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Assessment of Groundwater Quality in Ankpa Urban Kogi State, Nigeria

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Abstract: This study was conducted to assess the physical, chemical and bacteriological quality of groundwater in Ankpa Urban Area of Kogi State. Ten water samples were collected in August 2013 from boreholes located across the five wards that make up the urban area for analysis using standard laboratory techniques. Twenty three water quality parameters; temperature, pH, Electrolytic Conductivity (EC), Turbidity, Total Solid (TS), Total Suspended Solid (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen demand (COD), Calcium (Ca), Sulphate (SO_4^-), Lead (Pb), Magnesium (Mg), Sodium (Na), Copper (Cu), Potassium (K), Nitrates (NO_3^-), Cadmium (Cd), Alkalinity, Iron (Fe) and two microbiological parameters (*E. coli* and total coliform) were investigated and reported on. From the results, the water based on the parameters analyzed is relatively of good quality even though Cadmium, Iron and lead returned values which were above the WHO and Nigeria Standard for Drinking Water guidelines. Others parameters returned values which were either very low or closely approximated the limits recommended in the WHO and NSDWQ guidelines for drinking water. The bacteriological qualities of the water samples in the area were also within the recommended guidelines. The study advances appropriate recommendations to ensure that as Ankpa gets urbanized, groundwater resources within the area will remain properly managed to avoid pollution and in addition, meet the demands of the growing urban population.

Key words: Groundwater, water quality, urban population, pollutants, implications

INTRODUCTION

Nigeria is endowed with abundant groundwater resources estimated to be about 51.9 billion m^3 per annum (FMWR, 2007). As groundwater percolates through soil, sediment and rocks, many impurities such as disease-causing micro-organisms are filtered out (Freeze and Cherry, 1979). Nevertheless, groundwater can still and is often be polluted by surface runoff, feedlots, domestic sewage as well as by other sources of pollution (Gray, 2008; Fasunwon *et al*., 2008). Contaminants can also find their way into groundwater through activities like seepage of leachate, municipal landfills, septic tank effluents, etc. Also, the subsurface geology of an area may influence aquifers vulnerability to contamination. For instance if the subsurface geology allows rapid downward infiltration of water from the surface runoff, the aquifer may become very vulnerable to contamination (Fasuwon *et al*., 2008).

Therefore, the assessment of the suitability of groundwater for various purposes such as irrigation, drinking and manufacturing activities is not only essential but is frequently undertaken across the globe to determine the concentrations of some important parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Calcium (Ca), Sulphate (SO_4^-), Lead (Pb), Magnesium (Mg), Sodium (Na), Copper (Cu), Potassium (K), Nitrates (NO_3^-), Cadmium (Cd), Chlorine (Cl) and using appropriate guidelines stipulated by WHO and other national agencies (Srinivasamoorthy *et al*., 2009). This is because evaluation of water quality prior to its use will assist in freeing from water-borne diseases and other attendant problems associated with impaired water. It will also guide other users such as farmers in preventing probable deleterious effect on plant productivity or manufacturers in protecting industrial equipment against incrustation and corrosion, respectively.

The World Health Organization (WHO) had frequently and constantly noted that the single major factor adversely influencing the general health and life expectancy of a population in many developing countries is ready access to clean drinking water. Also, the United Nations estimated that about 1.2 billion people all over the world lack access to portable water (Oyeku *et al*., 2001; Ajewole, 2005). While Dada and Ntukekpo (1997) stressed that in the developing nations of the world, 80% of all diseases and over 30% of deaths are related to drinking water. Obviously, the usefulness of water depends not only on whether such water is timely and is of adequate quantity but also on its quality. In Nigeria, potable water

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is often accessed from both surface and underground sources. High rates of water-related diseases have been reported in many parts especially among women and children (Chima and Okpe, 2007).

In Ankpa Urban (the study area), the number of bore-holes and hand-dug wells keep increasing annually to meet the ever growing water demand arising from the influx of population into the area. Currently groundwater is the principal and the most sustainable source of drinking water for the people. The increasing groundwater usage is based on the fact that groundwater is believed to be both adequate and less polluted, since it is filtered as it percolates down the soil profile into the aquifer. However, the groundwater quality is uncertain. Groundwater contamination has been reported in various parts of the world and the danger is that once contaminated, it is difficult and costly to restore its quality. Hence, there is the need to evaluate the quality of groundwater used for domestic and other purposes. This is important for characterization and for the protection of users' health particularly in the study area where the water is the most dependable source of water for domestic and other uses.

MATERIALS AND METHODS

The study area: Ankpa Urban area is the oldest and fastest growing urban area in Kogi State. It lies appropriately between Latitudes 7°16'N and 7°4'N and Longitudes 7°22'E and 7°51'E. The area has warm Tropical Savannah Climate with clearly marked wet and dry seasons (Ali, 2010). Rainfall is well distributed and is of double maxima (Iloeje, 1980). The amount of rainfall ranges between 1,000-750 mm. Temperature is moderately high throughout the year, averaging 25°C. The maximum temperature of the area lies between 29.7-35.6°C while the minimum temperature ranges between 23.3 and 25.2°C (Ali, 2010).

The geology of the area is the false bedded sandstone of the Ajali and Mamu formations which falls within the Anambra Basin. These formations consist of thick friable poorly sorted sandstone, well drained soils, red or reddish brown in colour and sandy surface horizons which occur on the crest of inter-fluves and on upper and middle slopes. The vegetation is that of the Guinea Savannah type and is characterized by scattered trees, most of which are deciduous.

