International Journal of Ecological Science and Environmental Engineering
2018; 5(3): 71-78
http://www.aascit.org/journal/ijesee
ISSN: 2375-3854

American Association for Science and Technology

Assessment of Borehole Water Quality Consumed in Otukpo and Its Environs

Odoh Raphael*, Oko Odiba John, Udegbunam Ifeoma Sandra, Archibong Christopher Sunday

Department of Chemical Sciences, Faculty of Sciences, Federal University Wukari, Wukari, Nigeria

Email address

odohraf@gmail.com (O. Raphael)

*Corresponding author

Citation

Odoh Raphael, Oko Odiba John, Udegbunam Ifeoma Sandra, Archibong Christopher Sunday. Assessment of Borehole Water Quality Consumed in Otukpo and Its Environs. *International Journal of Ecological Science and Environmental Engineering.* Vol. 5, No. 3, 2018, pp. 71-78.

Received: May 31, 2017; **Accepted**: September 9, 2017; **Published**: August 10, 2018

Abstract: The research was carried out to evaluate physico – chemicals, elemental and microbial contamination of some borehole water in some area of Otukpo. The physico – chemical parameters determined included; temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, total hardness, and phosphate using conventional equipment and standard laboratory procedures and concentration of the elements "Ca, Mg, K, Na, Cd, Cu, Fe, Mn, Pb and Zn" were quantified with the aid of atomic absorption spectrophotometer (AAS), bacterial analyses were carried out and characterized using standard methods. The results found that physical parameters tested such as turbidity, pH, TDS, conductivity, and colour did not indicate any reason for concern. All the physico – chemical parameters remained almost constant with little variations over time. Concentration of the elements (mg/L) ranged from 9.30 – 48.44, 2.14- 17.99, 1.39 – 11.99, 1.24 – 7.43, 0.24 – 0.98, 0.70 – 0.89, 0.02 – 0.09, and 0.24 – 0.98 for Ca, Mg, K, Na, Cu, Fe, Mn, and Zn respectively, and generally varied in the order of Ca > Mg > K > Na > Zn > Na > Mn > Fe > Cu in all the borehole water analysis. Concentrations of elements determined in the water samples were not significantly ($P \geq 0.05$) different. The most probable number varied between 15 - 17 cfu/100 mL. The highest total coliform count value (17 cfu/100 mL) was recorded at Oweto in Otukpo town. *E. coli, Samonella* and *Clostridium perfringes* were not detected in any of the borehole water. Cadmium and lead were not detected in any of the water samples from boreholes in the study sites. Minerals and trace elements determined were within the WHO acceptable standard for drinking water. Low risk may be associated with the consumption of water from the boreholes. Continuous monitoring, however, is advisable to avert any unprecedented health hazard.

Keywords: Assessment, Borehole Water, Microbial, Mineral Elements, Trace Metals, Physico-chemical Parameters, WHO Standards

1. Introduction

Drinking water sources has always been a major issue in many areas, in Nigeria, many of the rural populace do not have access to adequate water and therefore, depend on other alternatives like wells, borehole, stream and river, rain water for drinking and domestic use. The assessment of these water quality statuses is important for socio-economic development of any area of the world. The determination of drinking–water quality for human consumption is important for the well-being of the ever increasing population (Odoh *et al* 2013). Good quality water will ensure the sustainability of socio-economic development, rather than channeling the resources towards combating outbreaks of water borne diseases due to consumption of contaminated drinking–water. Drinking–water quality depends, to some extent, on its chemical and microbial composition which may be modified by natural and anthropogenic sources. As a borehole drinking–water sources have a huge potential to ensure future demand for water, it is important that human activities on the surface do not negatively affect the precious resource. It was emphasized on the importance of these water sources locally as a source for human consumption and changes in quality with subsequent contamination can, undoubtedly, affect human health. The World Health Organization has estimated that 80% of all sickness and diseases in the world are attributable to unhygienic water (WHO 1993). Water borne diseases are among the leading causes of death in many developing countries today. In addition to the alarming mortality rates, it is estimated that people in developing countries lose 10% of their productive time because of disease related to poor and contaminated water.

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 (Iyashele and Idiate, 2011). Elements in water occur in inorganic or organic forms. Basic cations such as Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} commonly occur in water, mainly in the form of dissolved chlorides, nitrates, sulfates, hydrogencarbonates and carbonates (Nocoleta and Viera, 2010). In natural waters, minerals are the sources of the basic cations, and their concentrations vary. Underground water interacts with minerals present in soil and become concentrated with heavy metals and dissolved solids. This dissolution process continues until equilibrium is established between the water and the elements (Skorbilowicz, 2010).

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

Fecal pollution due to *E. coli* is responsible for high morbidity and mortality rate (Attoniette 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).

