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Evaluation of the physicochemical and heavy metal content of ground water sources in Bantaji and Rafin-Kada settlements of Wukari Local Government Area, Taraba State, Nigeria

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Boreholes and hand dug wells from Bantaji and Rafin-Kada settlements of Wukari L.G.A. were analyzed for fourteen physicochemical parameters and seven heavy metals collected within July, 2015 to March, 2016 using standard methods. The mean difference in concentration of dissolved oxygen between the wet and dry seasons in the Bantaji boreholes was statistically significant at $p<0.05$. In addition, the electrical conductivity, nitrate nitrogen, phosphate and dissolved oxygen concentration were also statistically significant in the Rafin-Kada Boreholes. For the well water samples, total dissolved solids (TDS), nitrate nitrogen and chlorides were also statistically significant between the wet and dry seasons of the Bantaji wells while in the Rafin-Kada wells, with only dissolved oxygen having mean concentration that was statistically significant at $p<0.05$. All the physicochemical parameters in the boreholes and hand dug wells fall within the Nigerian Standards for Drinking Water Quality (NSDWQ) acceptable limits. The heavy metals, Pb and Mn had mean concentrations in the wet and dry seasons that were statistically significant in the Bantaji borehole, Bantaji well and Rafin-Kada borehole while Rafin-Kada borehole had statistically significant mean concentrations of Cd, As and Mn at $p<0.05$. All the heavy metals analyzed fall within the NSDWQ acceptable limits except Pb which had higher mean concentrations in the wet and dry seasons than the acceptable limits from Rafin-Kada wells (0.0190 and 0.0203 mg/L), Bantaji boreholes (0.1487 and 0.1086 mg/L) and Bantaji wells (0.0145 and 0.0154 mg/L). The mean concentrations of Pb reported may indicate presence of lead containing materials around the water sources. Frequent monitoring of these water sources is recommended over time.

Key words: Boreholes, wells, Bantaji, Rafin-Kada, physic-chemical parameters, heavy metals, groundwater.

INTRODUCTION

Water is an essential component of life (Oyem et al., 2014) and is regarded as a universal solvent (Umedum et al., 2013). It is used for washing, cooking, agricultural and even for industrial activities. Water could be obtained

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from ground water and surface sources. The groundwater sources include boreholes and hand dug wells while surface water sources include rivers, streams, and lakes. No matter the source of water, it is consumed and used on a day to day basis. However, water sources are often contaminated. Contamination of water sources can emerge from leaching of rocks, industrial and agrochemical discharges that are washed into them (Lawal and Lohdip, 2011), especially during the rainy season (Obaroh et al., 2015). These contaminations can affect the clarity and the chemical constituents of the water source. Essentially, they can distort the quality of the water and even add odor thereby impacting negatively on economic activities (Uzairu et al., 2014).

One major contaminant of water sources from the environment is heavy metal. Heavy metals such as mercury, lead, arsenic and cadmium are harmful heavy metals (Igbinedion and Oguze, 2016). In addition, some other heavy metals such as copper and nickel which are not found abundantly in the earth's crust also tend to constitute health risks to consumers (Ndeda et al., 2017). The presence of these elements in the environment has been linked with toxicity in man and aquatic organisms. This becomes visible after bioaccumulation over a long period of time since heavy metals cannot be degraded (Ndeda and Manohar, 2014). Diseases related to the heart, kidney and blood have been associated with areas polluted with heavy metals and most importantly inhalation of arsenic has been closely linked with lung and skin cancer (Egbe and Ahunanya, 2016).

The study was therefore initiated to evaluate the physicochemical and heavy metal contents of boreholes and well water sources in Bantaji and Rafin-Kada settlements of Wukari Local Government Area in a bid to establish the quality of these water sources available to the community for consumption and other domestic and agricultural activities.

MATERIALS AND METHODS

Study area

Wukari Local Government Area is on the co-ordinates 7° 51ʹ N and 9° 47ʹ E and having an area of 4,308 km^2 with a population of 241,546 based on the census conducted in 2006. Rafin-Kada, which is a settlement in Wukari Local Government Area is on the co-ordinate 7° 43ʹ N and 9° 53ʹ E. It is about 23 km away from Wukari town. Bantaji on the other hand, lies on the co-ordinate 8° 6ʹ 0ʹʹ N and 10° 6ʹ 0ʹʹE. Agricultural products like yams and fishes can be found in these areas since the people are predominantly farmers (Ishaku et al., 2009). Rafin-Kada and Bantaji have very small population (Figures 1 and 2).

Sample collection, treatment and preservation

The water samples were collected from three boreholes and hand dug wells each located in Bantaji and Rafin-Kada communities of Wukari Local Government Area within the period of July, 2015 to March, 2016 covering the wet and dry seasons. Pre-cleaned plastic jars were used to collect the samples. The plastic jars were chosen for the collection of samples to ensure that the level of contamination from the jar to water especially from heavy metals is low (Odoh et al., 2013) or even absent. Six samples were collected from each of the borehole and well sites at 2 h intervals and mixed together to obtain a composite sample for each site.

