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Full Length Research Paper

Assessment of borehole water quality in Yola-Jimeta Metropolis, Nigeria

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This study investigates the chemical concentration of borehole water in Yola-Jimeta Metropolis so as to assess their suitability for domestic use. Water samples were collected from twenty-two boreholes, one sample from each of the twenty-two administrative wards (Wards are the lowest political units in Nigeria) in the metropolis. Samples were analyzed in the laboratory using standard guideline procedures suggested by American Public Health Association (APHA). Eleven contamination indicators were tested and results obtained were compared with chemical guideline values for drinking water provided by World Health Organisation (2011) and Standard Organisation of Nigeria (2007). The study reveals that chloride (Cl^-), iron (Fe^{++}), nitrate (NO_3^-), pH, sodium (Na^+) and total hardness ($CaCO_3$) are the main sources of borehole water contamination in the study area. This has health implications that include hypertensions and heart and kidney diseases which are on the increase in the region. Poor sanitary condition and intensive use of inorganic fertilizer are implicated as sources of contaminants. We therefore suggest the setting up of water sanitary agencies that will monitor and regulate health based targets of water quality at ward levels.

Key words: Borehole, chemical concentration, sanitation, water quality, WHO, Yola-Jimeta Metropolis.

INTRODUCTION

It is increasingly recognised that the provision of good quality water is central to any meaningful human development (Ahmad, 2003; Anand and Sen, 1997). This is why the multifaceted linkage between water quality on one hand and human health on the other is at the centre of development policies in Nigeria (Federal Republic of Nigeria, 2004). However, the lack of sufficient distribution network and weak treatment facilities coupled with high evapo-transpiration which exceeds precipitation are major challenges to achieving the development target of providing potable water supply in Nigeria (Dankano, 2006; Onugba and Aboh, 2009). Consequently, majority of the people rely on boreholes as their main source of water supply (Hazell et al., 1992; Okafor and Ogbonna, 2003). In Yola-Jimeta metropolis, over 40% of households depend on water from boreholes as their main source of domestic water supply (National Population Commission, 2006).

Unlike pipe borne water, boreholes are more susceptible to contamination (Ojelabi et al., 2001; Tole, 1997). This is particularly widespread and acute in the developing world where unchecked industrial growth, lack of monitoring facilities and failure to enforce environmental regulations add to the severity of the situation (Ntengwe, 2005; Oluwande et al., 1983). The presence of contaminants that deviate from the acceptable World Health Organisation (WHO) guideline values has been associated with the cause of different kinds of disease such as typhoid fever, dysenteries, gastrointestinal and infectious hepatitis (Hammer, 1996; Jiang, 2011). This makes it imperative to monitor levels of chemical contaminant in boreholes.

Previous records on groundwater condition in Yola-Jimeta metropolis (Onugba and Aboh, 2009) discussed

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a radioactive isotope content of the study area but lacked in-depth chemical information needed to determine concentrations of chemical contaminants. Although, few numbers of relevant studies in other part of Nigeria indicate that underground water is highly susceptible to contamination that has led to outbreaks of water borne diseases (Eneh, 2011; Obiefuna and Sheriff, 2011; Shittu et al., 2008), however, information specific to Yola-Jimeta metropolis is still needed to increase our understanding of the processes affecting borehole water quality in the area. In a society like Yola-Jimeta metropolis where borehole is the main source of domestic water supply, contamination will not only expose people to and increase occurrences of life threatening water borne diseases but also negate any development goals.

It is against this background that the chemical assessment of borehole water of Yola-Jimeta metropolis is carried out and sources of contamination investigated with the aim of providing information that can serve as a guide in monitoring water contamination in the area.

MATERIALS AND METHODS

Study area

The study area is a metropolis made up of the twin cities of Yola and Jimeta in the North Eastern Adamawa state of Nigeria. The Yola-Jimeta metropolis is located between 9° 11^{I} N and 9° 19^{I} N latitude and 12° 12^{I} E and 12° 30^{I} E longitude covering an area of about 1,213 km^2 (Adebayo and Umar, 1999) and has a population of 344,154 (National Population Commission, 2006). Closely related to the population is varied land uses which are associated with the urban status of the area and the various urban land uses generate a high demand for water resources. The water supply situation in the area is mainly characterized by scarcity especially in the dry season; most of the households do not have access to pipe borne water as such they rely on boreholes, hand dug wells, and water vendors for their daily water supply.

