

Fluoride in groundwater in Nigeria: Origin and human health impact

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To cite this article:

Lar Alexander Uriah, Dibal Hyeladi, Schoeneich Krzysztof. Fluoride in Groundwater in Nigeria: Origin and Human Health Impact. *American Journal of Environmental Protection*. Special Issue: Integrating Earth Materials, Diet, Water and Human Health.

Vol. 3, No. 6-2, 2014, pp. 66-69. doi: 10.11648/j.ajep.s.2014030602.19

Abstract: Until recently, the mottling and staining of teeth (dental caries) was believed to be an identity of certain ethnic groups or communities in Nigeria. Those born and reared locally within such communities had mottling teeth and fluoride as the causal factor was not known then. It was sooner discovered that dental caries extended beyond tribal or communal barriers. Even foreigners that came from far away Asia presented this disease condition. Records have shown that elsewhere in the world where dental caries was endemic, fluoridization of public water supplies was done and that reduced the prevalence of dental caries greatly. Dental caries is endemic and epidemic spread over a large range of superficial area mainly the north eastern half of Nigeria both in the crystalline basement and sedimentary areas. The few data available on fluoride in drinking water clearly establishes the relationship between dental caries and environmental fluoride in drinking water. With the failure of the water supply systems in most parts of Nigeria to meet the demand of the increasing human population, about 90% of people use groundwater (well and borehole) for drinking and other domestic purposes. Studies have shown that, fluoride values (0.2 – 8 mg/l) above the 1.5 mg/l WHO admissible value have been recorded in the groundwater from the crystalline Basement rocks (consisting of granites, gneisses, and migmatites). In the sedimentary terrain especially that of the Benue Trough, fluoride values of between 1mg/l to 4 mg/l have been recorded and the incidence of dental caries extends all along the 1000 m N-S long trough. A lot of awareness campaign still needs to be done on the health implications of drinking of fluoride-rich waters and to debunk the belief of its association to certain tribes or communities.

Keywords: Fluoride, Fluorosis, Dental Caries, Drinking Water, Nigeria

1. Introduction

The oral intake of very low fluoride level ($F \ll 0.5\text{mg/l}$) in drinking water (where it is almost completely absorbed by the human body) results in dental fluorosis. This causes staining, weakening and the eventual loss of teeth. Children are the first casualties. Fluoride content of 0.1 – 1.5 mg/l in drinking water [1] is beneficial to humans by reducing dental decay and facilitating proper bone development [2]. For these reasons fluoride has been recommended for pregnant women and children. Higher exposure to fluoride will manifest as osteosclerosis, which is the hardening and calcification of bones and causes pain, stiffness, and irregular bone growth. More advanced manifestations are crippling skeletal fluorosis resulting in bone deformation and debilitation.

Groundwater with high levels of fluoride exists in most

parts of Nigeria. The great danger associated with fluoride due to its lack of taste make it difficult to detect its presence until there is a significant spread of the disease fluorosis. For example all along the N-S stretch of the 1000 km Benue trough of Nigeria, where their groundwater contains high levels of fluoride, a whole generation of children, suffers from fluorosis.

2. Geology and Fluoride Levels/Distribution in Groundwater

Nigeria is situated in West Africa between the Republics of Benin and Cameroon bordering the Gulf of Guinea. It is precisely located between Latitude $N4^\circ$ and $N14^\circ$ and Longitude $E2.30^\circ$ and $E14.30^\circ$. Nigeria has a total superficial area of 927,770 km^2 made up of a landmass of about 910,770

km² and water of about 13,000 km². According to the 2006 Population Census, Nigeria has a population of about 140 million people with a growth rate of 2.9%.

Geologically, Nigeria is made up of three major geologic terrains viz: The Proterozoic-Lower Palaeozoic metamorphic Basement Complex, the Jurassic Younger Granites, the volcanic provinces and the Cretaceous sedimentary terrains. The crystalline Basement complex terrain is granitic, comprising of the metamorphic rocks (gneiss-migmatites, schist and granites associated with amphibolites, charnockites, diorites and serpentinites). The Younger Granite terrain is also granitic in composition and is centered in north central Nigeria. Tertiary to Quaternary volcanic provinces exist covering essentially the eastern half of Nigeria. This includes the Jos Plateau, the Biu Plateau, the Longuda Plateau and the Benue valley. The sedimentary terrain comprises of the Niger Delta, the Anambra basin, the Lower, Middle and Upper Benue trough, the Chad basin, the Sokoto basin, the Mid-Niger (Bida-Nupe) basin and the Dahomey embayment (Fig.1).

