CHAPTER ONE

INTRODUCTION

CHAPTER ONE

1.0 INTRODUCTION

1.1 WATER

Water related diseases remain an issue of major global public health concern, with the water-sanitation-hygiene risk complex globally accounting for about ten percent of the global burden of disease (Pruess et. Al., 2008). Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection (WHO, 2008). A person requires about three liters of potable water per day to maintain the essential fluids of the body (Fetter, 2007). Water is the major constituent of the human body, since sixty percent of adult body weight is due to water (WET, 2010). The chemical formula of water is H_2O, meaning that each molecule of water contains one Oxygen and two Hydrogen atoms jointed by covalent bond. Water is the liquid state of H_2O at standard temperature and pressure and is transparent, tasteless, odorless and colourless chemical substance.

Water is found in streams, rivers, lakes, oceans and voids underground. It covers about 71% of the earth's surface and is one of the most important natural resource that man is endowed with and is very vital for all forms of life.

There is a steady rise in the demand for groundwater in most hard rock areas, most of which cannot boast of any constant surface source of water supply (Adamu, 1994). Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies.

1.2 LOCATION

The area under investigation is Bauchi Metropolis, which is currently the State Capital of Bauchi State situated in the north-eastern part of Nigeria (Fig. 1 and 2). The study area is bounded by Longitudes $9^0$45'15" & $9^0$50'52" and Latitude $10^0$16'45" & $10^0$20'00". The entire city, for the purpose of this investigation was divided into four sectors; these are the north-east, the north-west, the south-east and the south-west. Five samples were collected from each of the aforementioned four sectors.

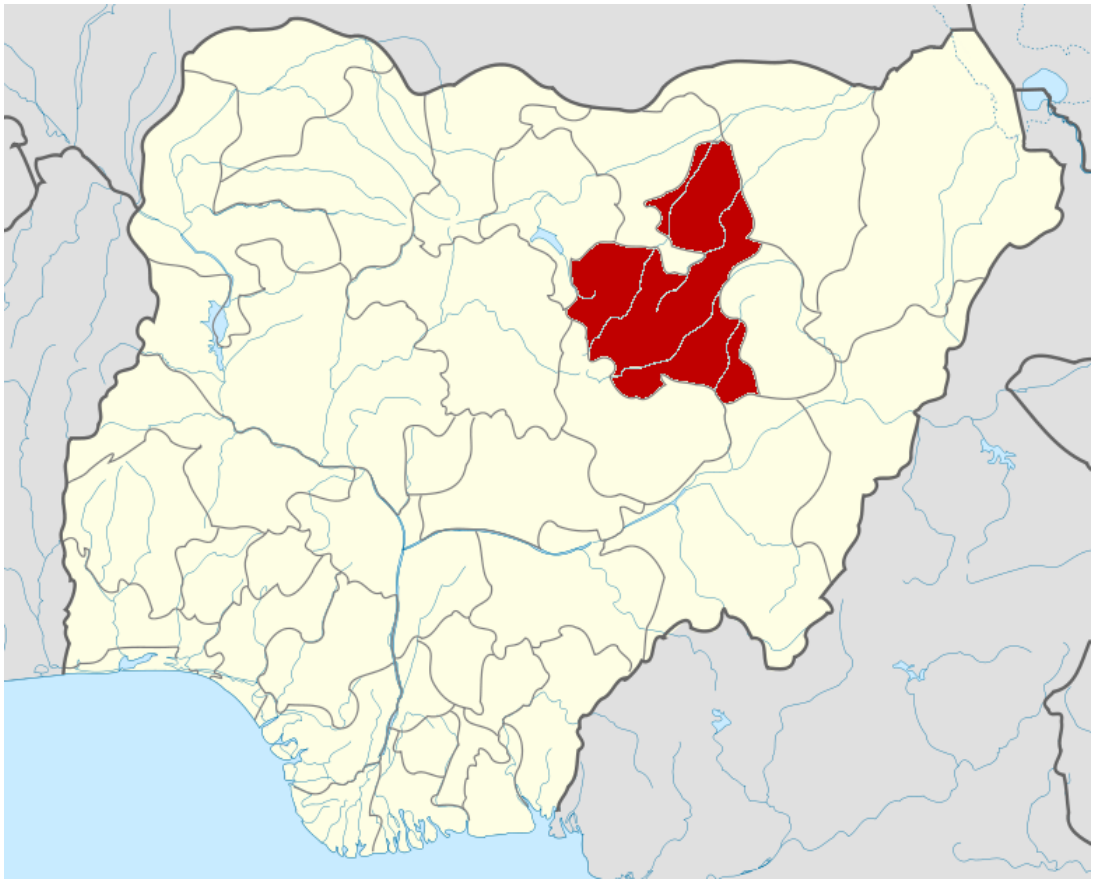

Figure 1 . Map of Nigeria showing Bauchi State

Figure 2. Map of Bauchi State showing the Study Area

1.3 CLIMATE AND VEGETATION

The area is chacterised by two distinct seasons; the Dry and the Rainy seasons. The dry season is further divided into Hot and Cold (Harmattan) periods based on the prevailing heat condition. The temperature of up to 45^0C was recorded for the hot season. The season last for about seven months from October to late April. The rainy season is relatively short and last for the period of five months (May to September). Though the rainy season is cold with temperature reaching as low as 25^0C but harmattan is the coolest period. The study area lies within the Savanna belt. The belt is characterised by abundant grasses, shrubs and dispersed short trees. Grasses dry up while trees shed-off their leaves during dry season and flourish again when rainy season returns.

1.4. REGIONAL GEOLOGY

The geology of Nigeria is made up of three major litho-petrological components, namely, the Basement Complex, the Younger Granites and the Sedimentary Basins (Obaje, N.G., 2009).

1.4.1. The Basement Complex

The Basement Complex, which is Precambrian in age, is made up of Migmatite-Gneiss-Complex, the Schist Belt and the Older Granites. The Migmatite-Gneiss-Complex is generally considered as the Basement Complex *sensu stricto* (Rahman, 1988 Dada, 2006) and it is the most widespread of the component unit in the Nigerian Basement. Rocks of the Basement Complex are exposed in four main areas of the country. These are: the north central, the South-western, the Oban Massif and the Hawaal Massif in the east.

1.4.2. The Younger Granites

The Younger Granites comprise several Jurassic magmatic Ring Complexes centered around Jos Plateau and other parts of northern Nigeria. Aeromagnetic anomalies suggest that a series of buried NE-SW lineaments of incipient rifts controlled the disposition of the individual complexes (Ajakaye, 1983). They are structurally and petrologically distinct from the Older Granites (Figure 1.4a).

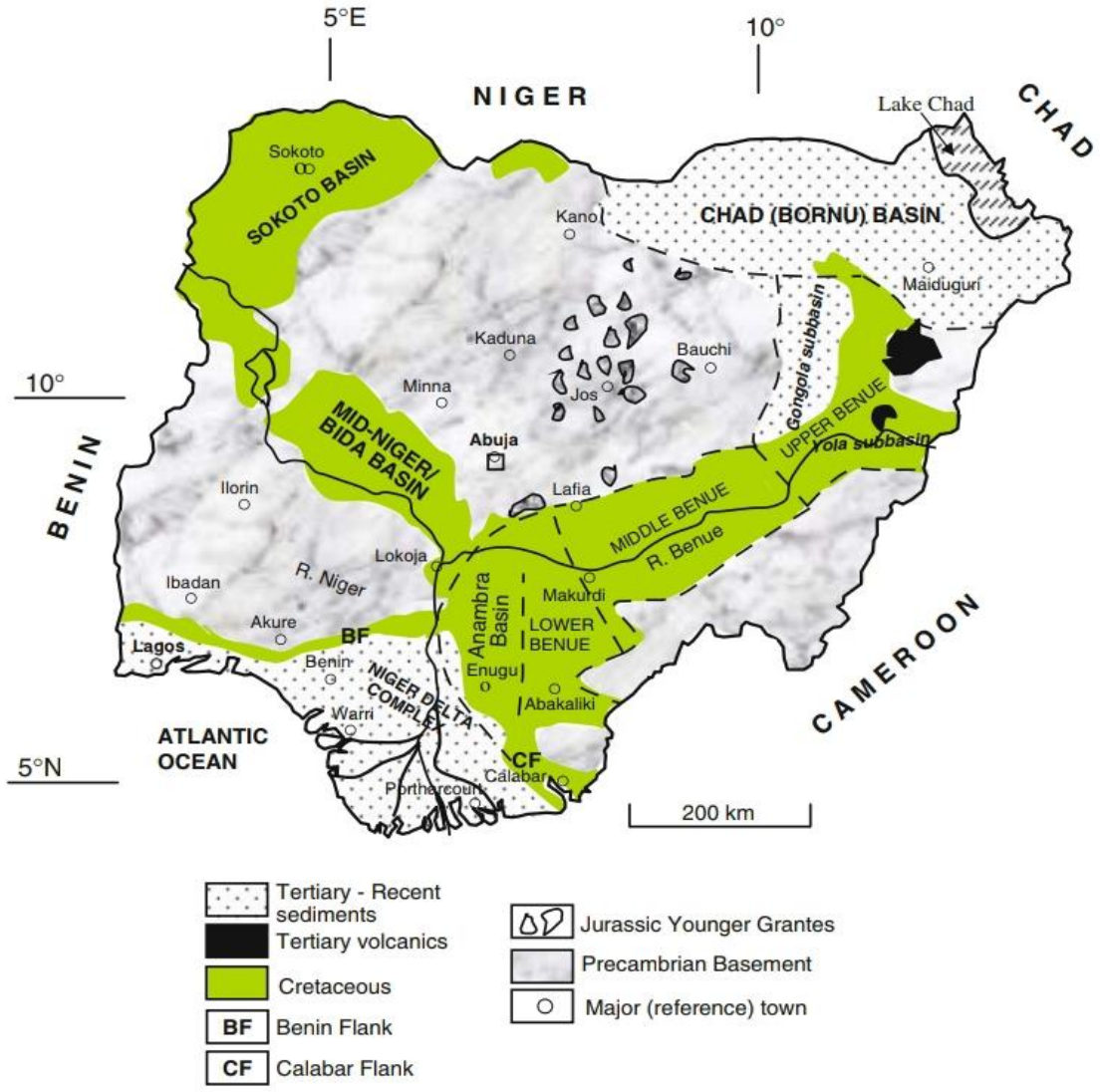

Figure 1.4a. Geological Map of Nigeria (After Obaje 2009)

1.4.3. Sedimentary Basins

Sedimentary Basins are depositional areas where sedimentary rocks are formed. The Precambrian Basement Complex constitutes the bedrock on which sediments ranging in age from Palaeozoic to Quaternary have been deposited (Madabuchi, 2006). There are seven sedimentary basins in Nigeria. These are; Niger Delta, Anambra Basin, Benue Trough, Chad Basin, Sokoto Basin, Bida Basin and Dahomey Basin (Figure 1.4b). Some aspects of the geology and stratigraphy of Nigerian sedimentary basins are available in (Whiteman, 1982).

