area as Ca-Mg-$HCO_3$ type, which implies slightly acidic water and this condition favours bedrock dissolution and weathering. Fluoride concentration in groundwater in Hong area ranged from 0.08mg/l to 2.58mg/l as against the maximum permissible value of 1.5 mg/l for drinking water recommended by WHO and NSDWQ. The fluoride content in the area is categorized into fluoride non-endemic zone (<1.5mg/l) and endemic zone (> 1.5mg/l). XRD-Empyrean diffractometre analyses of rock and soil revealed the presence of nacaphite (sodium-calcium-phosphate-fluoride), a fluoride bearing mineral ($Na_2CaPO_4F$). The spatial distribution map showed fluoride content above WHO and NSDWQ tolerable limit of 1.5mg/l. The health risk map indicates that 16,600 people in 8 villages out of the 13 villages investigated have dental fluorosis out of a total population of 123,865, while 112,165 people are potential dental fluorosis carriers. Alternative source of drinking water for households and community within the fluoride endemic zone should be used.

**Keywords:** Fluoride contamination, Geospatial distribution, health implication, groundwater resource, Hong, North-central Nigeria

## INTRODUCTION

Water is one of the essential needs of human beings and all living things. This vital resource is vulnerable to contamination emanating from either geogenic or anthropogenic activities. About 80% of all communicable diseases affecting human beings are either water borne or water related (WHO, 2006). The factors controlling the geochemical evolution and quality of groundwater in an area include the chemical composition of rain water, soil types, mineralogy of host rocks and dominant human activities in the area. The chemical composition of groundwater provides information about the environment through which water has circulated (Appelo and Postman, 1993, Amadi *et al.*, 2014). The initial composition or background chemistry of groundwater may be altered through anthropogenic influences which are now prevalent because of urbanization, industrialization and large scale agricultural activities as well as high population growth especially in developing countries (Gaciri and Davies, 1993; Choubasia and Sompura, 1996).

Fluoride has both beneficial and negative impact on human health (WHO, 2006). Small concentration of fluoride is essential for normal mineralization of bones and formation of dental enamel (Fung *et al.*, 1999). However, excess fluoride intake above 1.5mg/l causes dental enamel to lose its luster into the mild form of dental flourosis, which is characterized by white, opaque areas on tooth surface, or into severe form of dental flourosis, which is characterized by yellowish brown to black stains on the teeth (Choubasia and Sampura, 1996). Excessive fluoride intake also results in slow, progressive crippling scourge known as skeletal fluorosis. Fluorosis is a disease caused by deposition of fluorides in the hard and soft tissues of the body. It is usually characterized by discoloration of teeth and crippling disorders (UNICEF, 1999). Crippling skeletal fluorosis, which is associated with the higher levels of exposure, can result from osteosclerosis, ligamentous and tendinous calcification and extreme bone deformity (Columbus *et al.*, 2003; Shomar *et al.*, 2004, Aminu and Amadi, 2014; Amadi *et al.*, 2013).

Dental fluorosis is the damage of tooth enamel, caused by the long time consumption of water with high fluoride content during period of development of tooth (WHO, 2004). Hence, older children and adults are not at risk for dental fluorosis. Teeth impacted by fluorosis have visible discolouration from white spots to brown and black stains. Choubasia (1997) classified dental fluorosis based on the extent of damage of tooth into very mild, mild, moderate, severe and very severe. Similarly, Aminu and Amadi (2014) based on fluoride content in Zango area, Katsina, North-eastern Nigeria, classified the fluorosis in the area into three groups: low, intermediate and high.

An estimated 62 million people worldwide suffer from fluorosis because of consuming water contaminated with fluoride (WHO, 2004). The presence of high fluoride concentration in groundwater is often recognized only when people exhibit symptoms of fluorosis. Fluorosis once established is irreversible. Prior to this study, little or no geospatial, systematic and scientific investigation has been conducted on fluoride contamination in groundwater in Hong area. This research evaluates the geospatial and temporal distribution of fluoride in groundwater and health impacts in Hong Area, Adamawa State, and North-Eastern Nigeria.