Water quality is a term used here to express the suitability of water to sustain various uses or processes ((Ademorot 1996). Any particular use will have certain requirements for the physical, chemical or biological characteristics of water; for example limits on the concentrations of toxic substances for drinking water use, or restrictions on temperature and pH ranges for water supporting invertebrate communities (Saleh *et al* 2001). Consequently, water quality can be defined by a range of variables which limit water use. Although many uses have some common requirements for certain variables, each use will have its own demands and influences on water quality. Quantity and quality demands of different users will not always be compatible, and the activities of one user may restrict the activities of another, either by demanding water of a quality outside the range required by the other user or by lowering quality during use of the water (Josiah *et al* 2014). Efforts to improve or maintain a certain water quality often compromise between the quality and quantity demands of different users. There is increasing recognition that natural ecosystems have a legitimate place in the consideration of options for water quality management. This is both for their intrinsic value and because they are sensitive indicators of changes or deterioration in overall water quality, providing a useful addition to physical, chemical and other information (Nouyang *et al* 2009).

The aim of this study is to assess the physico – chemical parameters, some elemental (mineral and trace elements and microbial qualities of water from some boreholes within Otukpo local government areas of Benue state.

2. Materials and Methods

2.1. Study Area

Otukpo Local Government Area (LGA) is one of the oldest LGA in Benue State, but also the traditional headquarters of Idoma people where its paramount Chief the Och'Idoma has his palace. The LGA came into existence in 1923, with its headquarters at Otukpo. In addition to metropolitan Otukpo town other prominent places in the local government area include Ogobia, Upu, Otukpoicho, Otobi, Adoka, Oyagede and Akpa-Igede. It is located on 7°13^{1}N & 8°9^{1}E, and 7°21^{1}N & 8°15^{1}E. It is equally is bounded in the North by Apa and Ohimini local government areas in the Southeast, Ado local government in the South and Olamaboro local government area in Kogi state in the West. It has an estimated landmass of about 390 sq. km, and with an estimated population of 266,411 (2006, Census). LGA has a tropical sub-humid climate, with two distinct seasons, namely a wet and dry season. The wet season this lasts for seven months starts from April and ends in October. The annual rainfall total ranges from 1,200mm to 1,500mm. Temperatures are generally very high during the day, particularly in the months of March and April. Along the river valleys, these high temperatures plus high relative humidity produce inclement/debilitating weather conditions. Makurdi, the state capital, for example, records average maximum and minimum daily temperatures of 35°C and 21°C in summer and 37°C and 16°C in winter, respectively.

2.2. Sampling

Water were collected in pretreated containers (APHA, 1998) from boreholes located at different locations, Akpa, Asa, Eupi, Ogobia, Ojira, Otukpo Icho, Oweto, Ugboju Aje, Ugboju Icho and sabongari of the study areas,

2.3. Physico-chemical, Elemental and Microbial Analysis

Investigated physical parameters include pH, temperature, electrical conductivity, turbidity, total dissolved solid, and heavy metals were estimated using standard methods. All the water samples were acidified and digested by HNO_3 as specified by (APHA 1998). Samples were treated in triplicate and analysis was carried out following standard methods.

The instrument used was first calibrated with stock solutions of the prepared standards before analysis. The final processed samples were quantitatively analyzed using buck scientific VGP 210 Flame Atomic Absorption Spectrophotometer. After every five sample analyzed using AAS, the first sample was repeated for quality check. Only when the result was within 10% earlier readings did the analyses proceed further.

Microbioial characteristics were determined as described by Bezuidenhout et al., (2002). The Most Probable Number-multiple tube technique was used for coliform enumeration. Nutrient agar (NA), Salmonella- shigella agar, Thiosulphate citrate bile salt sucrose agar were used to determine heterotrophic bacterial, Salmonella andShigella, Vibrio cholerae respectively. All plates were incubated at 35°C for 24hrs. Presumptive colonies were confirmed by gram staining and biochemical reactions and each plate was given a positive or negative score. Isolates were confirmed by some conventional biochemical test SCA, (2002).

2.4. 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.

3. Results

The results of physico–chemical parameters selected in this study to assess the impact of such parameters on quality of the drinking water from the studied boreholes are presented in Table 1. The results were similar, because of the similar pattern in the sources relationship of the samples, focusing on the comparison between the sources will be futile; instead, the general profile of each parameter will be discussed focusing attention to any anomaly. The little discrepancies in the differing quantitative pattern among the samples were expected because each bore holes in study areas is may have a unique chemistry, which is acquired as a result of chemical alteration of the meteoric water recharging the system. For instance, turbidity is used to measure the clarity of the water. The average turbidity readings of the samples were above the WHO standard with average turbidity values of 6.730±1.740 NTU (Table 2). Presence of suspended particles and other materials are usually responsible for high turbidity values. Similar high turbidity values were also reported in similar research (Odoh and Dauda 2013) indicating that the wells may be unlined hence the high values. Soil particles may have found their way into the water sources either through runoff or from the unstable side walls thereby increasing turbidity of the water sources. The observed turbidity value in samples were slightly higher than the recommended value but all the values were however lower than the ones reported in the similar studies (Rajkumar et al., 2010).

Temperature: The temperature values of the drinking water samples from boreholes in the study areas are similar across the drinking water sources with a temperature range of 27.90–29.00°C. High water temperature enhances the growth of microorganisms and this may increase taste, odour and corrosion problems. There is no guideline value recommended for drinking water temperature since its control is usually impracticable (2006). The high temperature signified presence of active micro-organisms which resulted in the temperature increase.

