ASSESSMENT OF POTABILITY OF BOSSOCAMPUS BOREHOLE WATER, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA. NIGERIA

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Abstract
Groundwater is a main source of water supply for domestic needs for both rural and urban communities in Nigeria. This study assessed the potability of borehole water from Federal University of Technology, Minna, Bosso campus used by the students for their daily domestic water requirements. Physical, organic and chemical constituents in the borehole water were determined during the rainy season (June, 2009). The results showed that the sampled borehole water were within the acceptable limits recommended by World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ) with the exception of chemical oxygen demand (COD), manganese (Mn^{2+}), magnesium (Mg^{2+}) and phosphate (PO_4^{3-}) with average concentrations of 68.50±9.62 mg/L, 0.50±0.14 mg/L, 11.89±1.30 mg/L and 33.43±14.80 mg/L, respectively. Though, unlike microbiological contamination, chemical contamination do not pose immediate health hazards until after prolonged exposure, it is recommended to treat the borehole water before consumption. Also, measures should be put in place for continuous monitoring of the borehole water to ascertain its continuous potability. Continuous exploitation of our groundwater may increase these values (EC, TDS, COD, NO_3^- -N, PO_4^{3-} -P, and heavy metals), thus leading to deterioration of the water quality which will negatively impact the health of the people and the environment.

Keywords: Analysis, Borehole, Groundwater, Organic, Potability, Threshold limits

Introduction

Groundwater is considered to be a potable fresh water resource. Thus, potable water is that water that is certified free from disease producing organisms as well as chemical substances that are dangerous to human health (Devi & Premkumar, 2012). The uses of ground water include municipal water supply, agricultural and landscape irrigation, and industrial water supply (Asano & Cotruvo, 2004).The main factors to consider for the suitability of water for a particular purpose are physical, chemical, microbial contamination, hazards and risks (Asano & Cotruvo, 2004).

The quality of water refers to the physical, chemical, biological and radiological characteristics of water (Bano & Ahmed, 2014).The filtration process through which groundwater passes through the soil and sediments makes it free from organic contaminants (Saleem *et al.*, 2016).Similarly, the quality of groundwater can respond to the variation in physical, chemical and biological environments as the water passes through it (Perween & Fatima, 2015). Contamination of groundwater is a major public health and environmental threats to the world (Bano & Ahmed, 2014). Although, its rate of contamination is slower than that of surface water, it is difficult and expensive to remediate (Olatunji *et al.,* 2015). It is therefore necessary to ensure that groundwater drawn for domestic purposes are of acceptable quality (Asano & Cotruvo, 2004). This is becausegroundwater can be contaminated throughnatural and anthropogenic activities (Bano & Ahmed, 2014) including industrial discharges,chemical and organic fertilizerapplication, sewage,solid waste leachate, seepage from effluent bearing water bodies, mining activities and vehicle maintenance (Akpoveta *et al.,* 2011; Devi & Premkumar, 2012; Perween & Fatima, 2015) as well as infiltration of irrigation water, septic tanks, pits, lagoons and ponds used for storage (Pathak & Limaye, 2012). Thus, maintaining groundwater quality is vital for healthy communities, our economy and our way of life of the urban and rural communities in Nigeria and beyound.

This present study was conducted to determine the potability of groundwater (borehole) source by investigating the physical and chemical (inorganic) qualities of borehole water used mainly by the males resident on the university campus (Federal University of Technology, Minna, Bosso Campus) for their daily domestic water requirements (drinking, food preparation, bathing, washing clothes and dishes as well as for flushing toilets).

Materials and Methods

Description of study area

Bosso campus, Federal University of Technology, Minna is located on latitude $9^0$40' N and longitude 6^0 33' E of the equator at elevation of about 400 m above sea level (Egharevba and Ibrahim, 2006). Minna has two main distinct climates, rainy and dry seasons. The rainy season begins in April and ends in October while the dry season starts in November and ends in March. Minna has mean annual precipitation of 1300 mm from a record of 50 years with peak temperature of 40^0C between February and March and 35^0C between November and December. The study area is steep sloppy with sandy loam soil, acidic (4.9 – 5.6) in nature with high organic matter level. The selected borehole for this study is located between the boys' hostel and the school cafeteria. The borehole is about 50 m away from the boys' hostel soak away.

Sample collection and analysis

The borehole water samples were collected in duplicates into sterile containers of 1*l* capacity once every week for four weeks in June 2009 during the rainy season. Colour, odour and taste were determined. The pH, air and water temperature, dissolved oxygen (DO) and electrical conductivity (EC) were determined using handheld instruments.

