

Fluoride Contents of Community Drinking Water: Biological and Public Health Implications

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Abstract Drinking water supplies in Omoku, Nigeria was analyzed for its fluoride content investigated. For the analysis, twenty-four different water samples were systematically collected from stream, well water, public tap and private borehole in defined locations in Omoku. Level of fluoride was determined using standard method-Ion-Selective Electrode method. The mean values obtained were compared directly with the limit recommended by the World Health organization (WHO) of 1.0mg/L. Private borehole and public tap water had overall mean fluoride levels of 0.94±0.07 mg/L and 0.86±0.30 mg/L respectively, while stream had 0.95±0.09 mg/L and well water had the lowest level of fluoride (0.48±0.03 mg/L). Fluoride content of private borehole, public tap water and stream were approximately within the specified minimum limit of World health organization, while that of well water was below stipulated limit. ANOVA statistics indicated that there was no significant difference in the mean Fluoride levels of the water samples ($p>0.05$). Low levels of fluoride are associated with dental caries and hence such water should be fluoridated. Biological implications of low and high fluoride levels of water are highlighted in order to create awareness on the need to protect the general public from either dental caries or fluorosis of the teeth and/or skeleton respectively.

Keywords: fluoride, dental caries, water, fluorosis, fluoridation

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1. Introduction

Fluoride is a naturally occurring binary compound derived from fluorine. It is found in air, rocks, soil, fresh water and sea [1]. The fluorides released into air will eventually fall on land or water. Mean concentration of fluoride in air are in the magnitude of 0.5mg/m³ [2]. It is found more frequently in different sources of water with higher concentration in ground water due to the presence of fluoride-bearing minerals [1,2]. Fluoride levels in drinking water vary around the world and depend on the geographical location. High fluoride concentration is due to the depth of the water coming from groundwater with a high possibility of fluoride-bearing minerals. Thus, high concentrations of fluoride in water are generally found in ground waters [1,2,3]. It has been shown that with all the human exposure to fluoride that varies from region to

region, drinking water is generally on average considered as the largest single contributor to daily intake of fluoride [4]. For adults, the consumption of foodstuffs and drinking-water is the principal route for the intake of fluoride [5,6].

Fluoride causes significant effects on human health through drinking water and on other living organisms through bioaccumulation. Different forms of fluoride exposure are significant and have shown to affect the body's fluoride content and thus increasing the risks of fluoride-prone disease. Fluoride has beneficial effects on teeth at low concentrations and is detrimental at higher concentrations. There are maximum guiding values for fluoride in drinking water but no minimum imposed limits (Table 1). The recommended values are stipulated to ensure no potential health risks from lack of fluoride within the drinking water [1,5].

Table 1. Fluoride Guideline Standard for Drinking Water

State/Organization	Recommended Min. Value (mg/L)	Max. Value (mg/L)	Reference
WHO	0.5	1.5	WHO [2004]
USA –primary	0.5	4.0	USEPA (2002)
Secondary	0.5	2.0	
Nigeria*	0.5-	1.5	Standard Organization of Nigeria : NIS 554 (2007)

Source: UESPA (2002) [8,21]

Demineralization and some other treatment processes reduce fluoride levels in water. Fluoridation is the deliberate addition of fluoride to community drinking water to prevent tooth decay [6,7]. In view of the fact that excessively high levels of fluoride intake causes crippling skeletal fluorosis (SF) and possibly increased bone fracture risk and that ingestion of excess fluoride during tooth development, particularly at the maturation stage, may also result in dental fluorosis (DF), this research was therefore undertaken to investigate if private borehole, stream, well and public tap water in Omoku maintain the standard of fluoride intake in a quality drinking water recommended by the World Health Organization. This research is meant to create awareness on the status of the fluoride content and hence the potential for causing DC, DF and SF on the long run.

The amount of fluoride present naturally in non-fluoridated drinking-water (i.e. drinking-water to which fluoride has not been intentionally added for the prevention of DC) varies and depends on the individual geological environment from which the water is obtained. Levels may range up to 2.0 mg/L; however, in areas of the world in which endemic fluorosis of the skeleton and/or teeth has been well documented, such as China, India, Egypt etc, fluoride levels in drinking-water supplies range from 3 – more than 20 mg/L.

