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Physico-chemical characteristics of borehole water quality in Gassol Taraba State, Nigeria

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Many people in Africa depend on water from borehole, but purity of the drinking water from this source remains questionable. In a bid to ascertain the health risk local people are exposed to, this study analyses the physico-chemical characteristics of borehole water in Gassol Local Government Area (LGA), Nigeria. For this purpose, water samples were collected from the 12 administrative wards in the LGA. Two samples were collected from each ward, one in the rainy season (March) and another in the dry season (November), a total of 24 water samples in all. The water samples were analyzed for 18 different physical and chemical parameters to ascertain their comparability with the guideline levels recommended by the Standard Organization of Nigeria (SON) and World Health Organization (WHO). Results show that most parameters were within the guideline values in both seasons except for turbidity, pH, fluoride (F^-), chlorine (Cl^+), iron (Fe^{2+}), ammonia (NH_4^+) and manganese (Mn_2^+). Overall, all of the wards had at least one instance in which a parameter falls outside recommended guideline. A further analysis using the mean value test approach to assess level of contamination relative to guideline values showed that the upper bound value (US_{95}) of turbidity, iron, pH and chlorine are greater than their guideline values. This indicates that these are the parameters for which the most urgent action is needed. The high concentration of iron and turbidity outside the prescribed limits in the rainy season suggests that water managers need pay more attention to borehole water quality in the rainy season. There is need for further research across the region to better understand the quality and the contaminants (natural and anthropogenic) of borehole water so as to be able to proffer appropriate remediation strategy.

Key words: Groundwater, guideline value, mean value test, standard organisation of Nigeria (SON), World Health Organisation (WHO).

INTRODUCTION

Water is the most important nutrient essential to the survival of all humanity because it is involved in every bodily function, and makes up about 75% of total body weight (Mack and Nadel, 2011; Offei-Ansah, 2012; Shryer, 2007). The lack of this essential mineral can lead to serious implications such as hypertension, high cholesterol, and heart disease. Recent studies have also linked the lack of water to headaches, arthritis, and

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heartburn (Batmanghelidj and Page, 2012). Therefore, it is recommended that one should drink at least 64 ounces per day (Bellisle et al., 2010). However, despite the need to ensure sufficient water quantity, one of the biggest development challenge is ensuring sufficient water quality (Gundry et al., 2003).

Providing safe drinking water is one of the most complex challenges facing African rural communities. The continent has the highest number of people lacking access to safe, drinkable water. According to World Health Organization (2008), more than 3.4 million people die each year from water sanitation and hygiene-related causes and majority of these are in Africa. The impact of the consumption of unsafe drinking water in Africa has been likened to “death of children at a rate equivalent of a jumbo jet crashing every 4 h” (The United Nations Children's Fund, 2010). In a bid to stem the tide, programs such as the Millennium Development Goals (MDG) which aims at improving the quality of water are widely adopted (World Health Organization, 2006). Emphasis has also been placed on diversifying water sources from reliance on surface water to include rain water and groundwater.

Traditionally many societies have depended on surface water; however with increasing challenges of contaminated surface water resulting in diseases such as bilharzia, sleeping sickness, river blindness and guinea worm, many societies have adopted digging of boreholes (Carpenter et al., 1998; Chigor et al., 2012). Digging of borehole is encouraged by local, national and international organisations as alternative to polluted surface drinking water sources. A lot of funds is been allocated into building boreholes even though sometimes the purity of the drinking water from the boreholes is questionable (Ncube and Schutte, 2005). The quality of borehole water depends upon several factors including local geology, hydrology and geochemical characteristics of the aquifers (Bhattacharya et al., 1997). Apart from these factors, the activities of microorganisms, temperature and pressure are also responsible for the chemical characteristic of groundwater (Fournier and Truesdell, 1973).. Therefore, borehole water often contains dissolved mineral ions whose type and concentration can affect their quality . If certain mineral constituent are present in excessive amounts, some type of treatment may be necessary before the water can be used for the intended purpose.

Water should be free from any physical, chemical or bacteriological contaminant. But unfortunately water is not always found pure. It is for such reason that drinking water quality standard is set up to ensure the safety of drinking water supplies and the protection of public health. This is even more important now because the chemical quality of drinking water during recent years has deteriorated considerably due to the presence of toxic elements, which even in trace amounts can cause serious health hazards (Ikem et al., 2002). Therefore, there is need to ensure that the water people drink and use for household activities is reliable and safe. If not, adequate remedial measures can be put in place. It is the knowledge of the composition and properties of water that is significant for the evaluation of its potential use and management. Knowing the water's physical, chemical and biological characteristics allows experts to determine whether it is suitable for drinking and other domestic uses. On a global scale, World Health Organisation (WHO) produces international norms on water quality and human health in the form of guidelines that are used as the basis for regulation and standard setting, in developing and developed countries world-wide. Various countries have also enforced drinking water standards for the maximum permissible levels of different constituents. In United States, guidance to ensure that drinking water standards are in place to protect human health is set by United States Environmental Protection Agency (USEPA) while the Standards Organisation of Nigeria (SON) has this responsibility in Nigeria.

Nigeria is one of many African countries facing problems of accessibility to clean drinking water. Although it is reported that 27 million new Nigerians have gained access to clean drinking water since 1990, only 47% of the population can access safe water (The United Nations Children's Fund, 2007). The biggest population facing water shortages in Nigeria come in rural Northern Eastern region where over 70% of the population cannot access clean water (Voices, 2013). In a bid to stem the tide individuals, public and private entities have dug boreholes without any effort to ascertain their safety. The Nigerian government even launched a National Borehole Programme to supply water through a motorized system of boreholes to rural communities (Onugba and Sara). As far as North Eastern Nigeria is concerned, borehole water is popular in a region which is entirely within savannah zone. Due to this increased consumption of borehole water in the region, there has been a growing concern about the quality of water from this source. It is against this background that the physical properties and chemical contents in borehole water in Gassol Local Government Area of Taraba State are investigated with the aim of assessing the portability of borehole water and generating information that can serve as a guide in monitoring water contamination in the region. The data generated from this study will be used to create a baseline database of borehole drinking water quality in the region.

