

ASSESSMENT OF FLUORIDE CONCENTRATION IN GROUNDWATER IN HONG AND ENVIRONS, ADAMAWA STATE, NORTHEASTERN NIGERIA

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ABSTRACT

Groundwater is the main sources of water supply and is the major source of fluoride intake for humans. There is need to have representative data and information on the extent of human exposure to fluoride and its impact on human dental fluorosis. This study aimed at assessing the fluoride concentrations in drinking water sources in Hong and environs where cases of dental fluorosis have been reported in the area. Total of twenty groundwater samples were collected from ten boreholes and ten hand dug wells. The samples were analysed by Atomic Absorption Spectro- photometry method. The results show that, the fluoride concentrations in boreholes range between 1.51 mg/l to 1.71 mg/l with average value of 1.60 mg/l, while for hand dug wells range between range between 1.65 mg/l to 2.13 mg/l with average value of 1.89 mg/l, which is above the recommended standard. This implied that the inhabitant in Hong and environs that relied on groundwater source are exposed to health risk associated with high fluoride. To mitigate for the health impact of high fluoride, use of alternative sources of potable water as well as de-fluoridation is recommended. In addition, educating the community on dangers of using water with excess fluoride is recommended in order to ensure good health.

Keywords: Groundwater, Fluoride, Hong, Dental fluorosis, Borehole, Hand dug well

1 INTRODUCTION

Groundwater is the major source for various purposes in most parts of the world. The quality of the consumed drinking water may affect oral health. Though water covers about 70% of the earth's surface, only 2.53% is fresh water while the remaining is salt water [1] of the fresh water, 68.7% is glaciers, 30.1% groundwater, 0.8% permafrost and 0.4% surface and atmospheric water. Fluoride is an ion of the chemical element fluorine which belongs to the halogen group. Fluoride has a significant mitigating effect against dental caries if the concentration is approximately 1.0 mg/l [2]. However, continuing consumption of higher concentrations can cause dental fluorosis. High fluoride concentrations are especially critical in developing countries like Nigeria, largely because of lack of suitable infrastructure for treatment [3]. Fluoride is a common constitute of groundwater and its sources are connected to various types of rocks and to volcanic activities [4].

Most of the fluoride in groundwater is naturally present due to weathering of rocks rich in fluoride. Water with high concentration of fluoride is mostly found in sediments of marine origin and at the foot of mountainous areas like the research area [5, 6]. Granitic rocks which are a typical source of high fluoride, contain fluoride ranging between 500 and 1400 mg/kg [7], which is much higher than any other rock type. The weathering of these rocks results in increased fluoride content in groundwater. Longer residence time in aquifers with fractured fluoride rich rocks enhance fluoride levels in the groundwater. [8] put forth that granitic rock and clay in Pakistan contained average fluoride of 1939

and 710 mg/kg respectively. Granite and granitic gneisses in Nalgonda, India contain fluoride rich minerals such as fluorite (0% to 3.3%), biotite (0.1% to 1.7%) and hornblende (0.1% to 1.1%) [9]. [10] reported from the same area that the rocks contain 460 to 1706 mg/kg of fluoride. Laboratory studies conducted by [11] showed that leaching of fluoride from granitic rocks contributed 6 to 10 mg/l of fluoride to water. The occurrence of fluoride in groundwater is primarily ascribed to geogenic processes. The sources are usually related to the dissolution of various minerals present in rocks and soils, such as fluorite (or fluorspar), cryolite, fluoroapatite, topaz, villaumite, amphiboles such as hornblende, micas namely muscovite and biotite and also rock phosphate. Clay minerals for instance vermiculite, kaolinite, montmorillonite, illite, chlorite and spectite are also the sources of fluoride in groundwater. Among the above stated minerals, fluorite and fluorapatite have generally been considered as the foremost geogenic sources of Fluoride in groundwater [12]. The anthropogenic activities like the application of phosphatic fertilizers and pesticides, processing of phosphatic raw materials, use of clays in ceramic industries, electroplating, aluminum smelting operations, and mining & burning of coal may also have role in the elevated concentration of F^- in groundwater. Phosphate containing fertilizers add up to the fluoride content in soil and groundwater [13]. It is evident that superphosphate (2750 mg of F/kg), potash (10 mg of F^- /kg) and NPK (Nitrogen Phosphorous Potassium) (1675 mg of F /kg) which are phosphatic fertilizers contain remarkable amount of fluoride [14]. Also, fluoride concentration in irrigation water accounts to be 0.34 mg/l. In agricultural areas successive irrigation had led to the increase in fluoride concentration in groundwater [16].

The fluoride concentration ranging between 1.5 to 2 mg/l forms dental fluorosis, >4 mg/l forms dental and skeletal fluorosis, >10 mg/l forms crippling fluorosis [17]. Cases of fluorosis has been reported around the globe [18] and in northeastern Nigeria [19, 20, 21] The aim of the study is to assess the fluoride concentration levels in Groundwater where cases of dental fluorosis have been reported in the area.

