Assessment of Physico-chemical Parameters of groundwater in some communities of Nguru town, Nguru Local Government area, Yobe State, Nigeria.

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ABSTRACT

Water is one of the basic necessities for sustenance of life, and its impact nearly in all areas of life. With increasing population, there is an increasing demand for more water. This in turn results in increased abstraction and, hence a strain on groundwater resources. Given the widespread use of groundwater for domestic purposes in rural areas, maintaining groundwater quality is a critical livelihood intervention. This study assessed the physic-chemical parameters of groundwater in Nguru town, Local Government Area of Yobe State. Water Samples from boreholes, hand pumps and wells were collected from Hausari, Bulabulin, Tsohon Nguru, Sabon gari, and Garbi communities of Nguru town of Yobe State. Parameters analysed were Temperature, *pH*, Turbidity, Colour, Dissolved Oxygen, Nitrate, Phosphate, Total Dissolved Solid (TDS) and Total Suspended Solid (TSS). Temperature ranges from 28-32 ^oC, pH were within the control limits (6.5-8.5) as recommended by WHO. Colour values of 36.67ppmCU and 35.41 ppmCU were recorded for Tsohon Nguru A and Sabon Gari B water samples respectively. All other values did not exceed those recommended by both NSDWQ and the WHO of 15 ppmCU. Turbidity ranges from 0.3-36 NTU 70% of results meeting the 5 NTU WHO guidelines limit, Dissolved oxygen, nitrate and phosphate were all within the WHO and EU permissible limit for portable water. TDS ranges from 21-45mg/litre while TSS ranges from 31-70mg/litre. All values were below the permissible limit of 1000mg/litre for TDS and TSS according to the WHO guidelines. Results indicated significant contamination of the water samples which may be due to pollutants which contaminate the water source.

Key words: Groundwater, Physico-chemical Parameters

Introduction

Water is one of the basic necessities for sustenance of life, and its impact nearly in all areas of life. Water quality and the risk to waterborne diseases are critical public health concerns in many developing countries (UNICEF/WHO, 2012). Today, close to a billion people mostly living in the developing countries such as Ghana, Kenya, Uganda, Mali, Nigeria do not have access to safe and adequate water. It is estimated that around 94% of the global diarrheal burden and 10% of the total disease burden, inadequate sanitation, and poor hygienic practices are due to unsafe drinking water (Selendy & Janine, 2011).

In Nigeria, economic degradation has resulted in an increase in the number of people living in abject poverty in high density settlements areas with serious consequences on the environmental health resources (Majuru, *et al.*, 2011). Consequently, high density settlements are characterized by poor environmental and sanitary conditions that expose the inhabitants to poor health than those of the rich in the urban or developed areas (Earnest, 2013). The United Nations (UN) projected a rapid population growth in the urban areas between 2000 and 2030, indicating that access to safe drinking water and adequate sanitation in urban areas is likely to worsen (Musa *et al*., 2011). It was estimated that 65 million Nigerians had no access to safe drinking water and the situation is worse in rural areas where only 24% of the population have access to potable water (Abdullahi, 2010).

Physico-chemical parameters are physical and chemical parameters associated with water which have an influence on its quality and which also affect the biological constituents of the water (Oluyemi *et al.,* 2010). The physical factors such as temperature, turbidity, colour, etc. can affect the aesthetics and taste of the water and may complicate the removal of microbial pathogens during water treatment. The chemical parameters include *pH* and anions such as sulphates, phosphates, nitrites, nitrates and fluorides (Oluyemi *et al.,* 2010).

Groundwater pollution has been the focus of attention by many researchers in recent times (Howard *et al*., 2002; Priis-Ustun *et al*., 2004; Ayanlaja *et al*., 2005; Pritchard*et al*., 2007).

It is partly responsible for low access to potable water and sanitation problem especially in many developing countries (Earnest, 2013). Therefore, there is urgent need to provide an improved water supply and a safe means of excreta disposal (WHO, 2008).

Increase in ground water contamination in Nigeria has resulted in a greater death of many individuals in many communities (Musa *et al.*, 2015). Related study of water contamination in the area (Nguru) (Akaahan *et al*., 2012) indicated that, there are few in depth studies on assessment of physic-chemical parameters of ground water (Adelekan, 2010) despite the dangerous effect of ground water contamination in many areas that are still using the water as their drinking water source. Unpredicted changes in ground water quality in most areas may be due to contamination of water source as a result of exposure to pollutants such as pit latrine which tremendously causes a greater impact on the population of many area (Earnest, 2013; Musa, *et al.,* 2015; Makokha, 2017).

Pipe-borne water supply is less available and residents of Nguru town depend totally on groundwater (Hand Pumps and wells) as their main source of domestic water supply. Hand pumps are mostly constructed in the various communities and are usually accessed by the general public (Musa *et al.*, 2015).

These reasons make it necessary to carry out a study to assess the physico-chemical parameters of groundwater of Nguru town and to understand how these parameters affects the quality of ground water in our environment.

MATERIALS AND METHODS

Study Area

Nguru is a local Government headquarter of Nguru L.G.A in Yobe State of Nigeria, the town is located in the North Eastern geo-political zone in the extreme western part of Yobe State on Latitude 12˚53North and about longitude 12˚58East. It has an average area

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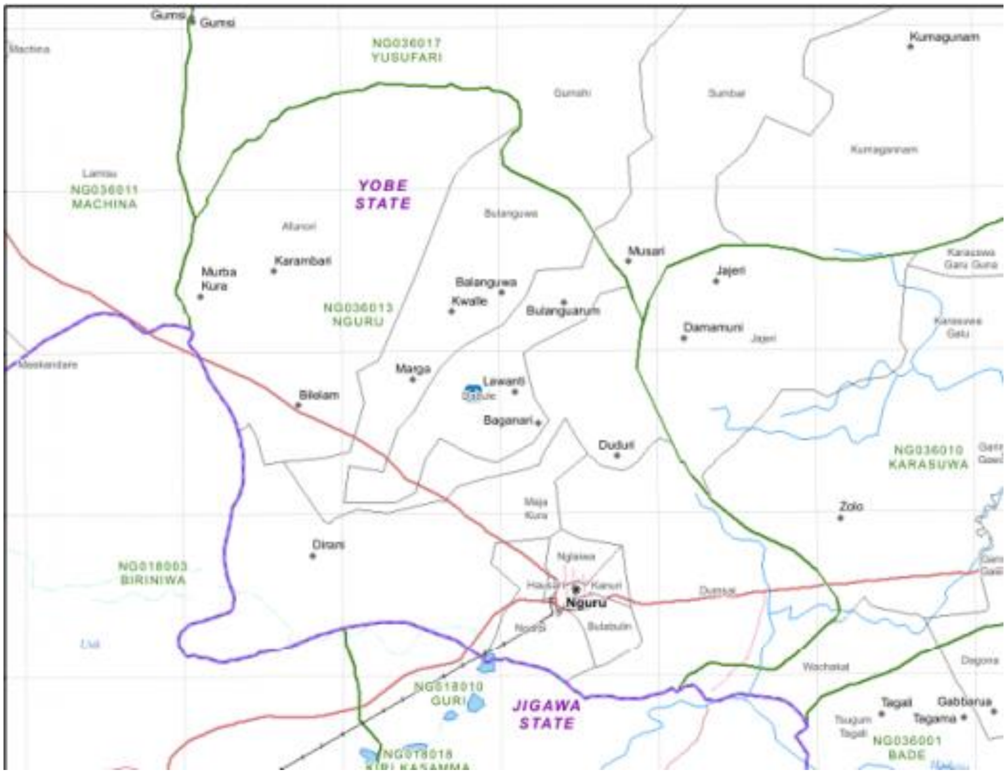
of 916 km² with a population of 150,632 (2006 census). The town is among the old settlements in the state which dates back to 15th century (Klimatafel 2016).



