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Physicochemical Assessment of Drinking Water in Sokoto State University and its Neighbouring Villages

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A total of eight (8) water samples collected within Sokoto State University and its neighbouring villages were evaluated. The parameters investigated are pH, temperature, electrical conductivity, chloride, sulphate, nitrate, sodium, potassium, lead, chromium, iron and manganese. Physicochemical properties were determined using standard methods while metal analysis was conducted using Atomic Absorption Spectrophotometer. The results for physicochemical parameters were in the range: 27.6±2.20-30.60±1.50 ºC, 6.36±0.15-7.34±0.30, 602.67±7.64-1670.67±3.06 μs/cm, 71.00±2.00-260.33±5.77 mg/L, 0.013±0.001-72.50±0.500 mg/L, 32.01±0.220-111.97±0.16 mg/L, 2.92±0.15-6.83±0.11 mg/L for temperature, pH, electrical conductivity, total hardness, sulphate, chloride and nitrate respectively. The values obtained for sodium, potassium, iron, manganese and chromium ranges from 2.42±0.11-14.10±0.36, 0.43±0.01-3.58±0.01, 0.0015±0.0003-0.4512±0.0187 and 00259±0.0052-0.7914±0.0075 mg/L respectively. Generally, temperature was above the acceptable limits while electrical conductivity of the sample from the male hostel was higher than the limit set by the Nigerian Industrial Standard. Additionally, the chromium content of samples from both female and male hostels were found to be above WHO's acceptable limit of 0.3 mg/L while Pb was not detected in any of the samples. Though some of the samples analysed could be use directly, the results show that others would need to be treated before usage.

Keywords: Water quality, metals, pH, temperature, total hardness.

1. Introduction

Water is the most widely circulated and abundant substances found on earth (Dhanaji *et al*., 2016). Ground water is the most useful component of the water cycle and a source of domestic water in most developing nations. It constitutes about two thirds of the freshwater resources of the world. This form of water is not evenly distributed or accessible to large sections of the global population. It provides a large constant supply for domestic use, livestock and irrigation, which is not likely to dry up under natural conditions thereby buffering the effects of rainfall variability across seasons. In many arid and semi-arid areas of African countries, ground water (Borehole and Well water) is a means of coping with water deficiencies in areas where rainfall is scarce or highly seasonal and surface water is extremely limited (David and Thomas, 2011).

Ground water and surface water appear to be vulnerable, due to water table being close to the soil surface and layers topping the table being permeable, and superficial sources of pollution being numerous (Singh *et al.,* 2012). There is practically no geological environment at or near the earth's surface where pH will not support some form of organic life (Chapman *et al*., 2002). Pathogenic bacteria can survive long underground and may have a life span of about 4 years. Boreholes and wells locally disturbed the natural flow field and create a path that opens up an additional possibility of heat and mass transfer of water between rock formations/aquifers, surrounding and atmosphere (Berthold, 2010). The aim of water quality management is usually to minimize the health problems associated with either direct or indirect use of ground water (Udom *et al.,* 2002).

Standard water quality stems from the need to protect human health (Minh *et al*., 2011). Water pollution has increasingly become an issue of serious environmental concern after years of pollution (Akpoveta *et al*., 2011). In 2012, Yisa *et al*. carried out a research on quality assessment of underground water in Doko community, Niger State, Nigeria. The study was to evaluate the level of contamination due to the reported prevalence of typhoid fever, skin rashes and guinea worm in the sampling areas. Natural water sources have many percent of dissolved substances and contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies due to inadequate treatment and disposal of wastes from humans and livestock, industrial discharges and overuse of limited water resources (Mosley and Singh, 2003). Contamination of water bodies has increasingly become an issue of serious environmental concern. Analysis of water is therefore necessary as it enables the determination of the nature of the water quality and contamination and thus helps to determine their quality for human consumption.

In Nigeria, Sokoto State University is in Bodinga Local Government of Sokoto State. Ground water, either as borehole or well water, is the only source of domestic water to the university community and its environs. Since it is important to ascertain the quality of drinking water, the need therefore arises for the assessment of water from boreholes and wells around Sokoto State University and its neighbouring villages to ascertain the water quality level, especially considering the brownish nature of the water and the presence of undissolved substances in it.This research work is therefore aimed at evaluating the quality of water from selected boreholes and wells within Sokoto State University and its neighbouring villages in order to establish the suitability of the water for drinking and domestic purposes.