## MATERIALS AND METHODS

### The Study Area

Hong area lies between longitude 12°50'E to 13°00'E and latitude 10°05'N to 10°22'N (Fig. 1). The area covers about 60km$^2$ and is accessible by major and minor roads. The area lies within the Adamawa highlands. Physiographically, it is divided into eastern highland with highly rugged hills running NW-SE direction comprising of peaks around Pella and environs which attain heights between 800 and 1500m above sea level that forms inselbergs and whalebacks. However a relatively flat to gently sloping land between 400 and 600m elevation above sea level occupies the western and southwestern part of the area. The topography of western and northwestern areas is characterized by good drainage system and drained by Shashau and Dugwaba Rivers (Bassey *et al.*, 2006). The soil in the area attains a thickness of up to 5m and contains varying proportions of clays, laterite, silts, sand and gravel/pebbles. Hong climate is characterized by dry and wet season. The wet seasons starts from May to October while the dry season commences by November to April. The relative humidity during such season is usually about 30-40 % while bright sunshine varies from 6-9 hours.

### Geology of Hong Area

Geologically, Hong area consists of predominantly porphyritic granites and migmatite which form inselbergs (Plates 1-4) while quartz veins, feldspartic veins and pegmatite were observed as intrusion in both rock types (Fig. 2). Structural analysis of the area based on structural elements revealed NE-SW orientation of lineaments which coincides with the regional structural trend (Bassey *et al.*, 2006; Dada, 2006).