Water sample collection: Ankpa Urban is made up of five long-standing wards, these are: Ankpa Township, Ankpa Suburb I, Ankpa Suburb II, Ankpa I, Ankpa II. Based on this delineation and observations during field survey, researchers selected two boreholes from each ward for groundwater sample collection. The selection of the sample site was guided by the centrality of the borehole and the readiness of the owners to allow samples to be collected for the study. The Global Positioning System (GPS) was used to determine co-ordinates of sampled boreholes as shown in Table 1. Figure 1 shows the spatial distribution of the sampled sites.

Two sets of groundwater samples were collected from ten boreholes within the five wards that make up the study area. The samples were collected from the boreholes after agitation for about 10 min in order to remove stored groundwater in the reservoir (Todd and Mays, 2005). Water samples were collected in August 2013. Sample rubber bottles of volume 2 L were label with the aid of indelible ink to prevent misidentification and thoroughly rinsed with distilled water. Upon reaching the sampling site, each container was again rinsed with water from the respective borehole water, thrice, before actual sample collection was taken. This is to prevent any likely contamination from the containers used for the samples.

Laboratory analysis: Laboratory analysis of water samples collected from boreholes in the study area were carried out in the Department of Soil and Environment Management, Kogi State University, Anyigba to determine their physical, chemical and biological properties. Standard equipment and procedures were adopted during the analysis. WHO drinking water quality guidelines formed the basis of the comparison. This is because according to McDonald and Kay in Nigeria the Federal and State Governments are guided by the recommendations of World Health Organization and Food and Agriculture Organization of the United Nations in their environmental policies. The parameters analyzed are shown in column one of Table 2-4.

Data analysis: Simple descriptive statistics were used to interpret the raw data on the physicochemical and bacteriological parameters generated in the cause of this investigation.

Table 1: Sample locations, sources, coodinates and identification codes

Code No.	Latitude	Longitude	Location	Ward name
GW1	N 7°24'55.6"	E 007°37'26.2"	Opulega	Ankpa township
GW2	N 7°23'59.1"	E 007°37'58"	Sabongari	Ankpa township
GW3	N 7°21'49.1"	E 007°37'43.3"	Ojelanyi	Ankpa suburb I
GW4	N 7°23'03.2"	E 007°37'36.1"	Coe area	Ankpa suburb I
GW5	N 7°23'32.9"	E 007°37'48.9"	Owelle	Ankpa suburb II
GW6	N 7°23'42.0"	E 007°37'00.4"	Ojede	Ankpa suburb II
GW7	N 7°26'04.0"	E 007°37'31.5"	Ejegbo	Ankpa I
GW8	N 7°24'48.6"	E 007°38'23.3"	Gra/Area 1	Ankpa I
GW9	N 7°24'11.3"	E 007°38'43.0"	Allor	Ankpa II
GW10	N 7°24'11.6"	E 007°38'42.9"	Ugolo/Allor new laypout	Ankpa II

GW = Ground Water; researcher's fieldwork, 2013

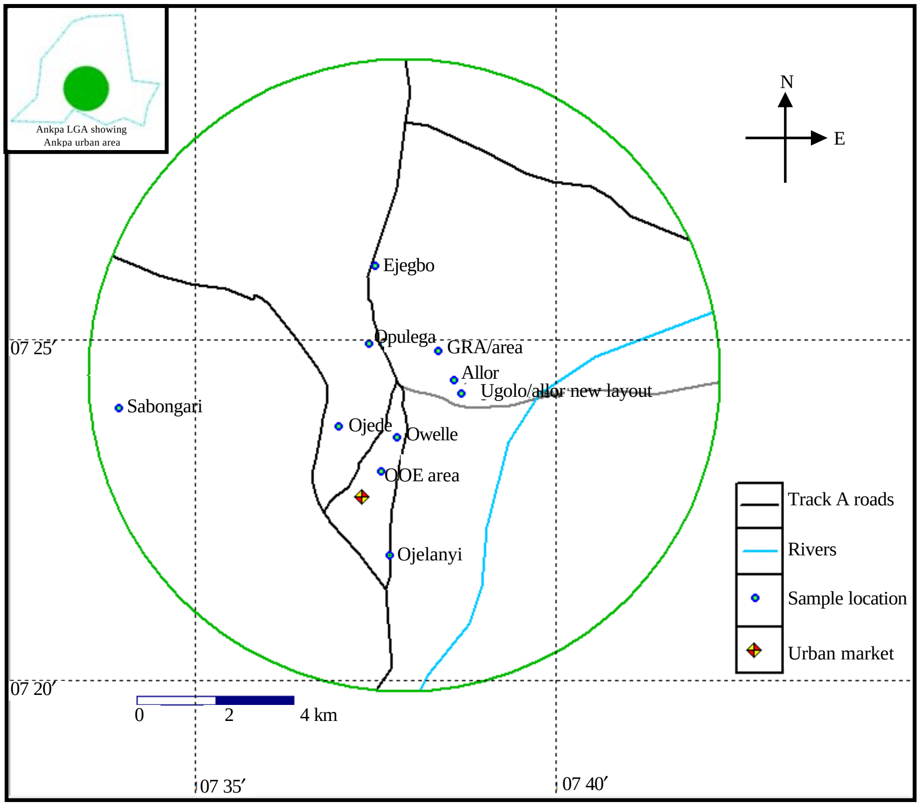

Fig. 1: Map of Ankpa urban area showing sample locations, cordinates and identification codes

