ASSESSMENT OF MINERAL ELEMENTS AND MICROBIAL QUALITIES OF BOREHOLE WATER IN SOUTHERN NASARAWA STATE, NIGERIA

Supported by tetfund

B. W. Tukura[1]*, I. Ibrahim[2] and E. U. Onche[3]

[1]Department of Chemistry, Nasarawa State University, Keffi, Nigeria
[2]Department of Chemistry, Plateau State University, Bokkos, Plateau State, Nigeria
[3]Department of Chemistry, Nasarawa State College of Education, Akwanga, Nigeria
*Corresponding author: bittytukura@yahoo.com

Received: December 20, 2016 **Accepted:** March 09, 2017

Abstract: Mineral elements and bacteria in water may have some adverse health effects. The research was carried out to evaluate mineral elements and microbial contamination of some borehole water in Southern Nasarawa state, Nigeria. Levels of Na^+ and K^+ were determine using flame photometry, while Ca^{2+} and Mg^{2+} were quantified with the aid of atomic absorption spectrophotometer (AAS). Bacteria were isolated and characterized using standard methods. Concentrations of mineral elements varied according to areas. The highest and lowest mineral contents were recorded at Obi (0.30±0.29 – 12.24±2.90 mg/L) and Keana (0.18±0.14 – 9.74±0.02 mg/L), respectively; and generally varied in the order of $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$. Concentrations of Ca^{2+} and Mg^{2+} ions at Awe, Doma and Keana were not significantly different ($P \leq 0.05$). Concentrations of mineral elements were within the WHO maximum permissible limits for drinking water. The most probable number (MPN) varied between $3.0 \times 10^0 – 1.0 \times 10^3$cfu/100mL. The highest total coliform count (TCC) value (18 cfu/100mL) was recorded at Agyaragu in Obi area. *Escherichia coli* (*E. coli*), *Samonella* and *Clostridium perfringens* were not detected in the borehole water. Minerals and total coliform counts were within the WHO acceptable standard for drinking water. However, low risk may be associated with the consumption of water from the boreholes. Monitoring of water quality from the boreholes is necessary in order to avert any unprecedented health hazard.

Keywords: Borehole, water, bacteria, mineral elements, quality, Southern Nasarawa

Introduction

Water with appropriate quality is useful for sustainable and socio-economic development (Abera *et al*., 2016; Choudhury *et al*., 2016; Hamaidi-Chergui *et al*., 2016; Obi *et al*., 2016). Many people around the world, especially in the sub-Saharan Africa, rely greatly on underground water as the major source of potable water (Iyasele and Idiata, 2011).Water potability is an important index for water quality control (Addo *et al*., 2016).

Drinking water containing bacteria and mineral element levels above threshold limits may pose some health risks; though mineral elements are known to aid some physiological processes in the body. Basic cations such as Ca^{2+}, Mg^{2+}, K^+, and Na^+ commonly occur in water, mainly in the form of dissolved chlorides, nitrates, sulfates, hydrogen carbonates and carbonates (Nicoleta and Viera, 2010; Tukura and Igube, 2017). As water moves through the soil, it comes in contact with minerals present in soil and become saturated with dissolved solids. This dissolution process continues until equilibrium is established between the water and the minerals (Skorbilowicz, 2010).

Industrial discharges, agricultural activities (Nouyang *et al*., 2016; Stephen and Kennedy, 2013), and change in seasons and geology of an area (Seth *et al*., 2014; Palamuleni and Akoth, 2015) affect underground water quality. Although soil and other materials purify most of the water as it moves through an aquifer, some toxic substances, including microbes do pass through with the water (Maamar *et al*., 2015).

Microbial quality is one of the primary indicators for the safety of a drinking water supply. This is commonly assessed by quantifying bacterial indicators which include *E. coli*, Total coliforms and *Clostridium perfringens*. *E. coli* has been reported to be the most specific indicator of faecal contamination in drinking-water (Gwimbi, 2011). *E. coli*is abundant in animal or human faecal materials, sewage, and treated effluent; and can also be found in natural waters and soils under faecal contamination from human or agricultural activities. *Clostridium perfringens* is normally present in faeces in much smaller number than *E. coli*. Total coliform is not index of fiscal pollution but provide basic information on the quality of the water source. The presence of *Clostridium perfringens* in groundwater in the absence of *E. coli* is an indication of pollution in the past, and there might have been intermittent contamination of the water source(Miner *et al*., 2016).