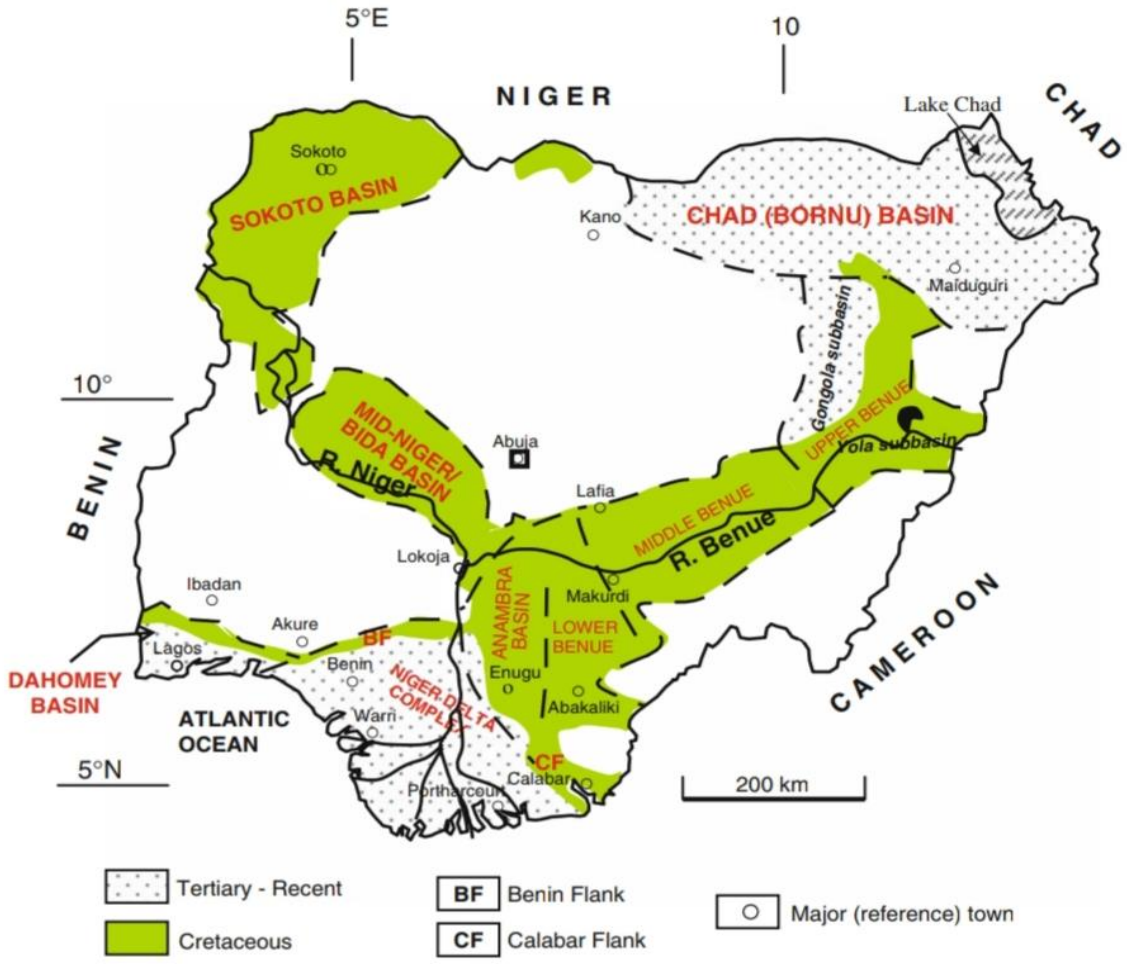

Figure 1.4b Map of Nigeria Showing the Sedimentary Basins (After Obaje 2009)

1.5 GEOLOGY OF THE STUDY AREA

The study area is underlain by crystalline rocks of the Nigerian Basement Complex of Pre Cambrian age. The geology of the area is made up two rock types, Granite Gneiss and Fayalite bearing Quartz Monzonite (Bauchite).

1.5.1 Granite-Gneiss

The Granite-Gneiss covers some parts of the study area; they are usually medium to coarse grained found at low level outcrops. These rocks were formed under extreme temperature condition of prograde metamorphism, where partial melting occurs in pre existing rock. These rocks were weathered and fractured in places. The rock is composed of quartz, feldspar and biotite.

1.5.2 Fayalite bearing Quartz Monzonite

Fayalite bearing Quartz Monzonite rock is widespread in and around Bauchi. The distinctive features of the rock were first described by Oyawoye, who named the rock Bauchite in 1961. Bauchites occur as platy exposures with deep-green colour when fresh and pinkish brown when weathered (Oyawoye, 1985). The rocks are massive, homogeneous and unfoliated. The mineral assemblages include biotite, hornblende, fayalite and pyroxene.

1.6 HYDROGEOLOGY OF BAUCHI

The earliest geophysical exploration work was done by Edok Eter Mandillas Limited in 1978. The company undertook the geophysical survey and construction of boreholes and installation of mechanized pump in the area. Duprez and Barbers worked on the distribution and chemical quality of groundwater in northern Nigeria while Oyawoye (1972) described the hydrogeologic condition found in Bauchi state, he concluded that water is found in the weathered and fractured zone within the Basement Complex.

1.7 JUSTIFICATION OF THE RESEARCH

In recent years, cholera, malaria and typhoid fever are wide spread in parts of Bauchi metropolis. Occurrences of these diseases appear to be increasing possibly due to intake of poor quality water. The need to investigate the quality of water people consumes in the absence of public water supply form the basis of this research, as water for human consumption need to be free from pathogens like bacteria, toxic substance like arsenic and chemical substances in concentration large enough to affect health. Public water supply in the city is grossly inadequate to cater for its inhabitants' need. This compels people to use other alternative sources of water such as bore-holes and most commonly hand-

dug wells. Hand-dug wells are prone to contamination especially those that are not properly protected.

1.8 AIM AND OBJECTIVES

1.8.1 AIM

This research is aimed at assessing the quality of the drinking water obtained from source/s other than the public water supply, especially hand-dug wells sited close to refuse dumps within Bauchi metropolis. Microbial concentrations of the sampled water sources could serve as a pointer to microbial contamination.

1.8.2 OBJECTIVES

1. To assess the quality of drinking water obtained from hand-dug wells sited close to refuse dumps.
2. To compare the result with the Nigeria Industrial Standard (2007) standards for drinking water quality (NSDWQ).
3. An attempt will be made to determine the extent of contamination and suitability or otherwise of water sources studied.
4. To provide basic information for organization interested in the development of ground water resource in the area.
5. To make recommendation based on the outcome of this investigation.

1.9 SIGNIFICANCE OF THE STUDY

The quality of water obtained from hand-dug wells must be assessed considering the reliance on such sources of water by the inhabitants for their daily consumption and usage. Absence or lack of adequate information on the quality of hand-dug wells' water used for consumption and other domestic uses could pose a health problem. This study would be helpful in the determination of whether the water sources investigated are healthy and therefore suitable for human consumption or not.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO

2.0 LITRATURE REVIEW

Bauchi is the capital city of Bauchi State situated in north-eastern Nigeria. The city, like many other cities in the developing countries such as Nigeria, public supply of potable water for their teaming inhabitants is grossly inadequate. Other sources of drinking water are sought for to complement the public water supply. These sources include hand-dug wells and boreholes, dug or drilled by individuals to meet their potable water supply for their day to day activities.

Usually, ground water is potable but natural, human activity or both may alter its physical, chemical or microbial condition at a particular location or region. Water quality issues may arise partly due to nature of the soil or proximity of the water source to pit-latrine, soak-away or refuse dump. Animals' dung and refuse dumps close to a hand-dug well may contaminates the water if the well is not properly protected. It was observed that majority of the hand-dug wells in the study area are not protected. The quality of water from such a water source at inception is usually good but may deteriorate over time due to lack of protection of the source.

In 2016, Josiah and others conducted an investigation which assessed water quality of some selected hand-dug wells in part of Bauchi metropolis and the results indicated that the concentrations of both total and faecal coliforms counts in all the water sources investigated were higher than the standards set by Nigerian Industrial Standard (2007) guidelines for drinking water quality.

They concluded that the water sources were contaminated due to lack of protection and close proximity to soak-away or refuse dump.

The World Health Organisation (WHO) classifies source of water supplies as either improved or unimproved (WHO, 2000). Improved water sources include public standpipes, household connection, boreholes, protected dug wells, protected springs, boreholes and springs connected via a pipe system to a tap, as well as rainwater collection. Unimproved water sources include unprotected wells, unprotected springs, vendor-provided water, rivers as well as tanker truck provision (WHO, 2000).

Several studies carried out in developing countries have determined the microbiological quality of those improved and unimproved water sources and depending on the water source, different results were obtained (Obi et al., 2002; Gundry et al., 2004). Studied conducted in Northern Sudan (Musa et al., 1999) and in Iran (Pournadeali and Tayback, 1980) have both showed that water at communal taps were microbiologically of a better quality than the untreated irrigation canal water. Surface water and groundwater of Ibokun, south-western Nigeria, were investigated by Elueze and others. They discovered that both water sources are slightly alkaline and are generally suitable for both domestic and agricultural uses requiring minor treatments (Elueze et al., 2004).

CHAPTER THREE

MATERIALS AND METHOD

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 MATERIALS

For the purpose of collecting water samples in the study area, the following instruments (Figure 3.1, 3.2 and 3.3) were used:

- Global Positioning System (GPS eTrex 10)
- TDS/EC Meter
- pH/ORP/Temperature Meter

The Gamin eTrex 10 GPS was used to get the coordinates (Longitudes and Latitudes) of the location of water source sampled. Turbidity and Electrical Conductivity of each the water samples were measured by the TDS/EC Meter in the field. Oxygen Reduction Potential (ORP), Hydrogen ion concentration (pH) and Temperature of the samples were measured using pH/ORP/Temperature Meter. Table 3.1 provides water source, location and coordinates of the water sampled for the purpose of this investigation. Field record of the physical parameters' measurements taken during the sampling exercise and their corresponding charts are presented in data sheet 3.2.1 – 3.2.7 (Appendix A) and Bar Chart 3.4.1 – 3.4.8 (Appendix B) respectively.

3.2 SAMPLING METHOD

Twenty water samples from Hand-Dug Wells were collected, preserved and analysed for the purpose of this investigation. The samples collected though small in volumes but were enough to accurately represent the whole individual water sources. Water sample from each of the twenty hand-dug well was collected by lowering a rope tied to a plastic bucket was lowered to the bottom of the well and water was collected by pulling the bucket out. Part of the water collected was used to rinse the sterilized container before sample was fetched. The sample container was then filled and tightly covered. Water samples were collected in sterilized plastic containers and were labeled according to sample's location. Finally, the water samples collected were preserved in the refrigerator before the analysis was done.

Figure 3.1 Gamin eTrex 10 GPS

Figure 3.2 TDS/EC Meter

Figure 3.3 pH/ORP/Temperature Meter

Table 3.1 Water Source, Location and Coordinates

Code	***Source***	***Location***	***Longitude***	***Latitude***
S1	Hand-dug Well	Near Wikki	9^0 49’ 50”	10^0 17’ 20”
S2	Hand-dug Well	W/Dada Primary	9^0 46’ 10”	10^0 18’ 55”
S3	Hand-dug Well	W/Dada Market	9^0 46’ 10”	10^0 18’ 10”
S4	Hand-dug Well	Alh. Mato Lame	9^0 46’ 10”	10^0 18’ 55”
S5	Hand-dug Well	Malam Abdullahi	9^0 45’ 15”	10^0 18’ 30”
S6	Hand-dug Well	Kara 1	9^0 51’ 10”	10^0 20’ 00”
S7	Hand-dug Well	Kara 2	9^0 50’ 54”	10^0 19’ 50”
S8	Hand-dug Well	Kara 3	9^0 50’ 50”	10^0 19’ 10”
S9	Hand-dug Well	Kara 4	9^0 50’ 18”	10^0 20’ 00”
S10	Hand-dug Well	IBB Square	9^0 50’ 52”	10^0 19’ 40”
S11	Hand-dug Well	Yalwa 1	9^0 49’ 10”	10^0 18’ 50”
S12	Hand-dug Well	Yalwa 2	9^0 49’ 10”	10^0 18’ 10”
S13	Hand-dug Well	Yalwa 3	9^0 48’ 40”	10^0 16’ 45”
S14	Hand-dug Well	Yalwa 4	9^0 48’ 10”	10^0 16’ 50”
S15	Hand-dug Well	Gwallaga	9^0 50’ 10”	10^0 18’ 55”
S16	Hand-dug Well	Baraya	9^0 49’ 58”	10^0 18’ 30”
S17	Hand-dug Well	T/Makabarta	9^0 50’ 12”	10^0 18’ 10”
S18	Hand-dug Well	Kasuwan Shanu	9^0 50’ 35”	10^0 17’ 40”
S19	Hand-dug Well	Near Gate	9^0 49’ 00”	10^0 18’ 20”
S20	Hand-dug Well	New Site	9^0 49’ 10”	10^0 18’ 50”

CHAPTER FOUR

RESULTS AND DICUSSION

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 PRESENTATION OF RESULT

Water quality assessment of the twenty water samples collected from twenty hand-dug wells was carried out in order to define the water quality of the individual water sources. Results obtained from the analysis were compared with the Nigerian Industrial Standard (2007) Guidelines for Nigerian Standard for Drinking Water Quality (NSDWQ) Maximum Permissible Levels (MPL) in order to determine the suitability or otherwise of the water sources sampled. According to the World Health Organisation (WHO, 2013) the quality of water whether used for drinking, domestic purpose, food production or recreational purpose has an important impact on health as poor quality water can cause disease outbreak. The twenty samples were assessed to determine their Physical, Chemical and Microbial characteristics.