Table 2: Physical characteristics of ground waters samples analysis in Ankpa urban

Parameters	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	Total	Mean	WHO	NSDWQ
Temperature (°C)	25.00	30.00	24.80	25.4	25.70	24.50	24.60	25.40	26.0	24.80	256.20	25.620	25	27-28
TS (mg L^{-1})	447.04	32.02	33.01	44.0	37.01	447.05	32.01	33.03	43.0	37.11	1185.28	118.528	-	-
TDS (mg L^{-1})	447.00	32.00	33.00	44.0	37.00	447.00	32.00	33.10	43.0	37.10	1185.20	118.520	500	500
TSS (mg L^{-1})	0.04	0.02	0.01	Nil	0.01	0.05	0.01	0.07	Nil	0.01	0.22	0.022	1	-
EC (mS cm^{-1})	0.65	0.03	0.06	0.06	0.05	0.65	0.04	0.05	0.05	0.04	1.68	0.168	400	1000
DO (mg L^{-1})	2.01	1.35	1.44	1.61	1.52	2.11	1.36	1.43	1.60	1.51	15.94	1.594	6	-
BOD (mg L^{-1})	1.30	1.90	1.70	2.1	3.80	2.30	1.40	1.20	1.10	3.60	20.40	2.040	10	-
COD (mg L^{-1})	3.20	2.70	1.80	5.6	3.40	4.60	2.30	3.90	4.70	5.40	37.60	3.760	10-20	-
Turbidity (NTU)	1.21	1.01	1.00	1.03	1.03	1.20	1.04	1.00	1.02	1.03	10.57	1.057	5	5

Table 3: Chemical characteristics of ground waters samples analysis in Ankpa urban

Parameters	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	Total	Mean	WHO	NSDWQ
pH	7.200	8.200	8.100	7.700	8.1	7.200	7.500	8.100	7.600	8.0	77.700	7.7700	6.5-8.5	6.5-8.5
Ca (mg L^{-1})	74.010	0.240	0.980	0.380	0.90	73.010	0.240	0.970	0.370	0.80	151.900	15.1900	75-200	-
K (mg L^{-1})	27.300	1.020	0.280	0.340	0.30	26.300	1.030	0.260	0.350	0.31	57.490	5.7490	-	-
Mg (mg L^{-1})	6.210	0.310	4.920	2.330	3.04	6.230	0.330	4.910	2.350	3.03	33.660	3.3660	200	0.20
Na (mg L^{-1})	33.280	1.240	0.840	4.280	1.44	33.270	1.230	0.830	4.290	1.45	82.150	8.2150	200	200
Cu (mg L^{-1})	0.240	0.110	0.190	0.160	0.08	0.220	0.120	0.180	0.150	0.07	1.520	0.1520	1.0	1.0
Fe (mg L^{-1})	5.510*	4.680*	4.390*	3.080*	3.33*	4.510*	4.660*	4.400*	3.070*	3.32*	40.950	4.0950	0.3	0.3
Cd (mg L^{-1})	0.100*	0.020*	0.010*	0.020*	ND	0.110*	0.030*	0.040*	0.020*	ND	0.350	0.0350	0.003	0.003
Pb (mg L^{-1})	0.210*	0.060*	0.120*	0.040*	0.03*	0.200*	0.040*	0.110*	0.030*	0.02*	0.860	0.0860	0.01	0.01
SO_4^- (mg L^{-1})	0.078	0.010	0.030	0.020	0.020	0.077	0.010	0.032	0.020	0.021	0.318	0.0318	100	100
NO_3^- (mg L^{-1})	0.046	0.019	0.028	0.024	0.020	0.045	0.017	0.026	0.024	0.020	0.269	0.0269	10	50
Alkalinity (mg L^{-1})	2.030	2.690	2.420	2.230	2.400	2.050	2.670	2.410	2.220	2.41	23.530	2.3530	80-120	-

*Above who limit

Table 4: Microbiological characteristics of ground waters samples analysis in Ankpa urban

Parameters	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	Total	Mean	WHO	NSDWQ
E. coli (cfu/100 m)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00	0.000	0	0
Total coliform (cfu/100 m)	2.11	0.67	0.78	0.35	0.85	1.12	1.00	0.10	0.11	0.85	7.94	0.794	10	10

ND = Not Detected

RESULTS AND DISCUSSION

Results of the physical parameters: The results of the physical parameters analyzed are summarized in Table 2.

Temperature: Temperature is an important biologically significant factor which plays an important role in the metabolic activities of organisms. It is also an important parameter in determining water quality as it influences pH, alkalinity, acidity and Dissolved Oxygen (DO). The temperature values recorded in water samples from the study area ranges between 24.6 and 30°C as summarized in Fig. 2 with mean temperature of 25.62, respectively. Therefore, the temperature values recorded were within the WHO standard for drinking water except GW2 in Ankpa Township ward that outstripped the WHO stipulated limit. Thus, this might retard dissolution of oxygen and therefore could amplify odour due anaerobic reaction at point GW2 with which the water conceivably unwholesome for drinking.

Total Solid (TS): The minimum TS value of 32.01 mg L^{-1} was recorded in GW7 while the maximum value of 447.05 mg L^{-1} was recorded in GW6 (Fig. 3). No limit have been set by WHO for drinking water and domestic uses but water with values similar to this has previously been described as good (WHO, 1997).