The study area has a typical dry tropical climate, with marked rainy and dry seasons. The drainage system in the metropolis is mainly dominated by the river Benue and other minor streams and ponds. The area is generally flat to gentle undulating with an elevation ranged from 160 to 190 m above sea level (Adebayo and Umar, 1999). The area is covered by light reddish to brown sandy soil underlain by the cretaceous Bima-Yola sandstone which is the main source of ground water in the area (Onugba and Aboh, 2009; Preez and Barber, 1965).

Sampling and analysis

Twenty-two water samples were collected from randomly selected boreholes, one from each of the twenty-two wards in the metropolis. The samples were collected using a 1.5 litre plastic container and chemical analysis was conducted using standard laboratory methods suggested by APHA (American Public Health Association, 1995). Samples were analyzed to determine concentrations of chemical contamination indicators such as bicarbonate (HCO_3), chloride (Cl^-), iron (Fe^+), magnesium (Mg^+), nitrate (NO_3^-), pH, phosphate (PO_3^{-4}), potassium (K^-), sodium (Na^+), sulphate (SO_4^{2-}) and total hardness ($CaCO_3$). Laboratory values were generally compared with the chemical guideline values for drinking water quality provided by the World Health Organisation (WHO) (2011) and Standards Organisation of Nigeria (SON) (2007). In situation whereby World Health Organisation (2011) does not provide a guideline value we have relied on guideline values from literature including other World Health Organisation publications. However, where Standards Organisation of Nigeria (2007) does not provide a guideline value, we have treated this as unavailable. Chemical concentration of these indicators from boreholes deviating from the guideline values are regarded as contaminated.

For most of the indicators, concentration below the guideline values are acceptable only values above the guideline values are considered contaminated. However, for iron and pH concentration outside the specified range is considered contaminated. Based on knowledge of the wards, the possible source(s) of contamination is identified.

Also, a statistical analysis to test variation between measured concentration and WHO and SON guideline values was conducted using the mean value test (an approach to assess contaminated sites relative to guideline values) suggested by the Department for Environment Food and Rural Affairs and the Environment Agency in United Kingdom (Department for Environment Food and Rural Affairs and The Environment Agency, 2002). The necessary calculation involves five steps as follows:

(i) Calculate the arithmetic sample mean, X.
(ii) Calculate the (unbiased) sample standard deviation, s.
(iii) Select an appropriate t value e.g. 95th percentile confidence limit, t.
(iv) Calculate the upper 95th percentile bound of sample as:

$$US_{95} = X + (ts / \sqrt{n})$$

(v) Compare the upper bound value, (US_{95}) with the guideline value (G). If the upper bound value is less than G, then the mean value test has been passed, and the site may be considered not to present a significant harm to human health. This indicator is used to determine the human health risk from contaminated sites.

RESULTS AND DISCUSSION

Results revealed that concentrations in some wards of six chemical contamination indicators (namely; chloride, iron, nitrate, pH sodium and total hardness) deviate from the chemical guideline values provided by either WHO or SON. But, concentration of bicarbonate, magnesium, phosphate, potassium and sulphate fall within the permissible limits. Table 1 shows chemical concentrations of water samples from the study area, with WHO and SON guideline values indicated in the last two rows. Concentration that deviate from both WHO and SON guideline values is indicated in bold, while those that deviate from only SON guideline values is indicated in bold and italics.

Chloride

Chloride concentration ranged between 25 and 411

Table 1. Chemical concentration of water samples from wards of Yola – Jimeta Metropolis.