MATERIALS AND METHODS

Study area

Gassol Local Government Area (LGA) is one of the 16 LGA’s in Taraba State, Nigeria (Figure 1). It covers a total land area of about 5,500 km^2 and extends between latitude 8°38′00″ north of the equator and 10°46′00″ east of the Greenwich meridian (Taraba State Government, 2015). The area is generally underlined by sedimentary rocks which are very good aquifers (reservoir) for water. The River Taraba which takes its source from the Mambilla plateau in the South is a source of water for domestic uses, fishing and also for irrigation farming during the dry season. The

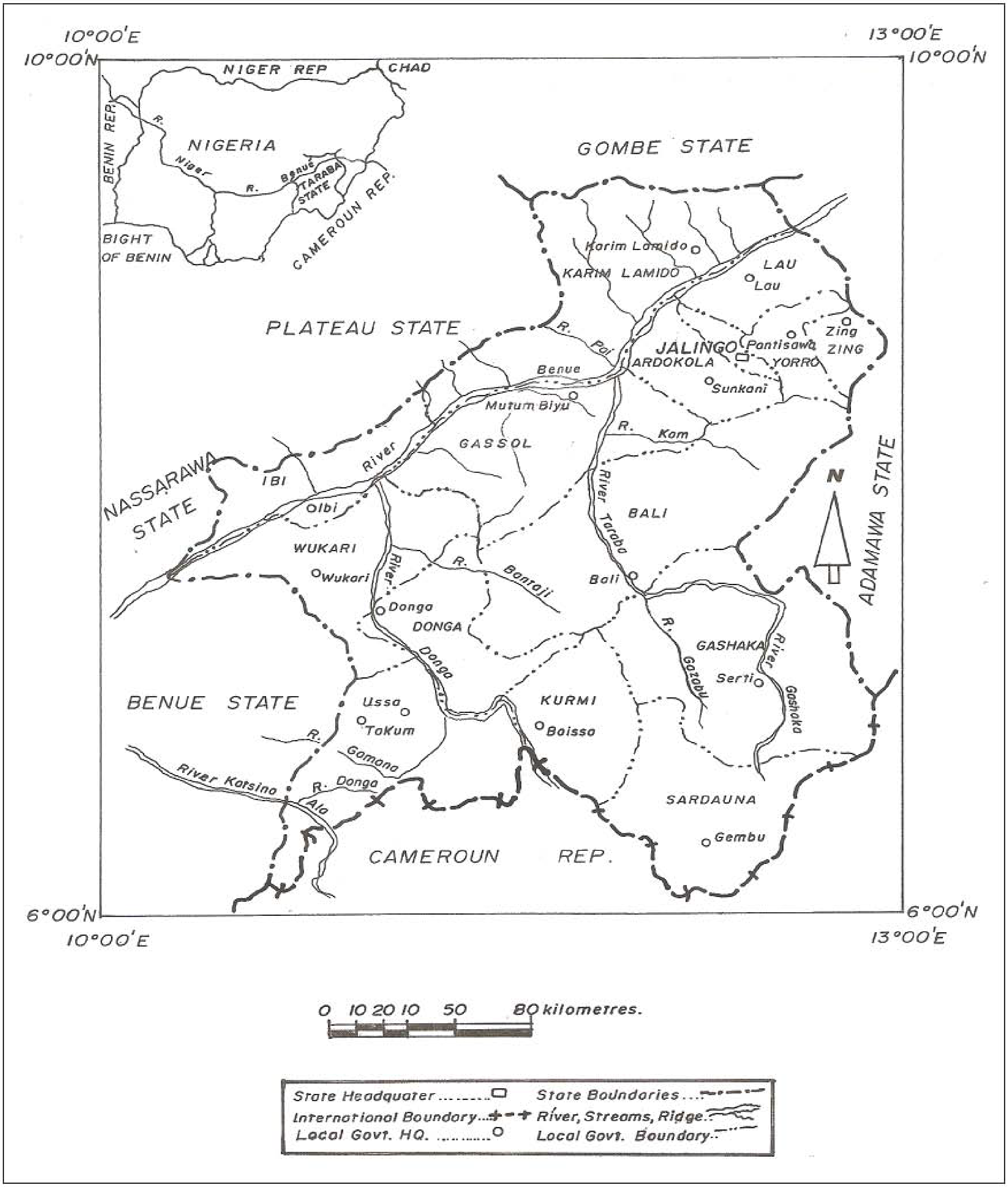

Figure 1. Map of Taraba State showing Local Government Areas (Including Gassol Local Government Area).

temperature regime is warm to hot throughout the year with a slight cool period between November and February. Temperature ranges between 23 to 40°C. There is a gradual increase in temperature from January to April, which also increases the demand of water for domestic uses in the area.

Gassol is an important economic centre because of its cattle market which is well linked to other part of Nigeria. The population of the local government is 245,086 (National Population Commission, 2006) in twelve (12) administrative wards, namely, Sansani, Sendirde, Wuryo, Sabon Gida, Namnai, Yarima, Gassol, Shira, Tutare, Gunduma, Mutum Biyu "A" andMutum Biyu "B".

Water sample collection and analysis

Water samples were collected from randomly selected boreholes. A borehole is selected from each of the 12 administrative wards within Gassol Local Government Area. Water samples were collected from each borehole twice. The first set of samples was collected in May corresponding with the rainy season and the second set in November corresponding with the dry season. In total, 24 water samples were collected for the study. The borehole water samples were collected in prewashed (with detergent, diluted HNO_3 and doubly de-ionized distilled water, respectively) polyethylene bottles. The determinations of the physical and chemical properties of the water samples were performed on the same day of sample were taken. This was done at the United Nations Children's Fund (UNICEF) assisted Rural Water Supply and Environmental Sanitation Agency. Analytical water test tablets (photometer grade) reagents for specific test were used for the preparation of all solutions. Water samples from the boreholes were analysed using a Palintest Photometer 5000, following the procedures set out in the instruction booklet (Palintest, 1980). Each sample was analyzed for 18 parameters. These were turbidity, conductivity, temperature, pH, total dissolved solids (TDS), nitrate (NO^3), fluoride (F^-), chlorine ($C1^-$), iron (Fe^{2+}), ammonia (PO_4^{3-}), hardness ($CaCO_3$), sulphate (SO_4^{2-}), manganese (Mn^{2+}), copper (Cu), magnesium (Mg^{2+}), calcium (Ca^{2+}), total alkalinity and total salinity.