2 THE STUDY AREA

The study area Hong is a very large settlement located about 135 km from Yola town. It lie between coordinates $10^{\circ}13'54''N$ $12^{\circ}55'49''E$ / $10.23^{\circ}N$ $12.93^{\circ}E$, in the State capital of Adamawa State, Nigeria. Hong town has a land area of about 480.65 square.km with population of about 169,183 people. Hong and environs are drained by Kilanye and Shashau Rivers [15]. The area falls within the Sudan Savannah vegetation type which consists of shrubs, grasses and trees especially along the river channels. Hong is a town with fast growing population due to human activities such as agriculture, large crop and animal market, schooling and commerce. This created the high demand for portable water. In the absence of portable water alongside poor infrastructure and housing development, people went into digging Wells at their convenience without considering hygiene.

The climate of the study area is characterized by the distinct seasons (wet and dry). The wet season picks up from April to October while the dry season picks up from November with mean annual rainfall of about 950 mm, the wettest month being August and September. Temperatures are generally high ($30^{\circ}C$ to $42^{\circ}C$) throughout the year except between November and February when harmattan winds tends to reduce temperature to $16^{\circ}C$. However, minimum temperature can be as low as $12^{\circ}C$ during the harmattan period. Relative humidity also varies seasonally in the study area, with low value of about 20% to 30% between January and March. Increasing in peak of 88% between April to August and September, and declining again in October [22]. The area falls within the arid and semi-arid ecological zone. Due to its low rainfall and poor soils in some areas the vegetation is also low. Trees mostly found in the area are mango, guava trees, baobab, and shrubs. Cultivation is low but during the wet season vegetation is lush and food crops such as green grams, cowpeas and tubers such as cassava are grown. Livestock such as goats, sheep and cows are kept by the community. The impact of human activity is indiscriminate tree felling for charcoal burning is having a toll on the vegetation.