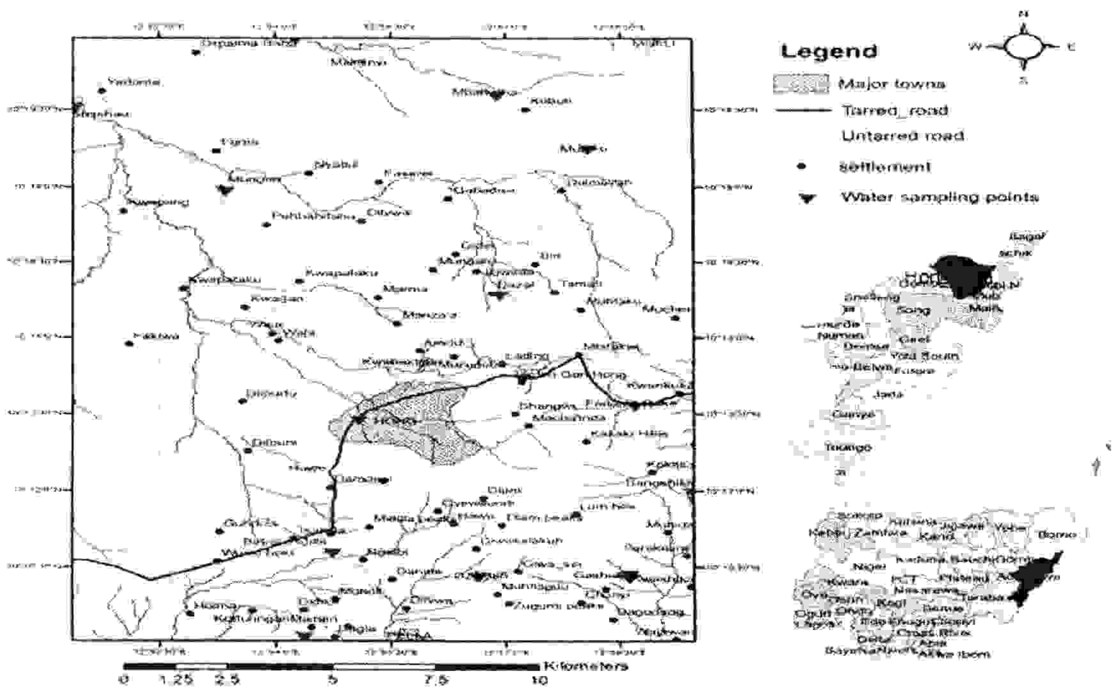


Fig.1: Location and Drainage Map of Hong area showing sampled points

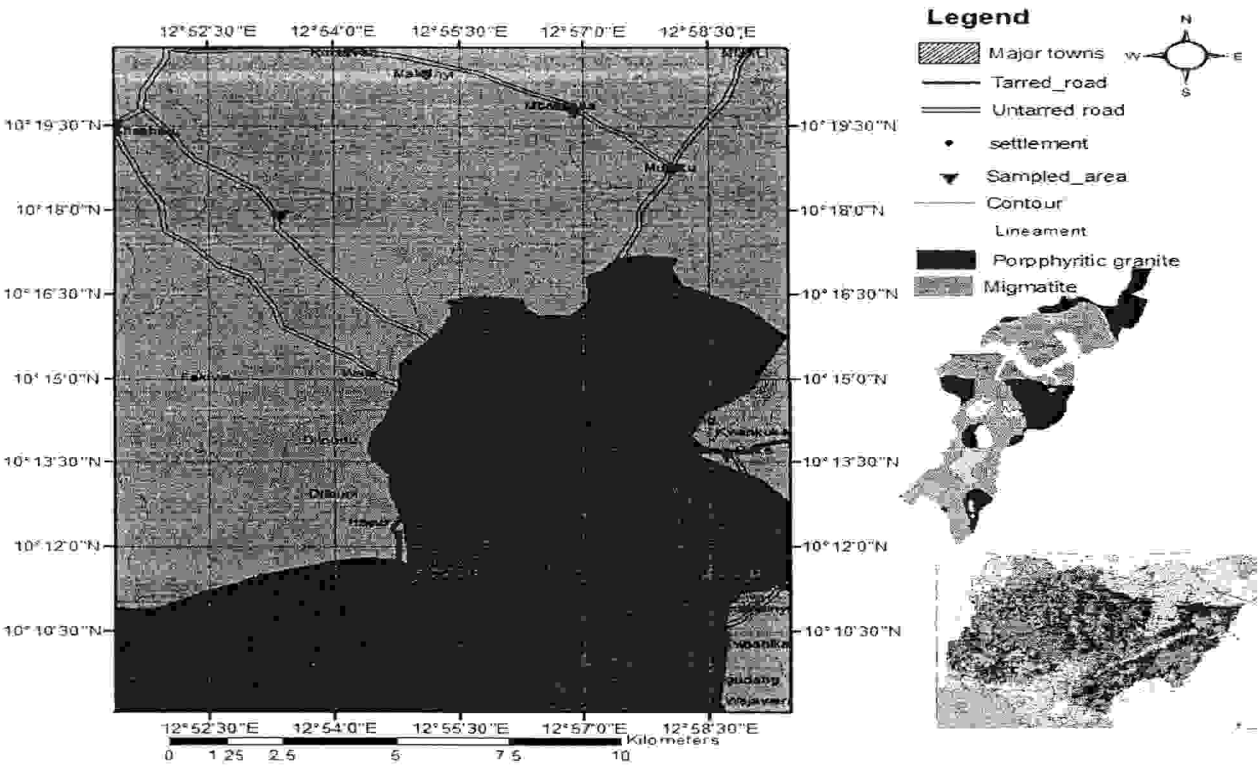


Fig. 2: Geology map of Hong area

**Laboratory Analysis**

Physical parameters such as temperature, electric conductivity (EC), pH and total dissolved solid (TDS) were determined in the field using portable Martini MI 806 with sensitive probe. Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) Model- Optima 200, by Perkin Elmer

Was employed to determine calcium, magnesium, potassium, cadmium, chromium, barium, iron, copper, arsenic and lead concentrations while the Hana Hatch 83300 Multi-parameter spectrophotometeric method was used for Fluoride determination. The colorimetry method was used for sulphate determination, titrimetry method for bicarbonates and Chloride determination while Ultra Violet (UV) visible spectrophotometer was used for nitrate determination. Digital maps and data interpolation were prepared using Geographic Information System (GIS) with ArGIS 9.3 Software application. The analyses were carried out in accordance with the American Public Health Association standards (APHA, 2005).

Rock and soil samples were analyzed using XRD- Empyrean diffractometre. The analyzed material was pulverized, homogenized and average bulk composition was determined. The powdered sample was prepared using sample preparation block and compressed in the flat sample holder to create a flat surface, smooth surface was mounted on the sample stage in the XRD cabinet. The sample was analyzed using the reflection-transmission spinner stage using the Theta-Theta settings. The peaks obtained from the analysis were matched with the minerals from powdered Diffraction file of International Center for Diffraction Data (ICDD) database. The analysis was done at the National Geosciences Research Laboratory of Nigerian Geological Survey Agency, Kaduna. All standard analytical procedures were water, soil and rock were duly followed. Figure 1 shows the geology map of the area and the samples locations

**Results and Discussion**

The pH is measure of the hydrogen ion concentration of a medium and it is one of the important parameter used in evaluating water quality. The pH range from 5.5 to 6.94 with a mean value of 6.55 and this implies slightly acidic water and may be responsible for the dissolution of nacaphite in the rock into the groundwater system.