Total Suspended Solids (TSS): In the water samples analyzed, the minimum total suspended solids value found was 0 mg L^{-1} while the maximum value was 0.07 mg L^{-1} (Fig. 4) from samples GW4 and GW6, respectively. TSS values in all water samples were far below the WHO recommended standard which is an indication of good water quality. The total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of Ca, Mg, Na, K, Mn, organic matter, salt and other particles. The effect of presence of total suspended solids is the turbidity due to silt and organic matter. When the concentration of suspended solids is high it may be aesthetically unsatisfactory for bathing (APHA, 2002).

Total Dissolved Solids (TDS): These are the measure of total inorganic substances dissolved in water (ANZECC, 2000). It indicates the general nature of water quality or salinity. Increase level of TDS decrease portability of water and may cause gastrointestinal irritation in human and may also have laxative effect particularly upon transits (WHO, 1997). Values of total dissolved solids concentrations was found in the water samples in the five wards to vary from 32-447 mg L^{-1} with a mean value of 118.52 mg L^{-1} (Fig. 5). GW1 and GW6 returned the highest concentrations values of TDS although not above the WHO limit of 500 mg L^{-1}. The range for TDS follows the same trend as conductivity,

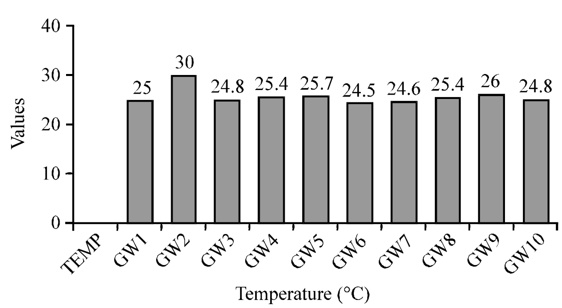

Fig. 2: Temperature values of sampled boreholes

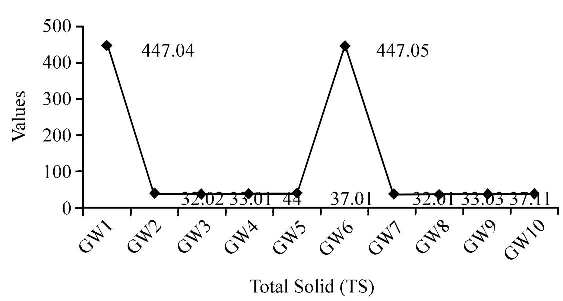

Fig. 3: Values of total solids in the water samples

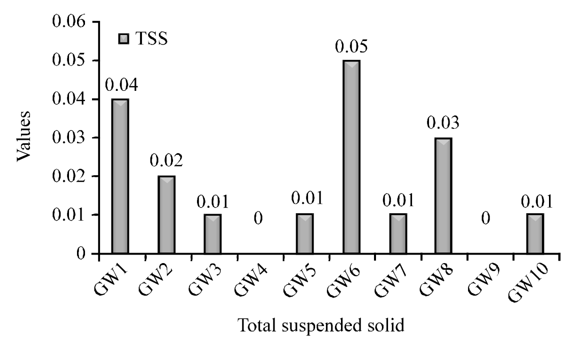

Fig. 4: Values of total suspended solids in the water samples

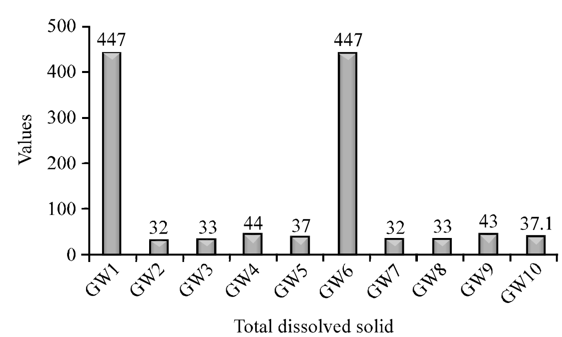

Fig. 5: Values of total dissolved solids in the water samples

where by water samples from GW1 and GW6 registered the highest values, respectively. This also confirms that conductivity is a function of amount of dissolved solutes (Ademoroti, 1996), although conductivity also depends on the nature of the dissolve solutes (Sharma and Sharma, 2000). The TDS concentrations of samples from all areas fell within the acceptable standard or limit for drinking water.

Electrical Conductivity (EC): Electrical Conductivity (EC) is a measure of water capacity to convey electric current. It's a determination of levels of inorganic constituents in water (Awofolu *et al*., 2007). It signifies the amount of total dissolved salts (Morrison *et al*., 2001; Sudhir and Amarjeet, 1999). EC values returned by the samples were in the range of 0.65-0.03 mS cm^{-1} (Fig. 6). The Electrical Conductivity (EC) from the analysis was far below the WHO recommended value of 400 mS cm^{-1} value indicating low amount of dissolved inorganic substances in ionized form. Consequently, the parameter does not give concern as waters from all the wards are suitable for domestic use.

Dissolved Oxygen (DO): Dissolved oxygen is an important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water. The DO values indicate the degree of pollution in water bodies. DO values as shown in Fig. 7 varied from 1.35-2.0.1 mg L^{-1}. This range was regarded as being acceptable even though they were lower than the recommended value of 6.0 mg L^{-1} by the WHO standards for drinking water.