Total dissolved solids (TDS) and electrical conductivity (EC) are the two main determinants used to determine salt content. TDS constitutes all the dissolved solids in the water. It is usually comprised of inorganic minerals (salts), small amounts of organic material and soluble minerals (Fe and Mn). The inorganic minerals (salts) are commonly found in nature and are deposited by the weathering of the sedimentary rocks and erosion of the earth's surface. TDS gives an indication of whether or not all suspended solids were contained in the drinking water sources. The TDS ranged from 150.00–260.00. High levels of TDS may also cause an objectionable taste, odour and colour to the water. It is evident from results (Table 1) that, there was no significant differences. TDS values were within drinking water standard of 1000 mg/L with average TDS values of 211.47±26.02 mg/L. The TDS for all drinking water sources from all the boreholes analyzed was within the recommended limits and may not have negative effects.

pH is one of the most important operational water quality determinants. The closer pH gets to 1, the more acidic the water becomes. According to WHO drinking water standard pH limits for drinking water are supposed to be between ≥ 5.0 to ≤ 9.5 (pH units). The pH values ranged from 6.10 to 6.90 in the borehole water samples studied. No significant variations were noticed during the period of study. International standards for drinking water suggest that pH less than 6.5 or greater than 9.2 would impair the portability of the water. All the drinking water sources tested were within the specified standard between 5.0 and 9.5 with average values of 6.62±0.25. The weakly acidic nature of drinking water may be traceable to some dissolved matter in the water. One of the major reasons why borehole water is likely to become more acidic is that more carbon dioxide from organic matters present in the soil could further dissolve in percolating water during percolation, before they reach an aquifer system.

Total Hardness: The values for the drinking water samples are not consistent. The water samples have a total hardness ranged from 29.00–50.50 mg/L. All the water samples are within the WHO (2005) 100-300 mg/L guideline limit for drinking water. According to WHO ecological and analytical epidemiological studies, there is a significant inverse relationship between hardness and drinking water. However the degree of hardness in the water may affect its acceptability to the consumer in terms of scale deposition.

Phosphate levels in all the water samples were in the range of 0.20-0.90 mg/L, with an average of 0.15±0.20 mg/L Table 1 and 2). The WHO guideline value for phosphate in drinking water is 5 mg/L. Thus, all the samples studied were within the limit. The water can be said to be of good quality in terms of phosphate content. The low level of phosphate may be due to low phosphate containing rocks system or absence of such rock system around the study areas. It could also be due to minimal use of phosphate containing fertilizers around these areas.

Table 1. *Results of Physicochemical Parameters of water from boreholes in the study area.*

Sample	Temp	pH	E.C	TDS	Turbidity	PO_4	Hardness
1	28.50	6.80	120.00	350.00	2.30	0.20	60.00
2	28.00	6.70	130.00	260.00	5.50	0.50	50.50
3	29.00	6.50	140.00	320.00	6.50	0.40	40.00
4	28.50	6.40	145.00	310.00	7.50	0.20	50.00
5	28.20	8.10	165.00	260.00	5.50	0.40	39.00
6	28.60	7.80	145.00	213.00	5.80	0.50	59.00
7	28.40	7.40	200.00	250.00	6.50	0.30	48.00
8	29.00	6.80	190.00	230.00	5.50	0.30	40.00
9	28.20	8.50	215.00	250.00	5.50	0.40	45.00
10	28.30	8.40	230.00	220.00	5.50	0.30	45.00
Mean	28.49	7.39	180.00	249.87	5.75	0.35	47.10
STD	0.35	0.82	36.01	44.15	1.14	0.11	6.36
MIN	27.90	6.20	120.00	200.00	2.30	0.20	39.00
MAX	29.00	8.80	230.00	350.00	7.50	0.50	60.00

Table 2. *Comparison of the results of the physicochemical parameters with WHO standard.*

	Range	Mean±S.D	W.H.O (2006)
Temp.	27.90 – 29.00	28.40±0.35	–
PH	6.10 – 6.90	6.62±0.25	6.50–9.20
E.C	110.00 – 215.00	171.27±33.23	500
TDS	150.00–260.00	211.47±26.02	500
Turbidity	2.30 – 9.00	6.73±1.74	–
PO_4	0.20–0.90	0.15±0.20	0–5.00
Hardness	29.00–50.50	41.30±7.68	0 – 1.00

Table 3. *Summary of the value of Mineral and Trace metals in the water samples from the Study sites.*