The resultant levels of the parameters were compared with the World Health Organization (WHO) (World Health Organization, 2011) and the Standard Organization of Nigeria (SON) (Standards Organisation of Nigeria, 2007) guideline values to ascertain their compliance with the prescribed recommended limits. These guideline values set maximum allowable limits in drinking water. While the WHO provides a general global guideline the SON is specific to Nigeria. However, while the WHO standards is constantly been updated, the SON standard has not been updated for almost a decade.

Mean value test

The mean value test is a statistical method used to guide decision-making in many regulatory contexts such as in assessment of contaminated land, soil and water quality. This approach which is defined in Appendix A of Contaminated Land Report 7 by Department for Environment Food and Rural Affairs and The Environment Agency (Department for Environment Food and Rural Affairs and The Environment Agency, 2002), assess contaminated sites relative to guideline values. This is based on the estimation of the 95% Upper Confidence Limit of the mean concentration of a contaminant (95%UCL, also referred to as US_{95}) and its use as the appropriate value to be compared with the relevant guideline value or site-specific assessment criterion. This 95%UCL is meant to provide a reasonably conservative estimate of whether the measured concentration is acceptable, considering the uncertainty and variability associated with site investigations.

The necessary calculation involves five steps (Dean, 2007) as follows:

(i) Calculate the arithmetic sample mean, X.
(ii) Calculate the (unbiased) sample standard deviation, s.
(iii) Select an appropriate t value e.g. 95th percentile confidence limit, t. The tabulated “t value” can be obtained from four figure mathematical table.
(iv) Calculate the upper 95th percentile bound of sample as:

$US_{95} = X + (ts / \sqrt{n})$

(v) Compare the upper bound value, (US_{95}) with the guideline value (G).

RESULTS

The results of the borehole water analysis for samples collected in the rainy and dry seasons are presented in Tables 1 and 2. The concentration of each parameter varies from one sample point to the other. This is then compared to the SON and WHO acceptable values to determine and compare the suitability and effect of continual consumption of such water.

Water quality evaluation: parameters within guideline levels

The results showed that all of the boreholes tested were well within the limits prescribed by SON and WHO both in the wet and dry seasons for electrical conductivity (EC), temperature, total dissolved solids (TDS), nitrate (NO_3^-), total hardness ($CaCO_3$), sulphate (SO_4^{2-}), Copper (Cu), magnesium (Mg^+) and Calcium (Ca^{2+}). Conductivity ranged between 392 Ω/cm in Shira to 818 Ω/cm in Gassol. Temperature ranged between 25.0°C in Gunduma and Mutum Biyu "A" in the rainy season to 38.0°C in Tutare and Gunduma in the dry season. Total dissolved solids ranged between 180 ppm in Shira and 428 ppm in Gassol. Nitrate ranged from 0.17 mg/L in Sendirde to 32 mg/L in Shira. Total hardness varied from 22 mg/L in Tutare and Mutum Biyu “B” in the dry season to 75 mg/L in Gunduma in the rainy season. Sulphate varied between 2.4 mg/L in Sendirde to 6.7 mg/L in Shira. Copper ranged between 0.01 mg/L in Sansani, Sendirde, Shira, Mutum Biyu "A", and Mutum Biyu "B" to 0.5 mg/L in Gassol. Magnesium was highest at 1.02 mg/L in Tutare, and Gunduma and lowest at 0.06 mg/L in Sabon Gida. Calcium varied between 2.1 mg/L in Gunduma to 11.5 mg/L in Wuryo. At these levels, these parameters do not pose any health impact and are within the SON and WHO guideline values. As such it will be sufficient to conclude that these parameters are unlikely to be sources of water contamination in Gassol LGA of Taraba State, North Eastern Nigeria. On the other hand, there were incidences in which Turbidity, pH, fluoride, chlorine, iron and manganese are outside guideline values (Appendixes 1 to 7).

Water quality evaluation: parameters outside guideline levels

Turbidity

Turbidity is a physical parameter, which is a measure of the cloudiness of water. It is caused by particles suspended or dissolved in water that scatter light making

Table 1. Chemical and Physical concentration of water samples from wards of Gassol Local Government Area in Rainy Season.

Parameters	Sansani	Sendirde	Wuryo	Sabon Gida	Namnai	Yarima	Gassol	Shira	Tutare	Gunduma	Mutum Biyu "A"	Mutum Biyu "B"	SON	WHO
Turbidity (NTU)	45.00	6.12	55.00	60.00	25.00	26.00	16.00	20.00	15.00	35.00	25.00	20.00	45.00	6.12
Conductivity (Ω/cm)	778.00	651.00	742.00	627.00	667.00	657.00	818.00	392.00	415.00	720.00	518.00	620.00	778.00	651.00
Temperature (°C)	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	26.00	25.00	25.00	26.00	27.90	27.90
pH	6.97	6.78	6.60	7.04	6.40	7.11	7.88	7.10	6.50	6.51	6.70	6.20	6.97	6.78
TDS (PPM)	375.00	328.00	371.00	317.00	329.00	330.00	428.00	180.00	210.00	410.00	250.00	310.00	375.00	328.00
Nitrate (NO_3^-) (mg/L)	0.91	0.17	0.28	0.29	0.21	0.79	0.41	32.00	25.00	15.00	16.00	15.000	0.91	0.17
Fluoride (F^-) (mg/L)	1.30	0.79	1.02	0.77	0.34	0.03	1.50	1.48	2.50	0.20	0.80	0.50	1.30	0.79
Chlorine (Cl^-) (mg/L)	2.60	3.20	2.80	3.30	3.30	3.50	2.20	2.90	35.00	20.00	16.00	25.00	2.60	3.20
Iron (Fe^{2+}) (mg/L)	0.80	0.45	0.75	0.63	0.62	0.67	0.45	0.30	0.20	0.01	0.20	0.20	0.80	0.45
Ammonia (PO_4^{3-}) (mg/L)	0.19	0.03	0.03	0.09	0.06	0.04	0.07	0.10	0.50	0.20	0.50	0.70	0.19	0.03
Hardness ($CaCO_3$) (mg/L)	59.00	41.00	37.00	59.10	60.10	65.00	49.10	60.10	72.00	75.00	65.00	62.00	59.00	41.00
Sulphate (SO_4^{2-}) (mg/L)	2.80	2.40	3.50	6.20	6.00	4.50	3.50	6.70	3.20	3.40	5.30	6.20	2.80	2.40
Manganese (Mn2+)(mg/L)	0.01	0.18	0.13	0.14	0.03	0.07	0.11	0.18	0.02	0.20	0.30	0.20	0.01	0.18
Copper (Cu) mg/L	0.01	0.01	0.21	0.19	0.25	0.02	0.50	0.01	0.02	0.02	0.01	0.01	1	2
Magnesium (Mg^{2+}) (mg/L)	0.13	0.09	0.11	0.06	0.53	0.62	0.15	0.25	1.02	1.02	1.00	1.00		100
Calcium (Ca^{2+}) (mg/L)	4.70	9.40	11.5	6.50	4.90	6.80	9.60	2.50	3.20	2.10	2.20	2.20		150
Total Alkalinity (mg/L))	40.00	37.00	42.00	54.00	47.50	50.20	40.10	49.10	29.00	15.00	0.02	2.30		
Total salinity (mg/L)	41.00	45.00	33.00	14.00	31.50	6.80	10.50	7.20	3.40	15.00	19.00	19.00		

