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Prevalence of Fluoride Concentration in Ground Water Sources in Kaltungo, Gombe State, Nigeria

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Abstract: Most children in Kaltungo town grow up with mottle (stain) teeth, thought to be caused by chemical characteristics of the town's sources of drinking water. This study carried out an assessment of physico-chemical properties of groundwater from selected hand dug wells and boreholes in Kaltungo town from same geological formation for 12 months. Physical parameters of Odour, Colour, Taste, Temperature, Turbidity, Total Dissolved Solids (TDS), and Chemical parameters of pH, Cl, Fe, Cu, Pb, Zn, F, Cd, NO_3^-, Total hardness (TH), Total alkalinity (TA) and Conductivity were tested. Standard statistical analysis was used to analyze the data and compare with World Health Organization guidelines for drinking water. All Physical parameters were within the acceptable limits, except temperature which had a mean value of 29.7 $^{\circ}$C, which is higher than WHO (2006) guide line limit of 25 $^{\circ}$C, but acceptable by NIS, SON and NAFDAC(2007) limits. Almost all the chemical parameters were below the recommended maximum. Mean value of fluoride concentration from hand dug wells was 1.81 mg/l and boreholes, 1.59 mg/l. Both are above the recommended maximum value of 1.5 mg/l. Mean concentrations of fluoride obtained in wells compared with those from boreholes indicated fluoride concentrations were much higher in wells than in bore holes. High fluoride concentration in the ground waters of Kaltungo town is responsible for teeth mottling among the people. Central water treatment plant is recommended to reduce high fluoride content before pumping the water for public consumption. The paired sample T-Test of the difference between the mean values of water physical parameters from hand dug wells and bore holes at $P \geq 0.05$ shows that there was no significant difference between the mean temperature values, mean total dissolved solid values and ambient temperature values but there was significant difference between the mean turbidity values at $P \geq 0.05$. While the paired sample T-Test of the difference between the mean values of water chemical parameters from hand dug wells and bore holes at $P \geq 0.05$ shows that there was significant difference between the mean Cl^-, Fe, Cu, Zn, F^-, NO_3^-, TH and TA values but there was no significant difference between the mean pH and Cond., values at $P \geq 0.05$.

Keywords: *Groundwater quality, Fluoride, Prevalence, Mottle teeth, Kaltungo, Gombe.*

I. INTRODUCTION

Water is one of the most important of all natural resources. Water is the only naturally occurring inorganic liquid and also the only chemical on earth that occurs naturally in three states of matter which are solid, liquid and gas (Revenga, 2000; Cunningham and Cunningham, 2004; Sodhi, 2005). The use of water by humans transcends the home, industry, agriculture and recreation (James *et al* 2001). Due to the importance of fresh water in human life, the demand for it is increasing though supply is decreasing. As a result of this, water is now a critical and limited resource (Botkin and Keller, 1998; Santra, 2005).

When rainfalls, it flows along the surface to streams or lakes, while some that sinks to the ground is used by plants; however, some evaporate to the atmosphere while some infiltrate into the ground (Gedzelman, 2009; James *et al* 2001). Groundwater is the water that is found underground in the cracks and spaces in the soil, sand and rocks that are fully saturated (Ward and Robinson 1990).

Groundwater can be found almost everywhere. The water table may be deep or shallow and may rise or fall depending on many factors. Heavy rains or melting snow may cause the water table to rise or heavy pumping of the groundwater supplies may cause the table to fall. Groundwater in aquifers can be discharged into lakes and streams. It can also be extracted through a well drilled (borehole) into the aquifer and brought to the surface by a pump. Groundwater is now prime water which has multipurpose uses ranging from drinking to industrial and agricultural use (Santra, 2005). Currently, humans withdraw approximately 600-700 km^3 of groundwater per year which is about 20 percent of global water withdraws (Revenga, 2000).