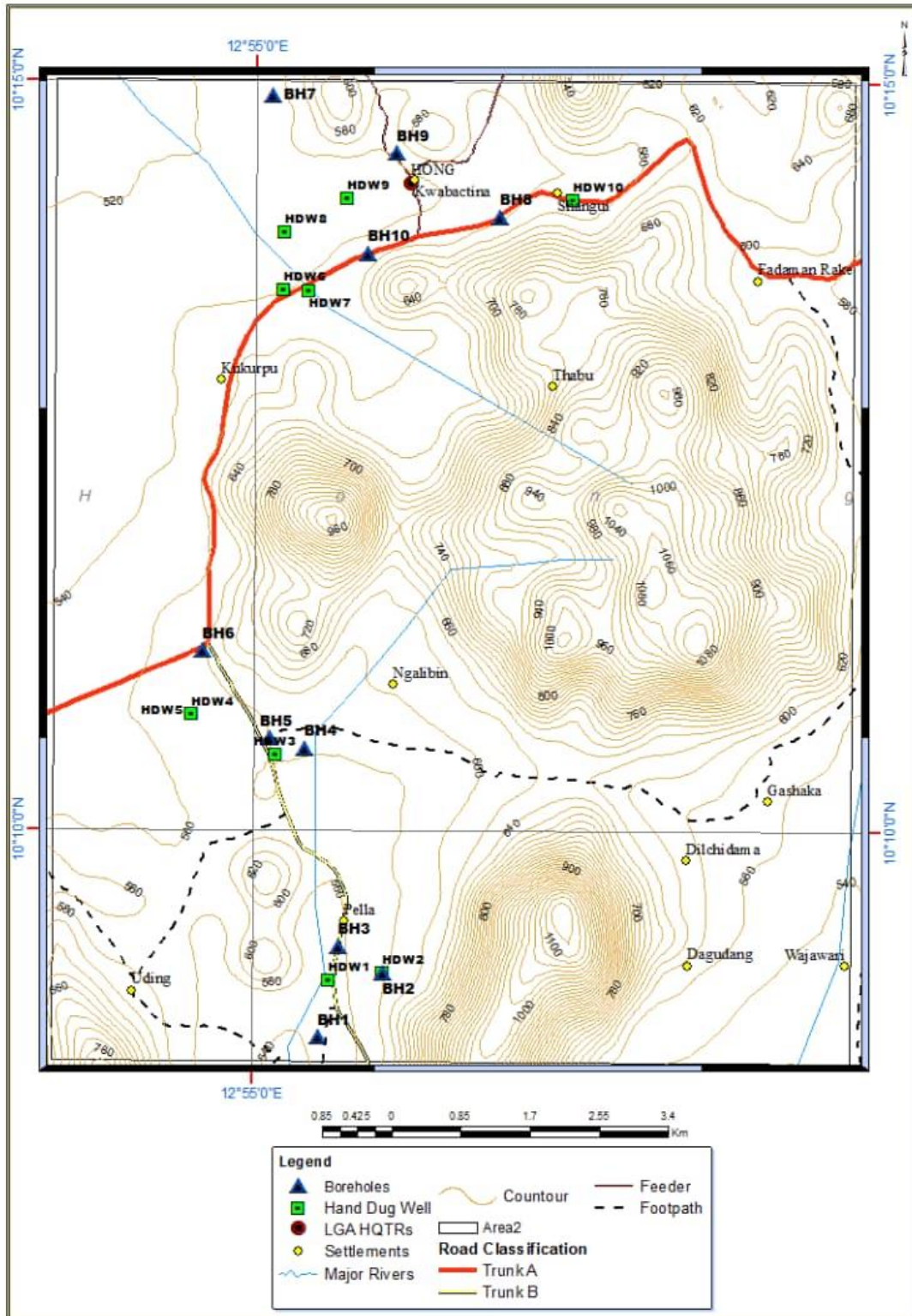


Figure 1. Topographic map of the study area showing sampling locations

2.1 Geology of the Study Area

The study area is underlain by the Pan African granites which occupy about two third of the study area, and enclosed the migmatite - gneiss - quartzite complex. 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 inselbe. Field observation

on the migmatitic and granitic outcrops show moderate weathering and presence of structural elements such as joints and faults. Hydrogeologically, the borehole and hand-dug wells in the area derived their water source from regolith deep and shallow aquifer while secondary porosity and permeability initiated via fractures account for the groundwater storage and yield [22].