Fluoride in groundwater is derived from the crystalline rocks and their derivatives (soils, clays etc), where it occurs in the constituent fluoride bearing minerals (topaz (Al₂SiO₄(F,OH)₂), fluorite (CaF₂), fluorapatite (Ca₅(PO₄)₃F), cryolite (Na₃AlF₆) and/or in mica muscovite (KAl₂(AlSi₃)O₁₀(OH, F) and biotite (MgFeAlK, OH, F). The interaction between water and the soil and the rock formations dissolves their constituent fluoride compounds, resulting in the presence of small amount of soluble fluoride in virtually all water sources (Fig 1).

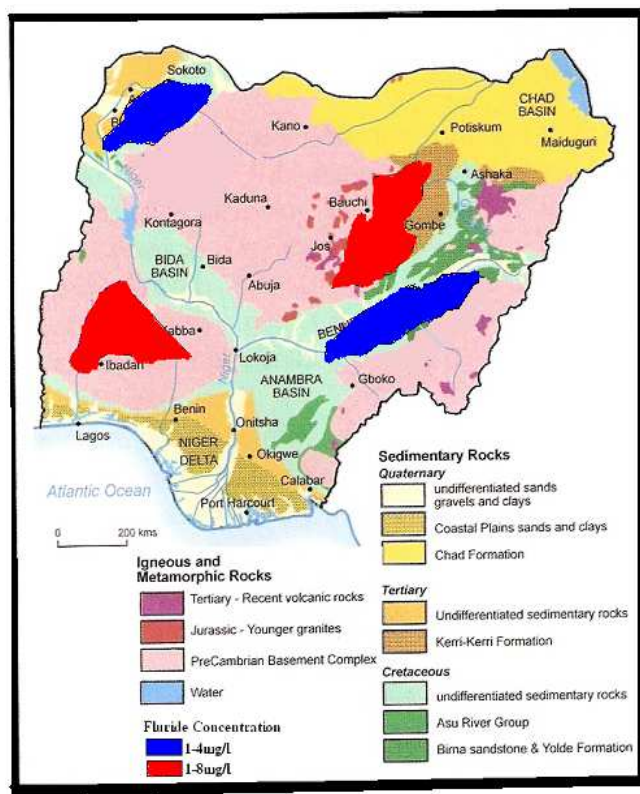


Fig. 1. Map of Nigeria showing the Geology and Fluoride-rich areas

Generally, natural fluoride concentration in groundwater in Nigeria varies depending on the types of aquifer. In the crystalline Basement aquifers, fluoride values vary from 1 mg/l to 8 mg/l [3] but in sedimentary aquifers it varies between 1 – 4 mg/l [4]. The higher value in the basement aquifer has been attributed to the long resident time. Most of the values exceed the WHO drinking water standards.

3. Origin of Fluoride-Rich Groundwater

Investigations have shown that the origin from which fluoride is released into groundwater is mainly from the weathering of the metamorphic basement rocks (granites, migmatite and gneiss), pegmatite veins and their derivatives (soils, clays, and sediments). Rock thin sections of these rocks have revealed the presence of some fluoride bearing minerals such as apatite, biotite and amphibole, where fluorine substitutes for hydroxyl positions. The occurrence of fluoride bearing minerals has also been reported in the Jurassic Younger Granites of the Jos Plateau [3].

In the Kerang volcanic province, Jos Plateau where spring water is the main source of potable drinking water for the inhabitants, the concentration levels of Fluoride in the spring water vary from 0.14 – 0.41 mg/l, whereas it ranges from 0.12 – 0.59 mg/l in the borehole water [4]. All the fluoride values in both the spring and borehole waters of the volcanic province are below the WHO admissible limit of 1.5 mg/l for drinking water [5]. Tooth decay and dental caries which are a common dental disease condition among the elderly people (30 years and above) in the province could be linked to this low fluoride level in the water sources. These disease conditions are however absent in the younger children, possibly due to the recommended use of fluoride tooth paste in recent times.

In the sedimentary terrains however, fluoride concentration of groundwater is controlled by mainly fluorite (CaF₂), fluoroapatite (Ca₅(PO₄)₃F) and clays. A contribution from anthropogenic sources cannot be ruled out especially through the use of phosphatic fertilizers where fluoride is contained as impurities. Also, fluorides are largely present in most pesticides.

Analysis has shown that fluoride evolves along groundwater flow path. Thus, its concentration tends to increase progressively in the direction of flow (from recharge to discharge area) [5]. Higher fluoride values from spring water, which originated from great depth, go to assert that fluoride concentration increases with depth and of course the residence time.