Fecal pollution is responsible for high morbidity and mortality rate (Anttoniette and Afolayan, 2012), as a result of water borne diseases which include typhoid, cholera, dysentery, and hepatitis (Nkamare *et al*., 2012; Nwachukwu and Ume, 2013; Miner *et al*., 2016).

Good quality drinking water should not contain any indicator organism, and the detection of any of such organism requires action. The aim of this study is to assess the mineral elements and microbial quality of water from some boreholes located near some health facilities in Southern Nasarawa state.

Materials and Methods

Study area

Nasarawa state is located in north-central Nigeria, bounded in the south by Benue State; east by Plateau State, west by Kogi State, and in the north by Kaduna State; with coordinates 8°32N and 8°18E. For political convenience, Nasarawa State is demarcated into the northern, western and southern zones. The southern area encompasses Lafia, Awe, Doma, Keana, and Obi Local Government areas (LGA) as shown in Fig. 1.

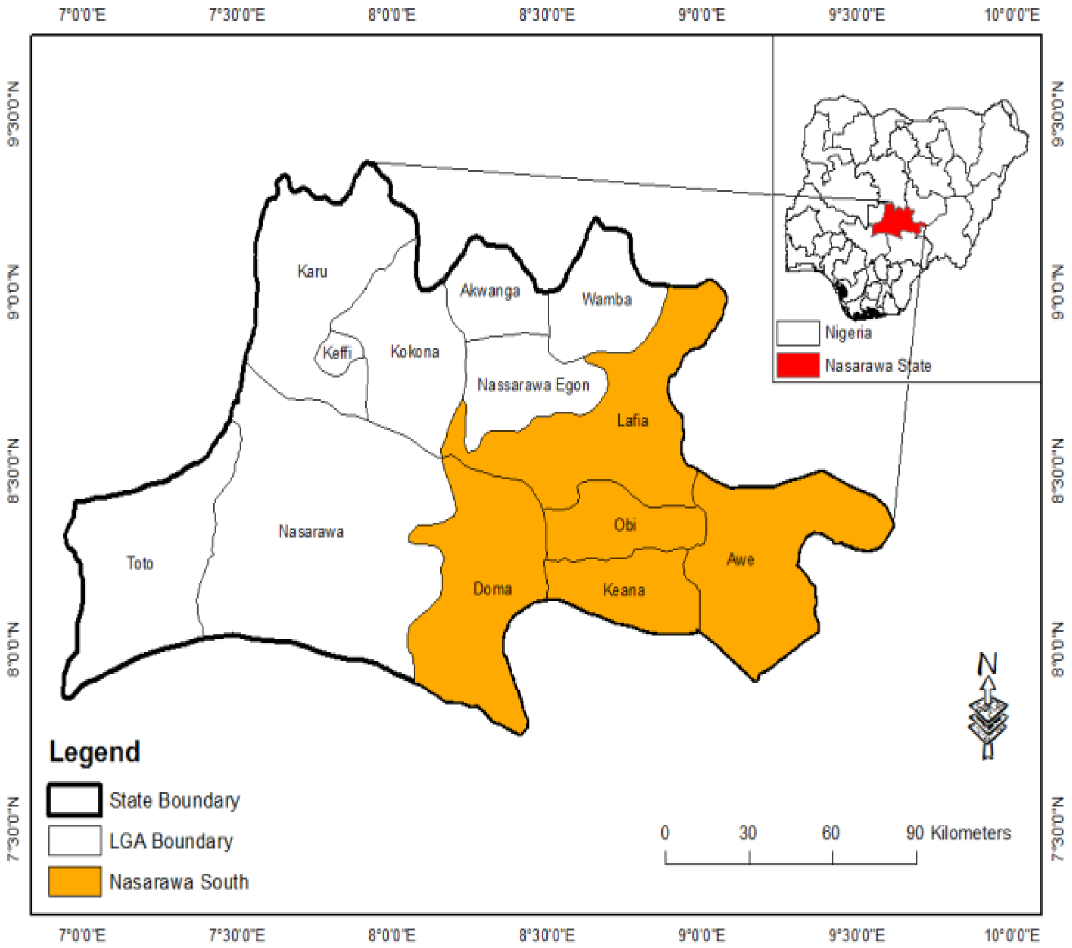

Fig. 1: Southern Nasarawa State showing sampling areas

Sampling

Water for microbial and mineral element determinations were collected in pretreated containers (APHA, 1998) during dry season from boreholes located at some Primary Healthcare Clinics (PHC) at GidanIhuman, Jangura, Akiri and Jangwa (Awe); Iwashi, Alwaza, Dadu and Agyema at Doma; Agbaragba, Owena, Chiata and Kalachi at Keana; Sabon Gari, Ombi II, Agyaragu Tofa, Angiri, Akunza, Ugah and Takpa at Lafia; and Utsuwababa, Ome, MCWC, Akpangwa, Angwa Sule, Idevi, Akaleku, Agyaragu, and Agewu at Obi LGA.