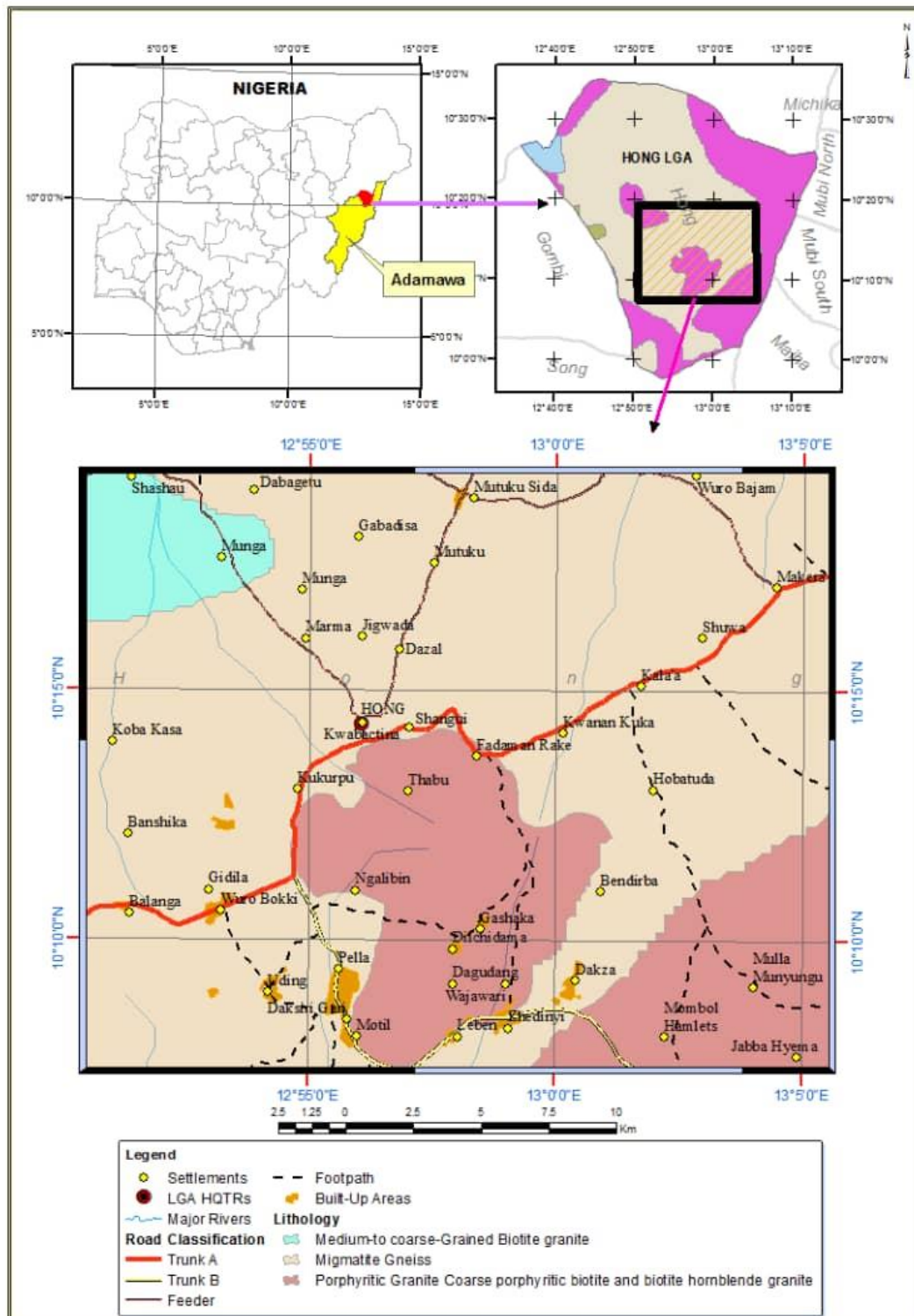


Figure 2. Geology of the Study Area

2.2 Effects of Fluoride on Human

Intake of fluoride higher than the optimum level is the main reason for dental and skeletal fluorosis. Depending upon the dosage and the period of exposure fluorosis may be acute to chronic.

[23] quoted that around 200 million people globally are under the dreadful fate of fluorosis of which India and China, the two most populous countries of the world, are the worst affected. In India 62 million people including 6 million children are estimated to have serious health problems due to consumption of fluoride contaminated water [24]. Endemic fluorosis is prevalent in 29 provinces of China, municipalities and autonomous regions [25]. Dental and skeletal fluorosis was predominant in China due to the indoor burning of coal to make brick tea or for heating purposes [26, 27]. [28] stated that dental fluorosis was predominant in the dry zone where fluoride concentration was high and dental caries was prevalent in wet zones where low fluoride occurs in groundwater of Sri Lanka. Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking-water have been carried out. These studies clearly establish that fluoride primarily produces effects on skeletal tissues (bones and teeth). Low concentrations provide protection against dental caries, especially in children. Fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental fluorosis (prevalence: 12% to 33%) at drinking-water concentrations between 0.9 and 1.2 mg/litre [29]; the period of greatest susceptibility is at the time of mineralization of the secondary upper central incisor teeth at about 22–26 months of age. This has been confirmed in numerous subsequent studies, including a recent large-scale survey carried out in China [30], which showed that, with drinking-water containing 1 mg of fluoride per litre, dental fluorosis was detectable in 46% of the population examined. The extent of exposure from food was not clear in these studies. In general, dental fluorosis does not occur in temperate areas at concentrations below 1.5 mg to 2 mg of fluoride per litre of drinking-water. In warmer areas, because of the greater amounts of water consumed, dental fluorosis can occur at lower concentrations in the drinking-water [31, 32].

3 MATERIALS AND METHODS

The groundwater samples were collected from ten boreholes and ten hand dug wells. These locations include Government Secondary School Hong (GSS Hong), Sabon Gari behind Lutheran Church of Christ of Nigeria No 1 Hong (LCCN No 1), Cottage Hospital Hong, Market Hong and Police Barracks Hong, in Pella the location of the borehole include former Pella Area court, Lutheran Church of Christ of Nigeria No 2 Pella (LCCN No 2) and Pella football field (Figure 1). The water samples from boreholes were collected by hand pumping and the hand dug wells water samples were collected using 2-liter plastic container. This is capable of obtaining water at predetermined depth incorporated with a closure function. The sampler was a clean and chemically inert container that has been sterilized to avoid contamination by any physical, chemical or microbial means. Table 1 shows methods and instruments used for the determination of the physicochemical parameters of the samples.

Table 1. Methods and instruments used for the determination of the physicochemical parameters of the water samples

S/N	parameters	Methods of analysis	Instruments used
1	Odour	Perceive	Water glass bottle, Human nostrils
2	Colour (TCU)	Laboratory	Lovibond colour disc
3	Taste	Mouth taste	Water glass, Human mouth
4	TDS (mg/l)	Gravimetric	Oven, petri dish
5	pH	Electrometric	pH metre
5	Turbidity (TNU)	Laboratory	Turbidimeter, Current source
6	Iron (mg/l)	Colorimetry	Atomic Absorption Spectro- photometry (AAS)
7	Copper (mg/l)	Colorimetry	Atomic Absorption Spectro- photometry (AAS)
8	Zinc (mg/l)	Colorimetry	Atomic Absorption Spectro- photometry (AAS)
9	Chlorine (mg/l)	Titration	Reagents and Lab Equipment
10	Nitrate (mg/l)	Titration	Reagents and Lab Equipment
11	Total hardness (mg/l)	Titration	Reagents and Lab Equipment
12	Fluoride (mg/l)	Colorimetry	Flame Photometer

Analysis of the results was done according to the standard methods for examination of groundwater fluoride. The result was compared with the world standard recommended optimal level of fluoride concentration for drinking water and as well its impact on dental fluorosis.