Physicochemical analysis of borehole and hand dug well samples

Fourteen parameters were analyzed in the samples collected. The parameters analyzed include temperature which was carried out at the site of collection using a calibrated thermometer, pH using a pH meter, conductivity using a conductivity meter, nitrates and phosphates by colorimetry using DR 2000 spectrophotometer (Model 50150), chloride by argentometry, alkalinity and hardness by titrimetry; while dissolved oxygen, chemical oxygen demand, biochemical oxygen demand by standard APHA methods were all determined. All the chemicals were of Analar grade and the determinations were in triplicates.

Heavy metal analysis

The water sample (100 ml) as collected was measured and transferred into a beaker and the concentrated HNO_3 (5 ml) was then added. It was warmed slowly and allowed to evaporate to about 20 ml in a fume cupboard. Heating with addition of concentrated HNO_3 continued until a light coloured, clear solution was observed. The beaker wall was washed down with deionized water and then filtered. The filtrate was transferred to a 100-ml volumetric flask, allowed to cool and made up to the mark with deionized water (APHA, 1999). The samples were then analyzed with UNICAM 969 atomic absorption spectrophotometer after calibrations with appropriate standards.

Statistical analysis

The data obtained was analyzed for mean and standard deviation using MS Excel and t-test analysis carried out using SPSS 20 version at 95% level of confidence.

RESULTS AND DISCUSSION

Physicochemical analysis of borehole water

The physicochemical analysis results of Bantaji boreholes in the wet and dry seasons are presented in Table 1. The result revealed that the mean values for temperature, total dissolved solids, conductivity, pH, chloride, alkalinity and dissolved oxygen were slightly higher in the dry season than in the wet season while turbidity, suspended solids, nitrate nitrogen, chemical oxygen demand and biochemical oxygen demand had mean values which were higher in the wet season than in the dry season. The mean difference values of dissolved oxygen between the wet and dry season were statistically significant. The borehole water from Bantaji was within the Nigerian Standards for Drinking Water Quality guidelines (NSDWQ) (SON, 2007).