Groundwater chemical quality studies are now an environmental concern, (Raven *et al* 1998). People thought that the underlying soil and rock through which surface water must seep in order to become ground water filters out any contaminants, thereby ensuring the purity of groundwater. The capacity of soils and rocks to remove pollutants from groundwater varies widely from one area to another. These contaminants which are mostly chemicals in composition can be independent of whether the means of extracting the groundwater supply is borehole, well or spring water.

The physical and chemical characteristics of water determine the quality of water in a particular area. Some may have harmful effect on the people who use it for drinking (Niel *et al* 2003). The concentration of total dissolved materials in raw sewage water can be similar to that found in many groundwater supplies used as drinking water Tebbut (1990). In Kaltungo town the people depend mostly on groundwater sources. It has been noticed that children from teething age grow up with mottled (stain) teeth (fluorosis) (plate 1). It has been observed that children who come into kaltungo after the critical age do not develop the fluorosis. It is being speculated that mottling of teeth is caused by chemical characteristics in the people's sources of drinking water, which is largely groundwater. Teeth mottling can also be aggravated by fluoridated water or tooth pastes added to prevent tooth decay (Alvarez *et al*, 2009).

The objectives of study were to determine the prevalence concentration of fluoride in Kaltungo town groundwaters and recommend solutions for its reduction.

Plate 1: Samples of Mottled Teeth from some Kaltungo residents

II. MATERIALS AND METHODS

The Study Area

Kaltungo town is the headquarters of Kaltungo Local Government Area, Gombe State, Nigeria (Fig.1). Kaltungo town is located on Latitude 09^0 48’ 54” N and Longitude 11^0 18’ 24”E, 121.8 sq km of land area. The average annual rainfall is 1000mm (May-October) and dry season from November-April in a year. Water storage formations of Gombe State, Nigeria and its hydrogeological sequence shows that the hydrogeology comprised of crystalline and sedimentary rocks.

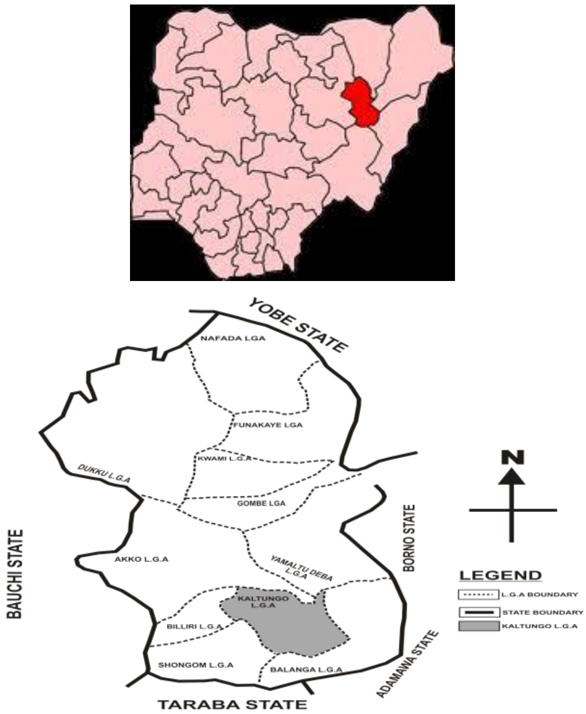

Fig. 1: Map of Nigeria Showing Gombe State and Kaltungo Local Government, the Study Area.

Crystalline environment has 3 to 4 zones, decompose (mostly topsoil), weathered, fractured and fresh crystalline zones with water normally found within weathered and fractured zones (Dike *et al.,* 1994). The sedimentary environments contain different rock formations with different water content depending on soil type and source of recharge. The fractured crystalline rocks are encountered in boreholes and hand dug wells at various depths in Kaltungo town (Lovelyn *et al.* 2016). The study area was demarcated into 3 major areas as follows: Termana - Area (T) with sampling points at (T_1 T_2 T_3), Kalarin - Area (K) with sampling points at (K_1 K_2 K_3) and Okra - Area(O) with sampling points at (O_1O_2 O_3).