Parameters	Ca	Mg	K	Na	Cd	Cu	Fe	Mn	Pb	Zn
Mineral and Trace metals (mg/L) in Boerholewater from Adoka area of study sites										
Mean	17.15	11.02	5.33	3.95	N.D	0.06	0.20	0.78	N.D	0.35
StD	1.33	1.17	0.66	0.67	N.D	0.01	0.20	0.09	N.D	0.08
Min	15.07	8.69	4.10	2.84	N.D	0.03	0.09	0.67	N.D	0.24
Max	19.10	12.80	6.33	4.96	N.D	0.09	0.77	0.92	N.D	0.75
Mineral and Trace metals (mg/L) in Boerholewater from Asa area of study sites										
Mean	17.63	10.02	5.00	3.05	N.D	0.05	0.20	0.79	N.D	0.34
StD	1.55	1.37	1.21	0.61	N.D	0.01	0.20	0.06	N.D	0.04
Min	15.07	7.80	3.68	1.95	N.D	0.03	0.09	0.70	N.D	0.25
Max	20.07	11.99	7.43	4.11	N.D	0.08	0.77	0.89	N.D	0.98
Mineral and Trace metals (mg/L) in Boerholewater from Akpa area of study sites										
Mean	24.76	9.72	5.00	2.90	N.D	0.04	0.79	0.20	N.D	0.84
StD	4.13	1.03	1.21	0.35	N.D	0.01	0.06	0.20	N.D	0.02
Min	18.76	7.80	3.68	2.43	N.D	0.02	0.70	0.09	N.D	0.24
Max	32.12	10.87	7.43	3.43	N.D	0.07	0.89	0.77	N.D	0.78
Mineral and Trace metals (mg/L) in Boerholewater from Eupi area of study sites										
Mean	31.38	7.62	3.59	2.09	N.D	0.04	0.79	0.20	N.D	0.36
StD	6.78	0.98	1.47	0.39	N.D	0.01	0.06	0.20	N.D	0.04
Min	18.76	5.99	2.07	1.39	N.D	0.02	0.70	0.09	N.D	0.24
Max	37.88	8.87	5.77	2.88	N.D	0.07	0.89	0.77	N.D	0.97
Mineral and Trace metals (mg/L) in Boerholewater from Ojira area of study sites										
Mean	36.99	10.02	5.00	2.58	N.D	0.03	0.79	0.79	N.D	0.33
StD	3.19	1.37	1.21	0.44	N.D	0.01	0.06	0.06	N.D	0.09
Min	31.21	7.80	3.68	2.16	N.D	0.02	0.70	0.70	N.D	0.25
Max	42.12	11.99	7.43	3.51	N.D	0.09	0.89	0.89	N.D	0.75
Mineral and Trace metals (mg/L) in Boerholewater from Otukpo Icho area of study sites										
Mean	17.09	11.02	5.33	2.91	N.D	0.04	0.20	0.79	N.D	0.40
StD	2.64	1.17	0.66	0.94	N.D	0.01	0.20	0.06	N.D	0.07
Min	11.35	8.69	4.10	2.10	N.D	0.02	0.09	0.70	N.D	0.27
Max	19.43	12.80	6.33	4.89	N.D	0.07	0.77	0.89	N.D	0.97
Mineral and Trace metals (mg/L) in Boerholewater from oweto area of study sites										
Mean	42.88	14.52	5.00	2.95	N.D	0.04	0.79	0.20	N.D	0.34
StD	3.43	2.05	1.21	0.75	N.D	0.01	0.06	0.20	N.D	0.05
Min	38.91	10.77	3.68	2.01	N.D	0.02	0.70	0.09	N.D	0.29
Max	48.44	17.99	7.43	3.96	N.D	0.09	0.89	0.77	N.D	0.54
Mineral and Trace metals (mg/L) in Boerholewater from Ogobia area of study sites										

Parameters	Ca	Mg	K	Na	Cd	Cu	Fe	Mn	Pb	Zn
Mean	20.89	10.82	10.02	5.00	N.D	0.03	0.79	0.20	N.D	0.44
StD	1.86	0.90	1.37	1.21	N.D	0.01	0.06	0.20	N.D	0.14
Min	18.43	9.77	7.80	3.68	N.D	0.02	0.70	0.09	N.D	0.33
Max	23.44	12.80	11.99	7.43	N.D	0.08	0.89	0.77	N.D	0.60
Mineral and Trace metals (mg/L) in Boerholewater from Ugboju area of study sites										
Mean	21.28	12.52	2.09	5.00	N.D	0.03	0.79	0.78	N.D	0.25
StD	2.97	1.51	0.39	1.21	N.D	0.01	0.06	0.09	N.D	0.05
Min	18.43	10.79	1.39	3.68	N.D	0.02	0.70	0.67	N.D	0.33
Max	26.99	14.77	2.88	7.43	N.D	0.07	0.89	0.92	N.D	0.88
Mineral and Trace metals (mg/L) in Boerholewater from Sabgn–gari area of study sites										
Mean	32.12	11.12	5.00	2.09	N.D	0.05	0.79	0.78	N.D	0.32
StD	3.14	1.39	1.21	0.39	N.D	0.01	0.06	0.09	N.D	0.02
Min	28.46	8.79	3.68	1.39	N.D	0.03	0.70	0.67	N.D	0.25
Max	38.46	13.87	7.43	2.88	N.D	0.09	0.89	0.92	N.D	0.54
All the Results										
Mean	26.66	10.78	5.13	3.22	N.D	0.04	0.79	0.53	N.D	0.67
StD	9.66	2.47	2.35	1.33	N.D	0.01	0.06	0.32	N.D	0.23
Min	11.35	5.99	1.39	1.39	N.D	0.02	0.70	0.09	N.D	0.24
Max	48.44	17.99	11.99	7.43	N.D	0.09	0.89	0.92	N.D	0.98

Table 4. *Comparison of the result from this Study with International Guidelines.*

Elements	Ca	Mg	K	Na	Cd	Cu	Fe	Mn	Pb	Zn
WHO (2004)	-	-	-	200.00	0.003	2.00	0.20	0.05	0.01	5.00
Australia 1996	-	-	-	180.00	0.020	2.00	0.30	0.05	0.01	3.00
Canada	-	-	-	200.00	0.005	1.00	3.00	-	0.01	5.00
USEPA 2005	-	-	-	-	0.004	1.00	-	0.65	0.005	5.00
This study range	11.35-48.44	5.99-17.99	1.39-11.99	1.39-7.43	N.D	0.02-0.09	0.70-0.89	0.09-0.92	N.D	0.24-0.98

4. Discussion

The summary results of the concentration of the metals found in the water samples from various boreholes in study areas are presented in Table 3.