The physicochemical analysis results of borehole water

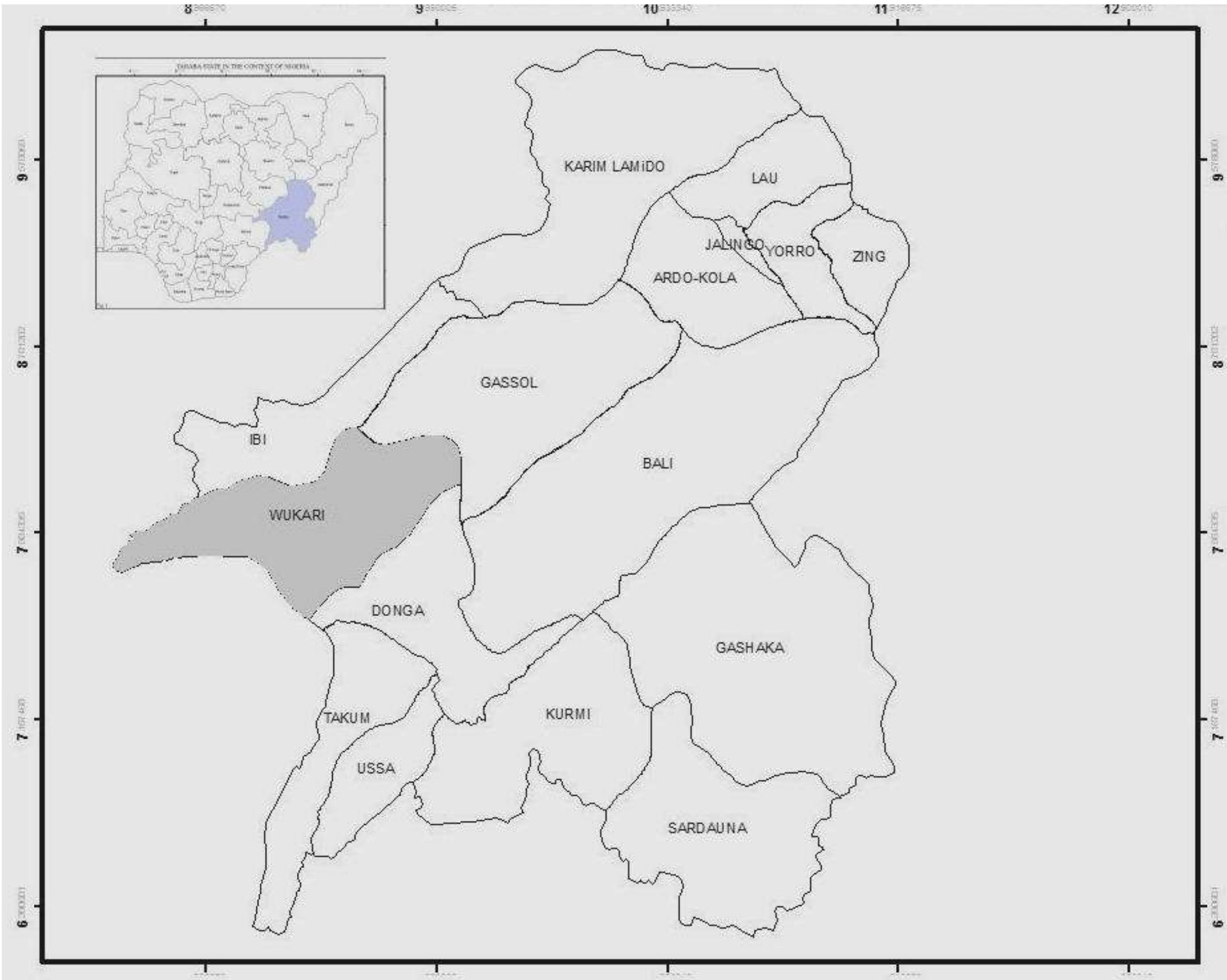

Figure 1. Map of Taraba State showing Wukari Local Government with map of Nigeria showing Taraba State inset.

from Rafin-Kada during the wet and dry seasons are presented in Table 2. The mean values showed that temperature, conductivity, phosphate, chloride, hardness and dissolved oxygen had higher values in the dry season than in the wet season while turbidity and suspended solids in the wet season were high when compared with their values in the dry season. In addition, nitrate nitrogen and alkalinity concentrations were slightly higher in the wet season than in the dry season. The mean values for conductivity, nitrate nitrogen, phosphate and dissolved oxygen were significant statistically between the wet and dry season. Generally, the mean values of all the parameters were within the NSDWQ acceptable limits.

A study which was conducted on borehole water samples from Akure (Akinbile and Yusoff, 2011) revealed that temperature values ranged between 26.5 to 27.5°C while dissolved oxygen had values in the range of 0.9 to 2.4 mg/L. These values are lower than the values for the present study [28.5°C, 4.1 mg/L (WS); 29.22°C, 4.4 mg/L (DS)] for water from Rafin-Kada boreholes and [28.3°C, 3.9 mg/L (WS); 29.2°C, 4.7 mg/L (DS)] for Bantaji borehole water. The level of dissolved oxygen in a water sample is a function of the temperature when measurement is carried out, thus dissolved oxygen values relative to temperature expresses the solubility of oxygen in the water source. Dissolved oxygen provides information on the health status of the water body such that the higher the dissolved oxygen, the lower the level of the water body's pollution.