The electrical conductivity (EC) varied from 10.0 µs/cm to 1320.0 µS/cm, with a mean value of 498.0 µS/cm as against the maximum permissible limit 1000.0 mg/l (WHO, 2006; NSDWQ, 2007). The value of total dissolved solid (TDS) ranged between 70.0 mg/l to 2690.0 mg/l with mean value of 776.0 mg/l as against 500.0 mg/l recommended by WHO (2006) and NSDWQ (2007). The observed high values of EC and TDS can be attributed to the presence of fluoride-rich minerals and other ions in the groundwater system in the area. The concentration of the major cations (calcium, magnesium, sodium and potassium) and major anions (chloride, sulphate, bicarbonate, carbonate, nitrate and phosphate) were found to be below their respective maximum permissible limit postulated by the WHO (2006) and NSDWQ (2007). The concentration of iron in the area ranged from season and 0.02 mg/l to 0.98 mg/l with mean value of 0.145mg/l as against the permissible limit of 0.30 mg/l. The presence of iron in water samples does not cause any health problem but it affects the colour, odour and taste of the water.

Fluoride concentration in groundwater in the area varied from 0.06 mg/l to 2.58 mg/l with a mean value of 1.33 mg/l as against the maximum permissible limit of 1.5 mg/l (WHO, 2006; NSDWQ, 2007). This implies that the region with fluoride content greater than 1.5 mg/l falls within the endemic region while the areas with values less than 1.5 are categorized as non-endemic. The high fluoride content in groundwater in the area can be linked to chemical weathering and rock dissolution processes, leading to the release of nacaphite into the groundwater system. The study revealed that geology of the area plays a vital role in the chemistry of the groundwater. Rock-water interaction allows fluoride rich minerals in bedrock to be decomposed resulting to its enrichment in groundwater system (Nwankwoala *et al.*, 2014, Aminu and Amadi, 2014).

The study revealed that the highest concentration of fluoride in groundwater in the area occurs in the areas underlain by coarse porphyritic biotite granite while fluoride concentration in areas underlain by the migmatites lithology were found to be generally low, which suggest that the high fluoride content in the area is geogenic and not anthropogenic as there are no industries in the area. The fluoride concentration map for dry and wet season are shown in figures 3 and 4 respectively.

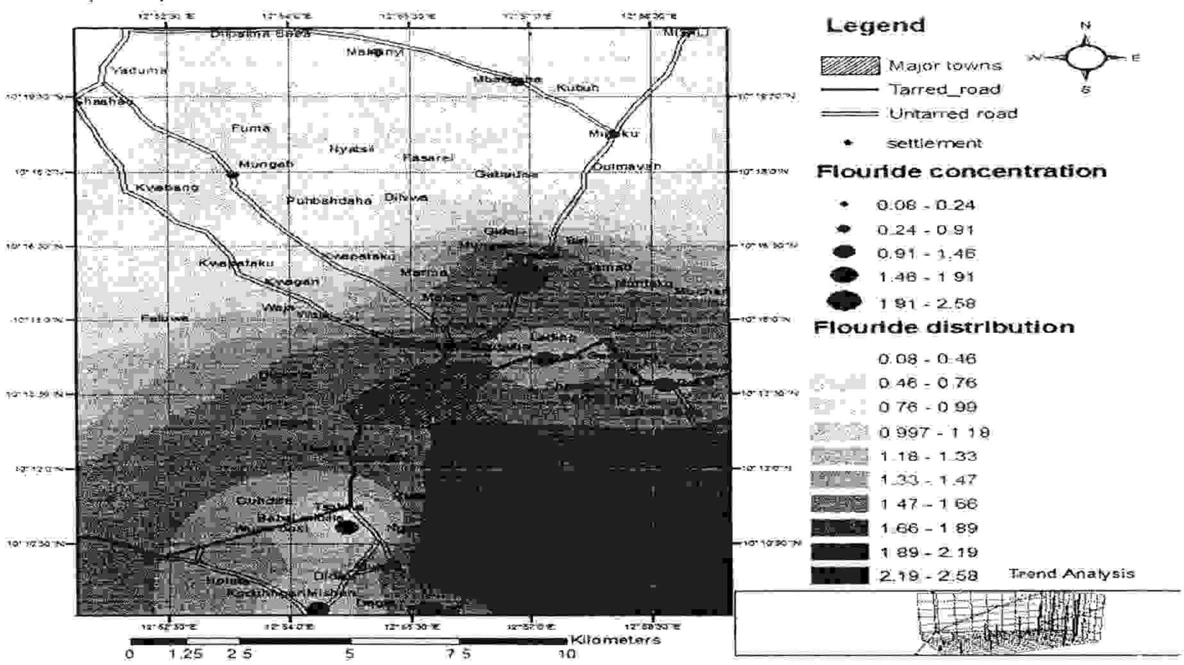


Fig. 3: Fluoride concentration map of groundwater in Dry season in Hong area, North-Eastern Nigeria