A Map showing the geographical location of Nguru Local Government Area of Yobe State

Water Sample Collection Sites

Water Sample collection was carried out at; Hausari, Bulabulin, Tsohon Nguru, Sabon gari, and Garbi of Nguru town. Three water sources were randomly selected from each community. A bottle water (Faro) was used as control.

Consent and collaboration with the communities was obtained before sample collection was conducted. Water samples from the water source of each community were collected in pre-washed and sterilised 500 ml bottles. The bottles were properly labelled. The collected samples were taken to Yobe State University Research Lab for analysis, in accordance with the protocols described by Ernest, (2013).

DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS

Temperature

The temperature of the water samples was measured in-situ with the use of digital thermometer. The thermometer was inserted in all the samples to know their various temperatures for physical parameter determination (Earnest, 2013).

pH

The *pH* of the water samples were determined using *pH* meter (PHS-3C) which consist of electrode. The electrode of the pH meter was immersed in each of the water samples. The reading on the *pH* meter was recorded after 2 minutes when the reading is stabilised (*pH* Meter Operation Manual, 2009).

Turbidity

The turbidity of the water samples were determined using a calorimeter. A turbidity of 098 was selected from the menu. A clean tube was rinsed with deionized water and filled to 10mil with the water sample. The tube was inserted into the chamber, closed and scanned. The readings from the calorimeter were recorded for three consecutive times. The mean from the readings was obtained (SMART Operation Manual, 2009).

Colour

The colour of the water sample was also determined using a calorimeter. Colour of 027 was selected from the menu. A clean tube was rinsed with distilled water and filled with 10mil of the water sample and inserted into the calorimeter chamber. The chamber was closed and scanned. Readings from the calorimeter were recorded for three consecutive times and the mean was obtained (SMART Operation Manual, 2009).

Dissolved Oxygen

The dissolved oxygen (DO) in the water sample was measured using a calorimeter. The dissolve oxygen menu was selected in the calorimeter. A clean tube was rinsed with untreated water sample and filled with 10mil of the water sample. The tube was inserted into the chamber, closed and scanned for three consecutive readings. The mean was obtained (SMART Operation Manual, 2009).

Nitrate

To measure the nitrate level of water, a calorimeter was used. The nitrate menu was selected. A clean tube was rinsed with sample water and filled to 10mil. The tube was inserted into the chamber, closed and scanned. The tube was removed from the calorimeter and one tablet of Nitrate spectrophotometric grade (3881A-H) was added. A tablet crusher was used to crush the tablet and the tube was capped. The tube was inserted 60 times per minute for 2 minutes (one inversion equals 180°). The tube was allowed for 5 minutes before inserted into the chamber, closed and scanned. The readings was obtained (SMART Operation Manual, 2009).

Phosphate

The phosphate level in the water samples were measured using a calorimeter. A clean tube was rinsed and filled to 10mil with the water sample. The phosphate ppb was selected from the menu. The tube was inserted into the chamber, closed and scanned. The tube was removed from the calorimeter and a pippete was used to add 10mil of Phosphate Acid Reagent (V-6282), capped and mixed. A phosphate reducing reagent was added with a spoon. The tube was capped and shaked until it dissolved. The tube was allowed for 5 minutes for a full colour development. After 5 minutes, the tube was inserted into the chamber, closed and scanned. The result was recorded (SMART Operation Manual, 2009).

Total Dissolved Solid (TDS)

To measure the TDS, 50mil of the water samples was measured and filtered through a filter paper into a pre-weight container. The filtrate was dried inside the pre-weight container over a Bunsen burner. The weight of the empty container (W1), container after drying (W2) and the volume of the water sample used were measured to determine the TDS (APHA, 2005).

Total Suspended Solid (TSS)

To measure the TSS, an empty filter paper was weighed (W1) and 50mil (V1) of the water sample was measured and filtered through the filter paper. The filter paper with the filtrate was dried and re-weighed (W2). The TSS was then calculated from the readings obtained (APHA, 2005).

RESULTS

Table 1: Physicochemical parameters of sampled communities of Nguru town.

SAMPLING POINT		WATER SOURCE	TEMPERETURE (^{0}C)	pH	TURBIDITY (NUT)	DO (mg/litre)	PHOSPHATE (mg/litre)
GARBI	A	HP	29.80	6.93	1.06	17.57	0.543
	B	W	30.60	7.27	5.44	16.84	0.520
	C	B	30.00	6.76	2.42	10.33	0.510
Mean			30.13	6.99	2.97	14.91	0.524
HAUSARI	A	HP	29.2	7.00	5.31	13.87	0.227
	B	B	29.9	7.20	4.71	12.93	0.217
	C	HP	30.1	7.20	2.56	16.63	0.533
Mean			29.73	7.13	4.19	14.48	0.326
BULABURIN	A	HP	30.0	7.13	0.32	11.57	0.213
	B	B	30.0	6.92	1.51	11.60	0.215
	C	B	28.6	7.04	0.51	11.58	0.511
Mean			29.53	7.03	0.78	11.58	0.313

TSOHON NGURU		B	30.0	6.96	24.18	14.40	0.233
	A	W	30.1	7.10	6.05	9.55	0.523
	B	HP	31.4	7.02	3.39	11.35	0.245
	C		30.50	7.03	11.21	11.80	0.334
Mean							
SABON GARI							
	A	HP	31.4	6.87	1.77	11.10	0.512
	B	W	31.6	7.04	35.41	11.73	0.213
	C	HP	31.5	6.94	4.96	11.22	0.514
Mean			31.5	6.95	14.05	11.35	0.413
CONTROL			28.0	6.91	0.00	11.77	0.012

Field survey 2019

Key: HP = Hand Pump, B= Borehole, W= Well, DO= Dissolved Oxygen.