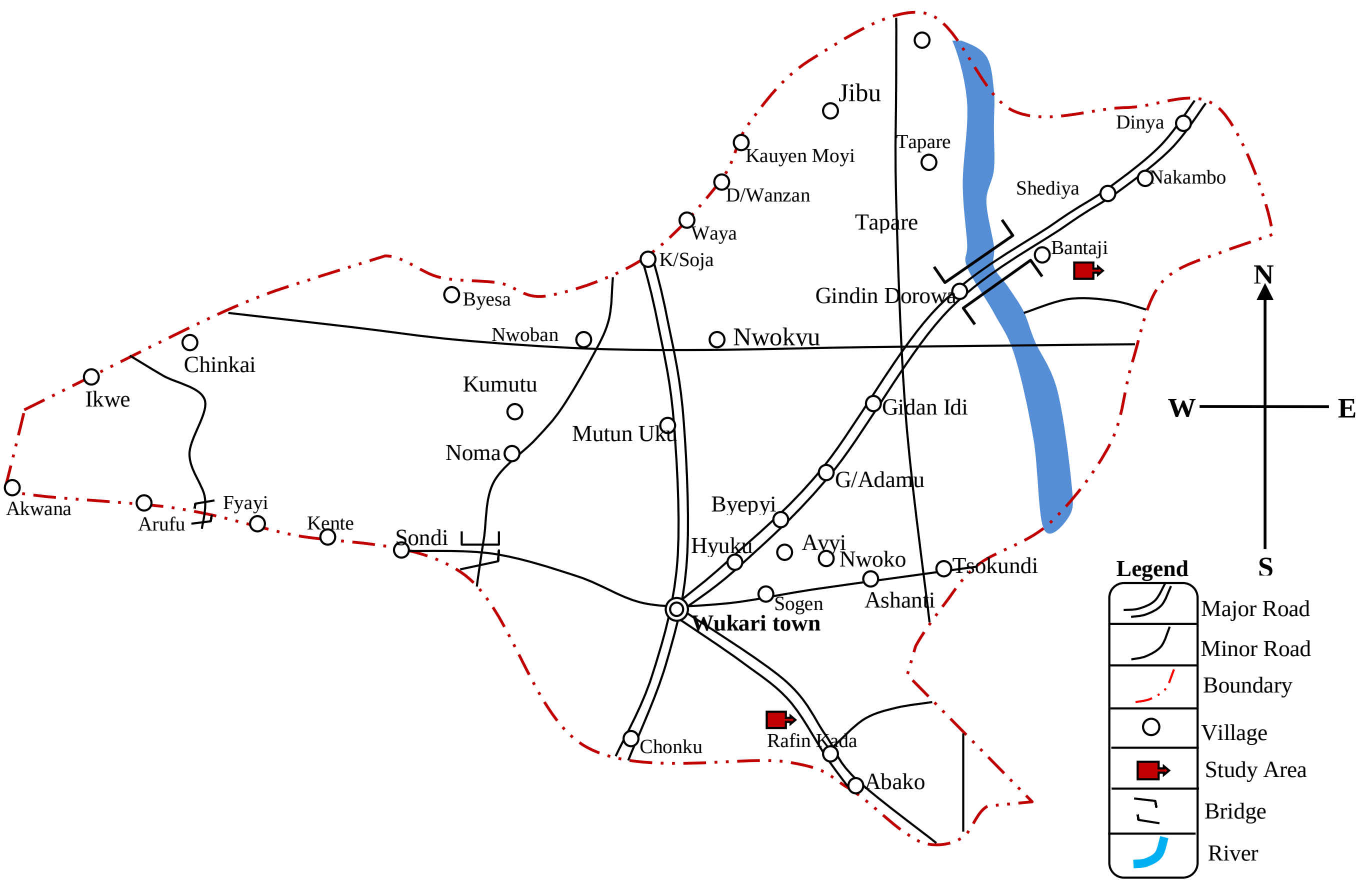

Figure 2. Map of Wukari Local Government showing the study area.

Table 1. Mean values of physicochemical composition of Bantaji boreholes in the wet and dry seasons.

Parameter	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ limits
Temperature (°C)	28.3±0.1*	29.2±0.2*	Ambient
Turbidity (NTU)	3.3±3.1	2±2	5
Suspended Solids (mg/L)	2±2	0.3±0.6	-
Total Dissolved Solids (mg/L)	28.9±2.83	29.5±4.2	500
Conductivity (µS/cm)	73.4±7.52	75.7±4.9	1000
pH	7.53±0.06	7.61±0.20	6.5-8.5
Nitrate Nitrogen (mg/L)	28.9±1.85	25.1±4.4	50
Phosphate (mg/L)	1.00±0.06	1.04±0.08	-
Chloride (mg/L)	31.6±3.0	33.4±3.0	250
Alkalinity (mg/L)	9.0±0.2	9.5±0.5	-
Hardness (as $CaCO_3$) (mg/L)	107±31	113±23	150
COD (mg/L)	63±28	53±23	-
DO (mg/L)	3.9±0.4*	4.7±0.46*	-
BOD (mg/L)	31±14	27±11	-

*Indicates mean values are statistically significant at $p<0.05$.

In addition, turbidity and suspended solids are indicators of the clarity of the water source. The turbidity and suspended solids in the borehole water sources are higher in the wet season than in the dry season. The

Table 2. Mean values of physicochemical parameters of Rafin-Kada boreholes in the wet and dry seasons.

Parameter	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ limits
Temperature(°C)	28.5±0.3*	29.2±0.4*	Ambient
Turbidity (NTU)	5.3±2.3	0.6±1.2	5
Suspended Solids (mg/L)	3±9	0.3±0.6	-
Total Dissolved Solids (mg/L)	25.4±0.7	25.9±1.1	500
Conductivity (µS/cm)	72.3±4.46*	73.8±4.6*	1000
pH	6.87±0.95	6.81±0.39	6.5-8.5
Nitrate Nitrogen (mg/L)	20.5±8.0*	17.1±7.2*	50
Phosphate (mg/L)	0.95±0.24*	1.11±0.27*	-
Chloride (mg/L)	26.9±1.2	28.9±1.7	250
Alkalinity (mg/L)	8.3±1.4	8.1±0.2	-
Hardness (as $CaCO_3$)	93±12	113±12	150
COD (mg/L)	74±7	64±4	-
DO (mg/L)	4.1±0.2*	4.4±0.1*	-
BOD (mg/L)	37±4	32±2	-

*Indicates mean values are statistically significant at $p<0.05$.

mean values for the present study were higher than that determined in a study conducted by Oko et al. (2014) in borehole water samples from Wukari town (1.25 NTU, 2.00 mg/L) at the point of collection and after storage for one week (0.54 NTU, 0.53 mg/L). Turbidity and total dissolved solids values reported by Nkansah and Ephraim (2009) was in the range of 0.2 to 45 NTU and 36 to 779 mg/L, respectively. The upper limit value for turbidity is far higher than the results reported in this study though the lower limit values are lower. For the total dissolved solids (TDS), the lower and upper limit values are higher than reported in the present study.

The mean conductivity values for the Rafin-Kada borehole water were in the same range as those from Bantaji. These values are however lower than values determined for a study conducted on borehole water samples in Bauchi (Hijab et al., 2012) which recorded mean values of 196 µs/cm.

BOD and COD measure relative oxygen-depletion effects of wastes on a water source (Sharma and Gupta, 2014). The mean values for COD and BOD from Rafin-Kada borehole water in the wet and dry seasons are higher than the values observed for the Bantaji samples. This could be an indication that the Rafin-Kada samples contain more chemicals and oxygen demanding microorganisms than the Bantaji boreholes.

It has been reported that hardness concentration of 60 mg/L in water is considered soft while 60 to 120 mg/L is moderately hard; 120 to 180 mg/L is said to be hard and more than 180 mg/L is very hard (McGowan, 2000). The mean values reported for total hardness in the borehole water samples from Bantaji and Rafin-Kada can therefore be regarded as moderately hard.