4.1.1 PHYSICAL PARAMETERS

The physical parameters such as Temperature, pH, Electrical Conductivity -EC, Total Dissolve Solids -TDS and Oxygen Reduction Potential -ORP were measured in the field and were presented as Field Data. With the exception of the ORP, all other parameters were further analysed in the Laboratory using different instruments. Tables 4.1.1a and 4.1.1b provide detailed measurements made in the Field and the Laboratory while Appendix B are the individual bar charts showing various values of Temperature, pH, Colour, Turbidity, Electrical Conductivity -EC and Total Dissolved Solids -TDS.

4.1.1 PROCEDURE FOR THE ANALYSIS OF PHYSICAL PARAMETERS

Physical Parameters analyzed in the Laboratory include Temperature, pH, Colour, Turbidity, Electrical Conductivity -EC and Total Dissolved Solids –TDS.

4.1.1a Temperature

Temperature, which is the degree of hotness or coldness, of the water sample was determined using a thermometer. The probe of the instrument was immersed into the sample for about ten seconds and its temperature appears on the screen. Finally, temperature values in ^{0}C were recorded.

4.1.1b Potential Hydrogen –pH

The pH of the water samples was determined using HACH pH Meter. Water sample with the pH value of 7 is said to be neutral. Sample with pH value less than seven is described as acidic. Acidity increases as the pH value decreases from 6-0 while pH value of 8-14 indicates that the solution is basic

4.1.1c Colour

The instrument used in the determination of the sample's colour is HACH Spectrophotometer. 25ml of the sample was taken and a standard colour of 50 units of Platinum-Cobolt pillow powder was added and left for four minutes before being transferred into the instrument. Appropriate corresponding colour value appeared on the instrument's screen.

4.1.1d Turbidity

This is measure of the amount of suspended particles in water. The procedure involves the use of HACH Spectrophotometer. 25ml of the sample was taken and place into the instrument program number 740 was coded and the result in NTU appeared on the screen.

4.1.1e Electrical Conductivity

Electrical Conductivity –EC is the ability of water to conduct electricity due to the presence of ionized solids. Electrical Conductivity is determined using EC (HACH) pocket meter. It is measured in µS/cm.

4.1.1f Total Dissolved Solid –TDS

Total Dissolved Solids –TDS is the amount of dissolved substance in the water sample. The total dissolved solid of each sample was determined using the TDS meter (IS3032) model in the Laboratory. The unit is mg/l.

Table 4.1.1a PHYSICAL PARAMETERS – Field Data

Location	Coordinates	Temp (°C)	pH	Oxygen Reduction Potential	EC (µS/cm)	TDS (mg/l)
Near Wikki	9^0 49' 50'' 10^0 17' 20''	32	9.3	128	718	376
W/Dada Primary	9^0 46' 10'' 10^0 17' 20''	33	8.8	193	490	245
W/Dada Market	9^0 46' 10'' 10^0 18' 50''	30	8.6	145	1170	573
Mato Lame	9^0 46' 10'' 10^0 19' 00''	31	9.1	135	660	325
Alh. Abdullahi	9^0 45' 15'' 10^0 18' 30''	31	9.2	133	1380	680
Kara I	9^0 51' 10'' 10^0 20' 00''	32	8.8	155	1220	555
Kara II	9^0 50' 50'' 10^0 19' 50''	31	8.7	152	1079	535
Kara III	9^0 50' 50'' 10^0 19' 00''	30	8.5	153	740	373
Kara IV	9^0 50' 18'' 10^0 20' 00''	31	8.7	140	770	340
IBB Square	9^0 49' 55'' 10^0 19' 40''	30	8.7	135	1035	540
Yalwa I	9^0 49' 10'' 10^0 19' 50''	30	9.5	312	113	131
Yalwa II	9^0 49' 10'' 10^0 18' 30''	32	9.3	608	111	260
Yalwa III	9^0 49' 10'' 10^0 18' 50''	30	8.2	163	1580	715
Yalwa IV	9^0 48' 10'' 10^0 16' 50''	30	8.9	143	378	209
Gwallaga	9^0 50' 00'' 10^0 18' 50''	31	9.2	145	1365	680
Baraya	9^0 46' 50'' 10^0 18' 30''	31	8.9	132	910	540
Tsohon Makabarta	9^0 50' 10'' 10^0 18' 00''	30	9.0	139	1776	870
Kasuwan Shanu	9^0 50' 40'' 10^0 17' 40''	32	9.0	125	1275	515
Near Gate	9^0 49' 50'' 10^0 18' 20''	31	9.1	129	1135	570
New Site	9^0 49' 50'' 10^0 17' 20''	28	8.5	118	540	140
NSDWQ*MPL		**Ambient**	**6.5-8.5**	**-**	**1000**	**500**

NSDWQ: Nigerian Standard for Drinking Water Quality MPL: Maximum Permissible Limit

Table 4.1.1b PHYSICAL PARAMETERS – Lab. Result

Location	Temp (°C)	pH	Colour	Appearance	Taste	Odor	Turbidity (NTU)	EC (µS/cm)	TDS (mg/l)
Near Wikki	28.4	8.4	1	Unobj	Unobj	Unobj	6.77	360	720
W/Dada Primary	28.4	7.9	0	Unobj	Unobj	Unobj	0.53	300	600
W/Dada Market	28.4	8.8	3	Unobj	Unobj	Unobj	0.76	520	1030
Mato Lame	28.3	7.7	0	Unobj	Unobj	Unobj	0.70	390	730
Alh. Abdullahi	28.7	7.6	0	Unobj	Unobj	Unobj	0.83	660	1300
Kara I	28.7	8.3	5	Unobj	Unobj	Unobj	7.19	370	730
Kara II	29.3	8.8	7	Unobj	Unobj	Unobj	0.37	520	1040
Kara III	29	8.6	1	Unobj	Unobj	Unobj	2.09	610	1220
Kara IV	29.3	8.4	0	Unobj	Unobj	Unobj	3.15	330	660
IBB Square	30	7.9	0	Unobj	Unobj	Unobj	1.08	740	1440
Yalwa I	26.1	8.1	0	Unobj	Unobj	Unobj	0.62	560	280
Yalwa II	26.2	8.2	5	Unobj	Unobj	Unobj	0.37	350	180
Yalwa III	26.1	7.8	5	Unobj	Unobj	Unobj	0.44	1630	810
Yalwa IV	26.1	8.1	0	Unobj	Unobj	Unobj	1.29	520	260
Gwallaga	26.0	7.9	0	Unobj	Unobj	Unobj	0.56	1210	610
Baraya	26.1	7.8	4	Unobj	Unobj	Unobj	0.78	1030	510
Tsohon Makabarta	26.2	7.9	0	Unobj	Unobj	Unobj	0.37	1700	850
Kasuwan Shanu	25.8	7.9	0	Unobj	Unobj	Unobj	0.51	1210	600
Near Gate	25.9	7.8	30	Unobj	Unobj	Unobj	2.21	1160	580
New Site	26.0	7.5	0	Unobj	Unobj	Unobj	2.45	330	160
NSDWQ*MPL	**Ambient**	**6.5-8.5**	**15**	**Unobj**	**Unobj**	**Unobj**	**5**	**1000**	**500**

NSDWQ: Nigerian Standard for Drinking Water Quality MPL: Maximum Permissible Limit

Unobj: Unobjectionable

4.1.2 CHEMICAL PARAMETERS

The twenty water samples collected in the study area were analyzed for chemical constituents which includes: Na^{+}, Ca^{+2}, Mg^{+2}, Fe^{+2}, Zn^{+2}, Cu^{+2}, Pb^{+2}, As^{+3}, NH_4^{+}, Cl^{-}, F^{-}, NO_2^{-}, NO_3^{-}, PO_4^{-3}, SO_4^{-2}, and HCO_3^{-}. Other parameters analyzed were Total Hardness and Alkalinity. All the samples were analysed in the UNICEF established Laboratory at **RU**ral **WA**ter **S**upply and **S**anitation **A**gency (RUWASSA)'s office, Bauchi -Nigeria. Results of chemical parameters analyses are shown in Tables 4.1.2a and 4.1.2b while Appendix C are the Bar Charts for the individual chemical parameters analysed in the Laboratory.

Table 4.1.2a CHEMICAL PARAMETERS

Location	Sodium, Na^{+} (mg/l)	Calcium, Ca^{+2} (mg/l)	Magnesium, Mg^{+2} (mg/l)	Total Iron, Fe (mg/l)	Zinc, Zn^{+2} (mg/l)	Copper, Cu^{+2} (mg/l)	Lead, Pb^{+2} (mg/l)	Arsenic, As^{+3} (mg/l)	Alkalinity (mg/l)
Near Wikki	5.3	106	78	0.2	0.11	0.0	0.0	0.0	120
W/Dada Primary	1.7	111	49	0.25	0.6	1.1	0.0	0.0	115
W/Dada Market	0.3	179	79	0.1	0.0	0.0	0.0	0.0	160
Mato Lame	4.0	107	47	0.5	0.25	0.0	0.0	0.0	144
Alh. Abdullahi	1.9	199	49	0.15	0.85	0.0	0.0	0.0	78
Kara I	3.8	117	39	0.09	0.8	0.0	0.0	0.0	224
Kara II	1.1	286	92	0.11	0.2	0.0	0.0	0.0	180
Kara III	1.6	201	87	0.18	0.09	0.26	0.0	0.0	188
Kara IV	0.7	239	111	0.35	0.15	0.0	0.0	0.0	136
IBB Square	0.2	290	80	0.05	0.95	0.0	0.0	0.0	168
Yalwa I	0.0	128	72	0.25	0.0	0.0	0.0	0.0	280
Yalwa II	36	82	18	0.10	0.1	1.1	0.0	0.0	76
Yalwa III	104	324	92	0.05	0.0	0.0	0.0	0.0	44
Yalwa IV	49	116	36	0.0	0.08	0.0	0.0	0.0	72
Gwallaga	139	120	92	0.0	0.0	0.0	0.0	0.0	76
Baraya	123	192	120	0.07	0.0	0.0	0.0	0.0	88
Tsohon Makabarta	182	208	112	0.0	0.74	0.0	0.0	0.0	64
Kasuwan Shanu	110	152	96	0.05	0.06	0.26	0.0	0.0	84
Near Gate	58	124	176	0.02	0.2	0.0	0.0	0.0	76
New Site	26	70	22	0.11	0.05	0.0	0.0	0.0	36
NSDWQ*MPL	**200**	**75**	**20**	**0.30**	**3.0**	**0.01**	**0.01**	**0.01**	**100**

NSDWQ: Nigerian Standard for Drinking Water Quality *MPL: Maximum Permissible Level*

Table 4.1.2b CHEMICAL PARAMETERS

Location	Chloride Cl^- (mg/l)	Fluoride F^- (mg/l)	Nitrate, NO_3^- (mg/l)	Nitrate NO_2^- (mg/l)	Sulphate SO_4^{2-} (mg/l)	Ammonium NH_4^+ (mg/l)	Phosphate, PO_4^{-3} (mg/l)	Bicarbonate HCO_3^- (mg/l)	Total Hardness (mg/l)
Near Wikki	8.2	0.91	10	0.05	116	0,2	0.72	146	184
W/Dada Primary	2.6	0.72	13.6	0.04	72	0.6	1.30	140	160
W/Dada Market	0.4	1.16	22.8	0.58	107	0.6	0.22	195	258
Mato Lame	6.1	0.64	18	1.05	60	0.0	0.11	176	154
Alh. Abdullahi	3.0	1.43	4.5	0.04	145	0.0	0.0	95	248
Kara I	5.8	1.05	21.6	6.40	12	0.3	0.50	273	156
Kara II	1.6	0.8	9.6	0.01	70	0.0	0.15	220	378
Kara III	2.4	0.25	21	8.70	131	0.1	0.20	229	288
Kara IV	1.0	0.0	16.8	0.63	37	0.2	0.25	166	350
IBB Square	0.5	0.11	17.2	0.32	69	0.2	0.30	205	370
Yalwa I	0.0	0.93	52	0.01	18	0.0	0.49	278	200
Yalwa II	55	1.47	42.8	0.01	21	0.0	0.21	93	100
Yalwa III	160	0.19	76	0.02	23	0.1	0.65	54	416
Yalwa IV	76	1.06	90	0.07	31	0.0	0.70	88	154
Gwallaga	215	1.15	180	0.25	24	0.1	0.47	93	212
Baraya	190	1.01	52	0.07	44	0.1	0.0	107	252
Tsohon Makabarta	280	1.28	42	1.00	92	0.5	0.0	78	320
Kasuwan Shanu	170	1.17	66.2	0.94	68	0.3	0.0	103	248
Near Gate	89	1.08	168	0.01	90	0.5	0.0	93	300
New Site	40	1.19	78	0.04	24	0.2	0.0	33	91
NSDWQ*MPL	**250**	**1.5**	**50**	**0.20**	**100**	**1.0**	**0.01**	**100**	**150**

NSDWQ: Nigerian Standard for Drinking Water Quality MPL: Maximum Permissible Level

4.1.3 MICROBIAL PARAMETERS

Coliform bacteria are present in the environment and faeces of all warm blooded animals and humans (NYSDH, 2011). Presence of Coliform bacteria in drinking water indicates contamination and disease-causing organisms (pathogens) could be present in the water system.