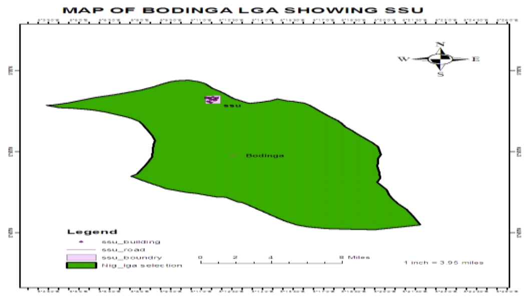

Figure 1. Bodinga Local Government showing Sokoto State University, Sokoto. Source: G.I.S Lab SSU,2018

2. Materials and Methods

2.1 Collection of Samples

Water samples were collected from selected boreholes and hand dug wells within the Sokoto State University and its neighbouring villages. The samples were collected with pre-treated 500 mL high bottles. The sample bottles were pre-treated by first cleaning with detergent solution, then rinsed with 10 % nitric acid solution to avoid metal contamination, rinsed again with distilled water and finally with a small portion of the water to be sampled. The samples were collected, such that the tap was allowed to run for about 5 minutes before collection while for the open well, a string was fastened to the sample container and the container was lowered into the well such that it does not touch the walls of the well. The container submerged into the water and was lifted carefully after it has collected some water. The sample bottles were labelled, and appropriate quantity of concentrated nitric acid was added to reduce the pH, in order to prevent loss of metals and growth of any microorganisms (Agrawal *et al.,* 2010; Manjare *et al.,* 2010; Yisa *et al*., 2012).

2.2 Determination of physicochemical parameters

Total hardness, pH and chloride ion were determined in accordance with methods described by Reda, (2016), sodium and potassium was determined by flame photometric method as described by Ogunbode, (2016). Olutona (2012) method was adopted for sulphate ion determination, electrical conductivity and nitrate content in the water were determined using the method described in APHA (1998 and 2005) respectively.

2.3 Determination of heavy metals

Metals content in the water was analyse using Atomic Absorption Spectroscopy as described by Sharma and Tyagi (2013).

2.4 Statistically analysis

The result obtained were statistically analysed using one-way analysis of variance ANOVA with Minitab version 17.0 statistical software. Results are reported as mean ± standard deviation at 95% confidence interval.

3. Results and Discussion

Results for physicochemical parameters and heavy metals contents of the water samples are presented in Table 1 and 2 respectively while Table 3 and 4 summarise the results obtained from physicochemical analysis and metal/heavy metal analysis of the samples in all the sample site and compare the result with that of Nigerian Standard and World Health Organisation

High potable water temperature may impart undesirable taste and odour as well as the corrosive ability of the water (Saana *et al*., 2016). This may also facilitate the growth of microorganisms, hence affecting water quality (WHO, 2012). In this study, as presented in Table 1, sample temperatures were between 27.60±2.20 and 30.60±1.50°C. These temperatures were all above the WHO maximum limit of 25°C. This could be attributed to the environmental temperature as well as other climatic conditions prevailing in the study area at the time of sampling, hence, the water temperatures recorded here may only highlight environmental characteristics without any suggestion for adverse effects on human health (Saana *et al*., 2016). In the study conducted by Khalid *et al.* (2011) and Bello *et al*. (2013), the temperatures recorded were lower compared to what was obtained in this study. They reported temperature ranges of 21-28 ^oC and 13-17 ^oC respectively. However, Saana *et al.* (2016) recorded a maximum temperature of 32.8, which is greater than 31 ^oC in this study.

The pH values of the water samples (Table 1) was in the range 6.360±0.15 in Faculty of Science and 7.34±0.30 in Tungam Mallam. This implies that the water in Madorawa/Hajj camp, Female Hostel, Senate Building and Faculty of Social Science were fairly neutral. The sample from Faculty of Science was slightly acidic while samples from Tungam Mallam and Masjid/Works were slightly alkaline but fall within the limit recommended by the World Health Organization (2012).