The presence of nitrates can enhance nutrient supply to a water body. High concentrations of phosphate and nitrate nitrogen in a water sample are indicators of pollution and are largely responsible for eutrophic conditions (Aremu et al., 2017). Mean nitrate concentration in the Bantaji borehole water is higher than that in the Rafin-Kada borehole though the phosphate concentrations were found to be in the same range. A study which was conducted by Abdel-Sater et al. (2017) revealed that the mean value of nitrates in groundwater sources in Saudi Arabia were 4.93 mg/L. These values are far lower than the values determined for the boreholes in the present study. The chloride and alkalinity concentrations in the water from Bantaji boreholes were a little higher than the concentrations recorded for the Rafin-Kada boreholes. In a study conducted by Kanmani and Gandhimathi (2013), the chloride of the groundwater samples were in the range of 215.15 to 4,098.73 mg/L. The values of which were far higher than the values determined for the present study in both the boreholes and wells. This may be reason for the higher total dissolved solids values in the Bantaji samples when compared with the values obtained for the Rafin-Kada samples. It has been reported that chlorides may not be harmful but could contribute a level of saltiness to a water source where it is present (Adewuyi et al., 2010).

The physicochemical analysis results of well water samples from Bantaji in the wet and dry seasons are presented in Table 3. The mean values showed that temperature, total dissolved solid, conductivity, pH, phosphates, chlorides, alkalinity, hardness and dissolved oxygen had slightly higher concentrations in the dry seasons than in the wet season. Turbidity, suspended solids, nitrates, chemical oxygen demand and biochemical oxygen demand on the other hand had higher values in the wet season than in the dry season. However, only the difference in mean values for TDS,

Table 3. Mean values of physicochemical parameters of Bantaji wells in the wet and dry seasons.

Parameter	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ acceptable limits
Temperature (°C)	28.1±0.1*	29.0±0.0*	Ambient
Turbidity (NTU)	5.7±3.2	3±2	5
Suspended Solids (mg/L)	2.3±2.1	1.3±1.2	-
Total Dissolved Solids (mg/L)	29.9±0.91*	30.9±0.8*	500
Conductivity (µS/cm)	75.7±0.70	77±1.0	1000
pH	7.63±0.30	7.8±0.1	6.5-8.5
Nitrate Nitrogen(mg/L)	27.9±0.1*	25.3±0.6*	50
Phosphate (mg/L)	0.86±0.07	0.89±0.08	-
Chloride (mg/L)	29.6±0.5*	31.3±0.6*	250
Alkalinity (mg/L)	10.3±0.7	10.5±0.5	-
Hardness (as $CaCO_3$) (mg/L)	100±0	107±12	150
COD (mg/L)	85±5	74±3	-
DO (mg/L)	4.0±0.2	4.3±0.5	-
BOD (mg/L)	43±3	37±2	-

*Indicates mean values are statistically significant at p<0.05.

Table 4. Mean values of physicochemical parameters of Rafin-Kada wells in the wet and dry seasons.

Parameter	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ limits
Temperature (°C)	28.1±0.2*	29.5±0.4*	Ambient
Turbidity (NTU)	1.0±1.0	1.3±2.3	5
Suspended Solids (mg/L)	0.66±0.6	1.3±2.3	-
Total Dissolved Solids (mg/L)	24.6±4.2	27.6±2.8	500
Conductivity (µS/cm)	67.1±3.5	73.1±1.0	1000
pH	7.7±0.3	7.2±0.7	6.5-8.5
Nitrate Nitrogen (mg/L)	28.3±1.6*	25.3±2.1*	50
Phosphate (mg/L)	0.9±0.1*	0.8±0.6*	-
Chloride (mg/L)	30.4±0.1	33.3±15.7	250
Alkalinity (mg/L)	9.1±1.1	8.3±0.3	-
Hardness (as $CaCO_3$) (mg/L)	73±23	93±23	150
COD (mg/L)	89±8*	80±5*	-
DO (mg/L)	4.7±0.1	4.7±0.5	-
BOD (mg/L)	45±4*	40±3*	-

*Indicates mean values are statistically significant at p<0.05.

nitrate nitrogen and chlorides in the wet and dry season were statistically significant.

The physico-chemical analysis results of the well water samples from Rafin-Kada are presented in Table 4. The mean values for temperature, turbidity, suspended solids, total dissolved solids, conductivity, chlorides and hardness in the dry season was higher than reported for the wet season though pH, nitrate nitrogen, phosphates, alkalinity, chemical oxygen demand and biochemical oxygen demand had higher mean values in the wet season than the dry season. Dissolved oxygen however has the same mean value in both the wet and dry seasons. Apart from nitrate nitrogen, phosphate, COD, BOD and temperature, the difference in mean values for all other parameters were not statistically significant at $p<0.05$. However the parameters were within the acceptable limits of the NSDWQ.

The turbidity values in well water sources studied in Abeokuta (Shittu et al., 2008) had values of 3 and 2.5 NTU, respectively which are lower than mean values determined for the wet season (5.7 NTU) in Bantaji though comparable with those obtained for the dry season (3 NTU). The values are however higher than the mean values observed for the Rafin-Kada well water in both the wet and dry seasons. The mean values for a study conducted in Doko for turbidity (Yisa et al., 2012) had mean value (11 NTU) which is higher than the results obtained for the present study.