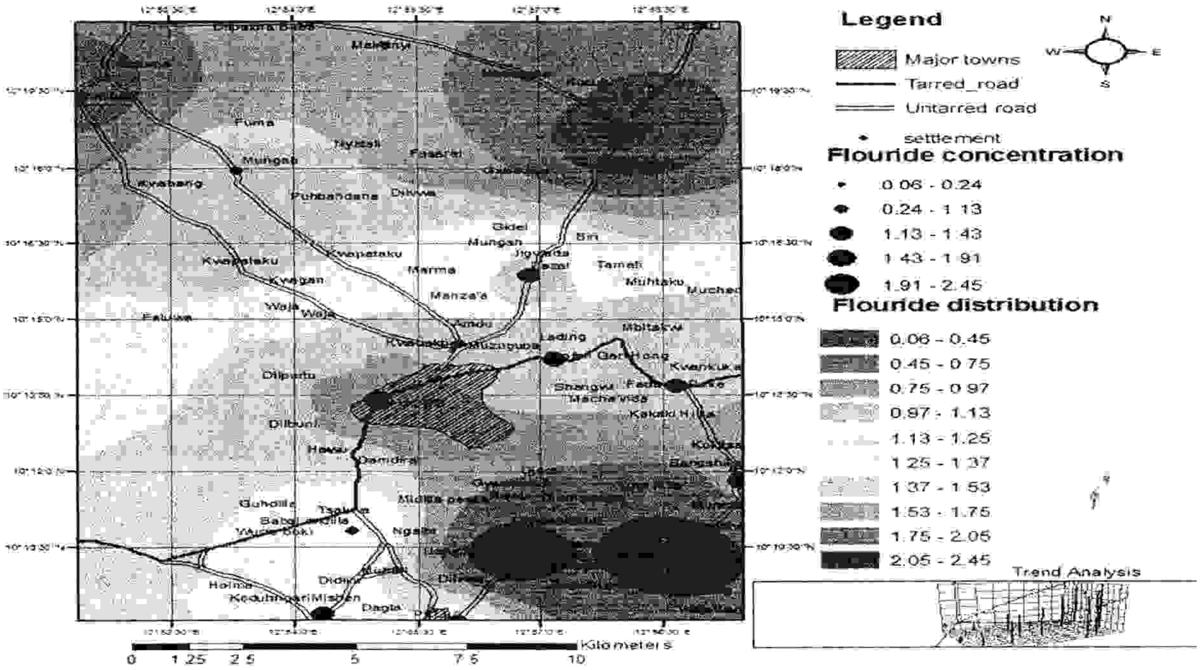


Fig. 4: Fluoride concentration map of groundwater in Wet Season in Hong area, North-Eastern Nigeria

Furthermore, the fluoride in groundwater in the area is primarily derived from decomposition, dissociation and dissolution of fluoride bearing minerals and occasionally from anthropogenic activities such as use of phosphatic fertilizers which have fluoride as an impurity (Saxena and Ahmed, 2002; Okunlola *et al.*, 2014; Amadi *et al.*, 2015). It may also be linked to presence of calcium fluorite ($CaF_2$) and weathering of coarse porphyritic biotite alkaline granitic rocks with Feldspars, mica and silicate minerals (Amadi *et al.*, 2013; Olasehinde *et al.*, 2004; Saxena and Ahmed, 2001). The prevalence rate of dental fluorosis in the area has been measured on the basis of number of affected people divided by the total population. Pictures illustrating the prevalence rate of dental fluorosis in the study area are given in plates (1-6). The dental fluorosis was mainly found to occur among children and teenagers between the ages of 10 to 20 years. The results of the investigation were used to produce the dental fluorosis prevalence rate map of Hong area (Fig. 5). No skeletal fluorosis was found in the study area at of the time of this research.