All the twenty water samples were analysed for the presence of bacteria. Each sample was assessed for the presence of Total as well as the Faecal Coliform bacteria. Result of the assessment is shown on table 4.1.3 while Appendix D shows the Bar Charts for the Total Coliform and Faecal Coliform respectively.

Table 4.1.3 MICROBIAL PARAMETERS

Location	Total Coliform (cfu/100ml)	Faecal Coliform (cfu/100ml)
Near Wikki	39	22
W/Dada Primary	26	14
W/Dada Market	0	0
Mato Lame	0	0
Alh. Abdullahi	2	0
Kara I	0	0
Kara II	1	0
Kara III	0	0
Kara IV	17	5
IBB Square	9	1
Yalwa I	0	0
Yalwa II	0	0
Yalwa III	3	0
Yalwa IV	0	0
Gwallaga	21	1
Baraya	14	2
Tsohon Makabarta	32	4
Kasuwan Shanu	18	1
Near Gate	27	5
New Site	0	0
NSDWQ*MPL	**10**	**0**

NSDWQ: Nigerian Standard for Drinking Water Quality

MPL: Maximum Permissible Level

4.2 DISCUSSION OF THE RESULT

Twenty hand-dug wells situated close to refuse dumps in Bauchi metropolis, north-eastern Nigeria, were selected for this investigation. The study assessed the water quality of these wells which for quite sometimes serve as alternative sources of drinking water due to inadequate public supply of potable water. Water from each of the selected hand-dug wells was sampled in a sterilized plastic container, preserved and taken to the **RU**ral **WA**ter **S**upply and **S**anitation **A**gency (RUWASSA)'s laboratory for analysis. Samples were analysed for physical, chemical and microbial parameters.

4.2.1. Physical Parameters

Physical parameters analysed include temperature, pH, colour, oxygen reduction potential (ORP), turbidity, electrical conductivity (EC) and total dissolved solids (TDS). The mean values of all the physical parameters are below the maximum permissible limits (MPL) set by the Nigerian Industrial Standard (NIS, 2007) as stipulated in the Nigerian Standards for Drinking Water Quality (NSDWQ) guidelines. Despite their proximity to refuse dumps, the water sources sampled appeared to have no issues with any of the physical parameters investigated. Tables 4.2.1a and 4.2.1b show the Range and Mean values for both the field and the laboratory measurements.

Table 4.2.1a Range and Mean for the Field Data

S/No	Parameter	Range	Mean	NSDWQ*MPL
1	Temperature (^{0}C)	28 -33	30.80	Ambient
2	pH	7.50 - 9.30	8.60	6.5 - 8.50
3	Oxygen Reduction Potential – ORP (mV)	111 - 193	139.35	Na
4	Electrical Conductivity –EC (uS/cm)	312 - 1,776	953	1000
5	Total Dissolved Solid –TDS (mg/l)	131 - 879	458.95	500

NSDWQ: Nigerian Standard for Drinking Water Quality
MPL: Maximum Permissible Level

Table 4.2.1b Range and Mean for the Lab. Data

S/No	Parameter	Range	Mean	NSDWQ*MPL
1	Temperature (^{0}C)	25.80 – 30.00	27.45	Ambient
2	pH	7.50 – 8.80	8.07	6.5 - 8.50
3	Colour (Co.Pt unit)	0 – 30	3.10	15.00
4	Turbidity (NTU)	0.37 – 7.19	1.65	5.00
5	Electrical Conductivity–EC (µS/cm)	350 – 1,700	958	1000
6	Total Dissolved Solid –TDS (mg/l)	160 - 850	482	500

NSDWQ: Nigerian Standard for Drinking Water Quality
MPL: Maximum Permissible Level

4.2.2. Chemical Parameters

4.2.2a Cations

Nine cations' (Sodium, Calcium, Magnesium, Iron, Lead, Zinc, Copper, Arsenic and Ammonium) concentrations were determined and their mean values, with the exception of Calcium and Magnesium, were below the maximum permissible levels set by the Nigerian Industrial Standard (NIS), 2007 standards for drinking water quality. Calcium mean value was 167.45mg/l against the maximum permissible level (mpl) of 75mg/l while that of Magnesium was 77.35mg/l against the maximum permissible level (mpl) of 20mg/l. Mean values for these two cations were on the high side, consequently, water from these sources are classified as hard. Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather (WHO, 2011). Both Calcium and Magnesium are essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences (WHO, 2011).

Table 4.2.2a Range and Mean values for Cations

S/No	Parameter	Range	Mean	NSDWQ*MPL
1	Calcium, Ca^{+2} (mg/l)	70 – 324	167.55	75
2	Magnesium,Mg^{+2} (mg/l)	18 - 176	77.35	20
3	Total Iron, Fe^{+2} (mg/l)	0.00 – 0.35	0.13	0.30
4	Copper, Cu^{+2} (mg/l)	0.00 – 0.26	0.14	0.01
5	Zinc, Zn^{+2} (mg/l)	0.00 – 0.95	0.26	3.00
6	Lead, Pb^{+2} (mg/l)	0.00 – 0.001	0.00	0.01
7	Arsenic, As^{+3} (mg/l)	0.00 – 0.002	0.00	0.01
8	Sodium, Na^{+} (mg/l)	0.00 – 182	42.37	200
9	Ammonium, NH_4^{+} (mg/l)	0.0 - 0.60	0.20	1.00

NSDWQ: Nigerian Standard for Drinking Water Quality
MPL: Maximum Permissible Level

4.2.2b Anions

Seven Anions' (Chloride, Fluoride, Nitrate, Nitrite, Sulphate, Phosphate and Bicarbonate) concentrations were determined. The mean values of Chloride, Fluoride and Sulphate were below the maximum permissible levels. The mean values for Nitrate and Nitrite were 50.21mg/l and 1.01mg/l respectively which are higher than their respective maximum permissible levels (mpl).

Table 4.2.2b Range and Mean values for Anions

S/No	Parameter	Range	Mean	NSDWQ*MPL
1	Fluoride, F- (mg/l)	0.00 – 1.47	0.88	1.50
2	Nitrate, NO_3^- (mg/l)	4.50 – 180	50.11	50
3	Nitrite, NO_2^- (mg/l)	0.01 – 8.70	1.01	0.20
4	Sulphate, SO_4^{-2} (mg/l)	12 – 145	62.70	100
5	Chloride, Cl^- (mg/l)	0.00 – 280	65.33	250
6	Bicarbonate, HCO_3^- (mg/l)	33 – 278	143.25	100
7	Phosphate, PO_4^{-3} (mg/l)	0.00 – 1.30	0.30	0.01

NSDWQ: Nigerian Standard for Drinking Water Quality
MPL: Maximum Permissible Limit

4.2.2c Other Chemical parameters

Total Hardness, Total Alkalinity, Bicarbonate and Phosphate concentrations' mean values are higher than the maximum permissible limits (mpl) set by the NIS, 2007 in the Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines.

Table 4.2.2c Range and Mean values for Total Alkalinity and Total Harness

S/No	Parameter	Range	Mean	NSDWQ*MPL
1	Total Hardness (as $CaC0_3$) mg/l	91 - 416	241.85	150
2	Total Alkalinity (as $CaC0_3$) mg/l	36 - 280	120.45	100

NSDWQ: Nigerian Standard for Drinking Water Quality
MPL: Maximum Permissible Limit

4.2.3 Microbial Parameters

The mean values for Total and Faecal Coliforms were 10.45cfu/100ml and 2.8cfu/100ml respectively. While the mean value for Total Coliform was slightly higher than maximum permissible level of 10cfu/100ml, the mean value for Faecal Coliform of 2.8cfu/100ml against the maximum permissible level of 0.00cfu/100ml was rather high. This is an indication that the water sources under investigation were recently contaminated and may contain pathogens responsible for water borne diseases. Table 4.2.3 provide the Range and Mean for the microbial parameters.

4.2.3 Range and Mean for Microbial Parameters

S/No	Parameter	Range	Mean	NSDWQ*MPL
1	Total Coliform (cfu/100ml)	0 - 39	10.45	10
2	Faecal Coliform (cfu/100ml)	0 - 22	2.75	0

NSDWQ: Nigerian Standard for Drinking Water Quality
MPL: Maximum Permissible Limit

CHAPTER FIVE

SUMMARY, CONCLUTION AND RECOMMDATIONS

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

Twenty hand-dug wells situated close to refuse dumps in Bauchi metropolis, north-eastern Nigeria, were selected for this investigation. The study assessed the ground water quality of these wells which for quite sometimes serve as alternative sources of drinking water due to inadequate public supply of potable water. Water from each of the selected hand-dug wells was sampled in a 500ml sterilized plastic container, preserved and taken to the **RU**ral **WA**ter **S**upply and **S**anitation **A**gency (RUWASSA)'s laboratory for analysis. Samples were analysed for physical, chemical and microbial parameters.

Result of the analyses for physical parameters, chemical parameters and microbial parameters are presented in tables 4.1.1a - 4.1.1b, 4.2.1a -4.2.1b and 4.1.3 respectively. The bar chart plots for the physical parameters, chemical parameters and microbial parameters are presented in appendixes B, C and D respectively.

Physical parameters analysed include temperature, pH, colour, oxygen reduction potential (ORP), turbidity, electrical conductivity (EC) and total dissolved solids (TDS). The mean values of all the physical parameters were within the standards set by the Nigerian Industrial Standard (NIS, 2007) as stipulated in the Nigerian Standards for Drinking Water Quality (NSDWQ) guidelines.

Nine cations' (Sodium, Calcium, Magnesium, Iron, Lead, Zinc, Copper, Arsenic and Ammonium) concentrations were determined and their mean values, with the exception of Calcium and Magnesium, were below the maximum permissible limits set by the Nigerian Industrial Standard (NIS), 2007 standards for drinking water quality. Calcium mean value was 167.45mg/l against the maximum permissible level (mpl) of 75mg/l while that of Magnesium was 77.35mg/l against the maximum permissible level (mpl) of 20mg/l. Mean values for these two cations were high, consequently, water from these sources are classified as hard. Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather (WHO, 2011). Both Calcium and Magnesium are essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences (WHO, 2011).

On the other hand, seven anions' (Chloride, Fluoride, Nitrate, Nitrite, Sulphate, Phosphate and Bicarbonate) concentrations were also determined. The mean values of Chloride, Fluoride and Sulphate were within the maximum permissible levels. The mean values for Nitrate, Nitrite, Phosphate and Bicarbonate were 50.21mg/l, 1.01mg/l, 0.31mg/l and 143.25 respectively which were higher than their respective maximum permissible levels (mpl). Total Alkalinity and Total Hardness concentrations' mean values were also higher than the maximum permissible levels (mpl) of the respective parameters.