Sample Collection and Analysis

Water samples were collected from 9 sources, 6 from boreholes (BH) and 3 from hand dug wells (HDW), one sample per month from each sampling point for 12 months. Samples from wells were drawn manually and poured into plastic bottles. Samples from boreholes were pumped out, allowed to run for 1 to 2 minutes before collecting in the bottles (Ademoroti, 1996). The samples were carried in a cooler and transported to the laboratory for analysis at Quality Control, Laboratory, Gombe State Water Corporation and Northeast Regional Water Quality Laboratory of Federal Ministry of Water Resources, Gombe Nigeria. The analyses were carried out according to standard methods set by APHA/AWWA/ WEF.(2012). The parameters determined were Temperature, colour, odour, taste, turbidity and total dissolved solids; the chemical parameters were pH, chloride, zinc, lead, fluoride, nitrates, cadmium, total hardness, total alkalinity and conductivity.

Statistical Analysis

The paired sample T-Test of the difference between the mean values of water parameters from hand dug wells and boreholes at $P \geq 0.05$ were carried out using SPSS statistics 20.

III. RESULTS AND DISCUSSION

A. Physical Parameters

Monthly mean concentrations of physical parameters of water from hand dug wells and boreholes are shown in Table 1, while the paired sample t-test of mean concentrations of physical parameters of water from hand dug wells and boreholes are shown in Table 2. The monthly mean concentrations of physical parameters of odour, colour from both the hand dug wells and boreholes indicated that, the water samples had no odour; colourless and had no offensive taste. This means the seasonal variation had no adverse effect on odour, colour and taste throughout the year.

The variation in temperature results for HDW was similar to that for BH, with a mean value of 29.7^0c. The turbidity of water samples from hand dug wells (HDW) and boreholes (BH) showed monthly mean results of 1.9 NTU for HDW and 0.9 for BH. Turbidities of HDW and that of BH followed similar trend throughout the period of the study. The monthly mean results were consistently higher for HDW than those for BH. The Total Dissolved Solids (TDS) for (HDW) and for (BH) had monthly mean results of 122.5 mg/l for HDW and 123.8 mg/l for BH. The results for both HDW and BH followed similar variation trends from month to month.

Result showed that all Physical parameters from the hand dug wells were within the acceptable limits, except temperature which had a mean value of 29.7 °C, which is higher than WHO (2006) guide line limit of 25 °C, but acceptable by NIS,SON(2007) and NAFDAC(2007) limits. Four (4) of the samples, appeared slightly coloured, but acceptable within the stipulated limit by NIS,SON (2007). Slightly coloured samples were recorded from hand dug well in Okra (HDW- O3). This was because the well had no cover and the opening edge was not raised high enough above the ground level, during rainfall peaks decayed materials are easily transported by surface runoff and by seepage into the well, hence the slight colouring of the water samples from the months of June to September (the rain peaks in the area). Turbidity, Total Dissolved Solids (TDS) were all found within the acceptable limits for drinking water.

The physical parameters analyzed from 6 boreholes showed that all the 72 water samples appeared colourless, odourless and tasteless, hence 'acceptable' for drinking. All the 72 water samples analyzed had temperatures above the stipulated maximum limit of 25 ºC (WHO, 2006) with a mean of 29.6 ºC for (BH) but acceptable under the town's ambient temperature.

Thus, both water samples from hand dug wells and boreholes showed high mean temperatures. The high mean temperature of Kaltungo town, Gombe state is obvious because it is in the northern part of Nigeria that is usually hot and dry. Kaltungo town is surrounded by mountainous crystalline rocks which have high heat retention capacity. The high water temperature could be attributed to heat transfer between water and the land surface (Egeneonu and Osuzu, 2005).