Table 5. Metal concentrations (mg/L) in water samples from Bantaji boreholes during the wet and dry seasons.

Metal (mg/L)	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ acceptable limits
Cd	0.0013±0.0002	0.0010±0.0002	0.003
Pb	0.1487±0.2531*	0.1086±0.1846*	0.01
As	0.0008±0.0001	0.0007±0.0002	0.01
Fe	0.0263±0.0003	0.0225±0.0009	0.3
Cu	0.0003±0.0001	0.0004±0.0001	1
Hg	0.0001±0.0000	0.0001±0.0000	0.001
Mn	0.0066±0.0058*	0.0066±0.0047*	0.2

*Indicates mean values are statistically significant at $p<0.05$.

The level of the suspended solids in the Bantaji wells (2.3 mg/L) was found to be higher than the Rafin-Kada wells (0.06 mg/L) during the wet season. Nevertheless, the mean values of the suspended solids in Bantaji and Rafin-Kada wells during the dry seasons were found to be the same. The total dissolved solid values from Rafin-Kada well water in the wet and dry seasons were 29.7 and 29.5 mg/L, respectively. This result was higher than values recorded for hand dug wells in Okene Local Government in the wet and dry seasons (0.62 and 0.57 mg/L, respectively) in a study conducted by Aremu et al. (2014). The mean conductivity values for Bantaji wells are higher in the wet and dry seasons (76 and 77 µS/cm) than their values in Rafin-Kada well (67.1 and 73.1 µS/cm). This result is far lower than results obtained for a study conducted in Dass and Ganjuwa well water with conductivity values of 720.7 and 728 µS/cm, respectively (Chindo et al., 2013).

The pH values in both the Bantaji and Rafin-Kada well water indicate that the water sources are alkaline. This result is comparable with results obtained by Chindo et al. (2013) for well water in Dass and Ganjuwa. Nitrate nitrogen (28.3 mg/L), phosphate (0.93 mg/L) and chloride (30.4 mg/L) in the Rafin-Kada well water in the wet season had concentrations which are higher than that of Bantaji well water (27.9, 0.86 and 29.6 mg/L, respectively). The concentrations of nitrates and phosphates from Rafin-Kada wells are however lower in the dry season than the reported values for the water from Bantaji wells though the chloride concentrations from both settlements were in the same range. The nitrate and chloride concentrations for both settlements are higher than results obtained for a study conducted by Anyanwu and Okoli (2012) on Nsukka well water where the nitrate concentrations ranged between 1.2 to 4.1 mg/L and chlorides ranged between 1.6 to 2.3 mg/L, respectively. Furthermore, the mean chloride concentration for a study that was conducted on well water in Gboko was 120.1 mg/L (Okoye and Nyiathagher, 2009). The concentration is higher than concentrations determined for the water from Bantaji and Rafin-Kada wells.

The BOD values in the Rafin-Kada and Bantaji well water samples are higher than the reported values (18.6 to 20.4) by Anyanwu and Okoli (2012) though DO values were however lower than reported by the researchers. In addition, the hardness values reported for Rafin-Kada and Bantaji wells can thus be described as moderately hard. The values are however lower than reported by Shittu et al. (2008) in a study conducted on well water samples from Abeokuta.

Metal analysis

The mean concentrations of the heavy metal (mg/L) in Bantaji borehole water for the wet and dry seasons are presented in Table 5. The concentrations in decreasing order were: Pb (0.1487) > Fe (0.0263) > Mn (0.0066) > Cd (0.0013) > As (0.0008) > Cu (0.0003) > Hg (0.0001) during the wet season. In the dry season, the concentrations followed the same pattern as the wet season. They include Pb (0.1086) > Fe (0.0225) > Mn (0.0066) > Cd (0.0010) > As (0.0007) > Cu (0.0004) > Hg (0.0001). The metal concentrations in the wet season are however higher for Pb, Fe and As though Hg and Mn had the same mean concentrations. The t-test analysis indicated that the difference in mean concentrations between the wet and dry season were statistically significant for Pb and Mn at $p < 0.05$. The other metals recorded no significant difference in means for the wet and dry seasons. Mean concentration of Pb in the Bantaji borehole water source have higher values than the NSDWQ acceptable limits. The reason for the high Pb concentration from the borehole water is not known but this may suggest the presence of Pb containing materials deposited around the borehole which may have seeped into the ground over time. All other metals in the borehole water were however within the NSDWQ acceptable limits. The heavy metal content (mg/L) in the Rafin-Kada borehole water is presented in Table 6. The results indicate that the mean concentrations of the metals during the wet season in decreasing order were Fe (0.0202), Mn (0.0116), Pb (0.0015), As (0.0010), Cu (0.0007) and Hg (0.0001) while for the dry season the metal concentrations were Fe (0.0288), Mn (0.0104), Pb

Table 6. Metal concentrations (mg/L) in water samples from Rafin-Kada boreholes during the wet and dry seasons.