Plate 1: Pella Plate 2: Dzumah Plate 3: Hong

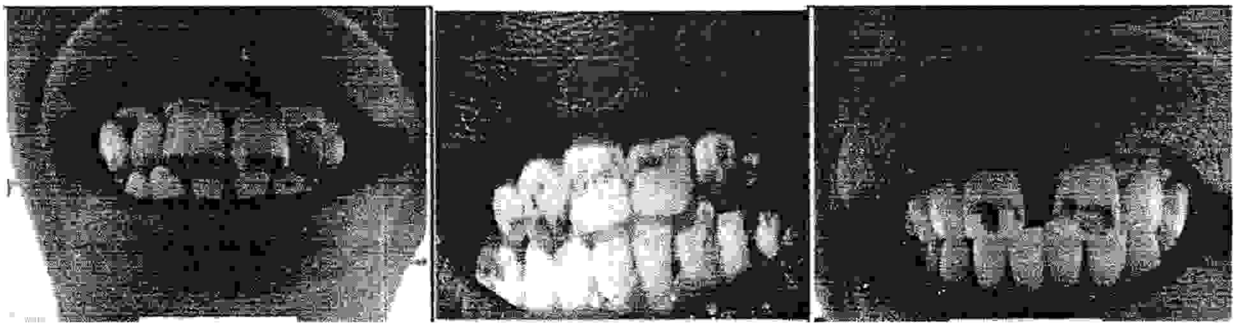

Plate 4: Gashaka Plate 5: Fadama Reke Plate 6: Dazal

Plates (1-6): Dental fluorosis from Hong endemic fluoride zone

Detailed correlation analysis of fluoride with pH and depth was carried out and the outcome of the result was revealing. The concentration of fluoride increase with a decrease in pH, which implies that more fluoride is released into the groundwater system under lower pH. This implies decomposition, dissociation and dissolution of fluoride bearing minerals are precipitated under acidic condition. On the reverse, fluoride content increases as the depth increases. This suggests that deeper wells or boreholes are richer in fluoride than shallow wells and this can be explained by residence time arising from rock-water interaction. The longer the residence time the higher the fluoride content.