Turbidity and Total dissolved solids (TDS) monthly results showed that all the 72 samples had mean concentrations below maximum limits. This means the waters from the boreholes are safe from excess turbidity (unlike mean turbidity from wells which is twice of those from boreholes though also below maximum limit). This is expected because, Kaltungo town is known to be dominated by crystalline basement formations of igneous, metamorphic rocks and sandy soils devoid of clayey and loamy soils, (BSWB, 1983). Total dissolved solids (TDS) obtained in this study had mean concentration of 125.1 mg/l, which falls far below the maximum limit of 600 mg/l by WHO (2006; 2012) and 500 mg/l by Excess Total dissolved solids in water affect taste which may become unacceptable if dissolved above the range from 600 mg/l (acceptable limit) to 1200 mg/l (manageable limit) (EPA, 2012).

The paired sample T-Test of the difference between the mean values of water physical parameters from hand dug wells and bore holes at $P \geq 0.05$ shows that the p-value of temperatures (0.878), total dissolved solids (0.515) and ambient temperatures (0.339) obtained exceed the p-value level of 0.05 while the p-value of for turbidity (0.000) is lower than the p-value level of 0.05. This indicates that there was no significant difference between the mean temperature values, mean total dissolved solid values and ambient temperature values but there was significant difference between the mean turbidity values at $P \geq 0.05$.

B. Chemical Parameters

The monthly mean concentrations of the chemical parameters of water from hang dug wells and boreholes are presented in Table 3, while the paired sample t-test of mean concentrations of chemical parameters of water from hand dug wells and boreholes are shown in Table 4. The monthly mean pH from hand dug wells ranged from 6.6 to 7.5, while concentrations from boreholes ranged from 7.0 to 7.6.

Iron showed a monthly mean concentration in hand dug wells from 0.8 to 1.2 mg/l and boreholes ranged from 0.4 to 0.9 mg/l. The monthly mean concentrations of fluoride from hand dug wells ranged from 1.6 to 2.1 mg/l, while concentrations from boreholes ranged between 1.5 and 1.7 mg/l.

Table 1: Monthly Mean Concentrations of Water Physical Parameters from Hand Dug Wells and Boreholes

Parameter	Water Source	Months												Mean	Max limits
		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec		
Odour	Hand Wells	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt		
	Boreholes	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt	Acpt		
Colour	Hand Wells	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL		
	Boreholes	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL		
Taste	Hand Wells	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL		
	Boreholes	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL		
Temperature (ºC)	Hand Wells	29.4	30	29.4	30.4	29.5	29.8	29.3	29.4	30.2	29	30.1	29.3	29.7	25
	Boreholes	29.4	30	30.1	30.3	30	29.7	29.1	28.6	30.4	29.1	30	29.3	29.7	25
Turbidity (NTU)	Hand Wells	1.6	1.63	1.8	1.9	2.0	2.0	2.0	2.2	1.9	2.1	2.2	1.8	1.9	5
	Boreholes	0.8	0.8	0.7	0.9	0.8	0.9	0.9	1.0	0.9	1.2	1.1	1.0	0.9	5
TDS (mg/l)	Hand Wells	106.3	102.7	99.7	112.7	111.0	123.0	137.7	153.7	144.7	136.7	128.3	113.7	122.5	600
	Boreholes	112	106	108	115	106	135	138	142	141	135.2	128.3	118.5	123.8	600
Ambient Temp (ºC)	Hand Wells	29.8	30.2	30.0	29.8	29.5	30.5	31.3	30.0	29.0	30.1	30.3	29.9	30.0	25
	Boreholes	29.8	30.2	29.6	29.8	29.5	30.5	31.3	30.0	29.0	30.1	30.3	29.9	30.0	25

*Acpt = Acceptable
*CL = Colourless
*TL = Tasteless

Table 2: Paired Sample T-Test of Mean Concentrations of Physical Parameters of Water from Hand Dug Wells and Boreholes