Fluoride has both beneficial and detrimental effects on tooth enamel. DC and DF prevalence is inversely related to fluoride concentration in drinking-water with a positive dose–response relationship. Factors, such as nutritional status and diet, climate (related to fluid intake), concomitant exposure to other substances and the intake of fluoride from sources other than drinking-water increases the disease development. Low level of fluoride in the water (0.1mg/L) may result in tooth decay and dental caries (DC) [2,3,5,8]. The recommended level to help reduce tooth decay is between 0.7 – 0.12mg of fluoride to every litre of water (1mg/L), while the minimum recommended value is 0.5mg/L [1,5,9,10].

Soluble fluorides are almost completely absorbed from the gastrointestinal tract; Fluoride is rapidly distributed by the systemic circulation to the intracellular and extracellular water of tissues; however, in humans and laboratory animals, approximately 99% of the total body burden of fluoride is retained in bones and teeth. In teeth and skeletal tissue, fluoride becomes incorporated into the crystal lattice. SF is a crippling disability with major public health and socio-economic impact, affecting millions of people in various regions of Africa, China and India. Intake of fluoride in water and foodstuffs is the primary causative factor for endemic SF [2,5,11]. Table 2 shows the extent to which fluoride levels and intake are correlated.

Table 2. Water Fluoride Concentrations and Risk of Skeletal Fracture

Water Fluoride Concentration (Mg/L)	Total Fluoride Intake (Mg/Day)	Odds Ratio For All Fractures (P Value)	Odds Ratio For Hip Fracture (P Value)
0.25–0.34	0.73	1.50 (0.01)	0.99 (0.99)
0.58–0.73	1.62	1.25 (0.17)	1.12 (0.85)
1.00–1.06	3.37	1.00	1.00
1.45–2.19	6.54	1.17 (0.33)	2.13 (0.15)
2.62–3.56	7.85	1.18 (0.35)	1.73 (0.34)
4.32–7.97	14.13	1.47 (0.01)	3.26 (0.02)

Source: Li et al (2001) [12]

Fluoride is a highly toxic substance, more toxic than lead. Serious crippling bone disease from drinking water, with very high levels of fluoride, over-ingestion of fluoridated dental products—including fluoride gels, fluoride supplements and fluoridated water can cause serious poisoning incidents, including death. Research already shows that fluoride can cause arthritis and bone fracture before the onset of crippling fluorosis, and can affect many other tissues such as the brain and thyroid gland [4]. In an epidemiological survey of fluorosis, [13] reported a 26.1 percent prevalence rate of enamel fluorosis in Langtang, Plateau state, Nigeria. Following this, levels of fluoride levels was assessed and found to range between 0.5 and 3.96 mg l⁻¹ with the highest levels being found in stream.

Evidence from several ecological studies has suggested that consumption of fluoridated water may be associated with hip fractures [14]. Symptoms of fluoride toxicity include emaciation, stiffness of joints and abnormal teeth and bones. Other effects include lowered milk production and detrimental effects on the reproductive capacity of animals [5]. The possibility of neurotoxicity and cancer due to elevated fluoride levels has also been elucidated [15].

When air-borne fluoride dust is deposited on land, they are strongly retained by soil and bind to soil components, from where they are taken up accumulate by plants, or they may be deposited on the upper parts of the plants in

dust. Tea plants are known to accumulate fluoride in their leaves [1]. Herbivorous animals that eat fluoride-containing plants may also accumulate fluoride. The uptake of fluoride by biota is determined by the route of exposure, the bioavailability of the fluoride and the uptake/excretion kinetics in the organism fluorides can be taken up by aquatic organisms directly from the water or to a lesser extent via food. Fluorides tend to accumulate in the leaves of plants such as tea plant and exoskeleton or bone tissue of aquatic animals. Mean fluoride concentrations of >2000 mg/kg have been measured in the exoskeleton of krill; mean bone fluoride concentrations in aquatic mammals, such as seals and whales, ranged from 135-18600 mg/kg dry weight [3]. Elevated levels are present in fish. Consumption of fish with bioaccumulated fluoride eventually increases that of human level, with resultant adverse effect. Current safety standards therefore are meant to protect public health. The upper limit of fluoride in water (4 mg/L) is the level added to water (0.7-1.2 mg/L) in community fluoridation programs, where very low levels are detected, whilst de-fluoridation is the management option for higher levels.