Temperature recorded in table 1 showed significant difference between the various communities. The mean concentrations of phosphate recorded in the study were very low (0.21 to 0.60 mg/l) as shown above, and were within the maximum allowable limit of 400 mg/l recommended by NSDWQ for drinking water.

Table 2: Nitrate, electrical conductivity, color, total dissolved solid and total suspended solid of water samples across five communities of Nguru town.

SAMPLING POINT		WATER SOURCE	NITRATE (mg/litre)	EC (uS/cm)	COLOUR (ppm CU)	TDS (mg/litre)	TSS (mg/litre)
GARBI	A	HP	0.08	10.99	0.00	22.43	31.24
	B	W	0.13	25.99	4.76	53.03	68.94
	C	B	0.20	20.83	0.16	42.52	55.27
Mean			0.14	19.27	1.64	39.33	51.82
HAUSARI	A	HP	0.24	20.63	1.82	41.48	55.06
	B	HP	0.43	18.38	1.71	36.10	46.93
	C	HP	0.51	21.65	0.19	44.18	57.44
Mean			0.39	20.22	1.24	40.59	53.14
BULABURIN							
	A	HP	0.28	16.24	0.29	42.10	54.62
	B	B	0.00	17.64	0.00	32.12	43.08
	C	B	0.04	19.49	0.15	21.00	34.23
Mean			0.18	17.79	0.37	31.74	43.98
TSOHON NGURU		B	1.64	84.63	36.67	32.12	44.12
	A	W	0.76	22.95	11.74	41.02	57.09
	B	HP	0.17	19.17	6.72	23.45	32.98
	C		0.86	42.25	18.38	32.20	44.73
Mean							
SABON GARI							

	A	HP	0.14	24.90	5.23	36.31	49.02
	B	W	0.28	123.49	35.41	23.80	31.98
	C	HP	0.27	20.28	3.31	41.25	53.07
Mean			0.23	56.22	14.65	33.79	44.69
CONTROL			0.00	15.62	0.00	2.48	2.63

Field survey 2019

Key: HP = Hand Pump, B= Borehole, W= Well, EC= Electrical Conductivity, TDS= Total Dissolved Solid, TSS= Total Suspended Solid.

The nitrate concentration in the samples varied from 0.01 to 1.64 mg/L as seen in table 2. Also colour values of 36.67ppmCU and 35.41 ppmCU were recorded for Tsohon Nguru A and Sabon Gari B water samples respectively. All other values did not exceed those recommended by both NSDWQ and the WHO of 15 ppmCU.

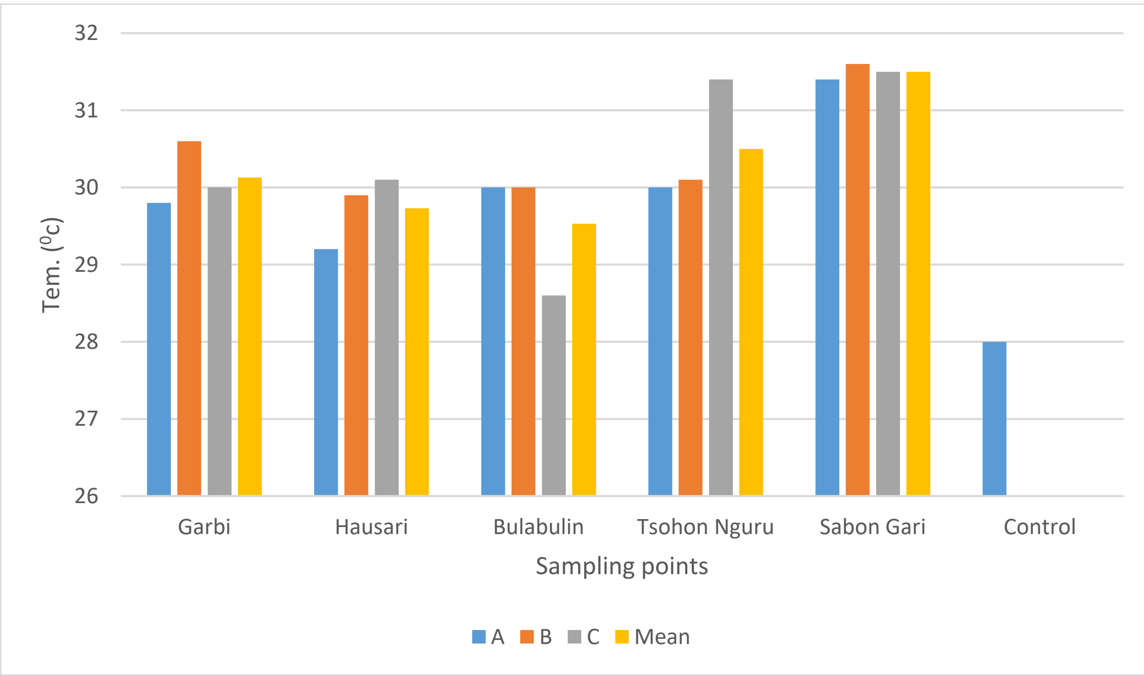


Fig 1: Samples from Different water sources showing Temperature

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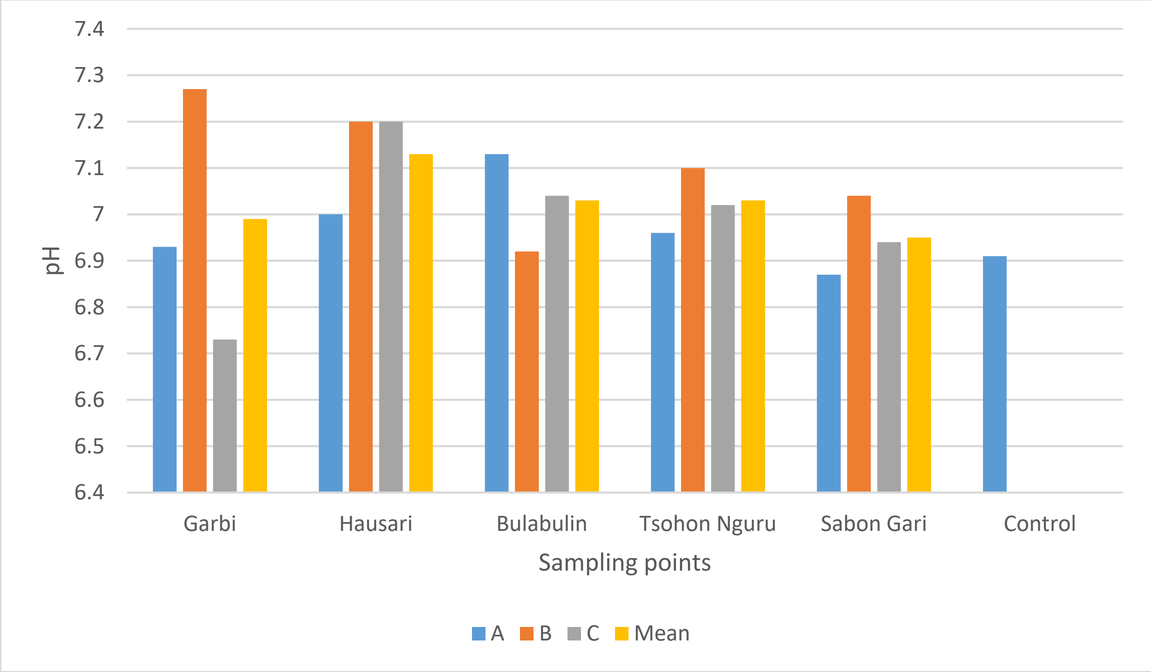

Fig 2: Samples from Different water sources showing *pH* level.