Bold values indicate incidences where parameters are outside guideline values.

the water appear cloudy or murky. The particulate matters can include sediment - especially clay and silt, fine organic and inorganic matter, soluble coloured organic compounds, algae, and other microscopic organisms (Nemade et al., 2009). Turbidity generally has no direct health effects; however, it can interfere with disinfection and provide a medium for microbial growth (Akoto and Adiyiah, 2007). This may indicate the presence of disease causing organisms such as bacteria, viruses, and parasites that can cause symptoms such as nausea, cramps, diarrhoea, and associated headaches (Payment et al., 2003).

In this study, all the boreholes had turbidity values outside the SON and WHO guideline value of 5 NTU. In the rainy season, turbidity value ranged between 6.12 NTU in Sendirde to 60 NTU in Sabon Gida. The concentration was generally better in the dry season with only Sansani (45 NTU) and Sendirde (6.1 NTU) having turbidity levels above the guideline value. On the average of both seasons, all the boreholes have turbidity level above permissible level. The source of turbidity in Gassol is most likely due to those generated as water moves through the loose soils of the area into the ground water supply. The high concentrations of turbidity in the rainy season when there is high likelihood of mud and silt been washed into underground water will suggest the need to constantly measure this parameter especially in the rainy season.

pH

pH is a measure of hydrogen ions (H^+) and negative hydroxide ions (OH^-) in water. It indicates whether the water is acidic or alkaline (World Health Organization, 2006). In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7 on

Table 2. Chemical and Physical concentration of water samples from wards of Gassol Local Government Area in Dry Season.

Parameters	Sansani	Sendirde	Wuryo	Sabon Gida	Namnai	Yarima	Gassol	Shira	Tutare	Gunduma	Mutum Biyu "A"	Mutum Biyu "B"	SON	WHO
Turbidity (NTU)	45.00	6.10	5.00	4.60	2.50	2.60	1.60	2.10	1.50	3.50	2.20	2.10	5	5
Conductivity (Ω/cm)	778.00	651.00	742.00	627.00	667.00	657.00	818.00	392.00	415.00	720.00	518.00	620.00	1000	2500
Temperature (°C)	30.90	37.00	27.90	35.90	30.90	30.90	37.00	32.00	38.00	38.00	35.00	36.00	23 – 40	23 - 40
pH	6.97	6.78	6.60	7.04	6.40	7.11	7.88	7.10	6.50	6.51	6.70	6.20	6.5 - 8.5	6.5 - 8.5
TDS (PPM)	375.00	328.00	371.00	317.00	329.00	330.00	428.00	180.00	210.00	410.00	250.00	310.00	500	1000
Nitrate (NO_3^-) (mg/L)	0.91	0.17	0.28	0.29	0.21	0.79	0.41	32.00	25.00	15.00	16.00	15.00	50	50
Fluoride (F^-) (mg/L)	1.30	0.79	1.02	0.77	0.34	0.03	1.50	1.48	2.50	0.20	0.80	0.50	1.5	1.5
Chlorine (Cl^-) (mg/L)	2.60	3.20	2.80	3.30	3.30	3.50	2.20	2.90	35.00	20.00	16.00	25.00		5
Iron (Fe^{2+}) (mg/L)	0.10	0.10	0.20	0.20	0.02	0.02	0.20	0.10	0.10	0.01	0.20	0.30	0.3	0.3
Ammonia (PO_4^{3-}) (mg/L)	0.19	0.03	0.03	0.09	0.06	0.04	0.07	0.10	0.50	0.20	0.50	0.70		0.5
Hardness ($CaCO_3$) (mg/L)	45.00	41.00	37.00	59.10	50.00	45.00	39.00	30.00	22.00	35.00	25.00	22.00	150	500
Sulphate (SO_4^{2-}) (mg/L)	2.80	2.40	3.50	6.20	6.00	4.50	3.50	6.70	3.20	3.40	5.30	6.20	100	250
Manganese (Mn2+) (mg/L)	0.01	0.18	0.13	0.14	0.03	0.07	0.11	0.18	0.02	0.20	0.30	0.20	0.2	0.4
Copper (Cu) (mg/L)	0.01	0.01	0.21	0.19	0.25	0.02	0.50	0.01	0.02	0.02	0.01	0.01	1	2
Magnesium (Mg^{2+}) (mg/L)	0.13	0.09	0.11	0.06	0.53	0.62	0.15	0.25	1.02	1.02	1.00	1.00		100
Calcium (Ca^{2+}) (mg/L)	4.70	9.40	11.50	6.50	4.90	6.80	9.60	2.50	3.20	2.10	2.20	2.20		150
Total Alkalinity (mg/L)	40.00	37.00	42.00	54.00	47.50	50.20	40.10	49.10	29.00	15.00	0.02	2.30		
Total salinity (mg/L)	41.00	45.00	33.00	14.00	31.50	6.80	10.50	7.20	3.40	15.00	19.00	19.00		

Bold values indicate incidences where parameters are outside guideline values.

a pH scale ranging from 1 - 14. The SON and WHO set a pH guideline value of between 6.5 and 8.5 as generally considered satisfactory for drinking water.