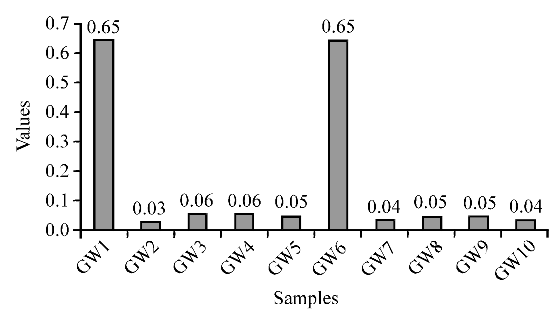

Fig. 6: Values of electrical conductivity in the samples

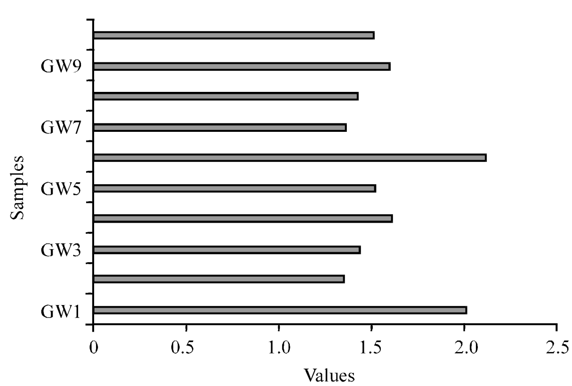

Fig. 7: Values of dissolved oxygen in the samples

Biochemical Oxygen Demand (BOD): The values returned under Biochemical Oxygen Demand (BOD) as shown in Fig. 8 range from 1.1-3.6 mg L^{-1} with a mean of 2.04 mg L^{-1}. The values are quite lower than the WHO recommended standard of 10 mg L^{-1} and so are acceptable. Itah and Akpan (2005) also obtained value which ranged from 0.16-3.40 mg L^{-1} from a similar study of borehole water samples from the oil impacted community in Eastern Obolo of Akwa Ibom State.

Chemical Oxygen Demand (COD): Chemical Oxygen Demand (COD) is also an important parameter of water quality assessment. According to WHO (2004), COD standard for drinking is within the range of 10-20 mg L^{-1}. The COD value obtained in this study ranges between 5.6-1.8 mg L^{-1} (Fig. 9). This is within the recommended limit by WHO. The possible reason for this occurrence might be due to the fact that the ground water samples were not polluted with both oxidizable organic and inorganic pollutants.

Turbidity: Turbidity is caused by suspended matter or impurities that interfere with the clarity of the water. These

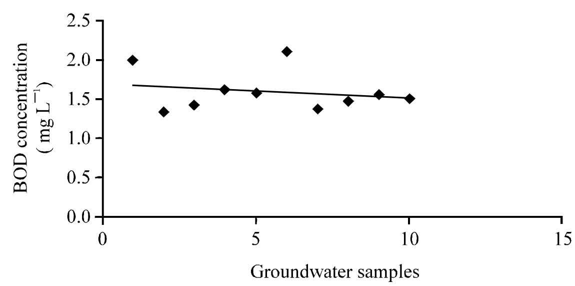

Fig. 8: Values biochemical oxygen demand in the samples

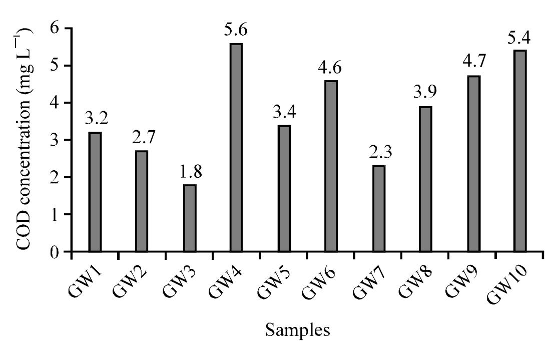

Fig. 9: Values of chemical oxygen demand in the samples

impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds and plankton and other microscopic organisms. Laboratory analysis revealed that the mean turbidity value of the groundwater water was 1.057 NTU while the range is 1.0-1.21 NTU. This means water samples from all the study sites were suitable for human consumption as their turbidity values does not exceeded the maximum allowable limit recommended by both the national and international drinking water regulatory authorities. Excessive turbidity in drinking water, apart from being aesthetically unappealing, may also present a health threat by providing food and shelter to pathogens.

Results of the chemical parameters: The results of the chemical parameters analyzed are summarized in Table 3.

pH: The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. Basically, the pH is determined by the amount of dissolved carbon dioxide (CO_2) which forms carbonic acid in water. According to Todd (1980), pH of ground water can also be lowered by organic acids from decaying vegetation or the dissolution of sulfide minerals. A low value, below 4.0 will produce sour taste and higher value above 8.5 shows alkaline taste. The pH values of the groundwater sampled in the area varied from 7.2-8.2 (Fig. 10) as against the WHO standard range of 6.50-8.50 and with mean value of 7.77. According to Stumn and Morgan (1981) pH value of natural water ranged from 6.0-9.0, hence the pH value of areas fall within the WHO set standard for drinking water.

Calcium (Ca^{2+}): The concentration of calcium ions (Ca^{2+}) in the water samples of the five wards ranges between 0.24 and 74.01 mg L^{-1} (Fig. 11) with a mean of 15.19 mg L^{-1}. These are below the 200 mg L^{-1} standard or limit set by the WHO for drinking water. Water samples in all the wards were characterized by low calcium ion except GW1 and GW6 where higher values of 74.01 and 73.01 mg L^{-1} were recorded. Ahmed *et al*. (2000) reported calcium concentration in groundwater of Khartoum State, Sudan in the range of 10.4-93 mg L^{-1}. Hoko (2008) found levels of calcium in the range of 6-71.6 mg L^{-1} in the groundwater of Bindura in Zimabwe. Calcium is a dietary mineral that is present in the human body in amounts of about 1.2 kg and no other element is more abundant in the body (ODNR, 1997). However, excessive intakes of calcium in drinking water have adverse effects as it can cause hypercalcemia (elevated levels of calcium in the blood), impaired kidney function and decreased absorption of other minerals such as iron, zinc, magnesium and phosphorus (NIHCC, 2009).