Conductivity is the capacity of water to carry an electrical current and varies both with number and types of ions the solution contains. Conductivity depends on the presence of ions, their total concentration, mobility, valence and relative concentration and on the temperature of the liquid. Solutions of most inorganic acids, bases, and salts are relatively good conductors (Dohare *et al*., 2014). Prakash and Somashekar (2006) had observed that ground water tends to have high EC when compared with surface water because of the presence of high amount of dissolved minerals. Table 1 shows that the conductivity values in the selected areas ranged from 602.67±7.64 μs/cm (Faculty of Social Science) to 1670.67±3.06 μs/cm (Male Hostel). In a similar study conducted by Saana *et al*. (2016), they reported values between 131-873 μs/cm. Though, Madorawa/Hajj camp and Tungam Mallam recorded high EC values (946 and 920 μs/cm), all the samples except samples from the Male Hostel gave values below 1000 μs/cm which was the WHO standard for portable water.

Total hardness is defined as the sum of calcium and magnesium hardness in mg/L as $CaCO_3$.Total hardness in fresh water is usually in the range of 15 to 375 mg/L as $CaCO_3$ (Sagar *et al*., 2015). Calcium hardness in freshwater is in the range of 10 to 250 mg/L often double that of magnesium hardness (5 to 125 mg/L) and total hardness of 6630 mg/L as $CaCO_3$. A high concentration of hardness may be due to leaching from the soils or due to the high background concentration of the waters (Nagamani *et al*., 2015). High concentration of hardness may cause problem of heart disease and kidney stones (Sagar *et al*., 2015). The value of total hardness in the study areas ranged from 71.00±2.00 mg/L (Faculty of Social Science) to 260.33±5.77 mg/L (Male Hostel) (see Table 3). The highest value obtained is lower than values obtained in similar studies by Ashfaq and Ahmad (2014) and Saana *et al*. (2016) which recorded 603 mg/L and 337.5 mg/L respectively. All values obtained for the total hardness (TH) in the samples (Table 1) were below the 500mg/L recommended for portable drinking water by the WHO. However, the Standards Organization of Nigeria (SON), the Nigerian Industrial Standards (NIS) and the National Agency for Food and Drugs Administration and Control (NAFDAC) set a lower standard for the total hardness (150mg/L), which is more closer to the values obtained.

The concentrations of sulphate in the samples were below the 200 mg/L acceptable standard (WHO, 2012), sulphate ion is one of the major anions occurring in natural waters, many of which are readily soluble in water (Jafar *et al*., 2012). Most of the sulphate components originate from the oxidation of sulphite ores, the presence of shale and the solution of gypsum and anhydrite. The low concentration of sulphate ion may be due to its conversion to sulphite ion which can easily combine with hydrogen and escape as hydrogen sulphide. The concentrations of sulphate ion obtained in this study range between 0.013±0.001 (Tungar Malllam) and 72.50±0.500 mg/L. These values were low when compared with those obtained from similar studies by Chindo *et al*. (2013), who reported values of 0.00-150 mg/L.

Ojo *et al*. (2016) and Saana *et al*. (2016) in their studies recorded chloride ion values, 11.4-13.7 and 5.30-44 mg/L respectively. These values are lower than values reported in this work, which are in the range of 32.0±1-111.97±0.16 mg/L. Excess chloride ions in water may not pose any health risk to consumers but high concentrations of chloride and sodium ions in water may interact to form sodium chloride which could impart a salty taste to the water (Cobbina *et al*., 2012). Chloride content in the water samples analysed were lower than the maximum acceptable limit of 200 mg/L recommended by the WHO (2012). Thus, the concentration of the chloride was considered satisfactory.

Nitrate (NO_3^-) and nitrite (NO_2^-) are the forms of nitrogen most commonly associated with groundwater contamination. Although, the presence of nitrate does not pose any health threat to adults, ingestion by infants can cause low oxygen levels in the blood, a potentially fatal condition (Bohlke *et al*., 2006). For this reason, WHO has established a drinking-water maximum allowable threshold of 10 mg/L nitrate as nitrogen (WHO, 2012). All borehole and open well samples analyzed contained varying concentrations of nitrate (in nitrogen form) ranging from 2.92±0.15 (Masjid/Works) to 6.83±0.11 mg/L (Tungam Mallam) (Table 1). The nitrate values obtained in this study are slightly higher than those obtained in a similar study by Saana *et al*., (2016), which reported 6.0 mg/L NO_3^--N as the highest value obtained.