4 RESULTS AND DISCUSSION

Average concentrations of physical parameters of groundwater from boreholes and hand dug wells are shown in Table 2 and 3 respectively, the mean results of Odour, Colour, Turbidity and Taste from both the HDW and BH Indicated that, the water samples had no odour; no colour and no offensive taste. So they are acceptable for drinking as compared with the World Standard. The average physicochemical constituents in groundwater (Tables 2 and 3) are correlated with the World Health Organization (WHO) standards. Hydro geochemical results which are considered in the evaluation of water quality for domestic purposes reveal that the physical properties pH and turbidity are below the recommended limit of 6.8-8.5 [6]. The pH values range from 5.33 to 6.99 in boreholes and hand dug wells respectively, while turbidity of the water samples range between 0.3 to 0.62 in boreholes and shallow wells respectively (Table 2 and 3). The chemical properties of selected water sample sources from deep and shallow aquifer shows that they varied differently as shown in Table 2 and 3 and their level of concentration in mg/l of Chloride (Cl), Fluoride (F), Copper (Cu), Potassium (K), Zinc (Zn), Iron (Fe), Sodium (Na), Magnesium (Mg) and Total Dissolved solid (TDS). The fluoride concentrations in boreholes range between 1.51 mg/l to 1.71 mg/l with average value of 1.60 mg/l, while for hand dug wells range between range between 1.65 mg/l to 2.13 mg/l with average value of 1.89 mg/l, which is above the recommended standard (Tables 2 and 3). This suggest that the concentration of fluoride is above the recommended standard [6]. in deep aquifer is higher that of shallow aquifer in the study area except the concentration of Nitrate (NO₃) is higher in shallow aquifer than in the deep aquifer and as well not in range with the [6].

Table 2. Physicochemical analysis of water sample for borehole in the study area.

S/N	Sample points	pH	Turb. (TNU)	Cl (mg/l)	F (mg/l)	Cu (mg/l)	K (mg/l)	Zn (mg/l)	Fe (mg/l)	NO ₃ (mg/l)	Na (mg/l)	Mg (mg/l)	TH (mg/l)
1	Pella LCCN No. 2	5.33	0.49	38.7	1.57	0.53	7.65	0.07	0.83	48.3	1.65	39.8	89.5
2	Pella LCCN No. 1	6.04	0.074	35.9	1.61	0.37	7.8	0.08	1.2	40.1	1.32	31.03	77.8
3	Pella Football field	6.71	0.56	33.5	1.68	1.11	8.35	0.06	0.7	46.4	1.58	34.01	78.1
4	Ngalbi LCCN No. 1	6.12	0.084	41.5	1.53	0.54	6.8	0.13	0.87	50.2	2.14	36.71	67.5
5	Ngalbi Dzuma Junction	5.81	0.099	34.5	1.58	0.49	8.7	0.08	0.91	57.7	1.47	29.8	75.5
6	Babal Midila	6.1	0.62	42.3	1.51	0.45	9.2	0.1	0.94	46	1.35	29.45	69.5
7	GSS Hong	6.25	0.06	49.2	1.63	0.28	8.01	0.09	0.82	41.4	1.72	30.35	77.9
8	Hong General Hospital	6.79	0.035	50.1	1.71	0.51	7.45	0.67	0.58	51.1	1.3	29.68	88.2
9	Unguwan Police Barack	6.99	0.49	34.4	1.62	0.39	6.96	0.05	1.1	44.4	1.29	33.4	75.3
10	Hong Market Square	5.01	0.57	42.1	1.55	0.41	8.9	0.08	1.01	43.2	1.56	30.76	69.1
	Average	6.12	0.31	40.22	1.60	0.51	7.98	0.14	0.90	46.88	1.54	32.50	76.84
	WHO 2011	6.8-8.5	0-5	0-250	1.5	0-2	0-200	4-0	0-0.3	50-70	0-200	0-200	0-150

The average concentration of fluoride distribution in boreholes and hand dug wells is 1.60 mg/l (Table 2) and 1.89 mg/l (Table 3) respectively, which is above the permissible limit of 1.5 mg/l [6]. There are several factors that may cause the colour teeth condition in humans including sugar rich diet, accidents, hereditary and level of teeth care among others. Consumption of high fluoride water may

also cause or exacerbate the occurrence of coloured teeth condition. Excess level of fluoride would course dental fluorosis which is a condition that results from the intake of excess levels of fluoride during the period of tooth development, usually from birth to approximately 6 to 8 years of age. It has been termed as hypoplasia or hypo-mineralization of dental enamel and dentine and is associated with the excessive incorporation of fluoride into these structures. The dental enamel is both post eruptive phenomena (i.e., acquired after tooth eruption and occur as a consequence of the enamel hypo-mineralization) [33]. These results show the impact of fluoride ingestion generally characterized as ranging from very mild to severe, is related to the extent of fluoride exposure during the period of tooth development. Mild dental fluorosis is usually typified by the appearance of small white areas in the enamel; individuals with severe dental fluorosis have teeth that are stained and pitted (“mottled”) in appearance. Mottled enamel usually takes the shape of modification to produce yellow brown stains or an unnatural opaque chalky white appearance with occasional striations patting.