The result of the analysis revealed various levels of these metals Ca, Mg, K, Na, Cu, Fe, Mn, and Zn in the borehole water samples from the study areas. The heavy metals such as Cd, and Pb were not detected in any of the water samples from the areas.

The value of macro elements in the water sample ranged, from 11.35 – 48.44, 5.99- 17.99, 1.39 – 11.99, and 1.39 – 7.43, for Ca, Mg, K and Na respectively. The concentration of these major elements (Ca, Mg, K and Na) were high, Ca varied according to studied sites, with the highest concentration in the water sample from Oweto with value of 48.44 mg/L, follow by water sample from Ojira with of 42.12 mg/L and the lowest value of 11.35 mg/L at Otukpo Icho. The highest concentration of Mg (17.99 mg/L) was recorded in the water sample from Oweto, while the lowest value (5.99 mg/L) of Mg was recorded in Eupi. The level of K and Na vary much according to locations, the highest levels of K and Na (11.99 and 7.43 mg/L) were recorded in Ogobia and Ugboju respectively. The value of the mineral elements in the borehole water samples from study areas varied in the order of Ca > Mg > K > Na in all the locations, except at Sarbongari, where the concentration of Na was higher than that of K.

All other water samples were free from coliform contamination except those at Ogobu and Oweto with total counts of 15 and 17 cfu/100 mL respectively, exceeding the WHO standard of zero cfu/100 mL (Adekunle *et al* 2007). Contamination in these two boreholes may be due to improper construction, sewage and seepage from refuse dump sites, shallowness, animal wastes, and proximity to toilet (WHO 1993).

The data on metals in Table 1 showed that the concentrations of these elements were below the WHO standards for drinking water (Voogt *et al* 1980). Sodium is very important for human body and regulates the water balance and the acid-base balance in the blood and tissues. Sodium in drinking water is not a health concern for most people because in healthy people, excess sodium is eliminated through the kidneys to maintain the correct balance of sodium and water. But for people with heart disease, hypertension, kidney disease and circulatory illness, it may be an issue of health concern because of their inability to maintain the required body balance of sodium (Mahajan *et al* 2006, Lau and Luk 2002). The WHO and USEPA have restricted people with hypertension or those on sodium restricted diet to drink water with sodium content more than 20 mg/L (Lau and Luk 2002) (Mahajan *et al* 2006). The Food and National Board of the National Research Council of America recommends that sodium intake be limited to not more than 2400 mg per day (Lau and Luk 2002).

There is no guideline value for the amount of potassium in water by the WHO since drinking water is not the major dietary source of potassium and its level in drinking water seldom reaches 10 mg/L. However, USEPA has set a maximum level of 100 mg/L. It has been reported that people on low potassium diets are more likely to suffer strokes, high blood pressure, and diabetes than those who consume sufficient or high potassium diets (Sale *et al* 2001). The potassium content of drinking water varies greatly depending on its source. The committee on Dietary Allowances recommends 1875-5625 mg per day of potassium in order to maintain adequate and safe levels of potassium balance (Lau and Luk 2002). It has been recommended that water with potassium exceeding 12 mg/L is not suitable for regular drinking because it may cause kidney stress and possible kidney failure (Codex Alimentarius 1985).

The levels of copper obtained ranged from 0.02 -0.09 mg/L, while detectable levels of zinc ranged from 0.24 – 0.98 mg/L, which are below the WHO permissible limits (Adekunle *et al* 2007). The level for zinc ranged between 0.24 - 0.98 mg/L which is within the levels recommended for good health, since the levels of zinc in all the water samples were much lower than the accepted value of WHO guideline, 15 mg/L for drinking water (1993). According to the report from similar study, zinc imparts an undesirable astringent taste to water. Water containing zinc at levels in the range 3-5 mg/L also tends to appear opalescent and develops a greasy film when boiled (Odoh *et al*, 2013). Therefore none of the analyzed water samples can show any of the problems mentioned above as the level of zinc in all sample is very low.

The value of Mn in all the water samples from the borehole in the study areas ranged from 0.09 – 0.92 mg/L showed values below the WHO limit (0.004) for Mn hence Mn does not pose any health problem if people drink water from these boreholes. Mn enters the water from soil, thus affecting the levels of Mn in natural waters, The concentration of Fe ranged from 0.78 – 0.89 mg/L, all the water samples from the borehole in the study areas had values below the WHO permissible limit of 1 mg/L for iron (Baroni *et al* 2007). Eupi has the highest value for iron (0.98 mg/L). The brownish precipitate or sediments found in underground water is mostly due to oxidation of Fe^{2+} to Fe^{3+} in form of $Fe(OH)_3$ which presents unaesthetic appeal (Adekunle *et al* 2007). All the samples showed no detectable levels of cadmium and lead. This is beneficial to consumers, since it has been reported that some of these minerals like Pb and Cd are highly toxic even at low concentrations (Asaolu *et al*., 1997).