For other parameters of interest, the samples were placed in ice-chest and taken to the laboratory for the determination of total hardness (TH) by adding 1 mL of NH_4Cl buffer solution to 10 mL of water sample and diluted to approximately 50 mL with deionized water, followed by the addition of 250 mg sodium Cyanide and 200 mg indicator power, this was well mixed. Titration was done within 5 min with 0.01 EDTA (ethylene-diamine-tetrathanoic) standard solution slowly with continuous stirring until reddish tinge disappeared. Calcium standard solution was titrated as above and total hardness was calculated based on the equation in Asadullahi and Khan (2013):

$$\text{Total hardness} = \frac{mL\ titration\ \ for\ sample \times mg\ CaCO_3\ equivalent\ to\ 1\ mL\ EDTA\ titrant}{mL\ of\ sample} \times 1000 \qquad (1)$$

Total alkalinity (TA) was determined by taking a known volume of water sample in a clean conical flask, 2 drops of methyl orange indicator was added shook. This was titrated with 0.2N H_2SO_4 acid until colour of the solution changed from yellow to orange which marked the end point. The total alkalinity was calculated using the equation below:

$$\text{Total alkalinity} = \frac{\text{Vol.(H2SO4)} \ \times normality\ (acid) \times \times 1000}{Vol.\ of\ sample} \quad (2)$$

Calcium (Ca^{2+}) was determined by pipetting 25 mL of borehole water sample into a conical flask, 100 Ml of distilled water was added to the sample, followed by adding 25 Ml of 20 %

KOH and a pinch of mure oxide indicator was then added to the sample. The sample was titrated with 0.02 normal EDTA. From pinkish red to pinkish purple end point. This titration was a measure of Ca alone in the sample.

Sulphate (SO_4^{2-}) was determined by mixing 50 ml of filtered sample containing not than 10 ml SO_4^2 or an aliquot diluted to 50 ml with 10 ml each of NaCl and HCl and glyce-vol-alcohol solution measure the absorbance against a water blank in calorimeter at any wavelength between 380 nm and 420 nm or in a turbidometer.

Chloride (Cl^-) was determined by mixing 100 ml of sample containing not more than 10 ml of an aliquots dilute to 100 ml, with 10 drops (0.5 ml) of indicator solution add 0.2 m HNO_3 drop wise until the solution become yellow. Add 5 drops or more of 0.2 m HNO_3. Titrate with Hg $(NO_3)_2$ to the point where the blue purple appears which does not disappear on shaking prior warning that the end point is near. Change in colour to orange indicate the end point.

The sampled borehole water was analyzed for biological oxygen demand (BOD) using Winkler method by treating with magnanimous sulphate solution, alkali-iodide azide solution and 1.00 mL concentrated sulphuric acid by inserting the can for several times. The samples were then allowed to stay for five minutes after the formation of brown precipitates. The DO was immediately determined in-situ using a multi-parameter water quality model (model 6000 UPG), the remaining treated solution was well stoppered and incubated prior to five days later before BOD analysis. BOD was determined using iodometric method as described by Akpoveta et al. (2011).Chemical oxygen demand (COD), orthophosphate (PO_4^{3-}-P) and nitrate-nitrogen (NO_3^-N) were determined using open reflux method, ammonium molybdate ascorbic acid reduction method and spectrophotometric method, respectively as described in Standard Methods for the Examination of Water and Wastewater(APHA, 2002).

The metals [manganese (Mn^{2+}), copper (Cu^{2+}), iron (Fe^{3+}) and lead (Pb^{2+})] were analyzed using standard procedures described in the Standard Methods for the Examination of Water and Wastewater(APHA, 2002).The analysis were determined by measuring 100 mL of each water sample into a beaker and 5 cm^3 of concentrated HNO_3 was added. The solution was evaporated to near dryness on a hot plate, making sure that the sample does not boil. The beaker containing the residue was cooled. 5 mL of conc. HNO_3 was further added and returned to the hot plate until digestion was completed (as described by Akpoveta *et al.* (2011)). Two milliliter of conc. HNO_3 was added and the beaker warmed slightly to dissolve the residue. The digested sample was filtered and the filtrate made up to 50 cm^3 mark with deionized water. The solutions were used for metal analysis using atomic absorption spectrophotometer.

Statistical analysis was performed for all the parameters using SPSS package 16.0 for Windows (SPSS Inc., Chicago, IL, USA; version 16.0).

Results

Physical and organic parameters

The mean results of the physical and organic parameters for the borehole water samples are presented in Table 1.Colour, odour and taste taken during the four weeks of data collections were all unobjectionable. The mean temperature of the borehole water sample was within ambient temperature with safe BOD content of 2.31±1.77 mg/L although with a higher COD concentrations (68.50±9.62 mg/L) above the threshold limits (Table 1).