Mineral elements and microbial analysis

The method of Ademoroti (1996) was employed for the determination of mineral elements. Na^{+} and K^{+} ions were determined using flame photometer. Atomic absorption spectrophotometer (AAS) was used for Ca^{2+} and Mg^{2+}. The most probable number (MPN) of coliforms, total coliform counts (TCC) and *Clostridium perfringens* were determined using the methods by APHA (1998), Saka *et al.* (2013) and Adogo *et al.* (2016).

Statistical analysis

Simple statistics (mean ± SD) were carried out on the data. One way analysis of variance (ANOVA) was also carried out to determine significant difference ($P \leq 0.05$) in the levels of the mineral elements among the sampling locations using SPSS (v. 20) software.

Results and Discussion

Mineral elements

Variations in the levels of mineral elements in borehole water from Awe area are presented in Fig. 2. Concentration of Na^{+} was highest in all the locations, recording the maximum value at Gidan Ihuman. The highest levels of Ca^{2+} and Mg^{2+} were observed at Jangwa and Jangura respectively. The level of K^{+} did not vary much according to locations. Agyema and Dadu at Doma recorded the highest and lowest levels of Na^{+} respectively (Fig. 3), Mg^{2+} decreased from Iwashi to Agyema. Concentration of K^{+} was highest at Agyema.

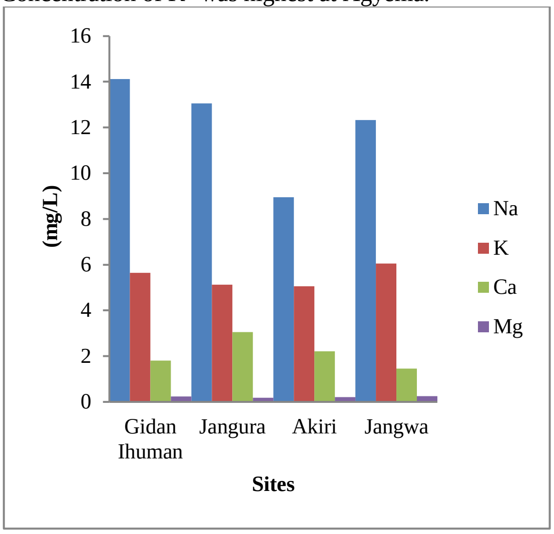

Fig. 2: Levels of mineral elements in borehole at Awe (mg/L)

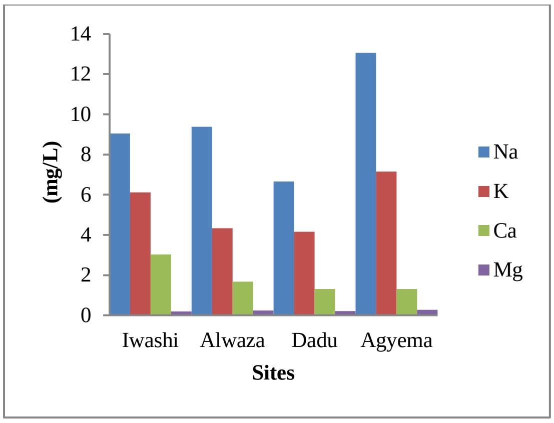

Fig. 3: Levels of mineral elements in borehole water at Doma (mg/L)