It has been observed that there is a relationship between Calcium, Sodium and Fluoride [4]. The higher the fluoride level, the lower is that of Calcium. This may be as a result of the substitution of Na by Ca during the circulation of water in an aquifer or through carbonate precipitation.

Studies [4]; [5] have shown that in water samples collected were from aquifers hosted by the metamorphic Proterozoic basement rocks, fluoride content is positively correlated with Na⁺, K⁺, Mg²⁺, Ca²⁺ and depth of water source and is negatively correlated with Cl⁻, HCO₃⁻ and pH. Unlike

fluoride, Cl^- contents exhibit a negative correlation with depth of water source. Fluoride is positively correlated with Na^+ , K^+ , Mg^{2+} , Ca^{2+} ions suggesting that the fluorite of these ions tend to be more soluble with depth. However, it is known that fluorites of these ions have low solubility [6]; [7] [8]; [9]. The positive correlation of Ca^{2+} with fluoride explicitly suggests that water hardness increases with depth, affirming the percolation of underground water through a medium rich in Ca (possibly limestone). Similar positive correlations have been reported elsewhere [10] and attributed to the presence of limestone. This study further confirms the increase in fluoride content with depth of water source, again suggesting that the supply of fluoride to the groundwater must be from the fluorite (CaF_2) and apatite ($\text{Ca}_5(\text{PO}_4)_3\text{F}$) minerals-bearing metamorphic Proterozoic bedrock. The occurrence of high fluoride in groundwater has been reported elsewhere in the Basement northeast (Borno, Yobe and Adamawa States) and southern portions of the area (Bauchi and Plateau States) [11]. The high fluoride as opposed to the low chloride content in the underground water, suggests that a single process such as evaporation cannot explain the different behaviour of both halogens. The high chloride contents in the surface waters could be attributed to the supply of Cl^- from rain water or river. The high fluoride contents coupled with some dissolved constituents such as Na^+ and HCO_3^- must have influenced positively the pH values (>7) [12].

4. Fluoride and Health

Like most chemical elements, fluorine is an essential element in the human diet. Lack of it has long been linked to tooth decay. The addition of fluorine toothpaste is to supplement for the needed fluorine to reduce tooth decay. Also, like in most urban centres in Nigeria where there are controlled water supply systems, fluorine is added to water supplies so as to boost the naturally low concentration.

Fluoride content of 0.1 – 1ppm in drinking water [13] is beneficial to humans by reducing dental decay and facilitating proper bone development [2]. High oral intake of fluoride results in physiological disorders, skeletal and dental fluorosis in humans [14]. Studies carried out in central Nigeria revealed fluoride concentrations between 0.21 – 4 mg/l [14]; [3]. Also, fluoride values of up to 4 mg/l have been recorded all along the sedimentary basins [4]. There is direct link between fluoride contents and the prevalence of dental caries [2].

5. Mitigation Strategies of Fluoride Related Problems

From investigations, fluoride concentrations in groundwater are controlled mainly by host rock composition and anthropogenic factors and this can have serious adverse effects on human health. Several methods of defluoridization exist to render it safe for drinking. However, the most simple and cost effective method adaptable to most Nigerian set-up is evaporation method. Other methods exist but will require skill

to operate and could be costly for most Nigerians. The most popular methods include adsorption/ion exchange and precipitation and electro-dialysis or reverse osmosis methods.

6. Conclusion

The source from which fluoride is released into groundwater is from the crystalline metamorphic Basement and igneous rocks and rarely by anthropogenic processes. In the sedimentary aquifers, fluoride finds its way into groundwater through the leaching of mainly fluorite or fluoroapatite. Depending on the level in which fluoride is present in the water, it could be beneficial or detrimental to both bone and dental development in human beings. Excessively high fluoride groundwater concentrations are from crystalline aquifer and this increases with depth (old water) where the water had considerable residence time. This work has established the relationship between fluoride content in water and the prevalence of dental caries in especially the northeastern portion of Nigeria.

More than 80% of Nigerians depend on groundwater for drinking and other domestic purposes. In view of the health hazards associated with fluoride intake, endemic communities must be made to appreciate the health risk and to understand the need to treat fluoride-rich or poor water destined for human consumption. Therefore, a lot more needs to be done to identify new areas of endemic dental caries. Thus, it is hereby advocated that more research should be initiated to investigate some other adaptation or mitigation strategies to be applied directly to water so as to reduce the associated health problems. There is need for geoscientists, apart from carrying out a closer study of the source rocks from which fluoride is being leached as well as the conditions under which it is being mobilized, establish a close working relationship with professionals in community health in addressing health issues arising from the intake of fluoride in water.

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