Wards	Iron Fe+ (mg/L)	Chloride Cl- (mg/L)	Sulphate SO_4^{2}- (mg/L)	Magnesium Mg^{+} (mg/L)	Nitrate Na^{-3} (mg/L)	Bicarbonate HCO_3 (mg/L)	Sodium Na^{+-} (mg/L)L	Potassium K^{-} (mg/L)	Phosphate PO_3^{-4} (mg/L)	Total Hardness $CaCO_3$ (mg/L)	pH
Adarawo	0.03	127.00	26.80	20.30	6.70	313.00	21.30	3.50	0.70	*230.00*	7.00
Ajiya	0.10	111.20	25.00	28.40	6.20	115.00	26.20	5.50	0.40	119.00	6.70
Alkalawa	0.10	53.50	31.00	28.00	7.50	222.00	29.50	4.40	0.80	*302.00*	7.10
Bako	0.30	105.50	26.80	21.50	3.40	225.00	36.20	7.10	0.40	*228.80*	6.20
Bole	0.04	411.00	45.50	39.50	74.50	315.50	161.00	5.30	0.40	144.50	6.10
Doubeli	0.10	117.00	50.10	30.80	5.50	307.00	310.00	5.50	0.50	43.80	6.70
Gwadabawa	0.01	130.80	31.80	40.70	47.73	159.90	142.30	6.30	0.90	123.80	7.10
Jambutu	0.30	399.00	30.20	39.50	49.50	130.00	119.00	7.80	0.80	150.00	6.70
Karewa	0.02	130.00	31.40	30.70	11.00	203.00	141.00	4.50	0.80	*235.00*	6.70
Limawa	0.30	162.80	37.80	21.00	44.80	152.80	47.70	3.90	0.70	*153.80*	5.60
Luggere	0.20	225.50	25.80	40.90	20.30	100.00	137.80	6.20	0.30	142.00	6.70
Makam B	0.40	186.00	29.00	22.30	0.50	105.00	21.05	5.00	0.70	122.50	7.00
Makama A	0.30	241.50	41.30	13.00	4.00	203.80	22.80	5.40	0.80	144.00	6.50
Mbamba	0.20	202.00	32.60	42.80	81.50	339.00	135.00	6.50	0.80	116.50	6.30
Mbamoi	0.03	84.10	35.50	24.30	5.10	239.50	39.30	6.50	0.60	137.30	6.30
Namtari	0.10	136.00	22.50	21.00	36.30	57.00	144.00	5.80	0.60	133.00	6.90
Nasarawao	0.20	25.00	30.90	30.90	6.50	110.00	31.02	5.40	0.60	54.50	7.10
Ngurore	0.05	363.00	21.00	28.90	65.50	119.00	160.50	6.50	0.70	59.50	7.10
Rumde	0.03	279.00	20.20	31.90	54.00	112.00	129.60	6.80	0.70	131.50	6.30
Toungo	0.10	124.00	21.50	12.00	10.50	307.00	20.00	5.30	0.50	150.00	7.00
Yelwa	0.02	158.50	24.50	20.50	29.80	112.00	22.40	6.50	0.50	*222.00*	6.70
YoldePate	0.07	99.50	31.50	35.50	65.00	333.00	136.00	6.60	0.40	*233.00*	6.50
Average	0.14	176.00	30.58	28.38	28.90	194.57	92.44	5.74	0.62	153.48	6.65
W.H.O Guideline	0.3	250	500	50[a]	50	500[b]	200	82[c]	1[d]	500[e]	6.5-8.5[f]
SON Guideline	0.3	250	100	-	50	-	200	-	-	150	6.5-8.5

a: no guideline value was proposed for magnesium in World Health Organisation (2011); value is based on Health Canada (1978) and United States Environmental Protection Agency (2003).
b: no guideline value was proposed for bicarbonate in World Health Organisation (2011), value is based on World Health Organisation (1980).
c: no guideline value was proposed for potassium in World Health Organisation (2011) and value is based on World Health Organisation (2009).
d: no health-based guideline value was proposed for phosphate in World Health Organisation (2011) and value is based on Fadiran et al. (2008).
e: no health-based guideline value was proposed for hardness in drinking-water (World Health Organisation, 2011), value is based on maximum consumers tolerate stated in World Health Organisation (2011).
f: no health-based guideline value was proposed for pH in World Health Organisation (2011), given value is based on World Health Organisation (2007).