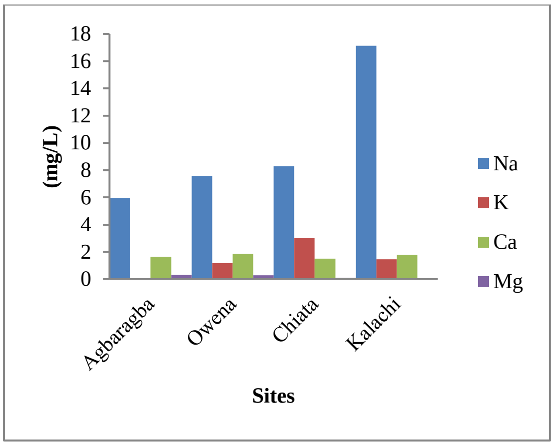

Fig. 4: Levels of mineral elements in borehole water at Keana (mg/L)

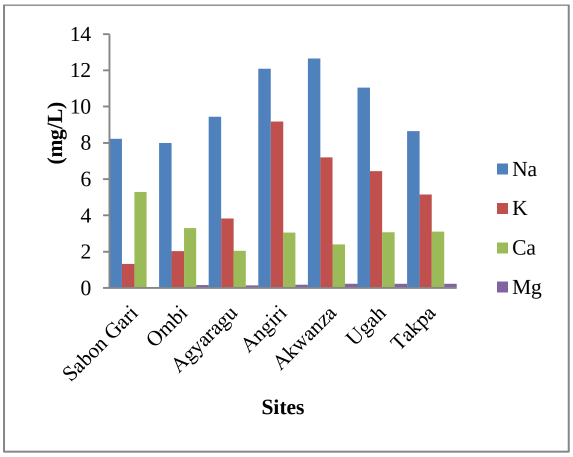

Fig. 5: Levels of mineral elements in borehole water at Lafia (mg/L)

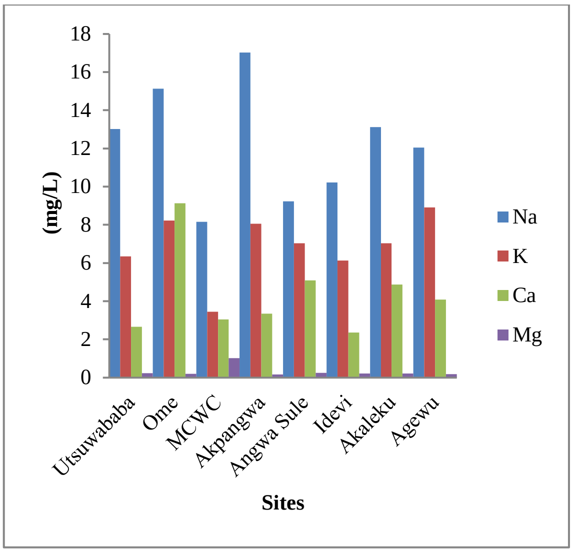

Fig. 6: Levels of mineral elements in borehole water at Obi (mg/L)

Variations in the levels of mineral elements at Keana (Fig. 4) indicated that the levels of Na^+ decreased from Kalachi to Agbaragba. Ca^{2+} levels were more or less the same in all the locations. K^+ was highest at Chiata. Mg^{2+} was the lowest in all the locations. Concentrations of mineral elements at Lafia (Fig. 5) increased from SabonGari to Akwanza, except at Ombi, and then decreased to Takpa. A similar trend was observed for K^+, where its concentration also increased from Sabon Gari to Angiri, then decreased to Takpa. Ca^{2+} levels varied according to studied sites, with the highest concentration at Sabon Gari and the lowest value at Agyaragu. Mineral element contents at Obi (Fig. 6) varied in the order of $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$ in all the locations, except at Ome, where the concentration of Ca^{2+} was higher than that of K^+. The levels of Na^+ and Mg^{2+} ions were highest and lowest in the studied areas respectively. Mineral levels (Table 1) were highest at Obi (0.30±0.29 – 12.24±2.90 mg/L), and varied in the order of $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$. Lowest concentrations (0.18±0.14 – 9.74±0.02 mg/L) were recorded at Keana.