Table 1. Results of physicochemical analysis of water

Sampling sites	T(°C)	pH	EC (µS/cm)	T H (m/gL)	SO_4^{2-} (mg/L)	Cl^- (mg/L)	NO_3^-N (mg/L)
TungamMallam	30.0±3.0	7.34±0.30	914.33±15.31	204.00±3.46	0.013±0.001	32.01±0.22	6.83±0.11
Madorawa/Hajj camp	28.6±2.0	6.93±0.05	934.67±13.20	83.00±3.00	0.072±0.05	50.30±0.14	6.37±0.20
Masjid/Works	27.6±2.2	7.23±0.03	632.00±8.50	260.33±5.77	0.108±0.01	78.18±0.13	.2.92±0.15
Female Hostel	30.0±2.4	6.47±0.15	765.00±3.00	128.33±1.52	0.622±0.041	111.97±0.16	4.58±0.10
Male Hostel	28.7±0.5	7.13±0.11	1670.67±3.06	258.0±1.73	0.049±0.01	74.22±0.21	5.94±0.22
Senate Building	30.6±1.5	6.56±0.12	640.33±15.4	91.67±2.31	0.305±0.01	60.23±0.20	5.54±0.12
Faculty of Science	29.8±15	6.36±0.15	644.0±5.57	122.0±1.73	0.437±0.013	73.36±0.80	4.83±0.11
Faculty of Social Science	2.9±1.2	6.93±0.21	602.67±7.64	71.00±2.00	72.50±0.500	43.31±1.09	4.00±0.20
NIS/SON/NAFDAC	22-24	6.5-6.8	1000	150	100	250	50
WHO	27-28	6.5-8.5	1000	500	200	200	10

Key: T= Temperature, EC= Electric Conductivity. T H = Total Hardness, NIS=Nigerian Industrial Standard, SON= Standard Organization of Nigeria, WHO= World Health Organisation

Table 2. Result of Metal/Heavy metal analysis

Sampling Site	Na (mg/L)	K (mg/L)	Fe (mg/L)	Mn (mg/L)	Cr (mg/L)	Pb mg/L
TungaMallam	3.90±0.17	2.30±3.03	0.3612±0.1340	0.09063±0.0241	0.0307±0.0032	BDL
Madorawa/Hajj camp	6.53±0.47	0.98±0.01	0.0015±0.0003	0.5660±0.4180	0.1094±0.01702	BDL
Masjid/Works	2.93±0.15	2.02±0.06	0.3517±0055	0.0259±0.0052	0.0423±0.0025	BDL
Female Hostel	4.36±0.20	0.40±0.02	0.1201±0008	0.1686±0.1195	0.4920±0.3590	BDL
Male Hostel	14.10±0.36	0.43±0.01	0.4512±0.0187	0.08923±0.0028	0.4890±0.3560	BDL
Senate Building	2.93±0.20	3.33±0.15	0.0673±0.0028	0.08587±0.0050	0.01931±0.0001	BDL
Faculty of Science	2.42±0.11	3.00±0.10	0.3100±0.0092	0.7914±0.0075	0.0731±0.0037	BDL
Faculty of Social Science	3.01±0.18	3.58±0.01	0.2523	0.1287±0.0029	0.0993±0.0013	BDL
Deionized Water (Blank)			0.1064	0.1270	0.0773	BDL
NIS/SON/NAFDAC	200	12	0.3	0.2	0.05	-
WHO	200	12	0.3	0.05-0.5	0.1	-

Key: NIS=Nigerian Industrial Standard, SON= Standard Organization of Nigeria, WHO= World Health Organisation

Table 3. Summary of the result of mean value of physicochemical analysis of the study area

Parameters	Mean	NIS/SON/NAFADAC	WHO
Temp (°C)	29.29±1.047	22-24	27-28
pH	6.86±0.359	6.5-8.5	6.5-8.5
EC (µS/cm)	851±356	100	1000
TH	152.4±77.60	150	500
SO_4^{2-} (mg/L)	9.33±25.37	100	200
Cl^- (mg/L)	65.35±24.64	250	200
NO_3^- (mg/L)	5.129±1.296	50	10

Key: NIS=Nigerian Industrial Standard, SON= Standard Organization of Nigeria, WHO= World Health Organisation

Table 4. Summary of the results of mean value of metal/heavy metal analysis of the study area

Parameter	Mean (mg/L)	NIS/NAFDAC/SON (mg/L)	WHO (mg/L)
Na	5.03±3.88	200	12
K	2.008±1.277	12	12
Fe	0.2428±0.1549	0.3	0.3
Mn	0.345±0.354	0.2	0.05-0.5
Cr	0.164±0.2007	0.05	0.1
Pb	-	-	-

Key: NIS=Nigerian Industrial Standard, SON= Standard Organization of Nigeria, WHO= World Health Organisation

The relative high concentration of nitrates as presented by the result shows the water sources have been affected by nitrate. The sources of nitrate in the water samples may be attributed to human and animal wastes, application of fertilizers and agricultural waste chemicals and domestic drainage system, since the University and its environment are agricultural-based community (Agrawal *et al*., 2010). The nitrates values in the water samples fall below the 10 mg/L maximum permissible by WHO (2012), thus making the water safe for consumption from the nitrate point of view.