Table 1: Descriptive statistics of organoleptic and organic constituent of borehole water sample taken during the rainy season (mean ± standard deviation)

Parameters	Concentrations	Min	Max	Threshold limits*
Colour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Temperature (^{0}C)	22.38±1.69	20	25	Ambient
BOD (mg/L)	2.31±1.77	0.51	5.0	10
COD (mg/L)	68.50±9.62	55.00	85.00	60

*NSDWQ: Nigeria Standard for Drinking Water Quality (NIS, 2007); **SPSS 16.0 Version

Chemical constituents of the borehole water

The mean results of the chemical parameters for the borehole water samples are presented in Table 2.pH values show the acidic and alkaline material present in water (Sarala and Ravi, 2012). The mean pH value of the borehole water was slightly acidic, it varied from weakly acidic (6.32) to normal (7.50) throughout the period of data collection (Table 2). It was observed to be within safe limit of drinking water recommended by the Nigeria Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO).

EC is a useful tool to assess the wholesomeness of water, the mean, minimum and maximum EC values of the sampled borehole water were within the acceptable limits (Table 2).It ranged between 245 and 300 µS/cm with a mean value of 270.00±21.36 µS/cm. The borehole sampled water had TDS ranging from 196 to 380 mg/L with mean TDS value of 269.00 ± 78.30 mg/L, with mean TH and TA values of 134.62 ± 18.61mg/L and 136.75 ± 20.58 mg/L, respectively which were all within NSDWQ and WHO threshold limits (Table 2). The sampled borehole water had K, Na,Cl^- and NO_3^- within the acceptable limits of NSDWQ and WHO (Table 2). And, Mg^{2+}(11.89±1.30 mg/L), Mn^{2+} (0.50±0.14 mg/L) and PO_4^{3-} (33.43±14.80 mg/L) were above the threshold limits.

Table 2: Descriptive statistics of chemical constituent of borehole water sample taken during the rainy season (mean ± standard deviation)

Parameters	Concentrations			Threshold limits	
	Mean	Min	Max	NSDWQ	WHO*
pH	6.85±0.43	6.32	7.50	6.5 – 8.5	6.5 – 8.5
EC	270.00±21.36	245	300	1000	1000
TDS	269.00±78.30	196	380	500	1000
TH	134.62±18.61	110	155	150	500
TA	136.75±20.58	110	165	-	200
K^+	2.03±0.50	1.32	2.54	-	75/100
Na^+	121.28±13.34	100	136	200	200
Cl^-	24.81±7.46	20	38	250	250
HCO_3^-	38.27±6.84	30.66	48	-	250
NO_3^-	2.23±0.94	1.15	3.55	50	50
PO_4^{3-}	33.43±14.80	10	50.00	5	-

Note: All parameters are in mg/L except for EC in (µS/cm); *WHO – World Health Organization (1993).

The mean results of the heavy metal content in the sampled borehole water taken during the rainy season are presented in Table 3. The mean concentrations of the heavy metals were below the threshold limits of WHO and Nigeria standards (NIS 554:2007) for drinking water quality with the exception of Mn^{2+} and Mg^{2+}. Generally, Cu, Fe and Pb ranged from 0.00 to 0.05 mg/L while Ca ranged from 5.88 to 7.20 mg/L. These values were below maximum tolerable limits of Nigeria standards (NIS 554:2007).

Table 3. Metal content for the groundwater

Parameters	Concentrations			Threshold limit	
	Mean	Min	Max	NSDWQ	WHO*
Cu^{2+}	0.02±0.02	0.00	0.05	1.00	2.00/1.00
Fe^{2+}	0.01±0.01	0.00	0.02	0.30	0.30
Pb^{+2}	0.01±0.01	0.00	0.02	0.01	0.01
Mn^{2+}	0.50±0.14	0.21	0.61	0.20	0.40
Mg^{2+}	11.89±1.30	10.25	13.68	0.20	0.2
Ca^{2+}	6.74±0.48	5.88	7.20	-	75.0/200

Note: All parameters are in mg/L.

Discussion

The temperature of the borehole water was within acceptable limit, this may be as a result of the low TDS as reported in Kassa (2015). However, high temperatures can negatively impact water quality by enhancing microorganism growth (Mustapha *et al.,* 2015), and may increase taste, odour, colour and corrosion problems (Asadullahi & Khan, 2013). This was not the case in this present study because colour, odour and taste of the borehole water were all unobjectionable. Thus, temperature can positively and negatively influence water qualities such as alkalinity, salinity, EC and TDS (Kassa, 2015).

The borehole water for this present study is classified as good based on the EC classification for the suitability of water for particular purposes according to Perween and Fatima (2015).Furthermore, the low EC indicate that the borehole water contain low amount of dissolved inorganic substances (Devi & Premkumar, 2012; Sarala & Rayi, 2012). This was also reflective in the low TDS results recorded for this present study. TDS are composed of carbonates, bicarbonates, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, PO_4^{3-}, Na, K and Fe(Dalal et al., 2013), this study showed low TDS value which also corresponded to lower values of Cl^-, SO_4^{2-}, Ca^{2+}, Na, K and Fe. These low values may be due to dilution of the constituents in the borehole water as a result of infiltration of surface runoff, as well as effects of low water temperature on the dissolution of the rocky materials in the aquifer (Kassa, 2015).