mg/litre, with a mean value of 176 mg/litre. The 250 mg/litre guideline set by the WHO and SON is exceeded by water samples in Bole (411 mg/litre), Jambutu (399 mg/litre), Ngurore (363 mg/litre) and Rumde (279 mg/litre). Chloride contamination can originate from sewage and industrial effluents and saline intrusion (Vengosh and Pankratov, 1998). In our study, the high population density and poor sewage and waste disposal system in the wards with chloride contaminants suggest that discharge of household salts and other materials deposited close to the boreholes may be responsible. According to World Health Organization (2011), chloride in excess of 250 mg/litre gives rise to detectable taste in water because pure water should not have taste. In high concentrations, chlorides give water odour and a salty taste that makes it undesirable for consumption. There is evidence that high chloride intake may result in an increased risk of heart disease, stroke, congestive heart failure, and kidney disease (Hattersley, 2000; Hutchinson, 1970). Considering that kidney and heart related problems are ravaging, Nigerians (Awobusuyi et al., 2011) raises a need for urgent action to stem chloride contamination in Yola-Jimeta metropolis.

Iron

Iron concentration range between 0.01 mg/litre and 0.40 mg/litre with a mean of 0.16 mg/litre. All the boreholes passed WHO guideline at 2 mg/litre for iron. However, samples from seventeen wards show iron concentration less than 0.30 mg/litre, thereby deviating from 0.3 mg/litre guideline provided by WHO and SON. High rainfall is essential in increasing iron concentration in boreholes. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of groundwater for boreholes (Nemade et al., 2009). But in our study area rainfall regime is low; this can explain the low iron concentration in a large proportion of boreholes. According to the WHO, iron concentration below 0.3 mg/litre may develop turbidity and colour. Although, low iron concentration is not considered as serious health concern, the EU (European Union) even recommends a 0.2 mg/litre (The Council of the European Union, 1998). However, even at this, the fact that water concentration from fifteen boreholes in our study is less than 0.2 mg/litre raises concern because suspended particles as a result of turbidity may provide a place for harmful microorganisms such as viruses, parasites and some bacteria to lodge (Nemade et al., 2009). These organisms can cause nausea, cramps, diarrhoea, and associated headaches (Hoebe et al., 2004). The low iron concentration of water will also cause adverse taste of water and when used in laundry may result in stains or discoloration of clothing and soap wastage (Nemade et al., 2009).

Nitrate

The concentration of nitrate in five wards namely Bole (74.5 mg/litre), Mbamba (81.5 mg/litre), Ngurore (65.5 mg/litre), Rumde (54 mg/litre) and Yolde-Pate (65 mg/litre) deviate from the 50 mg/litre, suggested by WHO and SON. In the study area, nitrate concentrations ranged between 0.5 mg/litre in Makam B to 81.5 mg/litre in Mbamba, with an average of 29 mg/litre. The main source of nitrate contaminant in water is through run-off from farmlands (Chiroma et al., 2007; Fawell and Nieuwenhuijsen, 2003). Nitrate is a major ingredient of farm fertilizer and is necessary for crop production. Nitrate can also get into shallow groundwater from leaking of wastewater (where latrines and septic tanks are poorly sited) or other organic wastes (from animals livestock, fish and birds) into groundwater. Considering the fact that most of the wards with high nitrate contents are agrarian, the high nitrate in our study is related to runoff from farmlands due to the wide scale use of nitrogenous fertilizer [nitrogen-phosphorus-potassium (N-P-K)]. Nitrate can cause large-scale health effects through drinking-water exposure. The primary health concern regarding nitrate is the formation of methamoglobinaemia (blue baby syndrome). It causes cyanosis and asphyxia (Fan and Steinberg, 1996; Knobeloch et al., 2000). Nitrates can be reduced to life threatening toxic nitrites in the human intestine. When infants below the age of six months drink water containing nitrite in excess of the acceptable limit they could become seriously ill and, if untreated, may die. This is a reason for concern because as nitrate level in groundwater in Nigeria has been on the increase (Adelana, 2006); so also is infant mortality (Okafor and Ogbonna, 2003; Wall, 1998). Yet, agriculture is the major occupation and source of livelihood to many in the study area. Therefore, there is need to promote wise application of fertilizer to stem further runoff and any health impact.