Generally, the water quality usually affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. 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. The levels of Na and Mg in water from the boreholes in all the study locations are 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. The high values of these mineral elements may also attributed to dissolved bicarbonates such as calcium bicarbonate ($Ca(HCO_3)_2$), sodium bicarbonate ($NaHCO_3$), and magnesium bicarbonate $Mg(HCO_3)_2$); and carbonates such as calcium carbonate ($CaCO_3$) which are the major chemicals contributing to alkalinity in borehole water (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). Therefore all the borehole water studied can be a good source of mineral elements as the amount of these elements were detected in all the assessed boreholes water in the study areas. The high contents of these elements is advantageous since certain inorganic mineral elements (potassium, calcium, zinc, sodium, traces of iron, etc.) play important roles in the maintenance of normal glucose tolerance and in the release of insulin in the body (Choudhary and Bandyopadhyay, 1999). Other trace elements like Pb and Cd were not detected, this indicate that these minerals are not present in a detectable amount in borehole water from the study areas.

E. coli and TCC are indicators for water quality determination. MPNs were less than the values observed in similar research carried out in other part of the country, Nigeria (Josiah *et al*. 2014, Ajayi 2013). MPN exceeding the WHO limits (cfu/100 mL) 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 perfringes* were not observed in all the locations. This is similar to the results reported by Addo*et al.* (2016), which was an indication of the absence of fecal contamination.

5. Conclusion

Water, although an absolute necessity for life can be a carrier of many diseases. Paradoxically, the ready availability of water makes possible the personal hygiene measures that are essential to prevent the transmission of enteric diseases. Mineral contents varied according to areas. All the mineral determined were present and concentrations of mineral elements were varied in the order of $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$. Most of the trace metals examined were present at very low concentration but Cd and Pb were not detected in all the borehole water from the study areas. *E. coli, Samonella*species, and *Clostridium perfringes* were observed in water from the boreholes in two locations. All the parameters analyze (mineral and trace elements) 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 due to the consumption of the water from this source. The data procured are baseline and are representative of the geochemistry of the area.

References

[1] Abera S, Ahmed Z, Biruktawit K, Amare D, Solomon A &Endalew Z 2011. Bacteriological analysis of drinking water sources. *Afri. J. Microbiol. Res.*, 5 (18): 2638-2641.

[2] Addo MG, Oti-Boateng W&Obiri-Danso K 2016. Bacteriological quality and metal levels of boreholes and hand-dug well within the Golden Star Wassa mining areas in Ghana. *Afri. J. Microbiol. Res*., 10 (17): 584-590.

[3] Adekunle. I. M, Adetunji. M. T, Gbedebo. A. M, Banjoko. O. B 2007: Assessment of groundwater quality in a typical rural settlement in southwest Nigeria. Int. j. Environ. Res. on public health, 4 (4), 307-318.

[4] Ademorot CMA 1996. Standard methods for water and effluents analysis. Folder Press Ltd., Ibadan. Nigeria.

[5] Adogo LY, Ajji MA, Anyanwu NCJ &Ajide B 2016. Bacteriological and physico-chemical analysis of borehole water in AutaBalefi Community, Nasarawa State, Nigeria. *British Microbiol. Res. J.*, 11 (4): 1-7.

[6] Ajayi AO 2013. Microbes, mineral elements and geophysical nature of public water sources in Akungba- Akoko, Nigeria. *British Microbiol. Res. J.*, 3 (1): 58-72.

[7] Akpoveta OV, Okoh BE & Osakwe SA 2011. Quality assessment of borehole water used in the vicinities of Benin, Edo State and Agbor, Delta State of Nigeria. *Curr. Res. Chem.*, 3: 62-69.

[8] America Public Health Association (AOAC) 1998. Standard Methods for Examination of water and wastewater. 19th ed., American Public Health Association, Washington, DC, USA.

[9] Anttoniette NO & Afolayan JA 2012. Physico-chemical and microbiological assessments of borehole water in Okutukutu, Bayelsa State, *Nigeria. Advance Appl. Sci. Res.,* 3 (5): 2549-2552.

[10] Bag, H; Elci, L; 2006. Determination of lead, iron, manganese, and zinc in sea water samples by atomic absorption spectrometry after preconcentration with Chromosorb 105. *Eurasian. J. Anal. Chem.* 1: 42-45.

[11] Baroni. L, Cenci. L, Tettamntia. M and Berati. M 2007: Evaluating the environmental impact of various dietary patterns combined with different food production systems, *European Journal of Clinical nutrition,* 61, 279-282.

[12] Choudhury SS, Ajay K, Hiramoni D, Mukutamoni D, Chinmoy B, Aniruddha S & Parag D 2016. Preliminary Physicochemical and Microbiological Analysis of Bahini River Water of Guwahati, Assam, India. *Int. J. Curr. Microbiol. Appl. Sci*., 5 (2): 684-692.