Generally, the borehole water was slightly acidic to normal (Table 2). The buffering effect of the carbonate may have given raise to this condition. Water with low pH can cause corrosion in distribution pipes, thus releasing zinc, cadmium, lead and copper while high pH would induce the formation of toxic compounds such as trihalomethane (Perween & Fatima, 2015). The sampled borehole water had a mean BOD less than 3 mg/L, an indication of normal microbial activity (Nagamani *et al.,* 2015). However, COD concentrations were high. This may be an indication of toxic conditions as well as the presence of biologically resistant organic substances in the water (Mahre *et al.,* 2007; Mustapha *et al.,* 2015). High COD concentration can lead to oxygen depletion (Perween & Fatima, 2015).

Sewage can increase the quantity of chloride (Devi & Premkumar, 2012) and nutrient (Dzwairo et al., 2006) in water, despite the proximity of the borehole (50 m away) to a soak away, $Cl^-$and NO_3^-were within safe limits. In addition, Cl- plays an important role in balancing the level of electrolyte in the blood plasma while higher concentration can produce some physical disorder (Sarala & Ravi, 2012) and laxative effect (Bano & Ahmed, 2014). However, the PO_4^{3-} value showed negative health implications (Table 2).

The sampled water had maximum TH value higher than the NSDWQ (0.20 mg/L) limits though lower than the WHO guideline value (300 mg/L). Accordingly, Asadullahi and Khan (2013) in their paper classified water with total handness level > 120 mg/L to be hard. In addition, the high concentrations of Mg^{2+} and reasonable amount of Ca^{2+} in the borehole water may have contributed to the hardness of the water. Thus, hard water can cause scale deposition in distribution system and also increases soap consumption rate for washing, cleaning and laundry (Asadullahi & Khan, 2013; Dalal *et al.,* 2013) which may not be economical for students.

The high concentration of Mg^{2+} and PO_4^{3-} in the sampled borehole water may be due to anthropogenic sources, this can cause health problems (Dalal *et al.,* 2013). Although, Mg is an essential ion for the functioning of cells in enzyme activation, high Mg concentration cause laxative effect while the deficiency may cause structural and functional changes in human beings (Sarala & Ravi, 2012).

Cu, Fe and Pb had mean concentrations below the threshold limits of WHO and Nigerian Standards (NIS 554:2007). Although, Cu and Fe are essential elements for living organisms, excessive concentrations can become poisonous for them (Mustapha et al., 2018) whileexcessive doses of Fe can lead to hemorrhagic and sloughing of mucosa areas in the stomach of man (Mustapha *et al.,* 2018). Pb is a non-essential element to human, Pb-polluted water bodies can be a serious environmental threat throughthe contamination of drinking water and agricultural crops (Mustapha *et al.,* 2018).

Conclusion

The borehole water at Bosso campus of Federal university of Technology, Minnataken during the rainy season of 2009 was analysed for its potability. Thus:

(i) The results revealed low concentrations of the measured parameters as compared with the Nigerian threshold limits (1000 µS/cm EC; 500 mg/L TDS; 200 mg/L Na^+; 250 mg/L Cl^- and 50 mg/L NO_3^-), the rains may have diluted the concentration of the chemical constituents and dissolved salts in the groundwater since the grounwater is recharged by direct infiltration of precipitation.

(ii) Physical analysis of the water indicates that the water quality is good while the chemical analysis which is an indication of the chemical quality of the waterrevealed thatsome chemical parameters (COD, Mn^{2+}, Mg^{2+} and PO_4^{3-} -P) did not comply well with the WHO and Nigerian Standards (NIS 554:2007), this may be due to the nearness of the soakaway to the borehole. However, the chloride concentration was within the safe limit.

Recommendations

(i) Drinking water quality is expected to have high physical, chemical and biological quality. This study focused on physicochemical parameters only. Thus, it is recommended to carry out further study on biological analysis of the borehole water to establish its potability.

(ii) The study was conducted during the rainy season for one month only, it is recommended to extend the study to cover more months in the rainy season as well as in dry season in order to make more authentic conclusions.

(iii) It is recommended to treat the borehole water at Bosso campus, FUT Minna before consumption from the point of view of the concentrations of COD, Mn^{2+}, Mg^{2+} and PO_4^{3-} -P in the borehole water in order to prevent adverse health effects.

(iv) It is important to determine of the sources of contaminants (COD, Mn^{2+}, Mg^{2+} and PO_4^{3-} -P) in the borehole water in order to ensure its continued potability.

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