Metal (mg/L)	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ acceptable limits
Cd	0.0015±0.0001	0.0015±0.0001	0.003
Pb	0.0071±0.0036*	0.0057±0.0005*	0.01
As	0.0010±0.0001	0.0009±0.0001	0.01
Fe	0.0202±0.0009	0.0288±0.0014	0.3
Cu	0.0007±0.0001	0.0006±0.0004	1
Hg	0.0001±0.0000	0.0001±0.0000	0.001
Mn	0.0116±0.0003*	0.0104±0.0012*	0.2

*Indicates mean values are statistically significant at $p<0.05$.

(0.0057), Cd (0.0015), As (0.0009), Cu (0.0006) and Hg (0.0001). The results indicate slight variations in the metal concentrations in the wet and dry seasons. Cd and Pb had statistically significant mean differences in the wet and dry seasons while the others were not significant statistically at $p < 0.05$. The result suggests that As, Cu and Hg deposits do not have significant presence in the study areas which could imply the absence of a major deposit of their sources.

In a study of heavy metals conducted on boreholes in Calabar (Njar et al., 2012), mean concentration of Fe (0.065 mg/L) is higher than reported for the present study. Mean concentrations of Cu (0.000 mg/L), Pb (0.001 mg/L) and Mn (0.002 mg/L) are however lower. The concentrations of heavy metals in borehole water samples from Maiduguri were found to be present in the following ranges: Pb (0.04 to 0.14 mg/L), Cd (ND to 0.07 mg/L), As (0.02 to 0.04 mg/L) and Hg (ND) (Kolo and Waziri, 2012). Pb, Cd and As in this study had higher values than recorded for the present study while Hg which was not detected was only traceable in the present study. In a study conducted on the waters collected from Ghol Dam in Pakistan where Cu and Pb were analysed amongst other elements, the results revealed that Cu levels was 0.6968 while Pb levels was 0.0000 (Azeem et al., 2016). The value for Cu is higher than reported in the present study while the Pb levels which was not detected was not the case in the present study which had higher concentrations of Pb. Furthermore, a study conducted on borehole water in Ghana revealed the concentrations of the following metals in the ranges indicated: Mn (below detection limit to 0.8 mg/L), Cu (0.1 to 1.00 mg/L) and Pb (Below detection limit to 0.038) (Nkansah and Ephraim, 2009). The upper limits of this study for Mn and Cu were lower than the results reported for the present study. Nevertheless, the results for this study are higher than the lower limits. Pb concentrations in the Bantaji boreholes recorded higher concentrations than the upper limit of the study.

The heavy metal concentrations (mg/L) in the Bantaji well water samples during the wet and dry seasons as presented in Table 7 indicate that in the wet seasons, the metals in decreasing order of concentrations were: Fe (0.0359) > Mn (0.0190) > Pb (0.0145) > Cd (0.0014) > As (0.0013) > Cu (0.0010) > Hg (0.0001) while for the dry season, mean concentrations were in the order; Fe (0.0422) > Mn (0.0221) > Pb (0.0154) > Cd (0.0020) > As (0.0015) > Cu (0.0014) > Hg (0.0002). Pb and Mn had statistically significant mean differences between the wet and dry seasons at $p < 0.05$.

Furthermore, the heavy metal levels (mg/L) in Rafin Kada well water samples during the wet and dry seasons as presented in Table 8 showed that in the wet season, the metal concentrations in decreasing order of concentrations were: Fe (0.0457) > Mn (0.0241) > Pb (0.0190) > As (0.0029) > Cd > Cu (0.0024) > Hg (0.0002) while in the dry season, the pattern was Fe (0.0460) > Mn (0.0249) > Pb (0.0203) > As (0.0033) > Cd (0.0028) > Cu (0.0027) > Hg (0.0003). All the metals had higher concentrations in the dry season compared to the wet season. In addition, Cd, As and Mn had mean differences that were statistically significant at $p < 0.05$. The mean concentrations of Pb in the wet and dry seasons are slightly above the acceptable limits. Oko (2013) reported the contamination of Pb in dried goat faecal discharges. The presence of such Pb containing materials around the hand dug wells and washed into the water could be responsible for the concentrations of Pb recorded.

The study revealed that Cd, Pb, As, Fe, Cu and Mn concentrations in the Rafin-Kada well water had higher concentrations in the wet and dry seasons than their concentrations obtained in the Bantaji well water. The reason for this is not clear though it may be associated with activities of the people around the well areas. The locations are far apart and are not connected by any waterway. A study conducted in Ogun State on the heavy metal concentrations in hand dug wells gave concentrations in the ranges: Fe (0.11 to 0.98 mg/L), Cu (0.08 to 0.26 mg/L), As (ND to 0.07 mg/L) and Pb (0.01 to 0.14 mg/L) (Amori et al., 2013). This study had higher concentrations of Fe, Cu and As though Pb concentrations were in the same range as the results obtained for the water from wells in the present study. In another study conducted on well waters in Aliero, Kebbi State, the concentrations recorded were Pb (0.234 mg/L), Fe (1.260 mg/L), Mn (0.100 mg/L) and Cu (0.060 mg/L)

Table 7. Metal concentrations (mg/L) in water samples from Bantaji wells during the wet and dry seasons.