The pH of borehole water of our study area was generally within the guideline value except in Mutum Biyu "B" where pH value was 6.2 and Namnai where pH was 6.4. The highest pH value of 7.88 was recorded in Gassol. pH is generally considered to have no direct impact on humans. However, long-term intake of acidic water can invariably lead to mineral deficiencies (Fairweather-Tait and Hurrell, 1996). Because virtually all groundwater comes from precipitation that soaks into the soil and passes down to the aquifer, high pH if widespread could also be an indication of acidic rain in the area.

Fluoride

The concentration of fluoride in Tutare ward both in the rainy and dry season when concentration was up to 2.5 mg/L deviate from the 1.5 mg/L suggested as guideline value by SON and WHO. In the study area, fluoride concentrations ranged between 0.03 mg/L in Yarima to 2.5 mg/L in Tutare.

High concentration of fluoride contaminant in ground waters tend to be found in association with crystalline rocks containing fluorine-rich minerals, especially granites and volcanic rocks, shallow aquifers in arid areas experiencing strong evaporation, sedimentary aquifers undergoing ion exchange and inputs of geothermal water. Fluoride has long been found to have a beneficial effect on dental health as such it is an additive in toothpastes and food. However, when present in drinking water at concentrations much above the guideline value of 1.5 mg/L, long term use can result in development of dental fluorosis or at its worst, crippling skeletal fluorosis. Although, the incidence of Fluoride concentration outside guid-eline value in our study is only restricted to one ward, it is important for water managers to constantly monitor this parameter as other studies in the region have also revealed high incidences of water samples showing high F concentrations (Waziri et al., 2012).

Chlorine

The use of chlorine in drinking water as a disinfectant has played a critical role in the prevention of waterborne diseases. According to the (World Health Organization, 1993), the adoption of drinking water chlorination has been one of the most significant advances in public health protection. However, when concentration of chlorine in water is above the guideline value of 5 mg/L, it could result in irritation of the oesophagus, a burning sensation in the mouth and throat, and spontaneous vomiting. It has also been suggested that episodes of dermatitis and asthma can be triggered by exposure to chlorinated water (Eun et al., 1984; Watson and Kibler, 1933). In this study, there are four wards in which chlorine concentration was outside the guideline values of 5 mg/L. These are Tutare (22 mg/L), Gunduma (35 mg/L), Mutum Biyu "A" (25 mg/L) and Mutum Biyu "B" (22 mg/L).

Iron

Similar to turbidity, the concentration of iron was generally found to be within guideline values of 0.3 mg/L in the dry season. However the concentration of iron in seven wards was well outside the guideline value in the rainy season. These wards are Sansani (0.8 mg/L), Sendirde (0.45 mg/L), Wuryo (0.75 mg/L), Sabon Gida (0.63 mg/L), Namnai (0.62 mg/L), Yarima (0.67 mg/L) and Gassol (0.45 mg/L). Iron concentration range between 0.01 and 0.8 mg/L in the rainy season; and 0.01 and 0.3 mg/L in the dry season. The mean concentration in the rainy season is 0.42 and 0.15 mg/L in the dry season.

It has been suggested that high rainfall is essential in increasing iron concentration in boreholes (Abubakar and Adekola, 2012). Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of ground water for borehole. Therefore it is not surprising that iron concentration is highest in the rainy season.

Ammonia

Concentration of ammonia in water samples from our study ranges from 0.03 to 0.7 mg/L with an average value of 0.21 mg/L both in the dry and rainy seasons. The value of 0.7 mg/L which is the only one above the 0.5 mg/L guideline value was recorded in Mutum Biyu “B”.

Ammonia can occur naturally in ground water, while in the environment, ammonia originates from metabolic, agricultural activities especially from the intensive rearing of farm animals. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution.

Manganese

Manganese occurs naturally in groundwater sources and in soils. However, human activities such as automobile emission are also responsible for manganese concentrations in the environment (Loranger et al., 1996).

In this study, manganese is well within WHO standard but the level in Mutum Biyu A (0.3 mg/L) is outside permissible level for manganese under the SON standard of 0.2 mg/L, but within the WHO standard of 0.4 mg/L.

Water quality across the wards

All the wards in Gassol LGA has at least one incidence of water contamination. This is not helped by the fact that all the boreholes had levels of turbidity outside guideline values in the rainy season. The result show that water samples from Shira ward is of the best quality only falling outside the guideline values which was for turbidity in the rainy season. Mutum Biyu “B” appear to have the worst water quality having four parameters (turbidity, pH, Chlorine and Ammonia) falling outside guideline values in the rainy season alone. Water quality improved in the dry season with five wards (Wuryo, Sabon Gida, Yarima, Gassol and Shira); free from any incidence of water contamination.

Mean value test

The mean value test was conducted using data from each season and then the average value over the two season. The essence of the mean value test as earlier pointed out is to assess the level of water contamination relative to guideline values.

The test to evaluate human health risk of water contamination in Gassol reveals that there is significant difference in mean concentration of contamination indicator and their guideline for turbidity, iron and chlorine (Table 3). The upper bound value (US_{95}) of these parameters are above the guideline value (G) suggested by SON and WHO. Thus, it can be concluded that action is needed to control these contaminants in the area based on the mean value test.

In this circumstance, it is suggested that there should be further sampling to gain a more representative picture of the site. However, precaution will suggest that remedial action is encouraged. This implies that overall; borehole water in Gassol is within guideline values for the majority of the parameters except for these four.

Table 3. Mean Value Test of water samples.