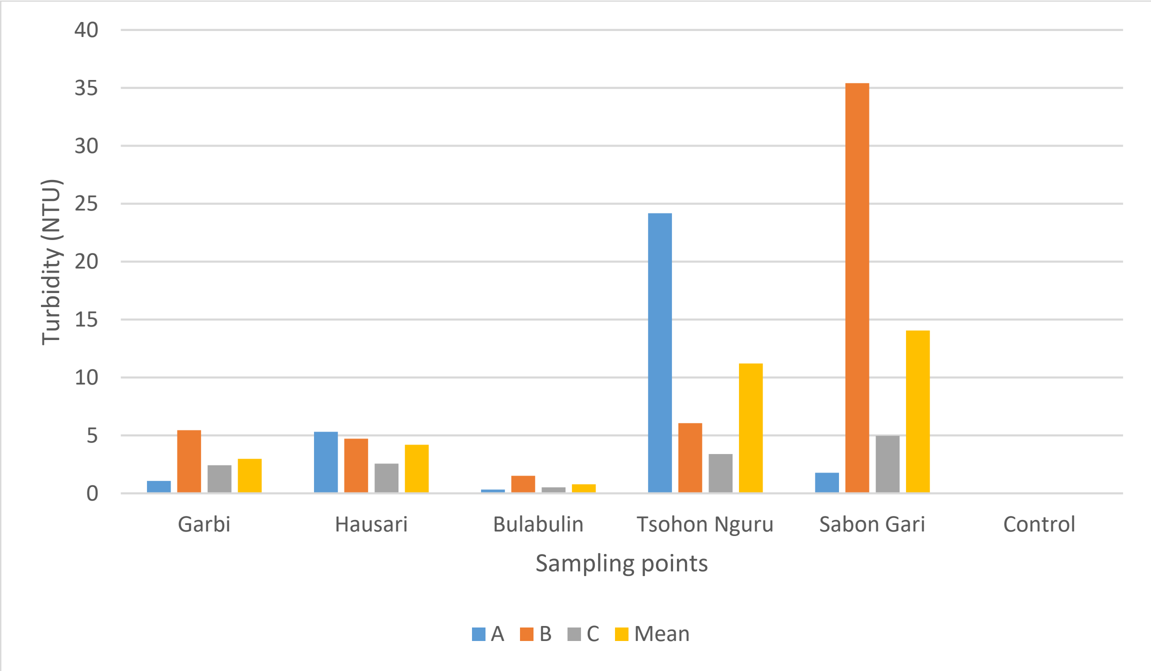

Fig 3: Samples from Different water sources showing level of Turbidity

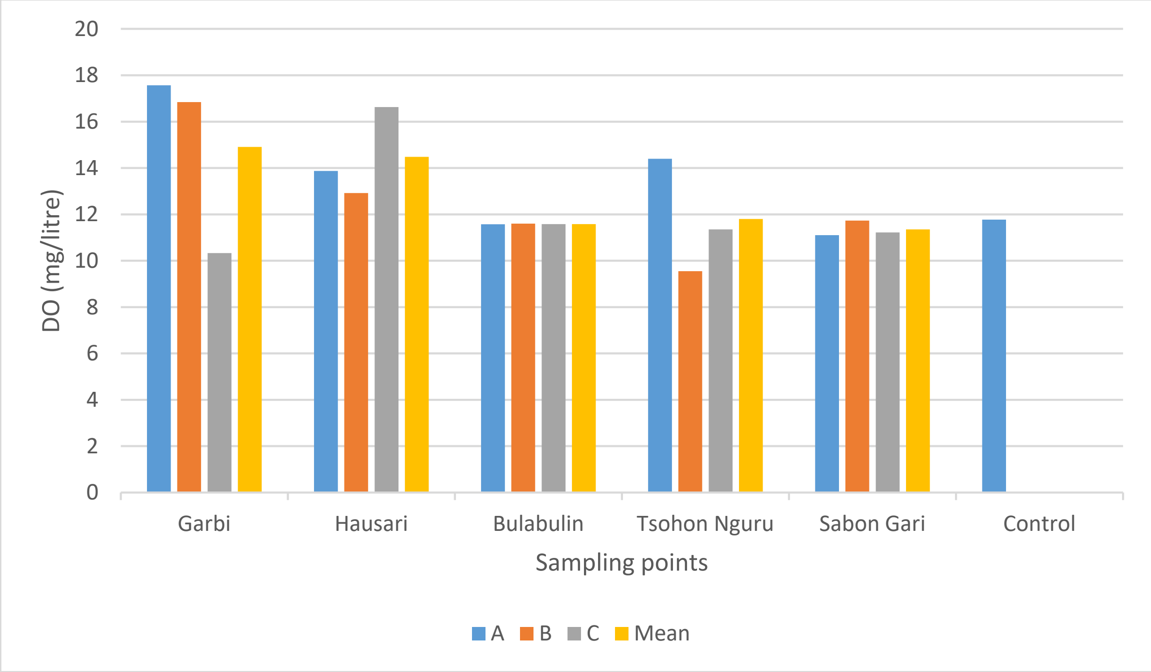

Fig 4: Samples from Different water sources showing level of Dissolved oxygen

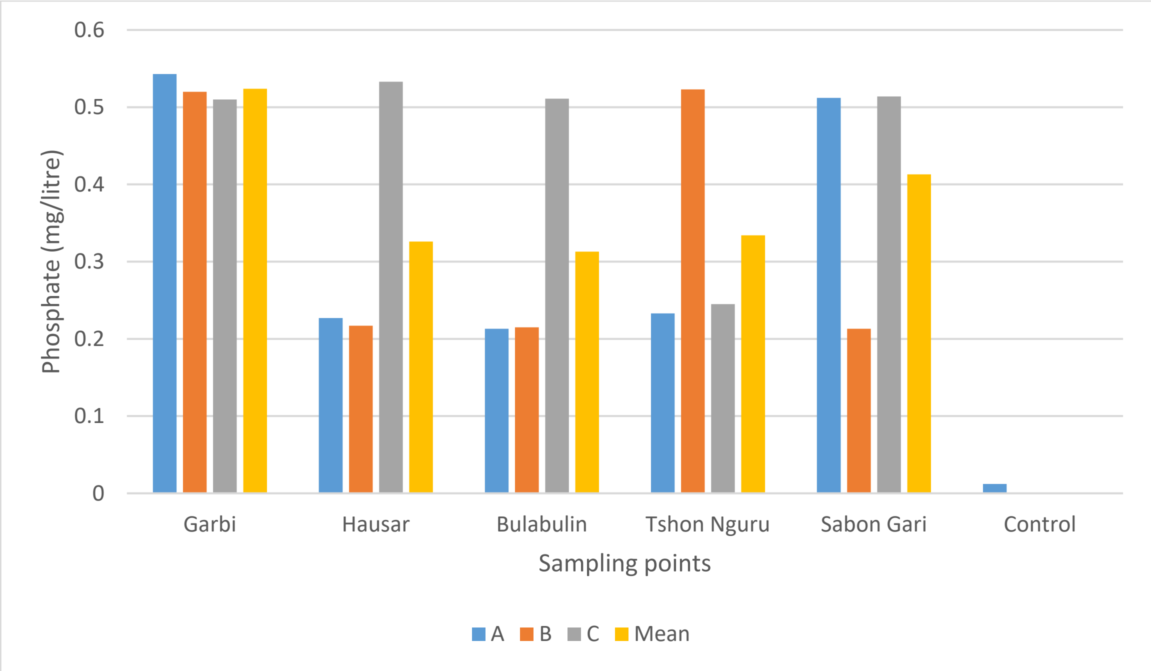