Metal (mg/L)	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ acceptable limits
Cd	0.0014±0.0001	0.0020±0.0002	0.003
Pb	0.0145±0.0003*	0.0154±0.0004*	0.01
As	0.0013±0.0001	0.0015±0.0004	0.01
Fe	0.0359±0.0011	0.0422±0.2818	0.3
Cu	0.0010±0.0001	0.0014±0.0003	1
Hg	0.0001±0.0001	0.0002±0.0001	0.001
Mn	0.0190±0.0004*	0.0221±0.0013*	0.2

*Indicates mean values are statistically significant at $p<0.05$.

Table 8. Metal concentrations (mg/L) in water samples from Rafin-Kada wells during the wet and dry seasons.

Metal (mg/L)	Wet Season (n=3) Mean±SD	Dry Season (n=3) Mean±SD	NSDWQ limits
Cd	0.0024±0.0001*	0.0028±0.0002*	0.003
Pb	0.0190±0.0036**	0.0203±0.0007	0.01
As	0.0029±0.0001*	0.0033±0.0002*	0.01
Fe	0.0457±0.0009**	0.0460±0.0010**	0.3
Cu	0.0024±0.0001**	0.0027±0.0002**	1
Hg	0.0002±0.0001**	0.0003±0.0001**	0.001
Mn	0.0241±0.0005*	0.0249±0.0005*	0.2

*Indicates mean values are statistically significant at $p<0.05$.

(Shabanda et al., 2014). The concentrations of all these metals analyzed for in the present study are lower than the concentrations recorded in the Aliero well water. Cd was not detected while Cu had mean concentrations of 1.42 mg/L in a study on well waters in Gboko, Benue State (Okoye and Nyiaghther, 2009). In a study of heavy metals conducted on groundwater samples in South Saudi (Alshikh, 2011), the mean concentrations were As (<0.001 mg/L), Cd (<0.0001 mg/L), Pb (<0.0001 mg/L), Cu (<0.001 mg/L), Hg ((<0.0005 mg/L) and Mn (<0.01 mg/L). These values recorded were lower than the values of the metals determined in the present study.

It is worthy to note that the heavy metals have gross health implications if their presence is more than the acceptable levels. Often times, the heavy metals are transported from one point of contamination to another in the form of dissolved species in streams and rivers or embedded as part of suspended matter (Duruibe et al., 2007). Cadmium (Cd) enters into the environment when it is discharged as a by-product of the refining of Zinc (Duruibe et al., 2007). Cadmium usually interferes with enzymatic processes involving reabsorption of proteins in the kidney. It has also been found not to degrade in the environment to products that are less toxic hence they tend to bioaccumulate in the kidneys and livers of animals (Mahaurpaw, 2015). This thus indicates that as cadmium bioaccumulates in the study area over time if not attended to it may cause kidney and liver failures in the people that consume water from the sources.

Arsenic (As) present in groundwater has also been linked to the fact that they adsorb strongly to soils (Wuana and Okieimen, 2011); hence they can be transported through short distances into the water sources. Arsenic has been linked with skin damage and increase in the risk of cancerous growths. In the same manner, exposure to mercury (Hg) is mostly through food such as fish. Fish has been reported to be a major source of methyl mercury exposure though no significant health risks have been reported for methyl mercury (Jarup, 2003). The study areas in the present study though are good providers of fish but the mercury level in the study were not significant. Nevertheless, the presence of mercury at deleterious levels can cause damage to the kidney.

Lead (Pb) which is present remarkably in the study area relative to the other metals have been reported to bioaccumulate in body organs such as the brain (Wuana and Okieimen, 2011) and even affecting the gastrointestinal tracts, kidneys and central nervous system. The implication therefore is that the presence of lead in amounts that are higher than the acceptable limits in the bodies of man and animals that drink from contaminated water sources would bring about brain retardation, nervous breakdown and even kidney failure.

Conclusion

The study assessed the physicochemical and metal content of borehole and well water samples collected from Bantaji and Rafin-Kada settlements of Wukari Local Government Area. The study revealed that the physicochemical parameters are within the acceptable limits of the Nigerian standards for drinking water quality (NSDWQ). However, the difference in the mean values for nitrate nitrogen, chemical oxygen demand and biochemical oxygen demand in the wet and dry seasons from Rafin-Kada well water was statistically significant at $p < 0.05$ as well as the conductivity, phosphate and dissolved oxygen levels in the Rafin-Kada boreholes. Bantaji hand dug well water had mean differences in the wet and dry seasons for total dissolved solids, nitrate nitrogen and chlorides which were statistically significant at $p < 0.05$ while the borehole water recorded differences in the mean concentrations of dissolved oxygen in the wet and dry seasons that were statistically significant. The metal concentrations of Cd, As, Fe, Cu, Hg and Mn from both settlements in the wet and dry seasons had mean values that are within the acceptable limits except Pb concentrations in Bantaji and Rafin-Kada wells which were slightly higher than the NSDWQ acceptable limits.

The present study provides baseline information on the physicochemical and heavy metal status of the borehole and well water samples from Bantaji and Rafin-Kada settlements of Wukari Local Government Area. Frequent monitoring is recommended especially for Pb concentrations in the area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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