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
Parameters	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Temperature (ºC)	-0.01667	0.36886	0.10648	-0.25103	0.21770	-0.157	11	0.878
Turbidity (NTU)	1.01083	0.14694	0.04242	0.91747	1.10419	23.831	11	0.000
TDS (mg/l)	-1.23333	6.35515	1.83457	-5.27120	2.80453	-0.672	11	0.515
Ambient Temp (ºC)	0.03333	0.11547	0.03333	-0.04003	0.10670	1.000	11	0.339

Table 3: Monthly Mean Concentrations of Water Chemical Parameters from Hand Dug Wells and Boreholes

Parameter	Water Source	Months												Mean	Max limits
		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec		
pH (mol/l)	Hand Wells	7.2	7.2	7.2	7.4	6.8	6.6	7.0	7.3	7.4	7.3	7.3	7.5	7.2	6.5-8.5
	Boreholes	7.0	7.1	7.0	7.3	7.3	7.0	7.4	7.6	7.3	7.1	7.2	7.1	7.2	6.5-8.5
Cl^- (mg/l)	Hand Wells	48.2	48.2	47.4	52.4	43.4	47.3	54.1	60.0	70.0	56.4	49.5	49.7	48.6	250
	Boreholes	58	61.9	70	73	65.5	64.2	76	86.2	81.5	56.9	60	62.2	68	250
Fe (mg/l)	Hand Wells	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.1	1.0	1.2	0.8	0.8	0.9	0.3
	Boreholes	0.5	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	0.6	0.4	0.4	0.7	0.3
Cu (mg/l)	Hand Wells	0.04	0.04	0.03	0.05	0.04	0.05	0.06	0.07	0.07	0.07	0.09	0.03	0.05	1.0
	Boreholes	0.06	0.06	0.06	0.07	0.06	0.7	0.9	0.9	0.9	0.06	0.09	0.05	0.33	1.0
Pb (mg/l)	Hand Wells	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01
	Boreholes	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Zn (mg/l)	Hand Wells	0.05	0.05	0.04	0.03	0.03	0.04	0.05	0.07	0.08	0.08	0.07	0.06	0.05	4.0
	Boreholes	0.06	0.06	0.05	0.05	0.06	0.06	0.09	0.1	0.09	0.1	0.07	0.07	0.06	4.0
F^- (mg/l)	Hand Wells	2.0	2.0	1.8	1.8	1.7	1.7	1.8	1.8	1.6	2.1	2.1	2.0	1.9	1.5
	Boreholes	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.6	1.5	1.5	1.6	1.5
Cd (µg/l)	Hand Wells	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.003
	Boreholes	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.003
NO_3^- (mg/l)	Hand Wells	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	45
	Boreholes	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.21	45
TH (mg/l)	Hand Wells	132.0	121.0	117.3	114.0	116.0	121.0	124.0	138.1	148.0	140	133	131	128	150
	Boreholes	146	147.4	150	149	130	137	140	177.3	160.2	161	153.2	149	139.2	150
TA (mg/l)	Hand Wells	X	X	x	145.3	171.0	187.0	199.3	138.1	148	X	x	X	164.8	200
	Boreholes	X	X	x	96	119.3	132	138.3	145	145	X	x	X	129.3	200
Cond (µS/cm)	Hand Wells	X	X	x	226.0	231.7	273.0	306.0	302.0	302.0	X	x	X	273.5	1000
	Boreholes	X	X	x	264.4	262.2	273.0	284.3	280	295	X	x	X	276.5	1000

*BDL = Below Detectable Level
*X: Laboratory Analysis was not done for these months.