Table 2 shows that the Senate building has low sodium content with a concentration of 2.42±0.11. The highest sodium content was observed for Male hostel (14.10±0.36 mg/L). The values were all below 200 mg/L upper limit permissible by Nigerian Institute of Standard (2015) and WHO (2012). Sodium plays an important role in the human body according to Jafar *et al*. (2012). It was further stressed that the flux of these ions through cell membrane and other boundary layers send signals that turn metabolic reactions on and off.

3.58±0.01 mg/L is the maximum concentration of potassium observed in this study (Table 2). These equally fall below the maximum permissible limit of 12 mg/L for both NIS/SON and WHO standard. According to Jafar *et al.* (2012), sodium and potassium concentrations are influenced by the cation exchange mechanism. The results imply that the water is safe for human drinking from the viewpoint of potassium contents. Where the potassium content in water is in excess, the consumption of such water poses a health threat as it may lead to nervous and digestive disorder (Raja and Venketesan, 2010).

The concentration of iron in the samples ranged from 0.0015±0.0003 mg/L to 0.4512±0.0187 mg/L, with Hajj Camp/Madorawa having the least, while the Male Hostel has the highest. 5.6 mg/L and 0.55 mg/L were obtained from similar studies conducted by Chindo *et al*. (2013) and Ojo *et al*. (2016) respectively. Iron can come in two forms in water, which could be dissolved and suspended. It is an essential element for human nutrition and metabolism, but in excess quantities results in toxic effect like hemochromatosis in tissues. The values obtained in this study were higher than the standard value of 0.3 mg/L recommended by WHO and NIS (2015) for iron in drinking water, and as such, the water needs to be subjected to further treatment before usage.

The concentrations obtained for manganese as seen above ranged from 0.0259±0.0052 mg/L for samples from Masjid/Works to 0.7914±0.0075 mg/L for samples from Faculty of Science. Although, these values are much higher than values reported by Chindo *et al*. (2013) (0.00-0.005 mg/L), these concentrations are within the acceptable limit of WHO standard except for that of Faculty of Science which exceeded the limit of 0.05-0.5 mg/L set by WHO standard for drinking water. Thus, all samples except for Faculty of Science are safe for drinking and other domestic purposes. Water with high levels of suspended manganese usually has a black colour or contains black flakes. Additionally, excess of manganese in water is assumed to have a damaging effect on liver (Chindo *et al*., 2013).

Chromium concentration has been set at 0.1 parts per million (ppm) because this level would not cause any of potential health problems (WHO, 2012). Both Faculty of Social Science and Madorawa/Hajj camp have concentration of 0.1009 mg/L which is slightly higher than the WHO stipulated values. High concentration of chromium can cause damage to liver, kidney, circulatory and nerve tissues and skin irritation (Jafar and Loganathan, 2012).

Lead is an undesirable poisonous component in water, food, air and in the body. It readily replaces the oxygen carried by haemoglobin in the blood and gets easily transported to all part of the body. The concentration of lead in the water samples was not up to the detectable level and thus the samples are free of lead. In a similar study conducted by Chindo *et al*. (2013), zero level of lead was also reported. The low levels of lead in the water samples studied may suggest that the environment is free of lead and hence water samples from the wells and boreholes are safe for human and animal consumption.

4. Conclusion

Water quality parameters of selected underground (borehole and hand dug well) water sources were assessed within Sokoto State University and its neighbouring villages to evaluate their level of purity. All parameter determined were found except Lead which was not detected in the various water samples. From water quality point of view, most of the data for the physicochemical parameters indicated tolerable quality, as recommended by NIS/SON/NAFDAC and World Health Organization (WHO) for drinking water. Consequently, the water samples are not harmful to human beings and could be utilized with treatment. Additionally, it was observed that the hand dug well have relatively higher concentrations of many of the investigated parameters than the boreholes. This was attributed to wind deposition, runoff, use of fertilizers and manure around the sampling sites.

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Conflict of interest

The authors declare no conflict of interest.

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