Parameters	Upper bound value (US_{95})			Guideline value	
	Rainy Season	Dry Season	Average	SON	WHO
Turbidity (NTU)	**37.60**	**12.89**	**23.94**	5	
Conductivity (Ω/cm)	702.92	702.92	702.92	1000	2500
Temperature (°C)	27.73	35.90	31.38	23 - 40	
pH	7.05	7.05	7.05	6.5 - 8.5	
TDS (PPM)	358.86	358.86	358.86	500	1000
Nitrate (NO_3^-) (mg/L)	14.73	14.73	14.73	50	50
Fluoride (F^-) (mg/L)	1.29	1.29	1.29	1.5	
Chlorine (Cl^-) (mg/L)	**15.79**	**15.79**	**15.79**		5
Iron (Fe^{2+}) (mg/L)	**0.57**	0.18	**0.35**	0.3	
Ammonia (PO_4^{3-}) (mg/L)	0.33	0.33	0.33		0.5
Hardness ($CaCO_3$) (mg/L)	64.58	43.46	51.69	150	500
Sulphate (SO_4^{2-}) (mg/L)	5.27	5.27	5.27	100	250
Manganese (Mn2+) (mg/L)	0.18	0.18	0.18	0.2	0.4
Copper (Cu) (mg/L)	0.19	0.19	0.19	1	2
Magnesium (Mg^{2+}) (mg/L)	0.71	0.71	0.71		100
Calcium (Ca^{2+}) (mg/L)	7.17	7.17	7.17		150
Total Alkalinity (mg/L)	43.44	43.44	43.44		
Total salinity (mg/L)	27.67	27.67	27.67		

Bold values indicate incidences where parameters are outside guideline values.

However, this analysis is made with great caution, as it is not possible to aggregate boreholes from different wards that are distinct even if it is possible, the presence of a contaminant is enough concern.

DISCUSSION

This study assessed some physical and chemical contamination indictors in borehole water in Gassol Local Government Area of Taraba State, Nigeria. The study reveals that borehole water in the area is not of the best quality as far as the WHO and SON guidelines are concerned. especially considering the fact three para-meters, namely turbidity, chlorine and iron has upper bound value (US_{95}) that are above guideline values. This study like similar studies carried out in the North Eastern region of Nigeria, showed that there are incidences of contamination of borehole water. For instance, Abubakar and Adekola (2012) found borehole water from Yola-Jimeta metropolis to have levels of chloride (Cl^-), iron (Fe^{2+}), nitrate (NO_3^-), pH, sodium (Na^+) and total hardness ($CaCO_3$) which are the main sources of borehole water contamination in the study area. In that study the upper bound value (US_{95}) of pH was found to be above the guideline value. However, this was not the case in the current study.

The presence of these contaminants at levels above guideline values in borehole water poses serious health effect to the population. This underscores the need for water managers to promote efficient water treatment/ management techniques. One approach that might come handy and prove to be easily accessible, low cost and environmentally friendly is the use of natural supplement such as Moringa oleifera seeds as natural absorbent and antimicrobial agent for purification of ground water for drinking purpose. A recent study by (Mangale Sapana et al., 2012) showed that Moringa oleifera seed powder has the potential to be used as treatment for turbidity, TDS, hardness, chlorides, alkalinity and acidity. This is recommended for eco-friendly, nontoxic, simplified water treatment where rural and peri-urban people living in extreme poverty are presently drinking highly turbid and microbiologically contaminated water. We therefore, advocate for water agencies to partner with local communities and researchers to ascertain the sustainability of this method.

North Eastern Nigeria is the poorest region in the country where majority lack access to qualitative water for consumption. The region is also the worst hit in terms of access to quality water. The poor water supply in the region has been blamed for causing typhoid fever, cholera and bilharzias especially where water source are not appropriately or sufficiently treated (Alexander, 2010, Uzomah and Scholz, 2002).

It is also noteworthy to point out that while the WHO guideline is been constantly updated, the SON guideline has never been updated since the first version in 2007. Although the SON report stated that “the standard shall be reviewed every three years” (Standards Organisation of Nigeria, 2007), yet this has not happened since the first edition. The lacklustre attitude to updating water guidelines is reminiscent of the poor funding and focus on this sector in Nigeria. There is a need for more attention by local and national government on delivering qualitative water to the populace. It is expected that the Nigerian Standard for Drinking Water Quality will speed up the process of upgrading non-protected water systems and improving the management of all drinking water systems in the country.