[13] Codex Alimentarius 1985. The code of hygienic practice for the collecting, processing and marketing of natural mineral waters containing the provision on authorization of springs, wells and drillings. CAC/RCP 33-1985, Codex Alimentarius Vol. 11: Section 3.1.

[14] Dabeka, R. W; Conacher, H. B. S; Lawrence, J. F; Newsome, W. H; Mckenzie, A; Wagner, H. P; Chadha, R. K. H and pepper, k. 2002. Survey of bottled drinking waters sold in Canada for chlorate, bromide, bromated, lead, cadmium and other trace elements. *J. Food Addit. Contam.* 19: 721-732.

[15] Daskalova, B. N. 2007. A method for determination of toxic and heavy metals in suspended matter from natural waters by inductively coupled plasma atomic spectrometry (ICP-AES): part 1 Determination of toxic and heavy metals in surface river water samples*. J. Univ. Chem. Technol. Metal.* 42: 419-426.

[16] Dezuane. J 1997: Handbook of drinking water quality. 2nd Edition p 116, 88, 130-132.

[17] Donato F, Monarca S, Premi S & Gelatti U 2003. Drinking water hardness and chronic degenerative diseases. Part III. Tumors, urolithiasis, fetal malformations, deterioration of the cognitive function in the aged and atopic eczema. (In Italian.) *Ann Ig*, 15: 57-70.

[18] Egboka B. C. E, Nwankwo. G. I, Orajaka. I. P. and Ejiofor. A. O. (1989): Principles and problems of Environmental pollution of Groundwater resources with case Examples from Developing Countries. *Environmental Health Perspectives* p 41-46, 59-63.

[19] Egereonu. U. U 2005: A study on the groundwater pollution by nitrates in the environ, Aba, Nigeria, J. chem. soc. Nigeria vol. 30 No. 2. p 211-212.

[20] Environmental Protection Agency (EPA) 2003. Safe drinking water. Act. EPA 816 – F – 03 –016.

[21] EPA (2002): US Environment Protection Agency, Safe Drinking Water Act Amendment http://www:epa.gov/safe water/mcl.Html. 10-05-02.. "pH and its effects on water quality", http://www.kywater.org 11-06-2009.

[22] Fraga C 2005. Relevance, essentiality and toxicity of trace elements in human health. *Molec. Aspects of Med.,* 26: 235-244.

[23] Gupta. D. P, Sunita and Saharan. J. P (2009): Physicochemical analysis of groundwater of selected area of Kaithal city (Haryana) India. http://www.sciencepub.net.

[24] Hamaidi-Chergui F, Errahmani MB, Debib A &Hamaidi MS 2016. Bacteriological analysis and public perception about drinking water of boreholes in Arib (Ain Defla, Algeria). *J. Fund. Appl. Sci*., 547-551.

[25] Iyasele JU & Idiata DJ 2011. Physio-chemical and Microbial analysis of boreholes water samples: A case of some boreholes in Edo North, Edo State. *J. Emerg. Trends Eng. Appl. Sci.,* 2 (6): 1064-1067.

[26] Josiah JS, Nwangwu COS, Omage K, Akpanyung OE & Dike DA 2014. Physico-chemical and microbiological properties of water samples used for domestic purposes in Okada town, Edo state, Nigeria. *Int. J. Curr. Microbiol. Appl. Sci*., 3 (6): 886-894.

[27] kovacs, T; Bodrogri, E; Dombovari, P; Somlai, J; Nemeth, Cs; Capote, A; and Tarjan, S. 2004. ^{238}U, ^{226}Ra, ^{210}Po concentrations of bottled mineral waters in Hungary and their committed effective dose. Radiation Protection Dosimetry 108: 175-181.

[28] Kumar TJR, Chinadurai DBT, Radhakrishnan SSVR &Mailare S 2016. Major and trace element characterization of shallow groundwater in coastal alluvium of Chidambaram Town, Cuddalore District, South India. *J. Geosci. Environ. Prot.*, 4: 64-76.

[29] Lau, O-W. and Luk, S-F. 2002. A survey on the composition of mineral waterand identification of natural mineral water. Intern. J. Food sci. Technol. 37: 309-317.

[30] Maamar Y, Mohammed E, Kenza D&Mimoun Z 2015. The microbiological quality of water in IbnSina Hospital of Rabat (Morocco). *J. Chem. Pharm. Res*., 7 (5): 356-362.

[31] Mahajan, R. K.; Walia, T. P. S. and Sumanjit, B. S. 2006. Analysis of physical and chemical parameters of bottled drinking water. Intern. J. Environ. Health Res. 16: 89-98.

[32] Miner CA, Dakhin AP, Zoakah AI, Zaman M &Bimba J 2016. Physical and microbiological quality of drinking water sources in Gwafan community, Plateau State, Nigeria. *Pyrex J. Res. Environ. Stud.*, 3: 1- 6.

[33] Ministry of Health 2005: Draft Guidelines for Drinking-water Quality Management for New Zealand, 2nd ed.. Ministry of Health, Wellington.