pH

pH in water is an indication of the hydrogen ions (H^+) and negative hydroxide ions (OH^-) in water, to indicate whether the water is acidic or alkaline (World Health Organisation, 2006). In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7. The WHO and SON set a pH guideline value of between 6.5 and 8.5 as generally considered satisfactory for drinking water. The pH of borehole water of our study area ranged between 5.6 and 7.1. Boreholes with pH below 6.5 are generally considered acidic. This relates to borehole water in Bako (6.2), Mbamoi (6.3), Bole (6.1), Mbamba (6.3), Limawa (5.6) and Rumde (6.3). pH is generally considered to have no direct impact on humans. However, long-term intake of acidic water can invariably lead to mineral deficiencies (Fairweather-Tait and Hurrell, 1996). Prolong exposure to such acidic water will only negate the various efforts of governments to enhance nutrition of the people. Non-health effects are aesthetic because acidic water tends to be corrosive to plumbing and faucets.

Sodium

Sodium concentration from our study ranged between 20 and 310 mg/litre with an average concentration of 93 mg/litre. Sodium concentration in one ward (Doubeli at 310 mg/litre) is in excess of 200 mg/litre guideline value provided by WHO and SON. The location of Doubeli, close to Bajabure Industrial Complex where chemicals such as Sodium hydroxide (NaOH) is commonly used in nearby foam industry may explain the source of sodium contaminant in the ward. Concentrations of sodium in excess of 200 mg/litre may give rise to unacceptable taste, and there have been reports of possible association between sodium in drinking-water and the occurrence of hypertension, but no firm conclusions can be drawn (Gavras et al., 1975; World Health Organisation, 2006). This should be a source of concern considering the fact that hypertension is a major health challenge among adult Nigerians (Akinkigbe, 2003; Cappuccio et al., 2004; Kaufman et al., 1996). Further study of this link may lead to better understanding of the high risk for hypertension among Nigerians.

Total hardness

Water hardness in boreholes of the metropolis varies from 43.8 to 302 mg/litre with an average value of 153 mg/litre. None of samples exceed the guideline value of 500 mg/litre for drinking provided by WHO. However, SON recommends a total hardness of 150 mg/litre. Water from Adarawo (230 mg/litre), Alkalawa (302 mg/litre), Bako (228 mg/litre), Karewa (235 mg/litre), Limawa (153 mg/litre), Yelwa (222 mg/litre), and Yolde Pate (233 mg/litre) deviate from the SON guideline value. Hardness in water is mainly a natural occurrence indicating that there is a lot of calcium, magnesium, carbonate, hydrogen-carbonate and sulphate ions present in the water. The incidences of water hardness in our study site are as the result of the dissolution of calcium carbonate associated with the sandstone that underlies most parts of the metropolis. Therefore, we conclude that the water hardness is most probably a natural occurrence. Hardness will cause soap scum and need use of excess soap to achieve cleaning (World Health Organisation, 2011). The predominantly poor people of the area will have to spend more money buying soap.

Bicarbonate

There are no specific guidelines for bicarbonate in WHO (2006), however, we use the value of 250-500 cited in World Health Organisation (1980). Bicarbonate concentration in boreholes in the metropolis ranged from 57 to 399 mg/litre, with a mean of 195 mg/litre.

Therefore, borehole sources in our study can be regarded to be free from bicarbonate pollution.

Magnesium

There is no specific WHO (2006) guideline on concentrations of magnesium in drinking-water. However, recommended limits cited in literature ranged from between 50 and 150 mg/litre (Health Canada 1978; United States Environmental Protection Agency, 2003). In our study magnesium concentration ranged between 12 and 42.8 mg/litre, with a mean of 28.4 mg/litre.