Conflict of interests

The authors did not declare any conflict of interest.
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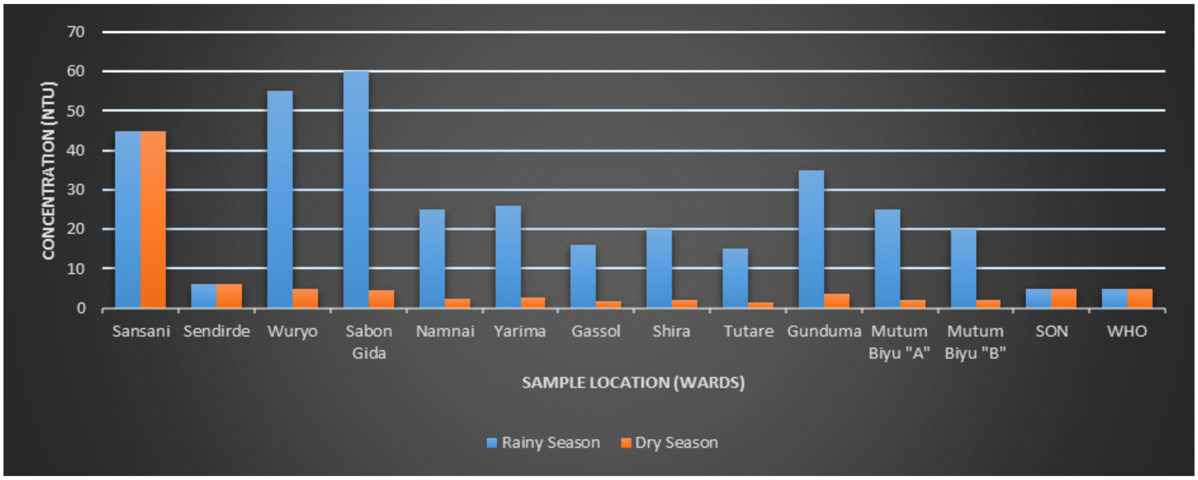
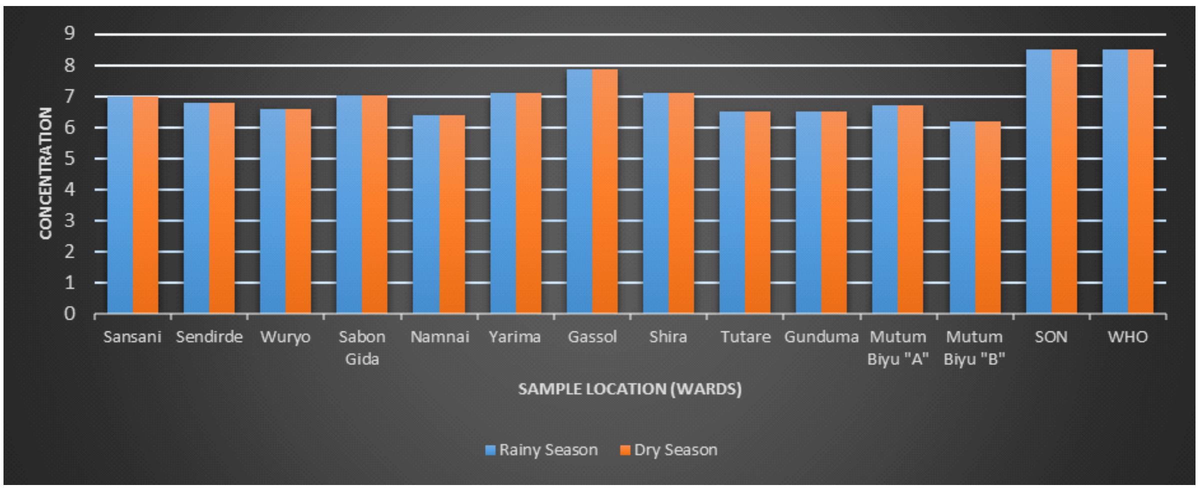
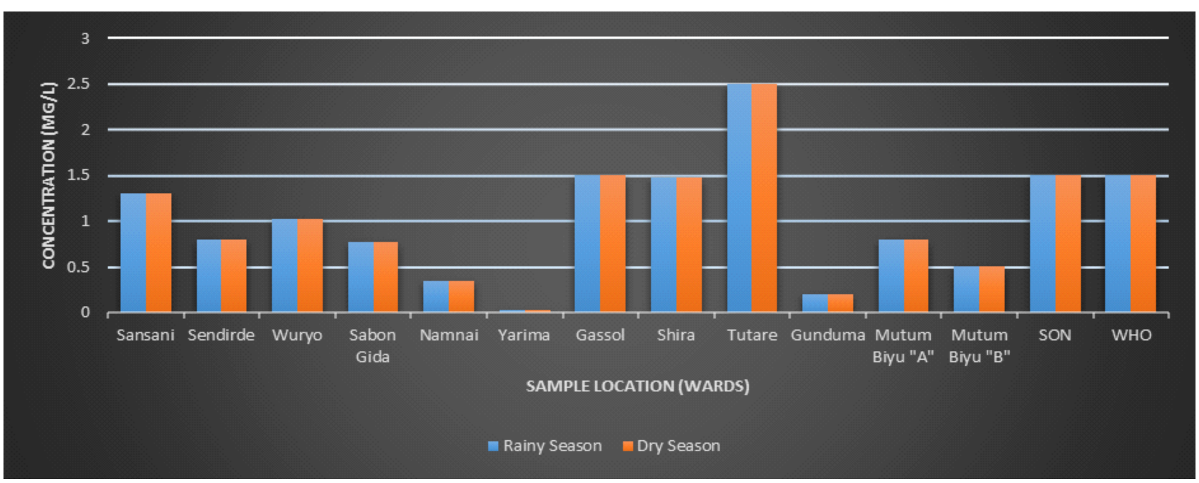


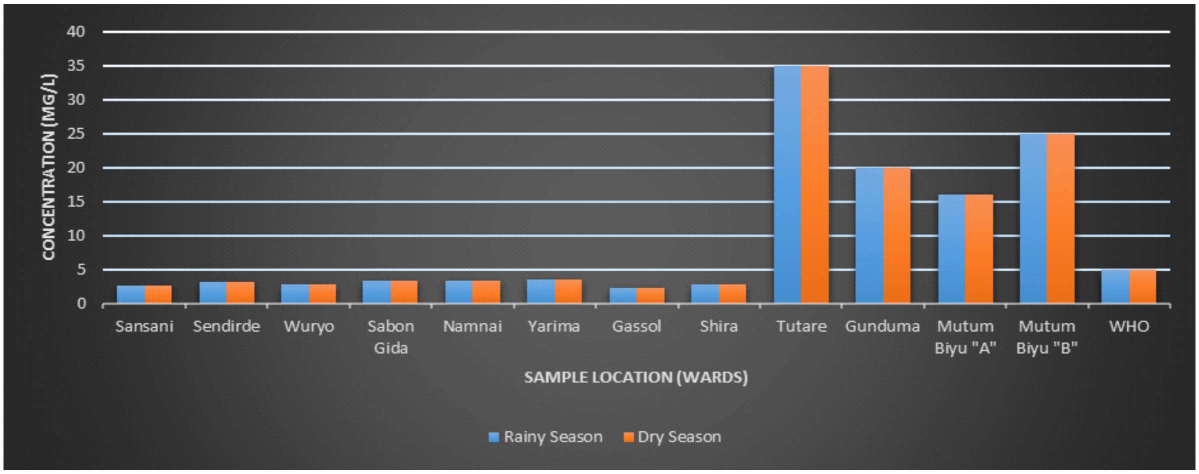
Appendix 1. Graph of analytical values of Turbidity (NTU) in the various wards with SON and WHO guideline values.