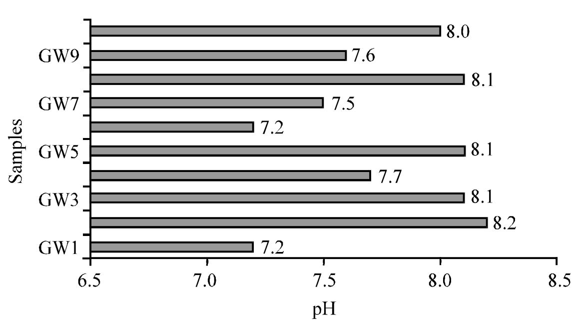

Fig. 10: pH values of the groundwater samples

Potassium (K^+): The major source of potassium in natural fresh water is weathering of rocks (Trivedy and Goel, 1986). Potassium content in the water samples varied from 0.28-27.3 mg L^{-1} (Fig. 12). It is found that the contents of potassium in GW1 and GW6 (27.3 and 26.3 mg L^{-1}) are higher than the rest of the sample points. The high value in GW1 and GW6 might be due to the presence of geochemical strata in both boreholes (Mahananda *et al*.,

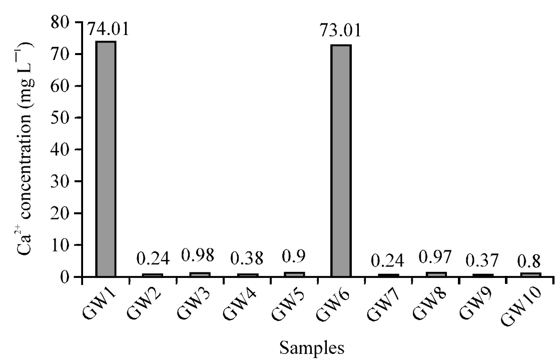

Fig. 11: Calcium concentration values in the water samples

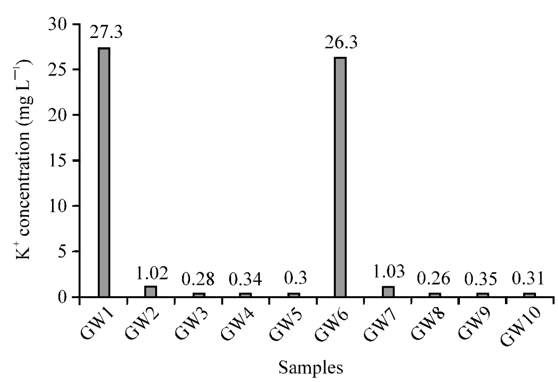

Fig. 12: Values of potassium concentration in the water samples

2010). No guide and acceptable limits have been specified for potassium levels in the WHO standards for drinking water.

Magnesium (Mg^{2+}): Magnesium ions are directly related to hardness. Magnesium content in the investigated water samples was ranging from 6.23-0.31 mg L^{-1} (Fig. 13) which are below the WHO guidelines of 200 mg L^{-1}. It is known that Ca^{2+} and Mg^{2+} ions in water are essential for human health and metabolism (Kortatsi, 2007).

Sodium (Na^{+}): Figure 14 shows the variation in sodium content of boreholes in the study area. The sodium content ranged from a minimum of 0.83 mg L^{-1} to a maximum of 33.28 mg L^{-1} (Fig. 14), respectively. The minimum value of 0.83 mg L^{-1} in GW8 and 0.84 mg L^{-1} in GW3 samples, respectively can be explained on the basis of lower microbial activity. While the maximum value of 33.28 mg L^{-1} in GW1 and 33.27 mg L^{-1} in GW6 might be due to high rate of mineralization in the sediments, increasing sodium concentration into the nutrient pool which make more sodium to solubilize. No limit is established by WHO for drinking water but a maximum standard of 100 mg L^{-1} has been proposed for general public (Mahananda *et al.*, 2010).