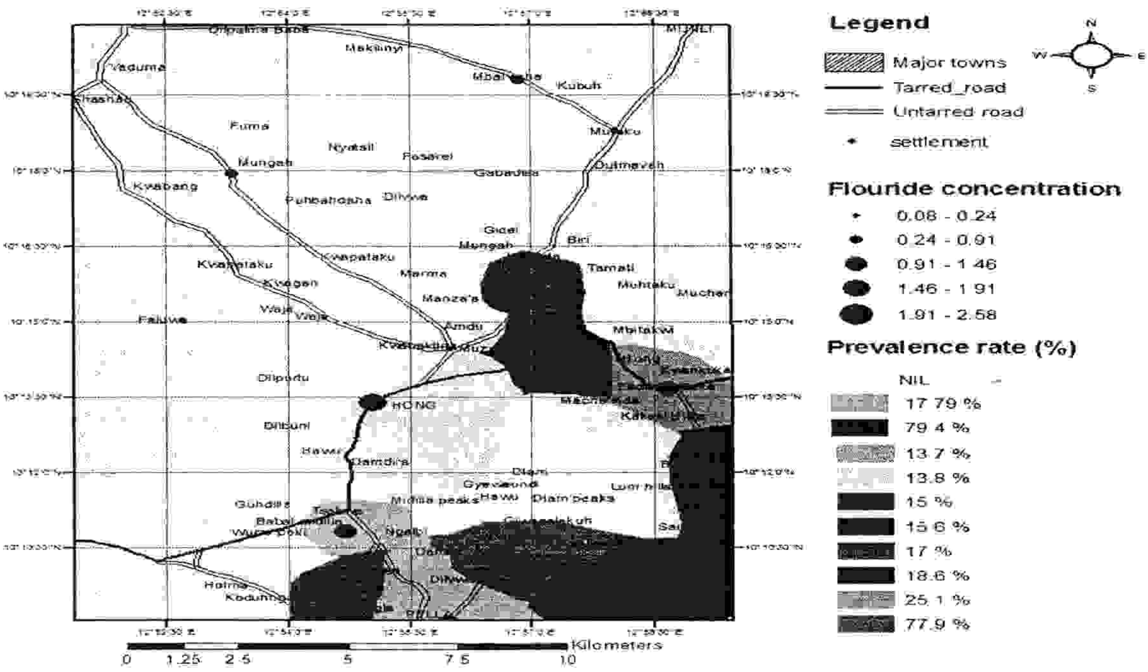


Fig. 5: Prevalence rate map of Dental Fluorosis in Hong and Environs

The results from the XRD analysis recognized the presence of sodium calcium phosphate fluoride (nacaphite) from the endemic granitic area (Fig. 6), which could be anthropogenic due to agrochemical farming activities, probably fertilizer application of super phosphate to groundnut farming as commonly practiced in Hong area, or geogenic via the in-situ basement weathered regolith (saprolite). On the contrary, the results of both the soil and rock samples from the non-endemic zone (migmatite terrain) did not show the presence of nacaphite (Fig. 7). The results of these findings led to the development of a health-risk map for Hong area (Fig. 8). Since groundnut is cultivated on both endemic and non-endemic zones and fertilizer applied in both zones, the absence of nacaphite (fluoride rich mineral) in the non-endemic zone is a testimony that the fluoride enrichment in the groundwater system in the area is due to the local geology.

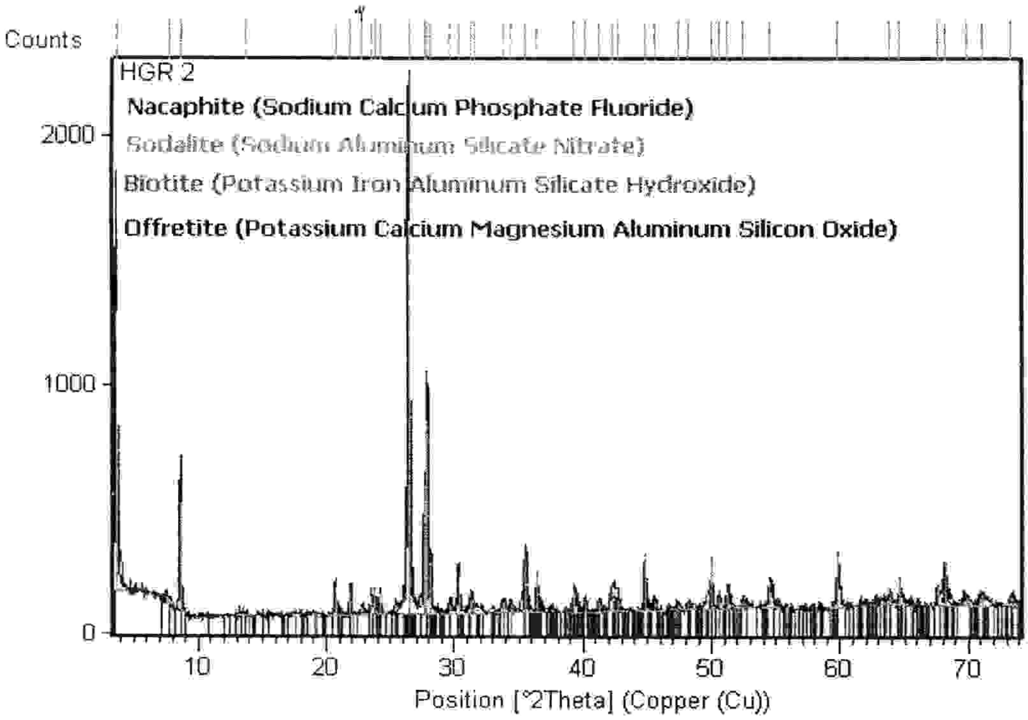


Fig. 6: XRD Chart of rock/soil samples from the endemic area showing Nacaphite mineral