Table 4: Paired Sample T-Test of Mean Concentrations of Chemical Parameters of Water from Hand Dug Wells and Boreholes

Paired Samples Test

Parameters	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
pH (mol/l)	-0.01667	0.29797	0.08602	-0.20599	0.17266	-0.194	11	0.850
Cl^- (mg/l)	-15.73333	7.30795	2.10962	-20.37658	-11.09009	-7.458	11	0.000
Fe (mg/l)	0.29167	0.14434	0.04167	0.19996	0.38337	7.000	11	0.000
Cu (mg/l)	-0.27250	0.38350	0.11071	-0.51617	-0.02883	-2.461	11	0.032
Zn (mg/l)	-0.01750	0.01138	0.00329	-0.02473	-0.01027	-5.326	11	0.000
F^- (mg/l)	0.27500	0.21794	0.06292	0.13652	0.41348	4.371	11	0.001
NO_3^- (mg/l)	-0.05833	0.05149	0.01486	-0.09105	-0.02562	-3.924	11	0.002
TH (mg/l)	-22.05833	9.12005	2.63273	-27.85294	-16.26373	-8.378	11	0.000
TA (mg/l)	35.51667	29.45297	12.02413	4.60767	66.42567	2.954	5	0.032
Cond (µS/cm)	-3.03333	25.89785	10.57275	-30.21146	24.14479	-.287	5	0.786

Copper had a monthly mean concentrations in hand dug wells from 0.03 to 0.09 mg/l and concentrations from boreholes ranged from 0.05 to 0.09 mg/l (Table 3). Cadmium mean values in hand dug wells and boreholes are all below detectable level (BDL). Lead values from both hand dug wells and boreholes are equally below detectable level. Nitrates mean concentration values from hand dug wells ranged between 0.1 to 0.2 mg/l while concentrations from those of boreholes ranged between 0.2 to 0.3 mg/l.Nitrates mean concentration values from hand dug wells ranged between 0.1 to 0.2 mg/l, while concentrations from those of boreholes ranged between 0.2 to 0.3 mg/l. Their concentration effects are explained under 'discussion'.

From literature and the general result, the most likely parameter that causes teeth mottling in the area of study is fluoride. Mean concentration values of fluoride from the 3 hand dug wells was found to be 1.9 mg/l, more prevalent than from the 6 boreholes with a mean of 1.6 mg/l (Table 3)((Figure 2). Both results showed high prevalence compared to the standard limit of 1.5mg/l set by (NIS/ SON/ NAFDAC 2007; WHO, 2012).

Hydrogen potential (pH) values of the analyzed water samples had a mean of 7.2. This indicated that the ground waters at hand dug well levels are within the acceptable level because the permitted range for drinking water ranges from 6.5 to 8.5, except one sample out of the 36 samples showed an acidic concentration of 6.3.

pH variation for this study area fluctuated within the permissible level in (HDW). Almost all other chemical parameters (Cl, Cu, Pb, Zn, Cd, NO3-, Total hardness (TH), Total alkalinity (TA) and Conductivity were below the recommended maximum limit except Iron and fluoride which were found to be above the recommended maximum limits.

Iron showed a mean concentration values of 0.90 mg/l. This value is by far above the acceptable stipulated maximum limit of 0.3 mg/l for (HDW). This result means Iron is high in the waters of Kaltungo town. The mean fluoride concentration was found to be 1.9 mg/l. This shows fluoride content was far above the stipulated maximum limit of 1.5 mg/l as recommended for drinking water by WHO (2006, 2012; NIS/SON/ NAFDAC, 2007)(Figure 2).