Fig 5: Samples from Different water sources showing level of phosphates.

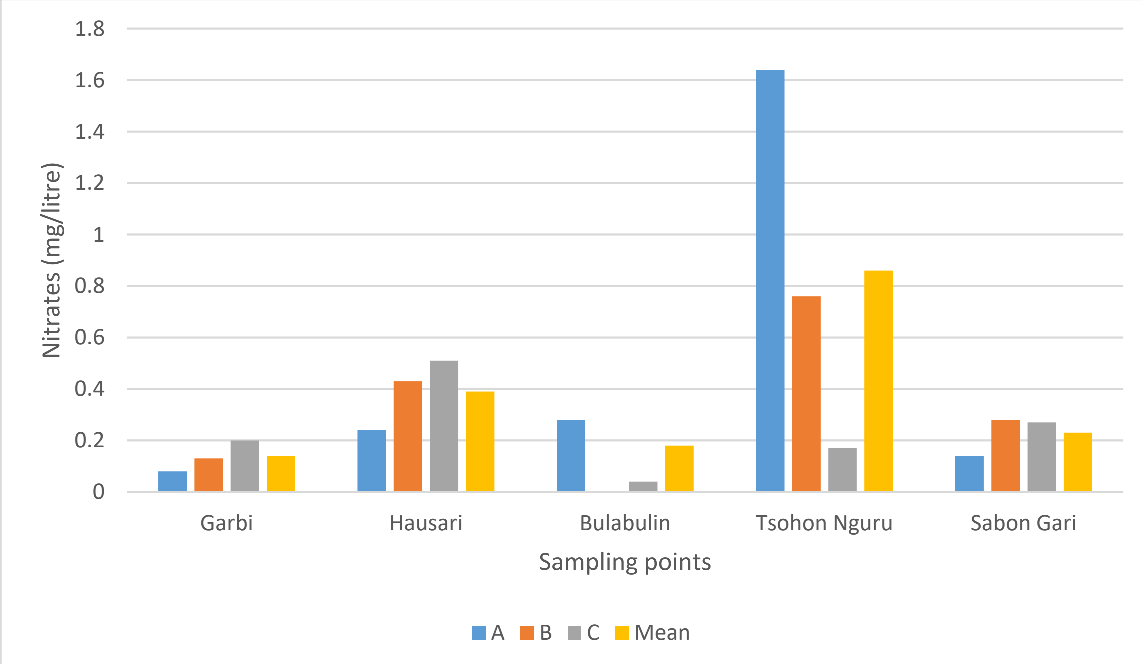

Fig 6: Samples from Different water sources showing level of Nitrates.

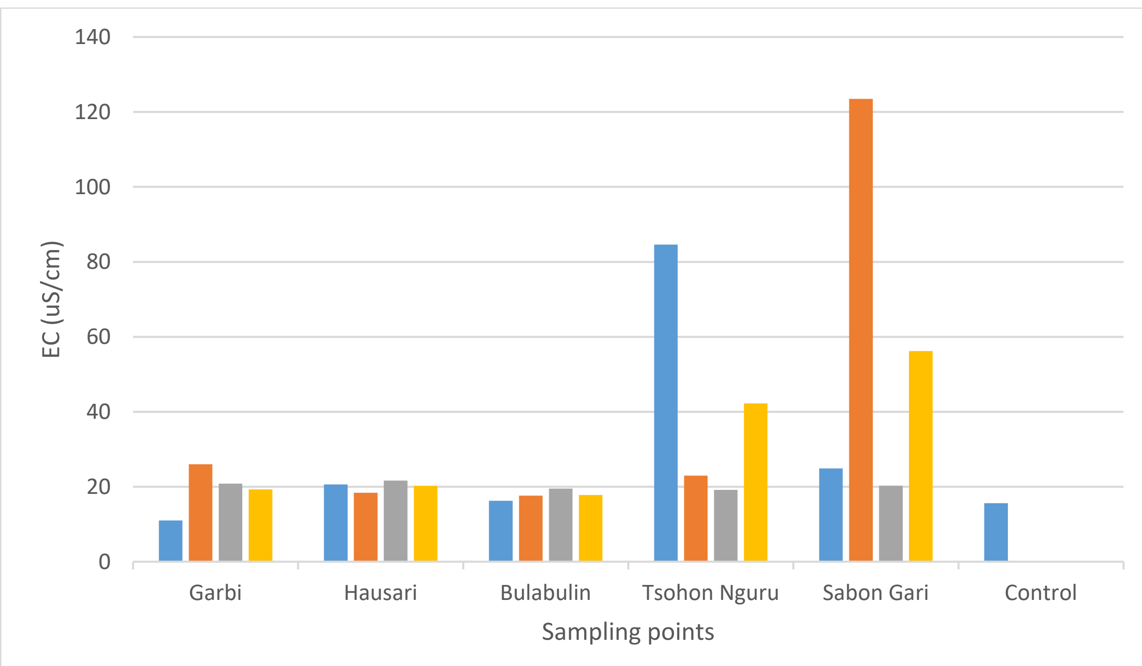

Fig 7: Samples from Different water sources showing the level of Electrical conductivity.