The mean values for Total and Faecal Coliforms were 10.45cfu/100ml and 2.8cfu/100ml respectively. While the mean value for Total Coliform was slightly higher than maximum permissible level of 10cfu/100ml, the mean value for Faecal Coliform of 2.8cfu/100ml against the maximum permissible level of 0.00cfu/100ml was rather high. This is an indication that the water sources under investigation were recently contaminated and may contain pathogens responsible for water borne diseases.

5.2 CONCLUSION

Twenty hand-dug wells situated close to refuse dumps were selected for this investigation. Samples were analysed for physical, chemical and microbial parameters.

The physical parameters assessed include: temperature, pH, Colour, oxygen-reduction-potential (ORP), turbidity, total dissolved solid (TDS) and electrical conductivity (EC). All the water sources assessed have no issues with any of the physical parameters investigated.

Nine cations' (Sodium, Calcium, Magnesium, Iron, Lead, Zinc, Copper, Arsenic and Ammonium) concentrations were determined and their mean values, with the exception of Calcium and Magnesium, are within the maximum permissible levels set by the Nigerian Industrial Standard (NIS), 2007 standards for drinking water quality. Mean values for Calcium and Magnesium were on the high side, consequently, water from these sources are classified as hard. Calcium and Magnesium are essential minerals and are beneficial to human health in several respect, inadequate intake of either nutrients can result in adverse health consequences (WHO, 2011).

Seven Anions' (Chloride, Fluoride, Nitrate, Nitrite, Sulphate, Phosphate and Bicarbonate) concentrations were also determined. The mean values of

Chloride, Fluoride and Sulphate were below the maximum permissible levels. The mean values for Nitrate, Nitrite, Phosphate, Total Hardness, Total Alkalinity and Bicarbonate were found to be higher than their maximum permissible levels.

The mean value for Total Coliform was slightly higher than maximum permissible level of 10cfu/100ml while the mean value for Faecal Coliform of 2.8cfu/100ml was rather high. Josiah et al., (2016) conducted similar investigation and found that coliforms counts were above the set standard. They attributed high coliforms counts obtained to proximity of the assessed wells to septic tanks or dumpsites. This is an indication that the water sources under investigation were recently contaminated and may contain pathogens responsible for water borne diseases.

5.3 RECOMMENDATION

This research realized that those hand-dug wells which serve as alternative sources of drinking water in the study area were not protected. The World Health Organization (WHO) classifies source of water supply as either improved or unimproved (WHO, 2000). Unprotected wells, unprotected springs as well as rivers belong to the class of unimproved water sources.

Below are a number of recommendations which the writer believed could help in no small measure towards ensuring good supply of quality drinking water from hand-dug wells.

- Individual who deem it necessary to dig a hand-dug well in his/her compound as an alternative source of drinking water, should be encouraged to protect the facility. A protected facility provides good quality drinking water over a long period of time without being contaminated. Relevant government agencies should design, putting economic reality into consideration, a simple and affordable model of a protected facility for the populace.

- Regular disinfection of the water sources is highly desirable and should form part of the monitoring processes. Relevant government agencies

should decide the time-intervals for the disinfection of all the available sources (hand-dug wells) of water to avert emergence of water related disease outbreak.

- Dumping of household refuse, allowing domestic animals urinate and defecate around or stacking of animal's dung close to hand-dug wells should be discouraged especially during the rainy season. Community Health Extension Workers and any other relevant body who are mandated to ensure that good sanitary condition prevail in our houses, to be up and doing. Their action may reduce water contamination and therefore improve health condition of the populace. Some sign posts which prohibit dumping of refuse were erected at strategic places where refuse dump appeared to be so close to existing water facility (Figure 5)

- Town Planning Unit of the State Ministry of Works also has a special role to play in averting groundwater contamination. They are to ensure that minimum distance of 10meters requirement between a hand-dug well and pit latrine or septic tank is adhered to.

- Further investigation/research is recommended to underscore the importance of protecting our water sources. This could be achieved by

selecting equal number of hand-dug wells from improved sources and unimproved sources in the same area. Water quality of the two sources (improved and unimproved) are to be assessed and the results be compared.