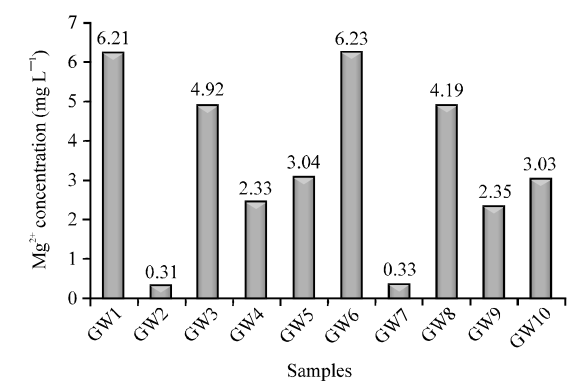

Fig. 13: Values of magnesium concentration in the samples

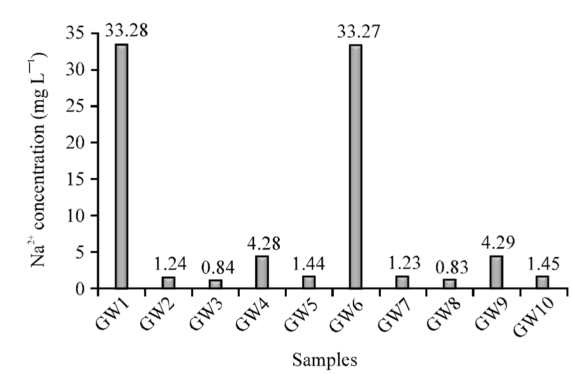

Fig. 14: Values of sodium concentration in the samples

Copper (Cu^{2+}): Copper detected in the water samples collected from the wards was very low and far below the recommended limits of 1.0 mg L^{-1} set by WHO (Fig. 15). Copper concentration was observed to vary from 0.07-0.24 mg L^{-1} with a mean of 0.152 mg L^{-1} for all the samples. Therefore, the levels of copper in the borehole water in the metropolis are not likely to cause any adverse impact on human health.

Iron (Fe^{2+}): Most groundwater supplies contain some iron because it is one of the most abundant metals in the earth crust and is essential for plant and human being. But excess iron in drinking water produces inky taste and muddy smelling (Sharma and Kaur, 1997). The world health organization recommends that the iron content of drinking water should not be greater than 0.3 mg L^{-1} because iron in water stains plumbing fixtures, cloths during laundering, incrusts well screens and clogs pipes (Deutsch, 2003). All the boreholes analyzed in Ankpa urban returned values which fell within the range 3.08-5.51 mg L^{-1} (Fig. 16) with a mean 4.095 mg L^{-1}. Total iron (Fe^{2+}) concentration in the water samples were above the WHO guideline (WHO, 2011). This can lead to the

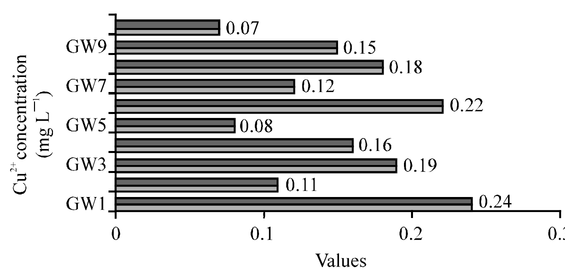

Fig. 15: Values of copper concentration in the samples

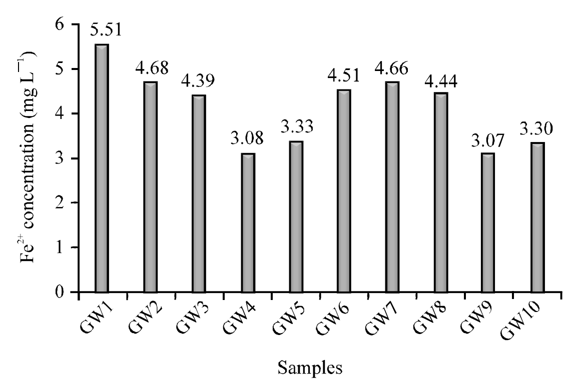

Fig. 16: Values of iron concentration in the samples

formation of blue baby syndrome in babies and goitre in adults as a results of consumption of water with large quantity of iron above the specified values (Ogedengbe and Akinbile, 2004; Shyamala *et al*., 2008).

Cadmium: Cadmium level was investigated for all the samples and it was observed that this element was detected in all the samples and was greater than the permissible limit of 0.003 mg L^{-1} set by both the WHO and NSDWQ. This could be attributed to the geological composition of the area. However, the element was not detected in GW5 and GW10. The concentrations of Cadmium varied from 0-0.11 mg L^{-1} (Fig. 17). Excess Cadmium concentration in water is highly toxic and is responsible for adverse renal arterial changes in kidneys (Sanjoy and Rakesh, 2013).

Lead: Lead level in all the samples were in the range of 0.02-0.21 mg L^{-1} with a mean value of 0.086 mg L^{-1}. Relative lead concentration for individual samples is also indicated in Fig. 18. GW10 has the least lead content and GW1 has the highest. The WHO has recommended 0.01 mg L^{-1} as the permissible limit for lead in drinking

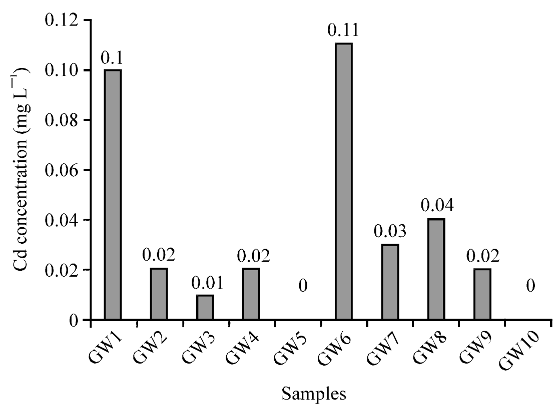

Fig. 17: Values of cadmium concentration in the samples

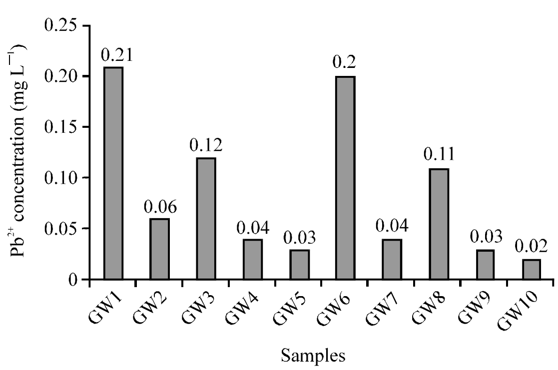

Fig. 18: Values of lead concentration in the samples

water and this could be of health concern to children within the age of 5 and below (WHO, 2011). Elevated lead level in borehole water at a concentration beyond this guideline value had also been reported in Zaria by Musa *et al*. (2004). This high concentration may be due to the geological composition of the area which is likely to be rich in lead.