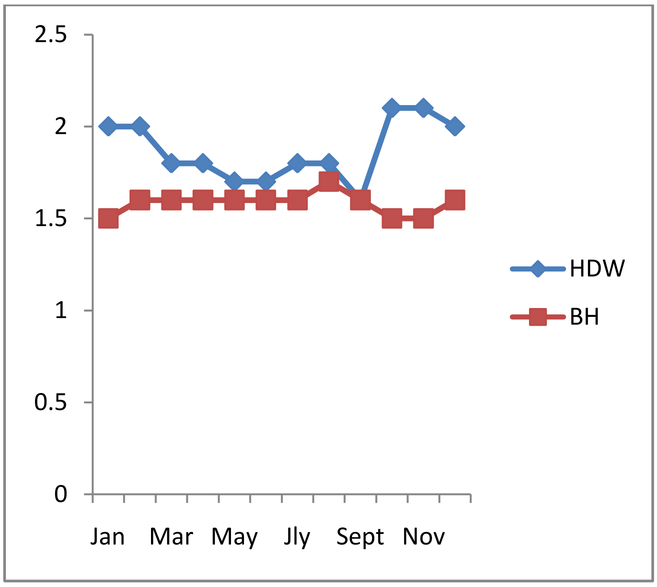

Figure 2: Compared Prevalence Concentration of Fluoride in HDW and BH

pH values of the analyzed water samples had mean concentration of 7.2. The bench marks for pH in drinking water ranged from 6.5 – 8.5. From this study, 3 samples out of the 72 samples showed an acidic concentration of 6.2, 6.3, and 6.4 pH respectively. This result also indicated that only 4 samples had pH at 6.5 range, and non above the 8.5 stipulated maximum limits for (BH). By comparison, both pH from hand dug wells and boreholes are all within the permissible limit for drinking water, although the variation showed that pH from boreholes are alkaline higher than pH from hand dug wells.

Low pH in waters (from 1 - 6 levels which is acidic in nature) can cause corrosion of pipes and leaching of metals which may elevate certain chemicals such as Lead to cause renal damage in humans (Park, 2005). From the mean concentrations of pH in the study area, it is an indication that the water is generally more alkaline than acidic. pH of a solution can affect the toxicity of other elements and has very pronounced effect on many chemical reactions which are important to industry, irrigation and domestic water treatment. pH value falling below 7 indicates the acidic nature of the water. This also accelerates the corrosion rate of metallic substances in water (Pradhan and Pirasteh, 2011).

All other chemical parameters (Cl, Cu, Pb, Zn, Cd, NO3-, TH, TA and conductivity) were below the recommended maximum limit, except Iron and fluoride which were found to be above the recommended maximum limits.

The chloride values from bore holes had a mean concentration of 68 mg/l. This means chloride content was equally below the maximum limit of 250 mg/l for drinking water indicating that the waters are also safe. However, the concentrations of chloride content from boreholes are higher than those from hand dug wells. Chlorides are very soluble in water and easily seep deeply into groundwater because it is a non reactive solute; hence it is regarded as a ubiquitous (very common) to sewage and potable water. Chlorides are the most stable components in water and its concentration is largely unaffected by most natural physico-chemical and biochemical processes. Presently scientists use its presence in water as a useful measure and reliable chemical indicator of river/ groundwater fecal contamination. Many water regulating companies around the world utilize chloride to check the contamination levels of the rivers and potable water sources (GA, 2011).Therefore, high concentration of chlorides in boreholes of Kaltungo town could be due to transportation of chloride ions by seepage from around the toilets into the boreholes which are deeper than the shallow hand dug wells.

The Iron values had mean concentration of 0.65 mg/l. This value is also far above the acceptable maximum limit of 0.3 mg/l, for (BH). Both samples from hand dug wells and boreholes therefore showed high iron content, but Iron content in hand dug wells are higher than those found in boreholes. This could be attributed to the presence of minerals usually associated with shale, crystalline basement rocks, sandstones and iron stones in Kaltungo area (Carter et al 1963), which are main sources of Iron. Minerals like mica, amphiboles, and hornblende are identified with rocks of crystalline basement rocks (Driscall, 1986) which are also sources of Iron releases. Iron in hand dug wells being higher than those found in boreholes could be due to Iron releases by decomposition from the rocky mountains which surrounds Kaltungo town and in the rainy season are washed and transported by running water into the wells by seepage because most of them are shallow wells between the depth of 5-25 m as against boreholes which are deep within the range of 25- 200 m (Agunwamba, 2008) and groundwater is highly filtered before getting to the boreholes.

High levels of Iron in water may produce bad odour and taste, which may affect the potability of water (Shiklemanov, 2000), and alters the appearance of the water. Iron deposit also cause staining of plumbing fixtures and laundry (AWWA, 2007).