Figure 5. Refuse Dump Prohibition Post in Bauchi

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APPENDIX A

3.2.1 DATA SHEET

Name: Near Wikki Code: S1 Date: 14/05 /2018

Longitude: 9^0 49' 50" Latitude: 10^0 17' 20" Temperature (^{0}C): 32

PH: 9.30 Electrical Conductivity (us/cm): 718

TDS (ppm): 376 Oxygen Reduction Potential (mV): 128

Colour: Unobjectionable Odor: Unobjectionable

Name: W/Dada Primary Code: S2 Date: 14/05 /2018

Longitude: 9^0 46' 10" Latitude: 10^0 19' 00" Temperature (^{0}C): 33

pH: 8.80 Electrical Conductivity (us/cm): 490

TDS (ppm): 245 Oxygen Reduction Potential (mV): 193

Colour: Unobjectionable Odor: Unobjectionable

Name: W/Dada Market Code: S3 Date: 14/05 /2018

Longitude: 9^0 46' 10" Latitude: 10^0 18' 50" Temperature (^{0}C): 30

PH: 8.60 Electrical Conductivity (us/cm): 1170

TDS (ppm): 573 Oxygen Reduction Potential (mV): 145

Colour: Unobjectionable Odor: Unobjectionable

APPENDIX A

3.2.2 DATA SHEET

Name: Alh. Mato Lame Code: S4 Date: 14/05 /2018

Longitude: 9^0 46’ 10” Latitude: 10^0 19’ 00” Temperature (^{0}C): 31

pH: 9.10 Electrical Conductivity (us/cm): 660

TDS (ppm): 323 Oxygen Reduction Potential (mV): 135

Colour: Unobjectionable Odor: Unobjectionable

Name: Malam Abdullahi Code: S5 Date: 14/05 /2018

Longitude: 9^0 45’ 15” Latitude: 10^0 18’ 30” Temperature (^{0}C): 31

pH: 9.20 Electrical Conductivity (us/cm): 1380

TDS (ppm): 680 Oxygen Reduction Potential (mV): 133

Colour: Unobjectionable Odor: Unobjectionable

Name: Karal Code: S6 Date: 16/05 /2018

Longitude: 9^0 51’ 10” Latitude: 10^0 20’ 00” Temperature (^{0}C): 32

pH: 8.80 Electrical Conductivity (us/cm): 1220

TDS (ppm): 555 Oxygen Reduction Potential (mV): 155

Colour: Unobjectionable Odor: Unobjectionable

APPENDIX A

3.2.3 DATA SHEET

Name: Kara II **Code: S7** **Date: 16/05 /2018**

Longitude: 9^0 50' 50" Latitude: 10^0 19' 50" Temperature (^{0}C): 31

pH: 8.70 Electrical Conductivity (us/cm): 1079

TDS (ppm): 535 Oxygen Reduction Potential (mV): 152

Colour: Unobjectionable Odor: Unobjectionable

Name: KaraIII **Code: S8** **Date: 16/05 /2018**

Longitude: 9^0 50' 50" Latitude: 10^0 19' 00" Temperature (^{0}C): 30

pH: 8.50 Electrical Conductivity(us/cm): 740

TDS (ppm): 373 Oxygen Reduction Potential (mV): 153

Colour: Unobjectionable Odor: Unobjectionable

Name: Kara IV **Code: S9** **Date: 16/05 /2018**

Longitude: 9^0 50' 18" Latitude: 10^0 20' 00" Temperature (^{0}C): 31

pH: 8.70 Electrical Conductivity (us/cm): 770

TDS (ppm): 340 Oxygen Reduction Potential (mV): 140

Colour: Unobjectionable Odor: Unobjectionable

APPENDIX A

3.2.4 DATA SHEET

Name: IBB Square **Code: S10** **Date: 16/05 /2018**

Longitude: 9^0 49’ 55” Latitude: 10^0 19’ 40” Temperature (^{0}C): 30

pH: 8.70 Electrical Conductivity (us/cm): 1035

TDS (ppm): 540 Oxygen Reduction Potential (mV): 135

Colour: Unobjectionable Odor: Unobjectionable

Name: Yalwa I **Code: S11** **Date: 18/05 /2018**

Longitude: 9^0 49’ 10” Latitude: 10^0 18’ 50” Temperature (^{0}C): 30

pH: 9.50 Electrical Conductivity (us/cm): 312

TDS (ppm): 131 Oxygen Reduction Potential (mV): 113

Colour: Unobjectionable Odor: Unobjectionable

Name: Yalwa II **Code: S12** **Date: 18/05 /2018**

Longitude: 9^0 49’ 10” Latitude: 10^0 18’ 30” Temperature (^{0}C): 32

pH: 9.30 Electrical Conductivity (us/cm): 608

TDS (ppm): 260 Oxygen Reduction Potential (mV): 111

Colour: Unobjectionable Odor: Unobjectionable

APPENDIX A

3.2.5 DATA SHEET

Name: Yalwa III Code: S13 Date: 18/05 /2018

Longitude: 9^0 49’ 10” Latitude: 10^0 18’ 50” Temperature (^{0}C): 30

pH: 8.20 Electrical Conductivity (us/cm): 1508

TDS (ppm): 715 Oxygen Reduction Potential (mV): 163

Colour: Unobjectionable Odor: Unobjectionable

Name: Yalwa IV Code: S14 Date: 18/05 /2018

Longitude: 9^0 48’ 10” Latitude: 10^0 16’ 50” Temperature (^{0}C): 30

pH: 8.90 Electrical Conductivity (us/cm): 378

TDS (ppm): 209 Oxygen Reduction Potential (mV): 143

Colour: Unobjectionable Odor: Unobjectionable

Name: Gwallaga Code: S15 Date: 18/05 /2018

Longitude: 9^0 50’ 00” Latitude: 10^0 18’ 50” Temperature (^{0}C): 31

pH: 9.20 Electrical Conductivity (us/cm): 1365

TDS (ppm): 680 Oxygen Reduction Potential (mV): 145

Colour: Unobjectionable Odor: Unobjectionable

APPENDIX A

3.2.6 DATA SHEET

Name: Baraya Code: S16 Date: 26/05 /2018

Longitude: 9^0 49’ 50” Latitude: 10^0 18’ 30” Temperature (^{0}C): 31

pH: 8.90 Electrical Conductivity (us/cm): 910

TDS (ppm): 540 Oxygen Reduction Potential (mV): 132

Colour: Unobjectionable Odor: Unobjectionable

Name: T/Makabarta Code: S17 Date: 14/05 /2018

Longitude: 9^0 50’ 10” Latitude: 10^0 18’ 00” Temperature (^{0}C): 30

pH: 9.00 Electrical Conductivity (us/cm): 1776

TDS (ppm): 879 Oxygen Reduction Potential (mV): 139

Colour: Unobjectionable Odor: Unobjectionable

Name: K/Shanu Code: S18 Date: 26/05 /2018

Longitude: 9^0 50’ 40” Latitude: 10^0 17’ 40” Temperature (^{0}C): 32

pH: 9.00 Electrical Conductivity (us/cm): 1275

TDS (ppm): 515 Oxygen Reduction Potential (mV): 125

Colour: Unobjectionable Odor: Unobjectionable

APPENDIX A

3.2.7 DATA SHEET

Name: Near Gate **Code: S19** **Date: 14/05 /2018**

Longitude: 9^0 49’ 50” Latitude: 10^0 18’ 20” Temperature (^{0}C): 31

pH: 9.10 Electrical Conductivity (us/cm): 1135

TDS (ppm): 570 Oxygen Reduction Potential (mV): 129

Colour: Unobjectionable Odor: Unobjectionable

Name: New Site **Code: S20** **Date: 14/05 /2018**

Longitude: 9^0 49’ 50” Latitude: 10^0 17’ 20” Temperature (^{0}C): 28

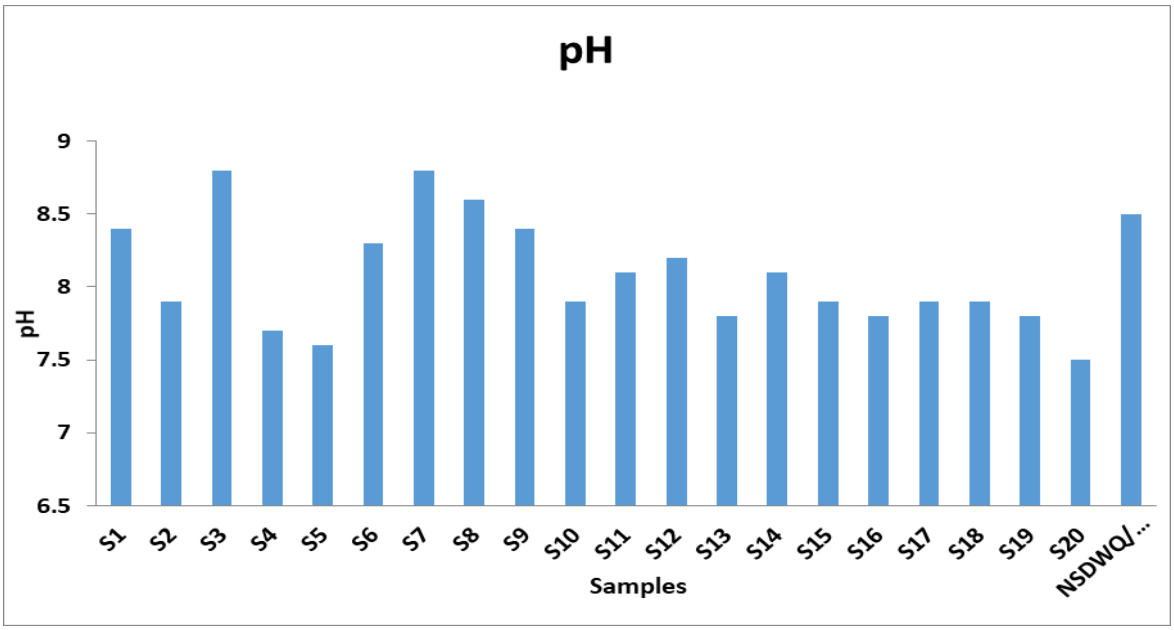
pH: 8.50 Electrical Conductivity(us/cm): 540

TDS (ppm): 140 Oxygen Reduction Potential (mV): 118

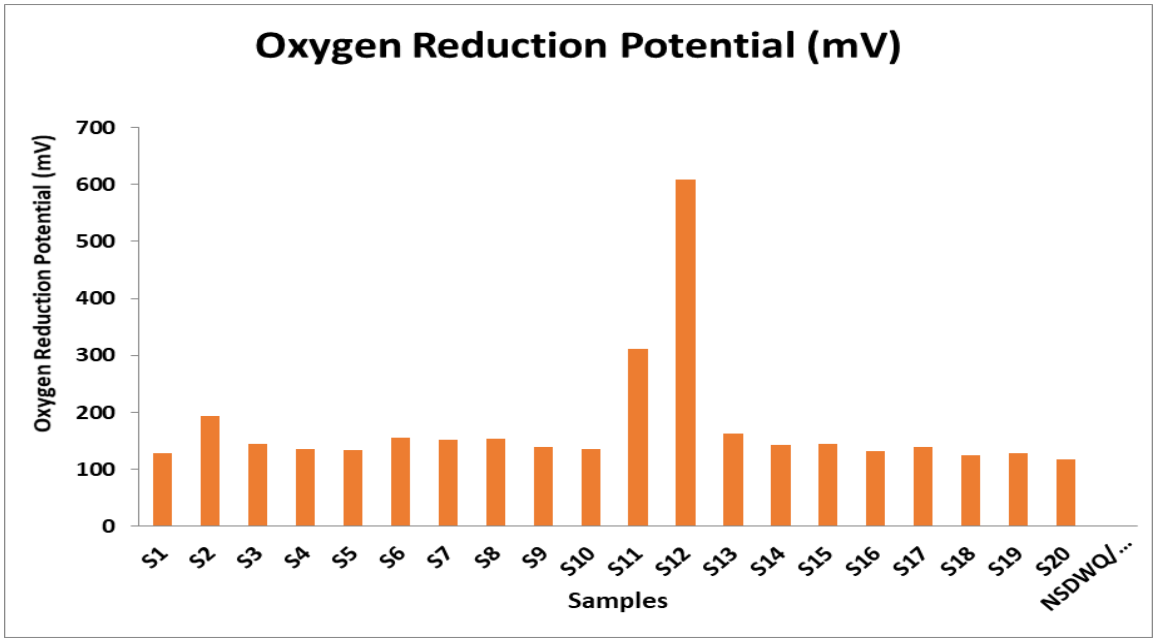
Colour: Unobjectionable Odor: Unobjectionable