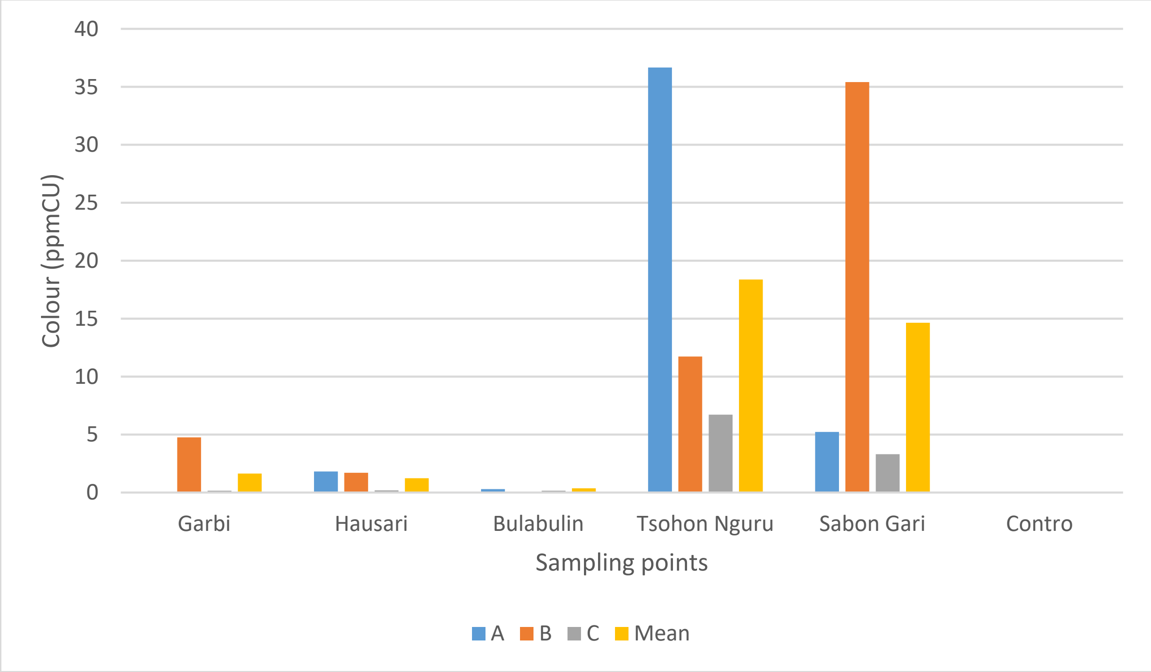

Fig 8: Samples from Different water sources showing the level of Colour.

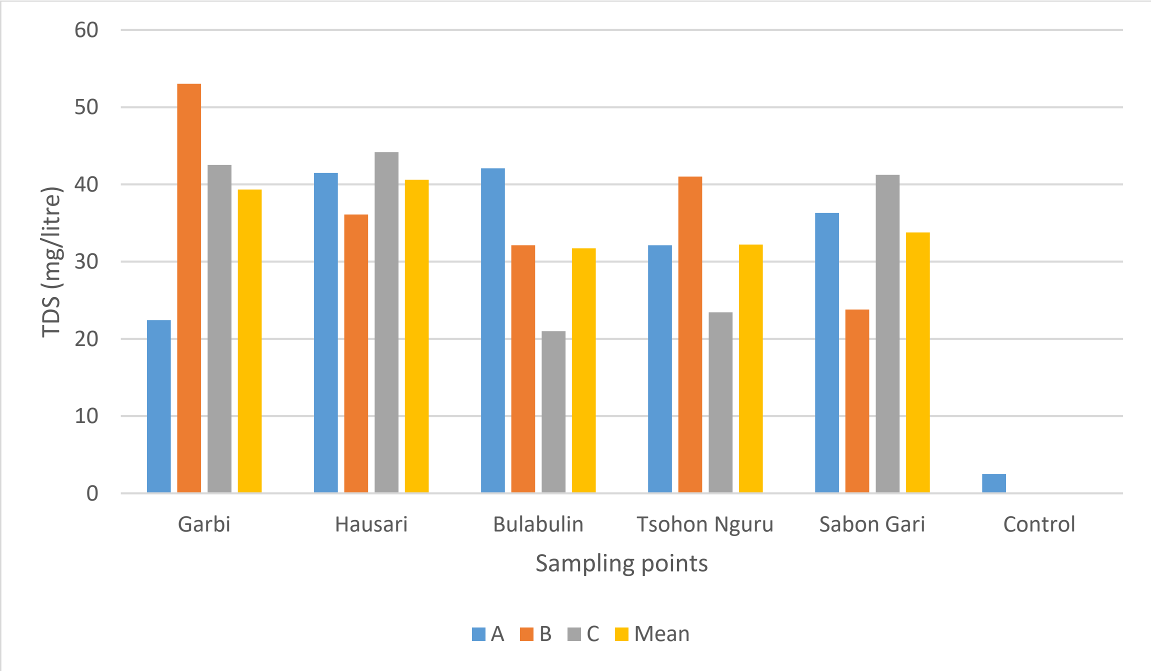

Fig 9: Samples from Different water sources showing the level Total Dissolved Solid.

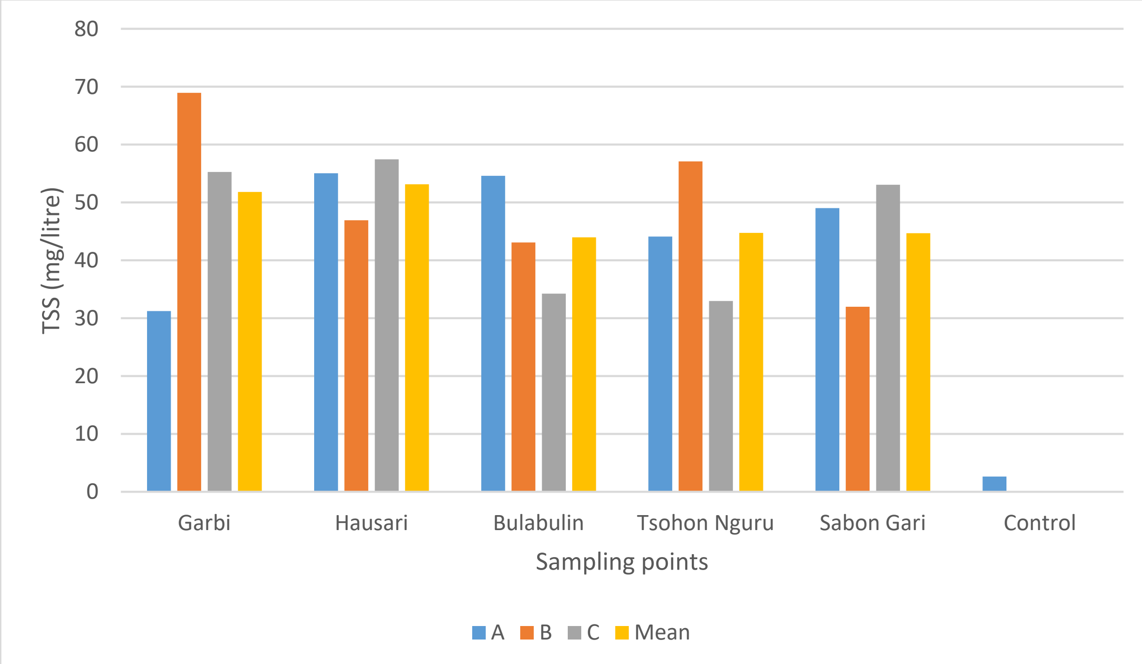

Fig 10: Samples from Different water sources showing the level of Total Suspended Solid.