In view of the fact those excessively high levels of fluoride intake causes crippling skeletal fluorosis (SF) and possibly increased bone fracture risk and that ingestion of excess fluoride during tooth development, particularly at the maturation stage, may also result in dental fluorosis (DF). this research was therefore undertaken to investigate

if private borehole, stream, well and public tap water in Omoku maintains the standard of fluoride intake in a quality drinking water recommended by the World Health Organization. This research is meant to create awareness on the status of the fluoride content and hence the potential for causing DC, DF and SF. It will enable the Water Authority to take informed decision on whether fluoridation or defluoridation programme should be carried out on drinking water in the study area.

2. Materials and Method

2.1. Description of Sampling Site

Water samples were collected from six different sites in Omoku, Headquarter of Ogba/Egbema/Ndoni local government area, Rivers State, Nigeria. Figure 1 shows map of study area.

The sampling sites are as follows:

Samples I-6: Stream water from six sites along *Onosi-Obosi* Stream, Creek Road, Omoku.

Samples 7-12: Well water from six compounds.

Samples 13-18: Private Borehole water from six residences.

Samples 19-24: Public tap water from six community taps.

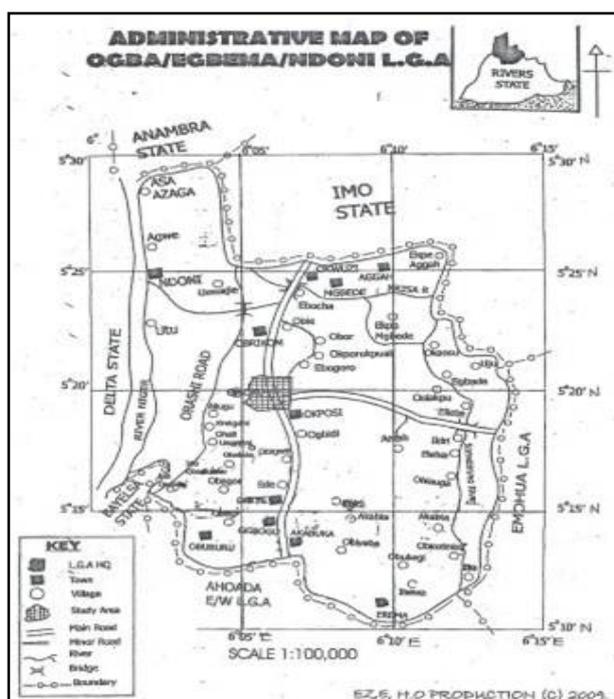


Figure 1. Map of Study Area

2.2. Sample Collection

Water samples were collected early in the morning at about 6:30am from the four sources using clean plastic bottles of 1.5L capacity. Stream water was collected at the depth of 3m to avoid contact with the surface water air and sealed in air tight plastic bottles to prevent contamination. The private borehole and public tap water were allowed to rush for a minute in order to clean the rust from the mouth of the tap to prevent contamination. The water sample was taken to the laboratory within 12 hours for analysis.

2.3. Determination of Fluoride Levels in Water

The method of analysis was purely laboratory method. Reagents used for the analysis are:

- i) Standard fluoride solution
- ii) Fluoride buffer
- iii) Fluoride Stock Solution (ACC or WTW).

Fluoride levels in samples of water were determined using the Ion-Selective Electrode method (Standard Methods 4500F-C) [5,9]. Calibration of Ion-Selective meter was carried out with the Fluoride electrodes using the standard fluoride solution and buffer provided with instrument. Thereafter, 25ml of each sample were transferred into a 100ml beaker. 25ml equal volume of buffer solution was added to the samples in the beaker. The beaker was placed on a magnetic stirrer and electrode was immersed inside the beaker. The electrode was allowed to remain in the solution for about 3 minutes (until the reading was stable). The corresponding fluoride concentration was read directly from the meter. After the reading the electrodes were removed, rinse with distilled water and blot dried between readings.