APPENDIX B

Bar Chart 4.1.1a



Bar Chart 4.1.2a

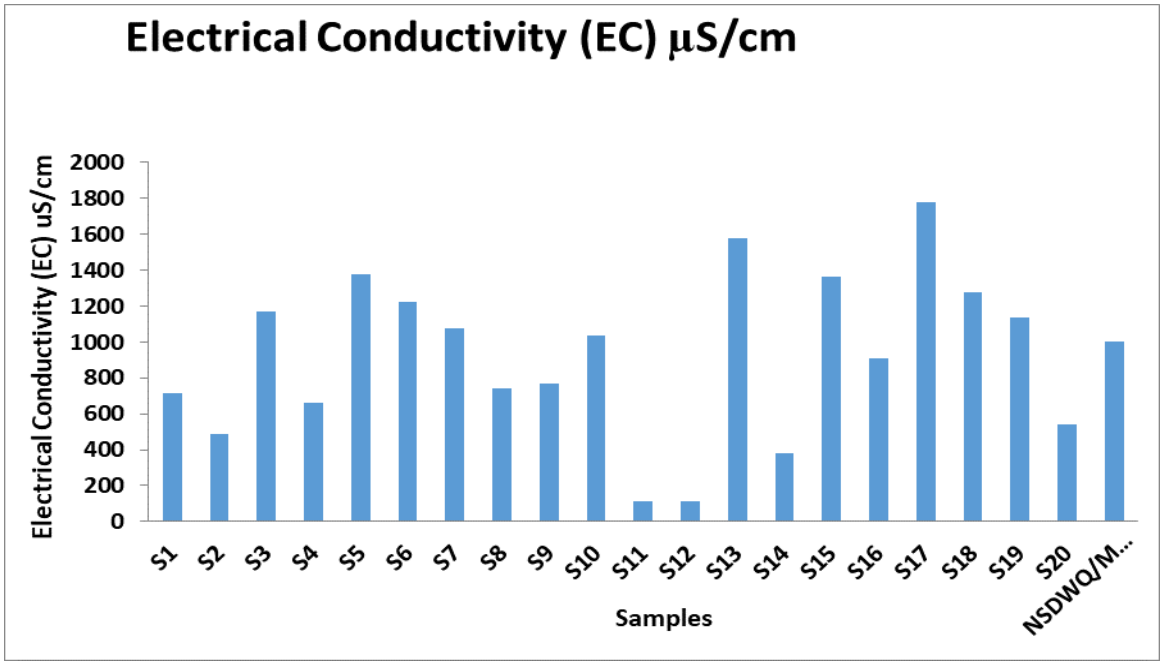


NSDWQ: Nigerian Standard for Drinking Water Quality

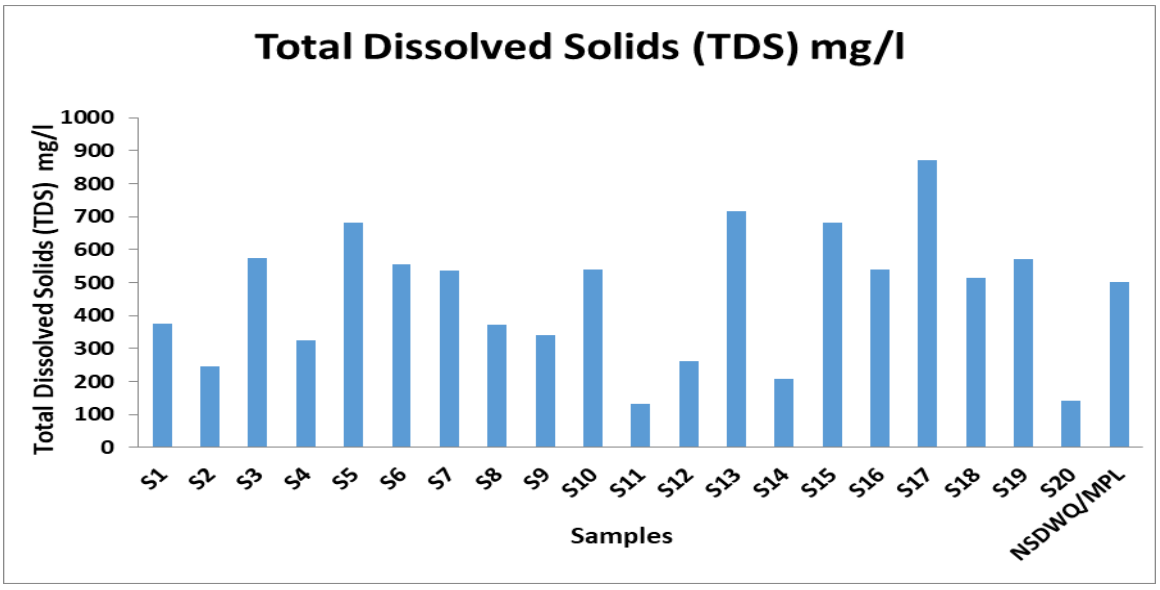
MPL: Maximum Permissible Level

APPENDIX B

Bar Chart 4.1.3a



Bar Chart 4.1.4a

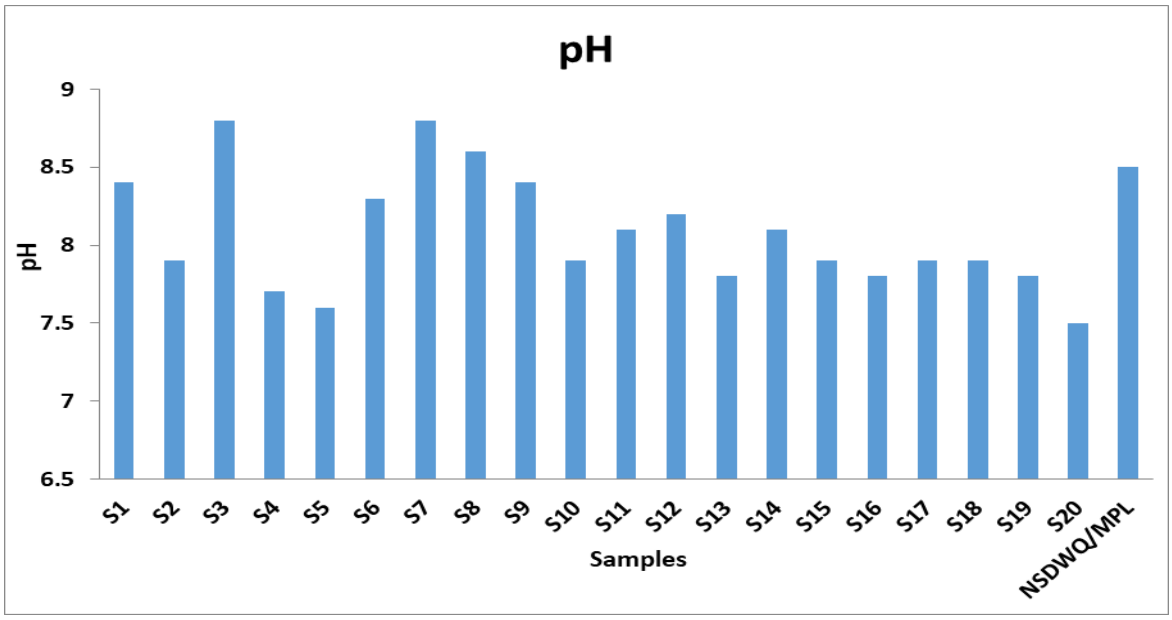


NSDWQ: Nigerian Standard for Drinking Water Quality

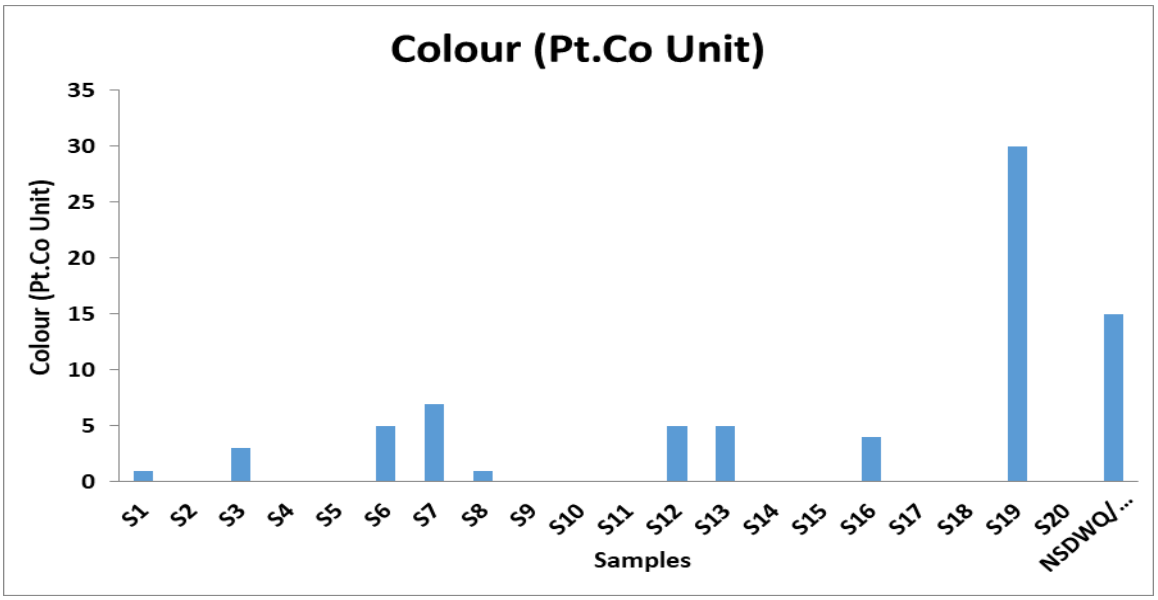
MPL: Maximum Permissible Level

APPENDIX B

Bar Chart 4.1.1b



Bar Chart 4.1.2B



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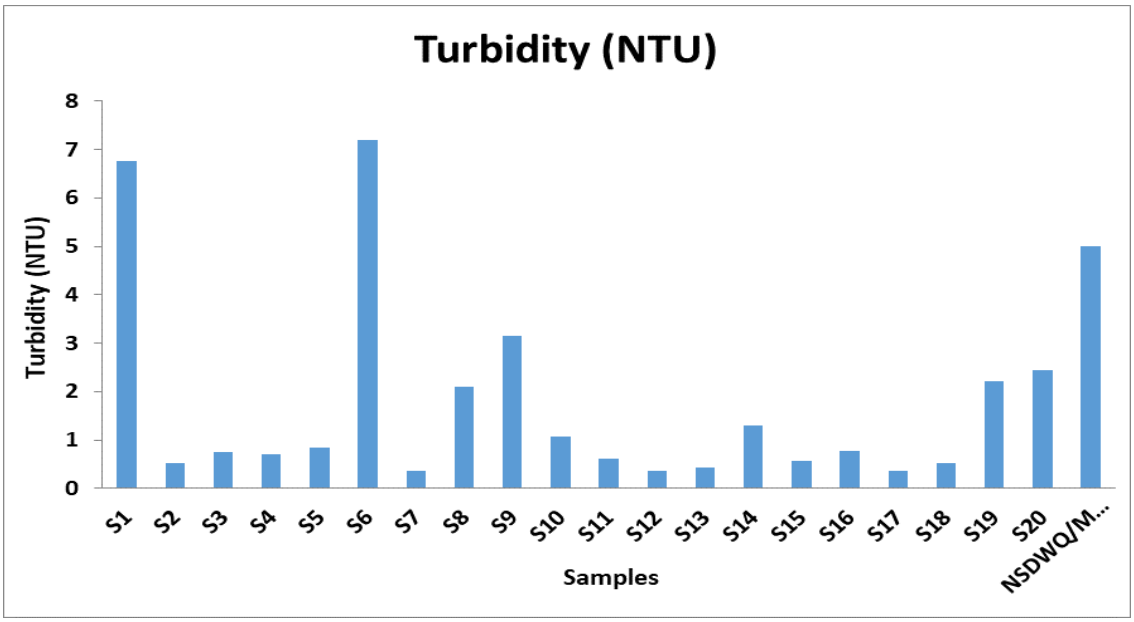
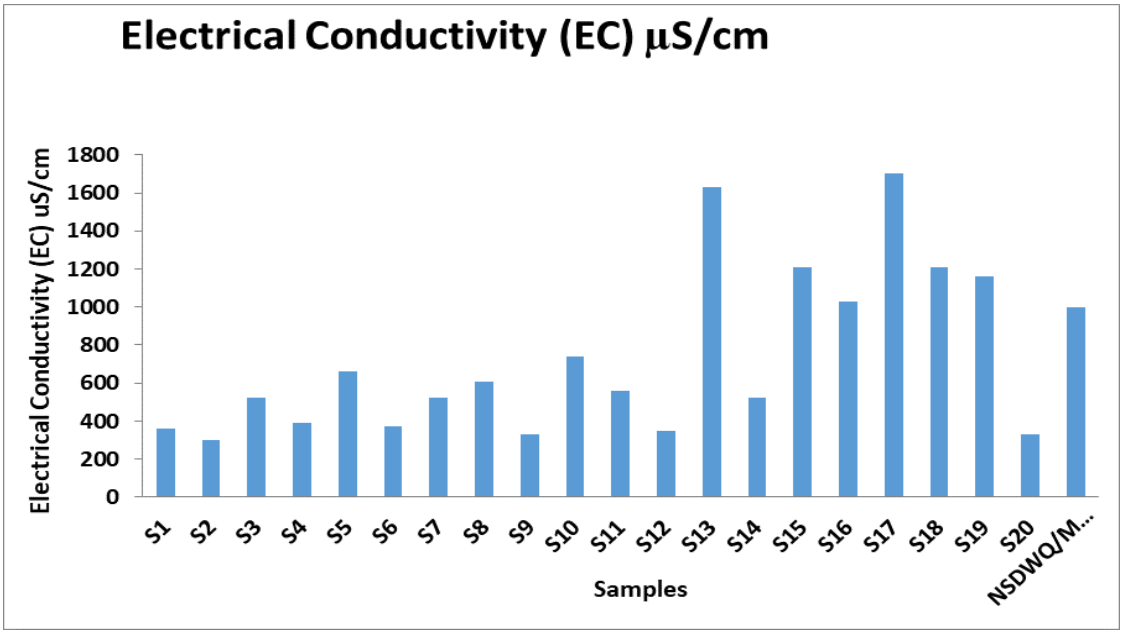
APPENDIX B

Bar Chart 4.1.3B



Bar Chart 4.1.4B



NSDWQ: Nigerian Standard for Drinking Water Quality

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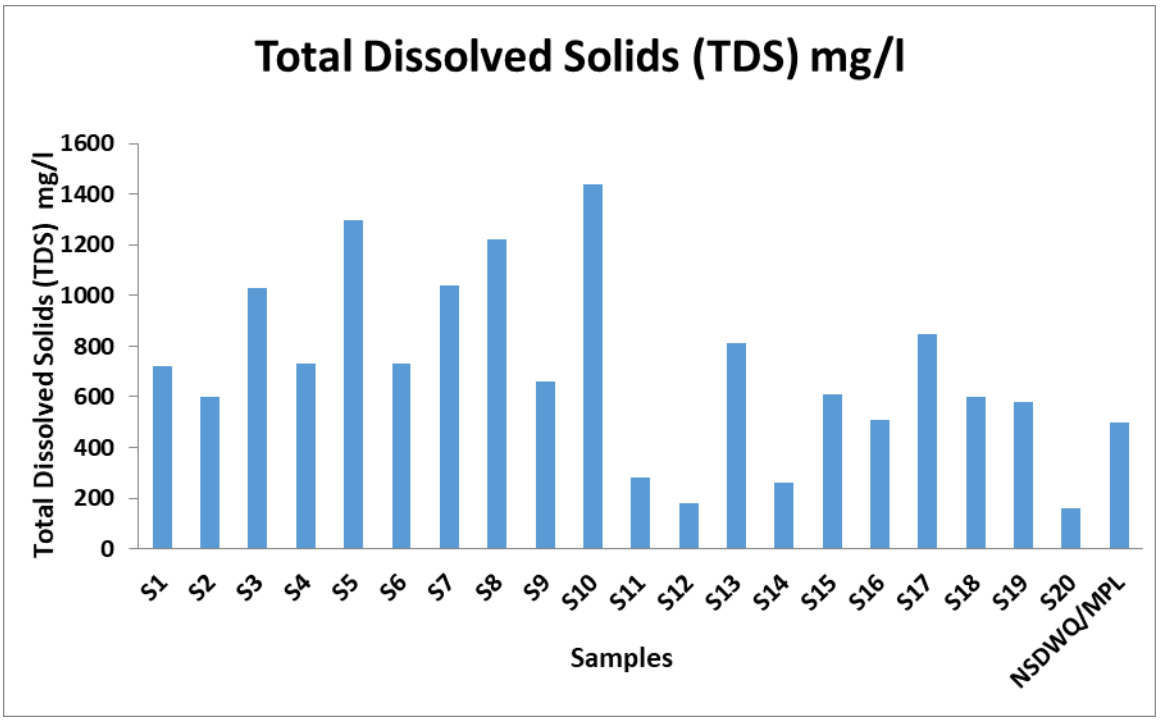
APPENDIX B