DISCUSSION

Temperature

Temperature recorded (Table 1) showed significant difference between the various communities. The mean increase or difference in temperature between the various water samples and the recommended value might be due to the depth of the water sources as well as the time of collection. Increase in the Global temperature might also be one of the possible reasons for the increase in water temperature. The impurities or contaminants also might alter the water temperature. Another possible reason is that, Nguru is located in the arid zone where temperature is usually high, so increase in temperature may be connected to location of Nguru being in the arid region of the country. The significant difference recorded between the control and the samples (wells, hand pumps and boreholes) may be associated with the depth of the wells, exposure to the sun, as well as the climate. This agreed with Patil (2012), that various chemical and biological processes depend on temperature and this is likely to affect water quality.

pH

From table 1, the study revealed that levels of *pH* were within the control limits (6.5-8.5) as recommended by WHO, (2006). The mean values obtained by Fasunwon *et al.* (2008), Adekunle *et al.* (2013) in similar studies are comparable to this value; No much difference was observed in the *pH* values among the various water source. The observed *pH* values however contradict results obtained by Adelekan *et al*. (2010) in an analysis of water samples from some boreholes near a landfill in Akure, Nigeria.

Turbidity

There was significant difference in turbidity levels in the study area as seen in Table 1. And this is in consonance with a study by Boman *et al.* (2012) where mean values recorded for turbidity differed with distance. It was observed that associated lower values of turbidity were obtained in Bulabulin C (0.51 Nephelometric Turbidity Units; (NTU), Garbi A (1.06 NTU), Sabon Gari A (1.77 NTU).

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In a related study, Hassan (2003) observed that low turbidity was due to the lack of side erosion within the water source possibly as a result of greater cohesion and vice versa. Water becomes turbid when substances like silt, clay, colloids and organic matter are present. The general mean for the turbidity of all the water samples collected from all the locations is 6.68 NTU which is against the recommended 0 NTU, with exception of the samples collected from Bulabulin C (0.51 NTU), which is slightly above the 0 NTU. The reason for the excessive turbidity is clearly from the high proportion of contaminant such as coliform and *E coli* among others. Another possible reason for high turbidity is location of the water sources and other water bodies which may add up to the total turbidity of the water sources around.

Dissolved Oxygen (DO)

Dissolved Oxygen DO is a very important parameter of water quality and an index of physical and biological process going on in water which favors solubility of oxygen among the study sites (Table 2). A definite trend in DO concentration was observed on all the samples showing highest values in Garbi A (17.57mg/l), Garbi B (16.84mg/l), Hausari C (16.63) and Tsohon Nguru A (14.40mg/l) is of great importance to all living organisms. DO may be present in water due to direct diffusion from air and photosynthetic activity of autotrophs. Concentration of DO is one of the most important parameters to indicate water purity and to determine the distribution and abundance of various algal groups (Niba RN. and Chrysanthus N. 2013; Patil *et at.*, 2012; Shyamala *et al.*, 2009).

Phosphate

The mean concentrations of phosphate recorded in the study were very low (0.21 to 0.60 mg/l) as in Table 1, and were within the maximum allowable limit of 400 mg/l recommended by NSDWQ for drinking water. The low concentration of the phosphate in the water samples might be due to the geology of the area and confirms similar work done by (Adekunle et al., 2013). The results also show that addition of nutrient from anthropogenic sources to the well water is minimal. Phosphate constitutes a very important pollution problem whenever it is found in significant amount. It promotes algae growth and microphytes, leading to the cyclic problem of eutrophication (Adelekan, 2010). It is established that high phosphorus concentration has no health implication except for its role in causing eutrophication of water bodies (WHO, 2004).

Nitrate

All the water samples fall within the WHO and EU permissible limit for portable water. Since the permissible limit is 50mg/L, the nitrate concentration would not have significant negative effect. The sources of nitrate to ground water include natural geologic deposit, mineralization of soil organic nitrogen, intense use of fertilizer, human and animal sewage (Akaahan *et al.*, 2012; Agbalagba *et al.*, 2011). Correlation analysis revealed that nitrate is significant to fecal and total coliform counts in the samples. This is an indication that nitrate from pit latrine escape to the shallow wells. A similar study by Adejuwon (2011) to determine pollution effect of pit latrines on shallow wells at Isale- Igbehin community, Abeokuta, Nigeria. The nitrate concentration in the samples varied from 22.5 to 50.6 mg/L. All the water samples except with the value of 50.6 mg/L fall within the WHO and EU permissible limit for portable water. Therefore the fear of methemoglobinemia is alleviated. Since the permissible limit is 50 mg/L, the nitrate concentration in Sample with high nitrate would have significant negative effect. The sources of nitrate to ground water include natural geologic deposit, mineralization of soil organic nitrogen, intense use of fertilizer, human and animal sewage (Vomocil, 1987; Hallerg & Keeney, 1993., Dillion, 1987).

Electrical conductivity

Electrical conductivity (EC) in water is the normalized measure of the water's ability to conduct electric current (Adelekan, 2010). This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. The water samples collected from Sabon Gari B and Tsohon Nguru A as seen in table 2 have relatively higher value of EC been 123.49 and 84.63 respectively but all values fall within the recommended limits of 1000µS/cm set by NSDWQ and WHO.

Colour

As seen in table 2, colour values of 36.67ppmCU and 35.41 ppmCU were recorded for Tsohon Nguru A and Sabon Gari B water samples respectively. All other values did not exceed those recommended by both NSDWQ and the WHO of 15 ppmCU. A similar study carried out by Ahmed Sabo to access the quality of ground water at Abubakar Tatari Polytechnic recorded mean values of 6.5ppmCU and 5.2ppmCU were recorded for dug well and borehole water samples respectively. The color of drinking water reflects the presence of suspended matter. Therefore the more suspended matter in water the greater is the color. In exceptional circumstances however, color may arise naturally from the presence of colloidal Iron/Manganese in water (APHA, 2002).