2.4. Statistical Analysis

One way analysis of variance (ANOVA) statistics was used to ascertain whether there was significant difference in the Fluoride levels of stream, public borehole private borehole and well water. Analysis will be conducted using Microsoft Excel data analysis Pak.

3. Result and Discussion

The fluoride content of the water samples from stream, well, private borehole and public tap water are shown in Table 3. Values are reported as mean + standard deviation.

Comparing results obtained in Table 3, stream water sample, private borehole and public tap water had overall mean fluoride levels of 0.95 ± 0.09 , 0.94 ± 0.07 and 0.86 ± 0.30 mg/L respectively, which is higher than the minimum but lower than the maximum safe level specified by the World health Organization and Standard Organization of Nigeria. On the other hand, Well water had a fluoride level of 0.48 ± 0.03 mg/L, which is below the specified minimum level. Fluoride levels in surface waters vary according to geographical location and proximity to emission sources. Surface water concentrations generally range from 0.01 to 0.3 mg/L [1,10]. Fluoride concentrations of 0.482 mg/L in groundwater and 0.506 mg/L in surface water have also been reported. Seawater contains more fluoride than fresh water, with concentrations ranging from 1.2 - 1.5 mg/L [11]. Mean Fluoride content of stream water in this study was higher (0.95mg/L). Between subjects and group ANOVA statistics indicated lack of significant difference in the mean fluoride levels of all water samples from the respective sampled sites ($p > 0.05$).

In a similar study of Egyptian's main source of tap water from River Nile, fluoride levels in the tap water ranged from 0.33 - 0.38 mg/L with an average of 0.36mg/L [16]. This level is said to be suitable for the hot climate in Egypt. On the other hand, their groundwater, which is artesian wells, contained higher levels of

fluorides with an average ranging from 0.76 - 0.93mg/L. These fluoride values are lower than the ones reported in this study. In these cases, these values needed to be modified if it is to be used for drinking. Also, fluoride

content of some private wells that exceeded the 4mg/L MCL (Maximum Contaminant Level) set by EPA was reported [17].

Table 3. Fluoride contents of Omoku community drinking water (mg/L)

SS	Source	SS	Source	SS	Source	SS	Source
	Stream/River		Well Water		Private Bore hole		Public Borehole
SS1	0.91±0.03	SS7	0.52±0.01	SS13	0.93±0.06	SS19	0.87±0.36
SS2	1.00±0.05	SS8	0.48±0.01	SS14	0.95±0.07	SS20	0.66±0.44
SS3	0.91± 0.19	SS9	0.47±0.05	SS15	0.89±0.05	SS21	0.84±0.21
SS4	0.91±0.14	SS10	0.42±0.03	SS16	0.91±0.09	SS22	0.65±0.32
SS5	1.03±0.05	SS11	0.49±0.04	SS17	0.95±0.08	SS23	1.01±0.32
SS6	0.96±0.06	SS12	0.48±0.04	SS18	0.97±0.05	SS24	1.11±0.17
Overall Mean±SD	0.95±0.09		0.476±0.03		0.94±0.07		0.86±0.30

SS- Sampling Site;

In non-fluoridated drinking water (i.e., drinking water to which fluoride has not been intentionally added for the prevention of DC) levels may reach up to about 2.0 mg/Litre. However, some places can have fluoride levels in drinking water of up to 20 mg/L. In a few areas of the United States, fluoride concentrations in water are much higher than normal, mostly from natural sources [5]. In areas in which drinking water is fluoridated, fluoride level in drinking water generally ranges from 0.7 to 1.2 mg/L [11]. In this study, it was established that the mean fluoride levels in the community drinking water was approximately 1.00mg/L except for well water which was below the stipulated standard. Therefore fluoridation is required in order to prevent dental carries especially among children in the area.

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