The fluoride concentration mean value for boreholes was 1.60 mg/l. This showed fluoride content was still above the stipulated maximum limit of 1.5 mg/l. Studies from both hand dug wells and boreholes results indicated high level of fluoride in the ground waters of Kaltungo town. The high level of fluoride in the groundwater may be due to the igneous and metamorphic rocks which are reported to contain fluorite minerals. Granite rocks of these areas are reported to contain minerals like fluomica, fluorapatite, amphiboles, pyrexes, etc, in Kaltungo area which are good sources of fluorine (Carter et al 1963). Another explanation for the fluoride- rich waters could be the weathering of the fluoride-bearing minerals in rocks and soils in the area. A borehole log recorded during drillings confirmed the presence of fluoride bearing mineral accessories in Kaltungo area (BSWB, 1983). Therefore, variation in fluoride concentration in hand dug wells (which was higher) and that of bore holes could be due to basement complex, i.e., underlying formation in the area.

Low levels of fluoride (0.00 – 0.6) mg/l, in drinking water can cause dental caries (tooth decay), but if level is within the acceptable range (0.7 – 1.5 mg/l), it prevents tooth decay (Park, 2005), while high level of fluoride (from 1.6 mg/l and above), in drinking water causes fluorosis (pains and tenderness of bones) and teeth mottling among the inhabitants, especially children of primary school age (Nanyaro et al 1984), (Mcdongh et al 2004). The above conditions can be prevalent among consumers of the water with high fluoride contents. Therefore it can be concluded that, among the children that grow up in Kaltungo town, what is noticed on their teeth is teeth mottling caused by high level of fluoride content from concentration level of 1.6 mg/l and 1.9mg/l as indicated in this study for both hand dug wells and borehole waters. Though by way of comparison, fluoride concentrations were higher in hand dug wells than in boreholes. Fluoride contents in both sources were higher than maximum recommended limit.

The paired sample T-Test of the difference between the mean values of water chemical parameters from hand dug wells and bore holes at $P \geq 0.05$ shows that the p-values are Cl - (0.000), Fe (0.000), Cu (0.032), Zn (0.000), F - (0.001), NO3 - (0.002), TH (0.000) and TA (0.032) obtained are below the p-value level of 0.05 while the p-value for pH (0.850) and Conductivity (0.786) exceed the p-value level of 0.05. This indicates that there was significant difference between the mean Cl -, Fe, Cu, Zn, F -, NO3, TH and TA values but there was no significant difference between the mean pH and Cond values at $P \geq 0.05$.

CONCLUSION

Groundwater quality assessments of Kaltungo were carried out for a period of one year. Physical characteristics of odour, colour, turbidity, total dissolved solids and taste were found to be within the acceptable recommended limits prescribed for human consumption. Temperature was found to be above the maximum limit of WHO guideline, but within the acceptable range set by Nigerian standards. The paired sample T-Test of the difference between the mean values of water physical parameters from hand dug wells and bore holes at $P \geq 0.05$ showed there was no significant difference between the mean temperature values, mean total dissolved solid values and ambient temperature values but there was significant difference between the mean turbidity values at $P \geq 0.05$.

Most of the chemical characteristics varied in concentrations and were all found within the acceptable maximum limits for drinking water, except Iron and fluoride which, were far above the stipulated maximum limit for drinking water.

High concentration of Fluoride has been the cause of teeth mottling among children while developing their teeth at tender age. Kaltungo Local Government council should construct a central water treatment plant in the town where sources of water from various boreholes will be pumped into, and treated to reduce the high concentration of fluoride in the water before pumping out for public consumption. Attempts can also be made to treat water to reduce Iron which is also above the recommended limit of 0.3 mg/l.

The paired sample T-Test of the difference between the mean values of water chemical parameters from hand dug wells and bore holes at $P \geq 0.05$ shows that there was significant difference between the mean Cl -, Fe, Cu, Zn, F -, NO3 -, TH and TA values but there was no significant difference between the mean pH and Conductivity values at $P \geq 0.05$.

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