Total Dissolved Solid (TDS)

The higher values recorded for total dissolved solids (TDS) was as a result of the higher turbidity as seen in Table 2. WHO guideline values for TDS is 1000 mg/l and all values were below this permissible level hence clean for human consumption contrary to results obtained by Boman et al. (2012). The differences in the levels of contamination were because of their distance to the nearest latrine (Kiptum *et al*., 2012). The concentration and composition of TDS in the water source is determined by geology, drainage, atmospheric precipitation and the water balance (Sakyi & Asare 2012).

Total Suspended Solid (TSS)

In the samples, the minimum TSS value was 31.24 mg/l in Garbi A and maximum value was 68.94 mg/l from Garbi B as seen in table 1. This might be due to the presence of several suspended particles in the water samples as Garbi A use hand pumps as their water source which resulted in low TSS concentration while Garbi B uses well attributing to the high TSS concentration. The total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of Ca, Mg, Na, K, Mn organic matter, salt and other particles. The effect of presence of total suspended solids is the turbidity due to silt and organic matter. When the concentration of suspended solids is high it may be aesthetically unsatisfactory for consumption (APHA, 2002).

CONCLUSION

The study was carried out to assess the physico-chemical parameters of groundwater in Garbi, Hausari, Bulabulin, Tsohon Nguru and Sabon Gari communities of Nguru town. The analysis revealed that samples obtained from the different water sources contained one form of contaminant or the other. From the results, it is clear that drinking water samples collected from all the underground water sources are not safe for human consumption.

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REFERENCES

Abdullahi, A.S., Funtua, I.I., Dewu, B.L.M and Alagbe, S.A. (2010). Study of the suitability of Groundwater for Household and Irrigation Purposes in Parts of Adamawa State, North eastern Nigeria. *Int. Arch. of Applied Science and Tech*; Vol. 2 P 48 – 56.

Adekunle, I.M., Adetunji, M.T., Gbadebo, A.M., and Banjoko, O.B. (2013). Assessment of Groundwater Quality in a typical rural settlement in Southwest. *Nigeria International Journal of Environment and Public Health;* 4(4):307–318.

Adelekan, B. A. (2010). Water quality of domestic wells in typical African communities: Case studies from Nigeria. International Journal of Water Resources and Environmental Engineering 2(6): 137-147.

Agbalagba O. E., Ononugbo C. P. and Alao A. A. (2011). Investigation into the physic chemical properties and hydrochemical processes of groundwater from commercial boreholes in Yenagoa, Bayelsa State, Nigeria. African Journal of Environmental Science and Technology Vol. 5(7), pp. 473-481

Akaahan, T. J., Oluma, H. O. and Sha'Ato, R. (2010). Physico-chemical and Bacteriological Quality of Water from Shallow Wells in Two Rural Communities in Benue State, Nigeria. Pakistan Journal of Analytical and Environmental Chemistry 11(1), 73-78.

APHA, Standard methods for the examination of water and wastewater (2005), 21st edn. American public health association, New York.

Ayanlaja, S.A., Kehinde-Philips, O.O., Ogunkola, F., Dada, B. and Senjobi, B. (2005). Quality of water from hand Dug Wells, Boreholes and Streams in two localities in South Western Nigeria. Implication of the 4th international groundwater quality conference, Waterloo, Canadian IAHS Publication; 47: 97-108.

Boman, B. J., Wilson, P. C. and Ontermaa, E. A (2012). Understanding Water Quality Parameters for Citrus Irrigation and Drainage Systems. The Institute of Food and Agricultural Sciences (IFAS), University of Florida Extension Services. Circular No. 1406.

Ernest A.A. (2013): Effect of pit latrines on dug-well water quality - a case study of the asankrangwa community in the wassa amenfi west district of Ghana. Department of Environmental science; College of Science. Kwame Nkrumah University of Science and Technology.

Howard, G., Pedley, S., Barret, M., Nalubega, M. and John, L. (2010). Contamination of Shallow Groundwater in Kampala, Uganda. *Water Res;* 27(14): 3421-3429.

Kiptum, C. K. and Ndambuki, J. M. (2012). Well water contamination by pit latrines: A case study of Langas. *International Journal of Water Resources and Environmental Engineering,* *4*(2), 35-43.

Klimatafel, V.N. (2016) Baseline Climate from all stations over the world. Deutscher wetterrdienst. Retrieved 2017.

Majuru, B., Michael, M.M., Jagals, P. and Hunter, P.R. (2011) Health impact of smallcommunity water supply reliability. *Int. J. Hyg.* and *Env. Health*; 214(2):162-166.

Makokha K.J. (2017) Analysis of Groundwater Quality and Identification of AbstractionPoints in Kahawa Wendani, Kiambu Country. Department of Geography and Environmental Studies, University of Nairobi.

Musa, H., Vakasai, I.A. and Musa, A.H. (2015). Determination of Lead Concentration in Well and Borehole Water in Nigeria. *Chem class Journal*; 14– 18.

Oluyemi, E.A., Adekunle, A.S., Adenuga, A.A. and Makinde, W.O. (2010). Physico Chemical Properties and Heavy Metal content of water sources in Ife North Local government Area of Osun State, Nigeria. *African Journal of Environmental Science and Technology;* (4(10): 691-697.

Patil, S.G., Chonde, S.G. Jadhav, AS. and Raut, P.D. (2012). Impact of Physico-Chemical Characteristics of Shivaji University lakes on Phytoplankton Communities, Kolhapur, India. Res. J. Rec. Sci. 1: 56-60.

Pritchard, M., Mkandawire, T. and Oneil, J.G. (2007). Biological, chemical and physical drinking water quality from shallow wells in Malawi: Physics and Chemistry of the earth 32(2007) 1167-1177.

Priis-Ustun, A., Fewiel, L., and Bartrain, J. (2004). Unsafe Water, Sanitation and Hygiene. In: Egzat, M., Lopez, A. D., Roger, A., Murray, C. J. (eds). Comparative Quatitative of Health risks, Global and Regional Burden of disease attributed to selected major risk factors.

Sakyi, P. A. and Asare, R. (2012). Impact of temperature on bacterial growth and survival in drinking-water pipes. *Res. Journal Environmental of Earth Sciences. 4*(8): *807-817*

Selendy, M. and Janine, M.H. (2011). Water and Sanitation-Related Diseases and the Environment Challenges, Interventions, and Preventive Measures. Hoboken, N.J.: Wiley-Blackwell. p. 25. ISBN 978-1-118-14860-0.

UNICEF/WHO (2012). Progress on Drinking Water and Sanitation: 2012 updates.

WHO (2004). Guidelines for Drinking Water Quality.

WHO/UNICEF. (2006). Meeting the Millennium Development Goal Drinking Water and Sanitation Target. The Urban and rural Challenge of the Decade. Geneva, Switzerland.