Table 1: Levels (mg/L) of mineral elements in water from boreholes at Southern Nasarawa State

Elements	Awe	Doma	Keana	Lafia	Obi
Na^+	12.11±2.23[a]	9.53±2.64[b]	9.74±5.02[b]	10.0±21.90[a]	12.24±2.99[a]
K^+	5.47±0.47[a]	5.44±1.44[a]	1.41±1.24[b]	5.02±2.83[a]	6.90±1.69[c]
Ca^{2+}	2.14±0.68[a]	1.83±0.82[a]	1.71±0.16[a]	3.19±1.03[b]	4.32±2.18[c]
Mg^{2+}	0.22±0.03[a]	0.23±0.04[a]	0.18±0.14[a]	0.17±0.08[a]	0.30±0.29[b]

Values within the same row with different alphabets are significantly different ($P \leq 0.05$)

Table 2: Microbial quality of borehole water at Awe

Parameters	Gidan Ihuman	Jangura	Akiri	Jangwa
MPN (cfu/100mL)	1.0×10^3	3.0×10^0	1.0×10^3	5.0×10^0
TCC (cfu/100mL)	1	NIL	NIL	NIL
E. coli	NIL	NIL	NIL	NIL
Salmonella sp	NIL	NIL	NIL	NIL
Clostridium p.	NIL	NIL	NIL	NIL

Concentrations of mineral elements in ground water are determined by the geology and the solubility of the mineral compounds (Nikarov and Brazhniokovee, 2012). Minerals, though important for biological functions, can be toxic at concentrations above threshold limits (Fraga, 2003). Ca^{2+} and

Mg^{2+} ions in water contribute to total hardness in water. Relationship exists between hardness of potable water and morbidity with heart diseases (Donato *et al*., 2003). Na^{+}, in combination with chloride ion in drinking water, impart salty test when present at high level, which is repulsive to consumers. High levels of Na^{+} and low of levels of Mg^{2+} ions in water from the boreholes is in agreement with the results reported by Roba *et al*. (2015). Ca^{2+} and Mg^{2+} levels in this study were lower than the values reported by Akpoveta *et al.* (2011) and Adogo *et al.* (2016). The relatively higher levels of Ca^{2+} and Mg^{2+} for some boreholes might be due to the seepage of water, or due to cationic exchange (Satyavani *et al*., 2011; Kumar *et al*., 2016). Concentrations of mineral elements were within the maximum permissible limits of 200 mg/L for Na^{+} and Ca^{2+}, 250 mg/L for Mg^{2+} (WHO, 2006), and 10 mg/L for K^{+} (WHO, 2011). The levels of Na^{+} at Doma and Keana (Table 1) were the same but significantly different ($P \leq 0.05$) from the values recorded at Awe, Lafia and Obi. Concentrations of K^{+} in the studied areas were similar, except at Keana and Obi. Ca^{2+} at Lafia and Obi, and Mg^{2+} at Obi were not the same.

Table 3: Microbial quality of borehole water at Doma

Parameters	Iwashi	Alwaza	Dadu	Agyema
MPN(cfu/100mL)	1.0x10^{3}	3.88x10^{2}	2.78x10^{2}	2. 62x10^{2}
TCC (cfu/100mL)	3	8	5	1
E. coli	NIL	NIL	NIL	NIL
Salmonella sp	NIL	NIL	NIL	NIL
Clostridium p.	NIL	NIL	NIL	NIL

Table 4: Microbial quality of borehole water at Keana

Parameters	Ageragba	Owena	Chiata	Kalachi
MPN (cfu/100mL)	2.78x10^{2}	1.0x10^{3}	1.0x10^{3}	3.3x10^{1}
TCC (cfu/100mL)	5	3	NIL	NIL
E. coli	NIL	NIL	NIL	NIL
Salmonella sp	NIL	NIL	NIL	NIL
Clostridium p.	NIL	NIL	NIL	NIL