Sulphate: Sulphate content in excess of 100 mg L^{-1} tends to give water a bitter taste and has a laxative effect on people not adapted to the water (Ibrahim and Ajibade, 2012). Also, ailment like catharsis, dehydration and gastrointestinal irritation have been linked with it when concentration is high (Bertram and Balance, 1996). In the water samples analyzed, the results revealed that all the water sampled have low sulphate content ranging from 0.010-0.078 mg L^{-1} (Fig. 19). Although, most water sources in the study area are of low sulphate content when compared to WHO permissive level they are considered to be within the limits set standard. In general, the SO_4^- ions are derived from rock weathering and pollution. Apart from the natural rock sources, sulphates can also be derived from the application of sulphatic soil conditioners (Karanth, 1987). Besides, sulphate reduction by bacteria has been established by the presence of bacterial genus *Desulfovibrio* (Jorgensen, 1982).

Nitrate: Natural nitrate concentrations in groundwater range from 0.1-10 mg L^{-1} (Adeyemo *et al*., 2002) and it is of health significance especially to pregnant women and infants under 6 months, though it is apparently tolerated by most adults. Nitrate content in the water samples analyzed ranged from 0.017 mg L^{-1} in GW7 to 0.046 mg L^{-1} in GW1 (Fig. 20). These fall within the allowable value when compared to the WHO and NSDWQ recommended guidelines. Nitrate fouls the water system and epidemiological studies have shown that exposure to nitrate causes Methemoglobinemia disease (Adeyemo *et al*., 2002).

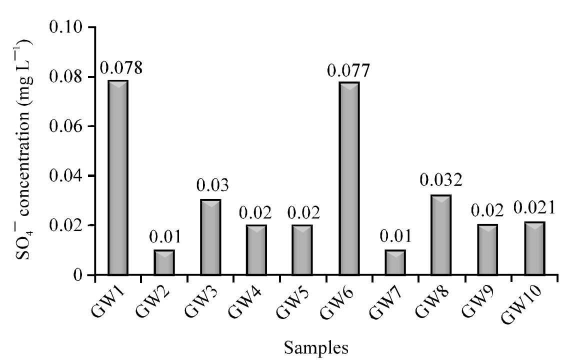

Fig. 19: Values of sulphate concentration in the water samples

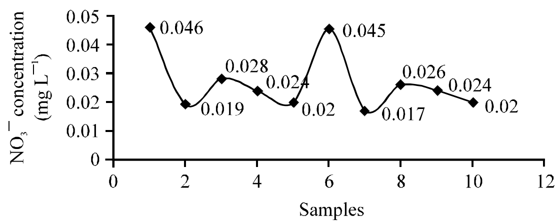

Fig. 20: Values of nitrate concentration in the samples

Alkalinity: Alkalinity is an estimate of the ability of water to resist change in pH upon addition of acid. Alkalinity of groundwater in the study area ranges from a minimum of 2.03 mg L^{-1} to a maximum of 2.69 mg L^{-1} (Table 3). Alkalinity of water is caused mainly due to OH, CO_3, HCO_3 ions. Therefore from alkalinities point of view, the qualities of water in the area is good since they fall within the permissible limits.

Results of the microbiological parameters: The results of the microbiological parameters analyzed are summarized in Table 4.

***Escherichia coli* (*E. coli*) and total coliform:** The bacteriological analysis revealed no *Escherichia coli* in all the water samples. However, the maximum numbers of total coliform were found to be 2.11 (cuf/100 m) and the minimum numbers of 0.1 (cuf/100 m) found (Table 4). Most of the faecal Coliform in faecal material comprised of *E. coli* and the serotype *E. coli* 0157:H7 is known to cause serious human illness (Health Canada, 2007). The NSDWQ recommends that drinking water may contain up to 10 (cfu/100 mL) total Coliform but WHO recommended <10 (cfu/100).

CONCLUSION

The results of the present study had revealed that groundwater is a good source of drinking water as most of the parameters returned values that fall within the acceptable limits set by both (NSDWQ) and World Health Organization (WHO). Few parameters however (Iron, Cadmium and Lead) returned values which exceeded the limits at a few sample locations. The water obtained from these boreholes if used for drinking purpose could bring about some health problems such as renal arterial changes in kidneys (Sanjoy and Rakesh, 2013), blue baby syndrome in babies and goitre in adults (Ogedengbe and Akinbile, 2004; Shyamala *et al*., 2008).

RECOMMENDATIONS

Based on these findings, the study recommends the need to create public awareness with respect to the dangers associated with the consumption of water from such polluted boreholes. Also, certain activities such as dumping of wastes, washing of cloths, motorcycles and cars, etc. within the borehole vicinity should be discouraged as that may have contributed to the infiltration of detergents and other chemicals into the aquifers. Also, the practice of water treatment in the state should be strengthened to protect the health of the users as pollution can occur any time.

Finally, government and communities should collaborate to organize sanitary and surveillance committees to protect the water sources in the rapidly urbanizing Ankpa urban area.

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