Table 3. Physicochemical analysis of water sample for hand dug well in the Study Area.

S/N	Sample points	pH	Turb. (TNU)	Cl (mg/l)	F (mg/l)	Cu (mg/l)	K (mg/l)	Zn (mg/l)	Fe (mg/l)	NO ₃ (mg/l)	Na (mg/l)	Mg (mg/l)	TH (mg/l)
1	Pella market square	5.95	0.03	45	1.75	0.67	7.31	0.05	0.97	59.2	1.03	30.8	79.8
2	Pella area court	5.68	0.4	44.8	2.06	0.35	6.3	0.07	0.66	49.45	1.66	22.03	77.1
3	Ngalbi mosque	6.83	0.41	33.7	1.71	0.72	6.01	0.16	0.58	56.2	0.93	36.02	73.01
4	Babal midila LCCN no. 1	6.31	0.45	28.8	1.65	0.64	7.4	0.05	0.71	52.1	1.7	35.72	78.11
5	Hong hayen gada	5.82	0.53	43.6	2.1	0.65	7.5	0.04	0.41	65.2	1.73	30.81	64.15
6	GSS Hong	5.91	0.05	49.2	1.81	0.21	8.03	0.07	0.82	59.5	1.21	32.45	68.5
7	Unguan wajah hong	6.23	0.04	23.3	1.87	0.43	6.07	0.13	0.8	61.8	1.42	37.35	77.7
8	Hong Emirate Palace	5.8	0.01	30.4	1.76	0.57	6.91	0.06	0.87	50.5	2.82	34.68	67.4
9	Hong General hospital	6.03	0.52	25.5	2.13	0.39	7.5	0.1	0.78	53.7	1.45	25.35	59.9
10	Tsohon Gari	5.95	0.12	40.2	1.89	0.4	5.7	0.08	0.69	55.01	1.18	32.7	70.9
	Average	6.05	0.26	36.44	1.87	0.50	6.87	0.08	0.73	56.27	1.51	31.79	71.66
	WHO 2011	6.8-8.5	0-5	0-250	1.5	0-2	0-200	4-0	0-0.3	50-70	0-200	0-200	0-150

The distribution of groundwater fluoride in the study area vary spatial from moderately to high level of concentration in the sub region as shown in Figure 3 for deep aquifer and Figure 4 for shallow aquifer respectively. The spatial distribution in deep aquifer in Maraban Pella was 1.51mg/l which is slightly above the permissible limit of 1.5 mg/l [6], and the concentration level of spatial distribution of 1.69 mg/l in Shangui as the highest value in Figure 3 below which is above the safe drinking water. The lowest spatial distribution in shallow aquifer was 1.71 mg/l in Ngalbi which is not in range with the safe drinking water, and the highest level of concentration in the study area were 2.08 mg/l in Hong Kwabactina which is high above the world standard and need to be de-fluoridated. Study by [34] in Shelleng and environs, Adamawa State obtained concentration of fluoride range between 0.69 mg/l to 2.20 mg/l with an average of 1.03 mg/l, their findings is similar to was obtained in this study. Less fluoride concentration 0.12713 mg/l was obtained by [35], in Toungo Area, Adamawa State. Physico-Chemical Characterization of Groundwater of Kaltungo, Gombe State Nigeria and Treatment for Fluoride Removal, the concentration level of fluoride were found to be 1.9 mg/l and 1.6 mg/l in deep and shallow aquifer respectively, on comparison with the concentration level of average level of 1.87 mg/l in shallow and 1.61 mg/l in deep aquifer respectively. The average concentration of 1.75 mg/l in Gombe and 1.74 mg/l in Hong and environs which shows that the level of exposure Inhabitant in Gombe State and Hong are exposed to impact of high fluoride like molted teeth or dental fluorosis due to the fact that daily intake was above the recommended standard. Study in Hong and environs by [36] reveals fluoride concentration of 2.00 mg/l which is above recommended level. Study by [21] in Damaturu Yobe state northeastern Nigeria revealed that fluoride concentrations in surface water ranges between 0.03 mg/l and 2.07 mg/l, while in groundwater ranges between 0.02mg/L and 2.42mg/L. the result is similar to the findings of the present study.