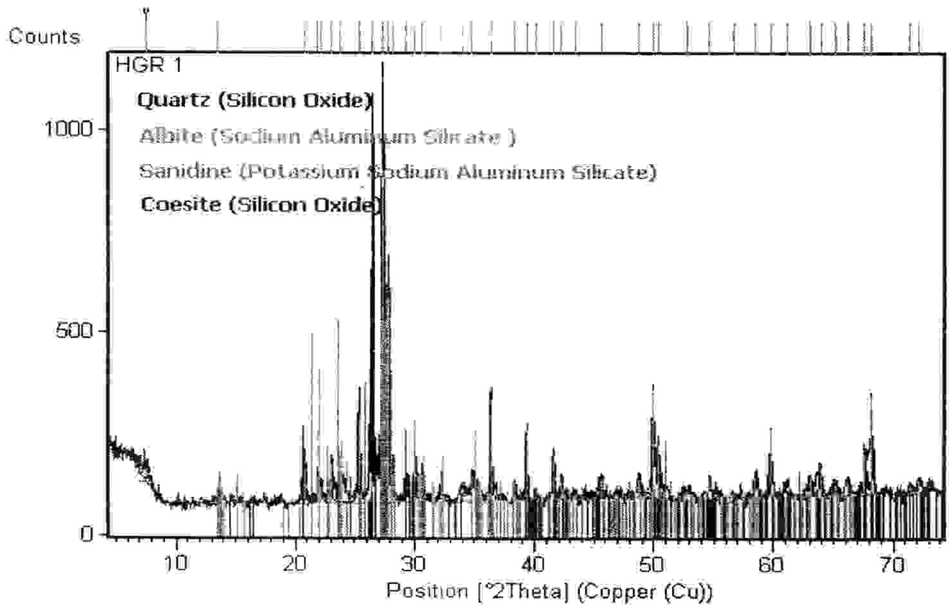


Fig. 7: XRD Chart of rock/soil samples from the non-endemic area without Nacaphite mineral

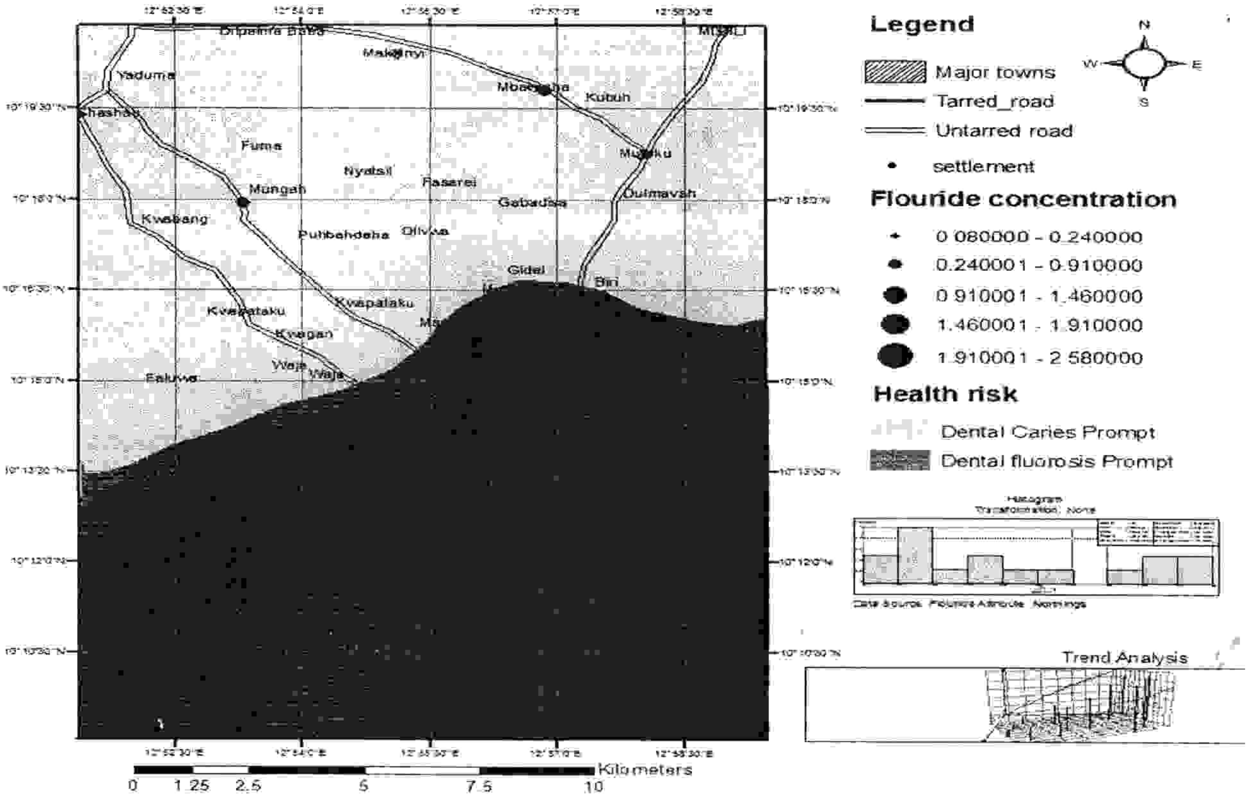


Fig. 8: Health-risk maps based on fluoride concentrations in groundwater in Hong Area

## CONCLUSION AND RECOMMENDATION

This study has 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) and the process is encouraged by the prevalent acidic condition of the groundwater (low pH). The high content of fluoride in the groundwater contributed to the high concentration of EC and TDS.

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