Microbial analysis

Results for Awe are presented in Table 2. MPN varied between 5.0 x 10^{0} at Jangwa and 1.0 x 10^{3} recorded at Gidan Ihuman and Akiri. TCC were obtained in all locations, except Gidan Ihuman. At Doma (Table 3), MPN varied according to locations, and ranged from 2.78 x 10^{2} (Iwashi) to 1.0 x 10^{3}cfu/100 mL at Dadu. The highest TCC was observed at Akwanza and the least content at Agyema. At Keana (Table 4), the lowest MPN was recorded for Kalachi, and the maximum level at Owena and Chiata. Zero level of TCC were recorded at Chiata and Kalachi, but were 5 cfu/100 mL and 3 cfu/100 mL at Agbaragba and Owena, respectively. MPN values at Lafia (Table 5) were the same in all the locations, except at SabonGari and Ombi where the values were relatively low. Concentration of TCC was highest at Ugah. From Obi (Table 6), MPNs were the same in all the locations.

Table 5: Microbial quality of borehole water at Lafia

Parameter	Sabon Gari	Ombi	Agyaragu Tofa	Angirir	Akunza	Ugah	Takpa
MPN (cfu/100mL)	1.89 x10^{2}	5.0 x 10^{0}	1.0 x 10^{3}	3.0 x 10^{0}	1.0 x 10^{3}	1.0 x 10^{3}	1.0 x 10^{3}
TCC (cfu/100mL)	NIL	NIL	8	3	NIL	13	1
E. coli	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Salmonella species	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Clostridium perfiringes	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Table 6: Microbial quality of borehole water at Obi

	Utsuwababa	Ome	MCWC	Akpangwa	Angwa Sule	Idevi	Akaleku	Agyaragu	Agewu
MPN (cfu/10mL	1.0 x10^{3}	1.0 x10^{3}	1.0 x10^{3}	1.0x10^{3}	1.0 x10^{3}	1.0 x 10^{3}	1.0x10^{3}	1.0 x10^{3}	1.0 x 10^{3}
TCC (cfu/100 mL)	1	1	NIL	NIL	NIL	NIL	NIL	18	NIL
E. coli	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Salmonella	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Clostridium perfiringes	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

E. coli and TCC are indicators for water quality determination. MPNs were less than the values observed by Josiah *et al*. (2014) and Ajayi (2013) for borehole water in Akungbo Akoko, Nigeria. MPN exceeding the WHO limits (cfu/100mL) in some of the water samples indicate the presence of bacteria that could make the water unsafe for certain applications. TCC obtained were higher than the 1.0 - 2.0 cfu/100 mL for some boreholes during winter, but less than the results (1.0 - 461 cfu/100 mL) reported during spring (Palamuleni and Akoth, 2015). TCCs were relatively low compared to values (19 - 27 cfu/100 mL) for borehole water at Arib, Algeria. Poor sanitary practices, location and construction of the boreholes might account for the presence of total coliform bacteria in water. *E. coli, Samonella* species, and *Clostridium perfringens* were not observed in all the points. This is similar to the results reported by Addo *et al.* (2016), which was an indication of the absence of fecal contamination.

Conclusion

Mineral contents varied according to areas. Levels of Na^{+} and Mg^{2+} ions in water from the boreholes were highest and lowest respectively. Concentrations of mineral elements were highest at Obi, while the lowest levels were recorded at Keana, which varied in the order of $Na^{+} > K^{+} > Ca^{2+} > Mg^{2+}$. Concentrations of Ca^{2+} and Mg^{2+} at Awe, Doma and Keana were not significantly ($P \leq 0.05$) different. *E. coli, Samonella* species, and *Clostridium perfringens* were not observed in water from the boreholes. Water from the boreholes was free of fecal pollution. Mineral elements and total coliform counts were within the WHO acceptable standard for drinking water. Continuous monitoring of the water quality, however, is necessary to prevent any unprecedented outbreak of water borne diseases.

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