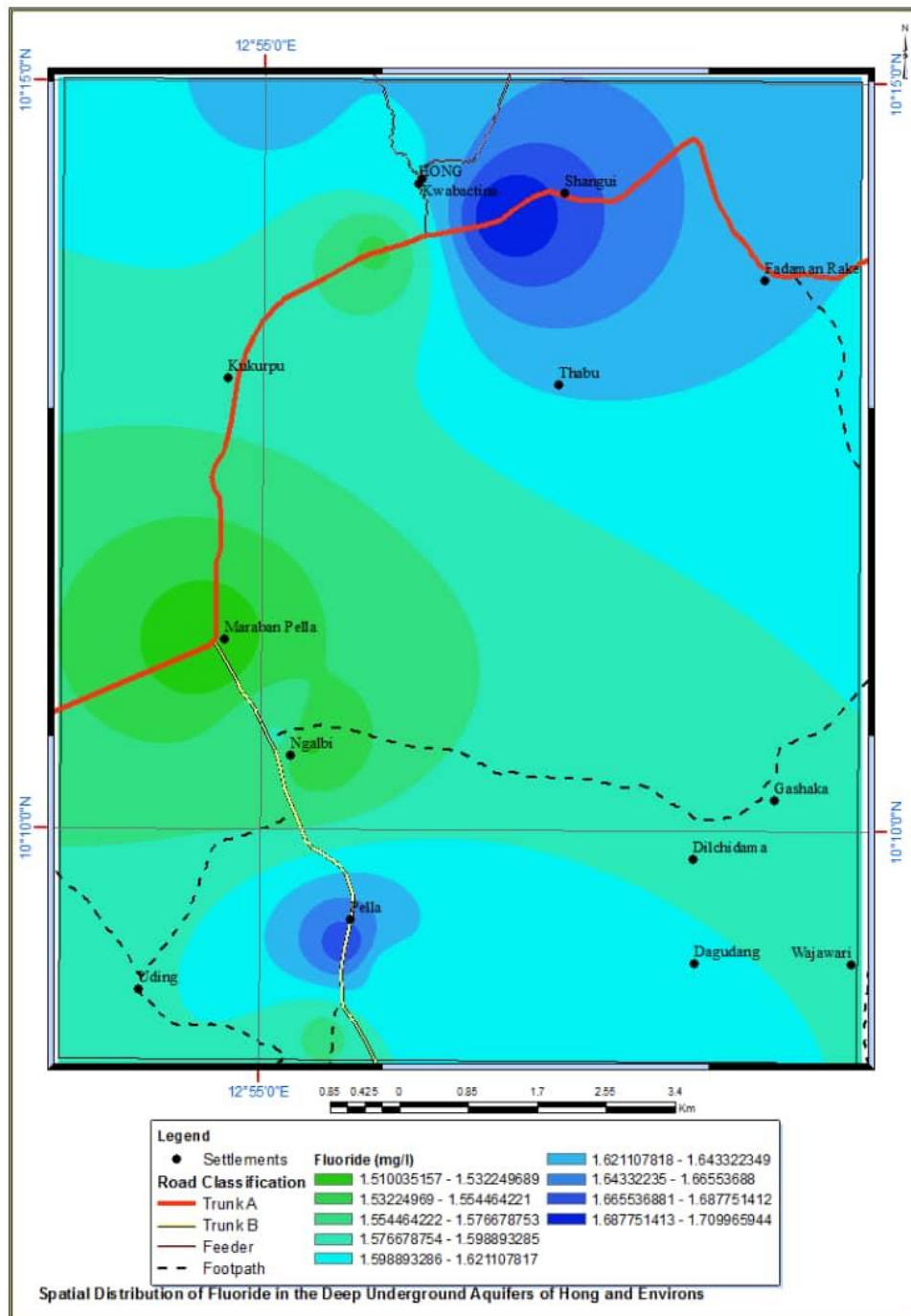


Figure 3. Spatial Distribution of Fluoride in deep aquifers in the study Area.