Phosphate

The WHO does not have a nutritional basis for the regulation of phosphorus levels in drinking water. Generally, limits quoted in literature ranged between 0.05 to 1.0 mg/litre (Fadiran et al., 2008). In our study phosphate level ranged between 0.3 and 0.9 mg/litre. These values are well below the maximum of 1.0 mg/litre suggested in literature.

Potassium

Concentration of potassium in water samples from our study ranges from 3.5 to 7.8 mg/litre with an average value of 5.7 mg/litre. This is within all standards cited in literature including the value of 82 mg/litre cited by (World Health Organisation, 2009) as average potassium concentration in drinking-water, based on the average potassium concentration in the Canadian province with the highest measured potassium concentrations.

Sulphate

The concentration of sulphate in our study area range

Table 2. Statistical significance of difference between all study area values compared with WHO /SON values.

Value	Fe+	Cl-	SO_4^{2}-	Mg^+	Na^{-3}	HCO_3	Na^{+-}	K^-	PO_3^{-4}	$CaCO_3$	pH
	(mg/L)										
Mean value test	0.2	233.5									
W.H.O guideline	0.3	250	500	50	50	500	200	82	1	500	6.5
SON guideline	0.3	250	100	-	50	-	200	-	-	150	6.5-8.5

between 20.2 and 50.1 mg/litre with the mean value of 30.6 mg/litre. According to WHO (2006), taste thresholds for sulphate in water have been found to range from 250 mg/litre for sodium sulphate to 1000 mg/litre for calcium sulphate. It is generally considered that taste impairment is minimal at levels below 250 mg/litre, hence the 250 mg/litre used for this study. In any case, the sulphate concentrations in all the wards are within the WHO guidelines.

Assessment of contaminated water relative to guideline values

Statistical test (Table 2) to evaluate human health risk of water contamination in Yola-Jimeta metropolis reveals that there is no significant difference in mean concentration of contamination indicator and their guideline values except for pH (based on both WHO and SON guideline) and total hardness (based on SON guideline value).

The upper bound value (US_{95}) of all the indicators (except for pH) are less than the guideline value (G) suggested by World Health Organisation. Thus, it can be concluded that no action is warranted in the averaging area based on the mean value test. However, when compared with the SON values, the upper bound value (US_{95}) of total hardness (188 mg/litre) is greater than the guideline value (G) of 150 mg/litre, thus the data do not pass the mean value test. In this circumstance, it is suggested that there should be further sampling to gain a more representative picture of the site. However, precaution will suggest that remedial action is encouraged. This should also be the case for pH concentration which did not pass the mean value test using both WHO and SON guideline values.

This implies that overall, borehole water in the Yola-Jimeta metropolis is within guideline values for the ten contamination indicators and that focus should be on improving pH compliance. However, this analysis should be made with great caution, as it is not possible to aggregate boreholes from different wards that are distinct even if it is possible, the presence of a contaminant is enough concern.

The case of total hardness where boreholes are within WHO standard but deviated from SON standard re-echo the need for individual societies to conduct research and set the best standards acceptable to their needs rather than depending on WHO guideline values which may not be a true reflection of the health and development challenges faced. A national standard is best able to capture and internalize these needs in any standard or guideline setting.

Conclusion

This study assessed some chemical contamination indictors in water and has revealed that borehole water in Yola-Jimeta metropolis is not of the best quality as far as the WHO and SON guidelines are concerned. We have found that concentrations of chloride, iron, nitrate, pH, sodium and total hardness in some wards deviate from the guideline value provided by WHO and SON. Borehole water from Makam A and Makam B is largely suitable for human consumption as there was no case of contamination. However, water from the remaining twenty wards deviate from guideline values for one or more of the indicators - Rumde ward has the highest incidence, water from the ward deviate from guideline values for four contamination indicators (Table 1). The presence of contamination in borehole water especially those with high nitrate content should be treated before use as it poses serious health effect to the population. The major contamination in the study area is linked to poor sanitation. This underscore the need to integrate water supply and sanitation related objectives in policies to achieve the optimum result of government developmental goals. We therefore, advocate the setting up of a water sanitary agency that will monitor water contamination at ward levels.

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