[34] Nicoleta DV & Vieru NP 2010. Levels of magnesium, calcium and other in organic compounds in water of the wells in rural areas of Botoşani country. *Present Environmental and Sustainable Development,* NR. 4, 139-406.

[35] Nikarov AM &Brazhniokovee LV 2012. *Types and properties of water*. Vol. II. http://www.eolss.net/ebooklib. Retrieved on 28th May, 2016.

[36] Nkamare MB, Anttoniette NO & Afolayan JA 2012. Physico-chemical and microbiological assessment of borehole water in Okutukutu, Bayelsa State, Nigeria. *Adv. Appl. Sci. Res*., 3 (5): 2549-2552.

[37] Nouyang ME, Nola M, Njine T, Zebaze TSH, Djaousda M & Djah M 2009. The influence of hydrochemistry on the distribution of pathogenic strains of *Escherichia coli* in urban groundwater of Yaounde, Cameroon. Proceedings of the Groundwater and Climate in Africa Conference, Kampala Uganda, June, 2008. *International Association of Hydrological Society Publication.* No. 334

[38] Nwachukwu E & Ume CA 2013. Bacteriological and physicochemical qualities of drinking water sources in local area of Eastern Nigeria. *J. Environ. Sci. Water Resour.*, 2 (9): 336 – 341.

[39] Obasi. R. A. and Balogun. O. 2001: Water quality and Environmentalimpact assessment of water resources in Nigeria, African Journal of Environmental studies, 2 (2), 228-231.

[40] Obi CN, Onyegbulam AL, Ejukonemu F &Ubogu M 2016. Microbiological and physico-chemical analyses of borehole water samples from private schools in Umuahia Metropolis, Abia State, Nigeria. *British Microbiol. Res. J*., 12 (1): 1-10. Odoh R. and M. S. Dauda (2013): Survey of Heavy Metal Contamination of Rain Water Harvested from Roofing Sheets in Abuja Metropolis, F. C. T. in Nigeria. International Journal of Modern Analytical and Separation Sciences, 2 (2): 91-102

[41] Palamuleni L & Akoth M 2015. Physico-chemical and microbial analysis of selected boreholewater in Mahikeng, South Africa. *Int. J. Environ. Res. Public Health*, 12: 8619-8630.

[42] Rajkumar N., Subramani T., and Elonga L. (2010): Groundwater water contamination due to municipal solid waste disposal-A GIS based study in Eroda city. Int. J. of Environ Sci. 1 (1): 39-55.

[43] Raphael Odoh, Odiba John Oko, Sunday Adebayo Kolawole and Ogbaji Eka Oche 2013: A Comparative study of the heavy metal content of drinking water in different storage vessels. *International Journal of Modern Chemistry, 5 (3): 166 – 180.*

[44] Roba C, Roşu C, Piştea I, Ozunu A&Mitrofan H 2015. Groundwater quality in a rural area from Buzăucounty, Romania. Science Papers Series. *Manag. Econ. Engin. Agric. Rural Develop,* 15 (2): 305-310.

[45] Saka AB, Benjamin CE, Adebayo AL &Abideen IA 2013. Microbiological and chemical assessment of spring water from a rural setting in Ondo State Southwest, Nigeria. *Afri. J. Environ. Sci. Technol.,* 7 (6): 555-559.

[46] Saleh, M. A; Ewane, E; Jones, J. and Wilson, B. L. 2001. Chemical evaluation of commercial bottled drinking water from Egypt. j. Food Comp. Anal. 14: 127-152.

[47] Satyavani CH, Venkateswararao B & Machi PVSR 2013. Physicochemical and microbial analysis of ground water near municipal dump site forquality evaluation. *Int. J. Bioassays,* 139-1144.

[48] Seth ON, Tagbor TA & Bernard O 2014. Assessment of chemical quality of groundwater over some rock types in Ashanti region, Ghana. *Amer. J. Sci. Indust. Res*., 5: 1–6.

[49] Skorbiłowicz M 2010. Concentrations of macroelements, zinc and iron ions in water of the Uppe Narew Basin, NE Poland. *Polish J. Environ. Stud.*, 19 (2): 397-405.

[50] Stephen TO & Kennedy KA 2013. Bacteriological profile and physico-chemical quality of ground water: A case study of borehole water sources in a rural Ghanaian community. *Int. J. Curr. Microbiol. Appl. Sci*., 2 (8): 21-40.

[51] Uma. K. O 1986: Analysis of transmissivity and hydraulic conductivity values of sandy aquifers of the Imo River Basin, Nigeria. Ph. D Thesis, University of Nigeria, Nsukka, Nigeria.

[52] Voogt. D. P, Van. H. B, Feemstra. J. P, Copius-peerebom J. W 1980: Toxicological and environmental chemistry review p 89-109.

[53] WHO Guidelines for Drinking water Quality Recommendations, World Health Organization, 2nd Edition Geneva, 1993.

[54] World Health Organization (WHO) 2006. International Standards for Drinking Water, 3rd Edition Geneva, 346 – 385.

[55] World Health Organization (WHO) 2011. Guidelines for drinking water quality. 4th ed. 20 Avenue Appia, 1211 Geneva 27, Switzerland.