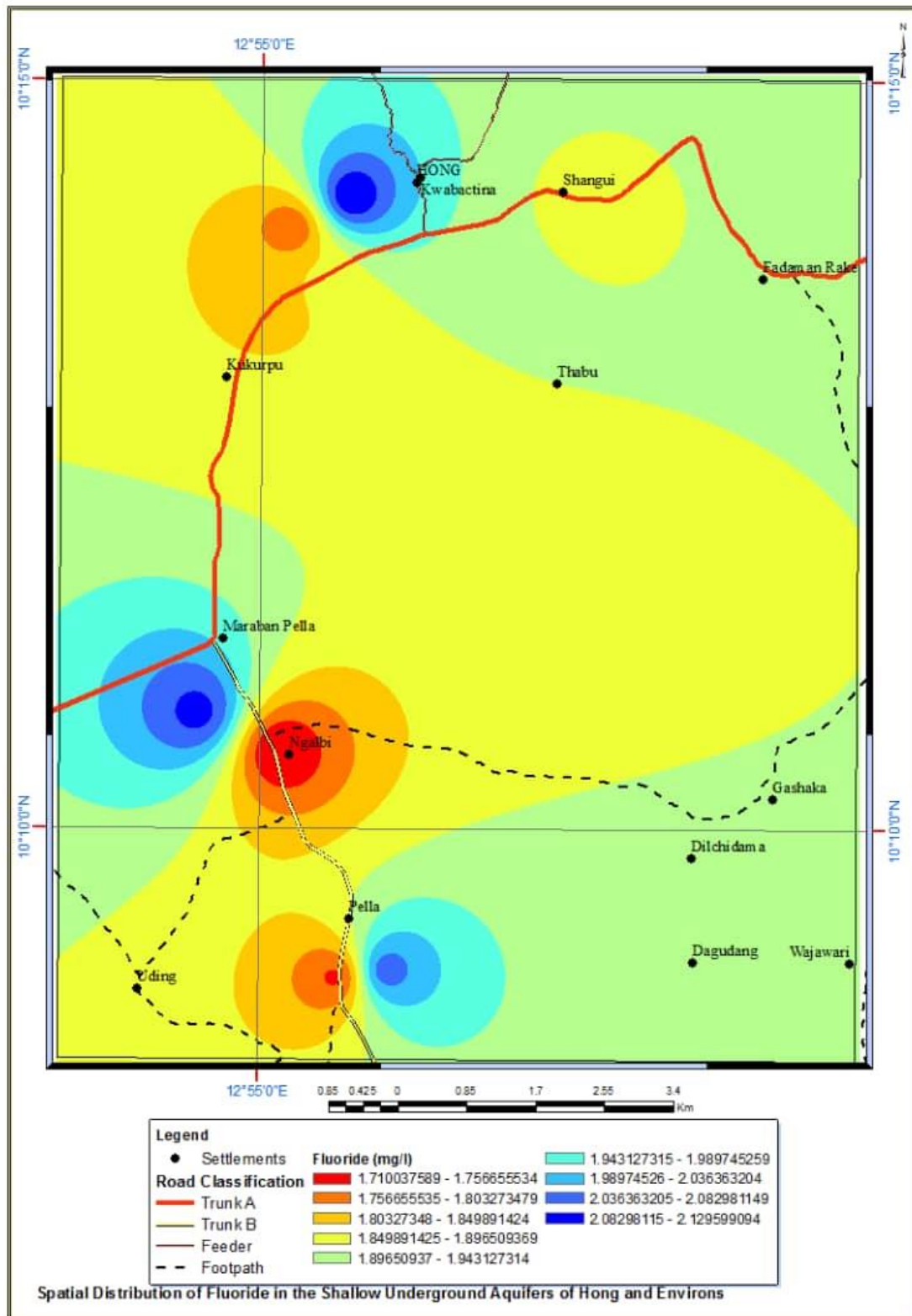


Figure 4. Spatial Distribution of fluoride in shallow aquifers in the study Area

From the result analysis (Figures 3 and 4) it shows that, the fluoride concentration in hand hug wells is higher in concentration than in borehole water. It is evident from studies by several researchers worldwide that fluoride in groundwater has been a potential problem to human society, especially dental fluorosis. The main source of fluoride in groundwater is the rocks which are rich in fluoride and the study area is a mountainous. Fluoride occurs in sellaite,

fluorite, cryolite, fluorapatite, apatite, fluormica, biotite, amphibole and several other rocks. Weathering of these rocks and prolonged residence time leads to high fluoride groundwater. The other sources for fluoride concentration could be from agricultural activities, runoff containing chemical fertilisers. Even though some amount of fluoride is essential for the human body for healthy teeth and bones. But when they are above the recommended limit of World Health Organisation (WHO) and BIS i.e. 1.5 mg/l it results in mild dental fluorosis to crippling skeletal fluorosis as the quantity and period of exposure increases. Dental fluorosis is more prevalent in children than in adults. Skeletal fluorosis occurs when an individual is exposed to fluoride of above 10 mg almost every day over a period of one or two decades. Apart from fluorosis there are also several health disorders due to ingestion of drinking water with high fluoride. To remediate the groundwater with high fluoride, defluorination techniques are adopted. They include adsorption, ion exchange, coagulation and precipitation, reverse osmosis and electrodialysis. Of these, reverse osmosis has been considered as the best available technology. Onsite treatment includes artificial recharge methods such as rain water harvesting, constructing check dams, percolation ponds, facilitating recharge of rain water through existing wells etc. Adopting a particular method depends on the initial fluoride concentration, source and cost effectiveness in area.

5 CONCLUSION

The study revealed that the fluoride concentration is generally above the recommended standard level for water consumption. Fluoride concentration is moderately low in borehole water and high in hand dug wells. Based on this findings people should use the borehole water with little treatment and avoid using the hand dug well water due to its high level of fluoride concentration.

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