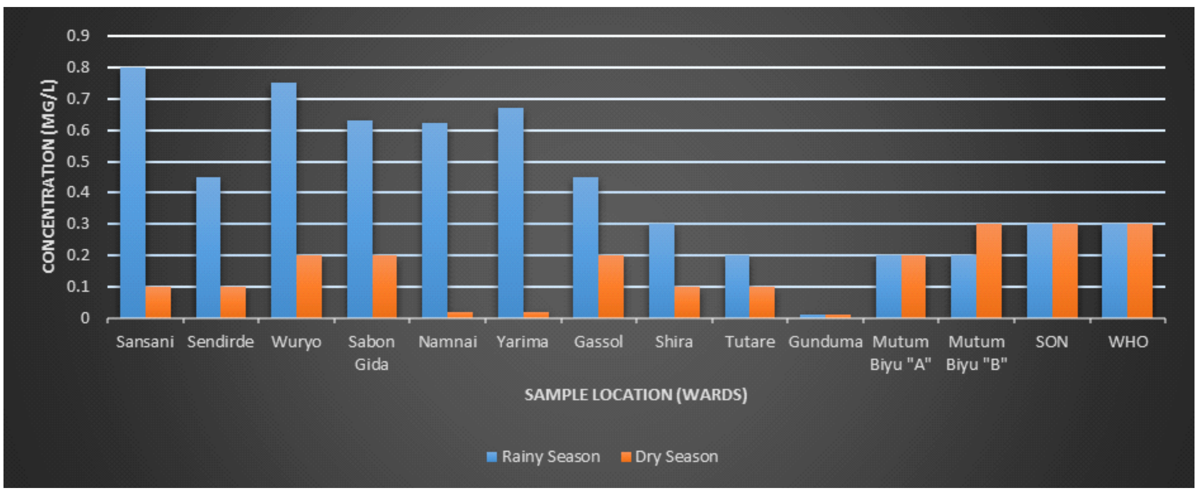
Appendix 2. Graph of analytical values of pH in the various wards with SON and WHO guideline values.



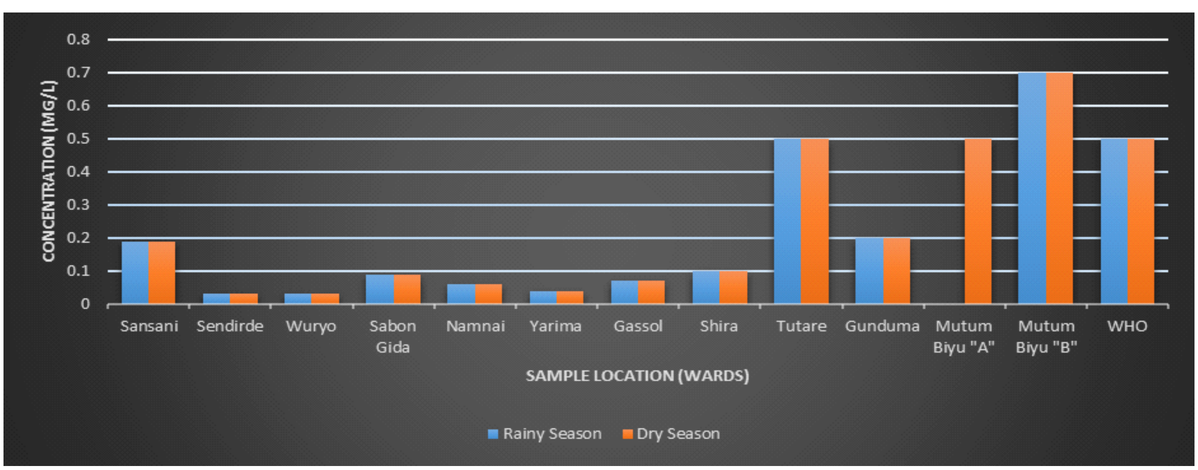
Appendix 3. Graph of analytical values of Fluoride (F-) (mg/L) in the various wards with SON and WHO guideline values



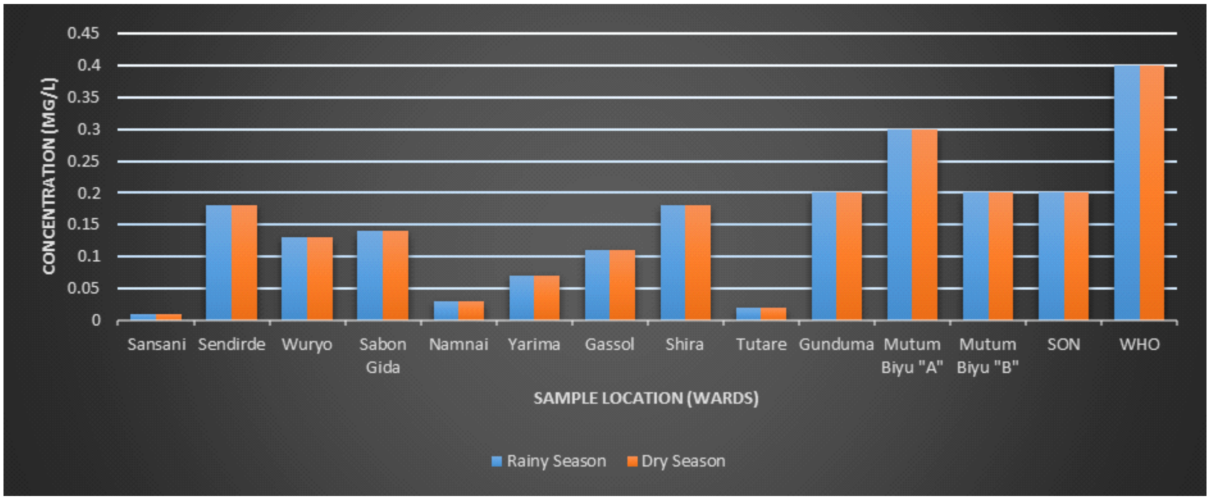
Appendix 4. Graph of analytical values of Chlorine (Cl-) mg/L in the various wards with SON and WHO guideline values.



Appendix 5. Graph of analytical values of Iron (Fe2+) mg/L in the various wards with SON and WHO guideline values.



Appendix 6. Graph of analytical values of Ammonia (PO43-) mg/L in the various wards with SON and WHO guideline values.



Appendix 7. Graph of analytical values of Manganese (Mn2+) mg/L in the various wards with SON and WHO guideline values.