Bar Chart 4.1.5b

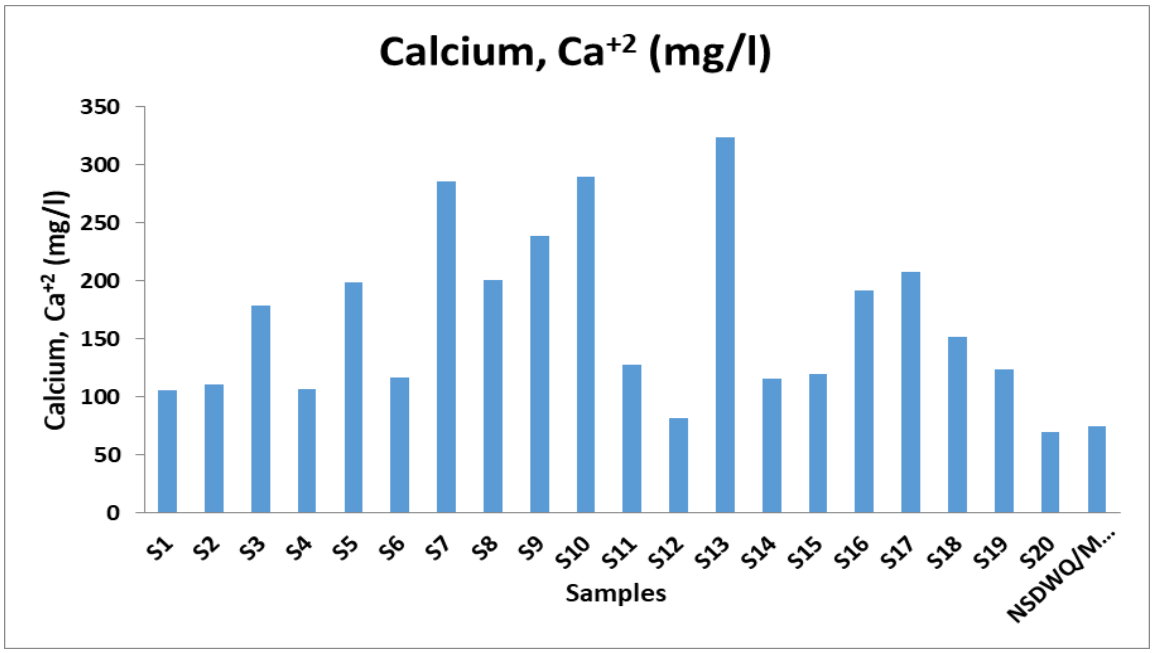


NSDWQ: Nigerian Standard for Drinking Water Quality

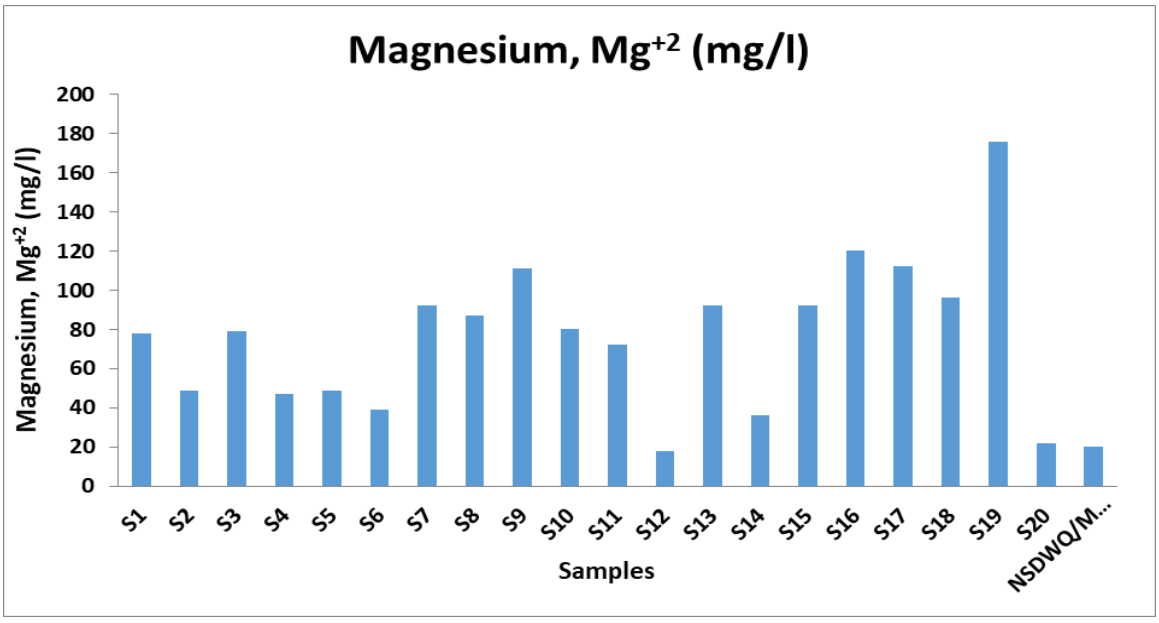
MPL: Maximum Permissible Level

APPENDIX C

Bar Chart 4.2.1



Bar Chart 4.2.2

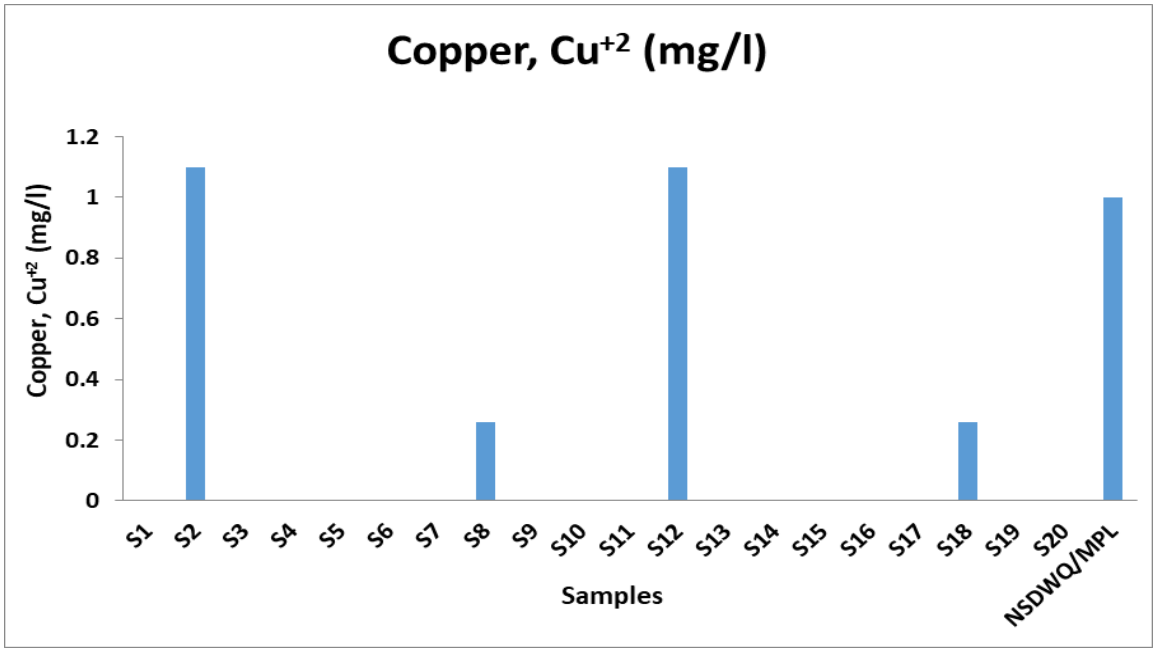


NSDWQ: Nigerian Standard for Drinking Water Quality

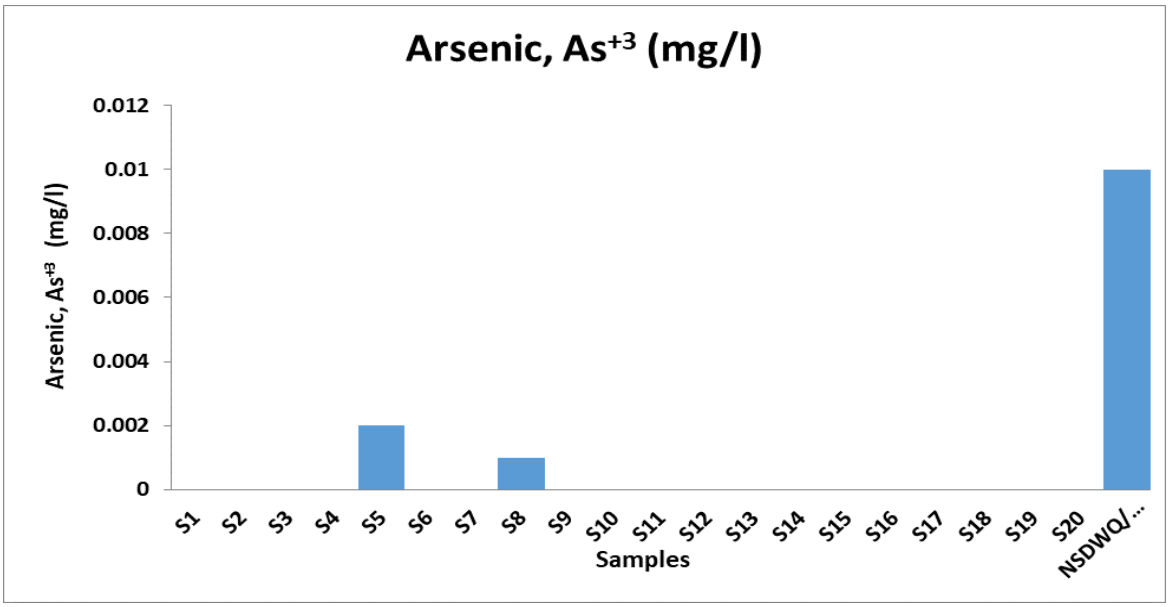
MPL: Maximum Permissible Level

APPENDIX C

Bar Chart 4.2.3



Bar Chart 4.2.4



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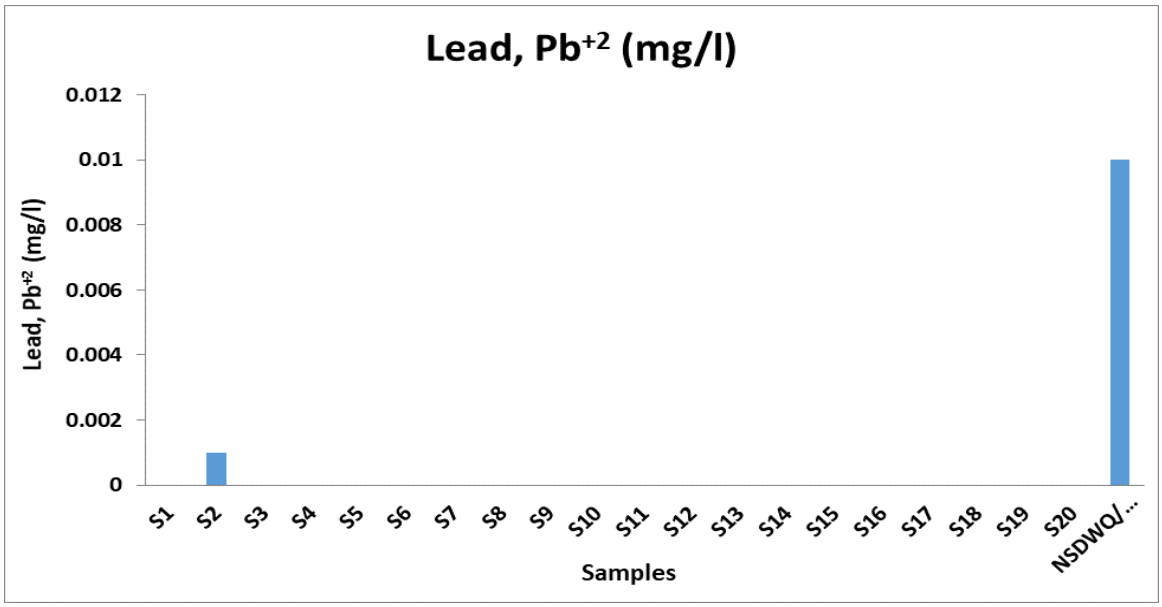
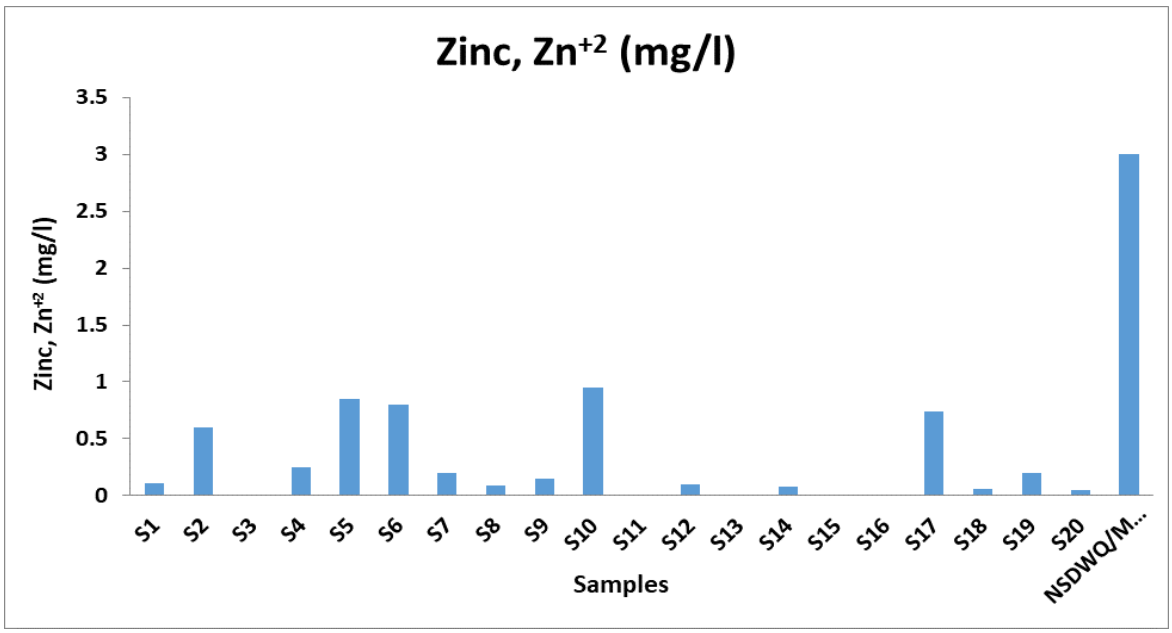
MPL: Maximum Permissible Level

APPENDIX C

Bar Chart 4.2.5



Bar Chart 4.2.6



NSDWQ: Nigerian Standard for Drinking Water Quality

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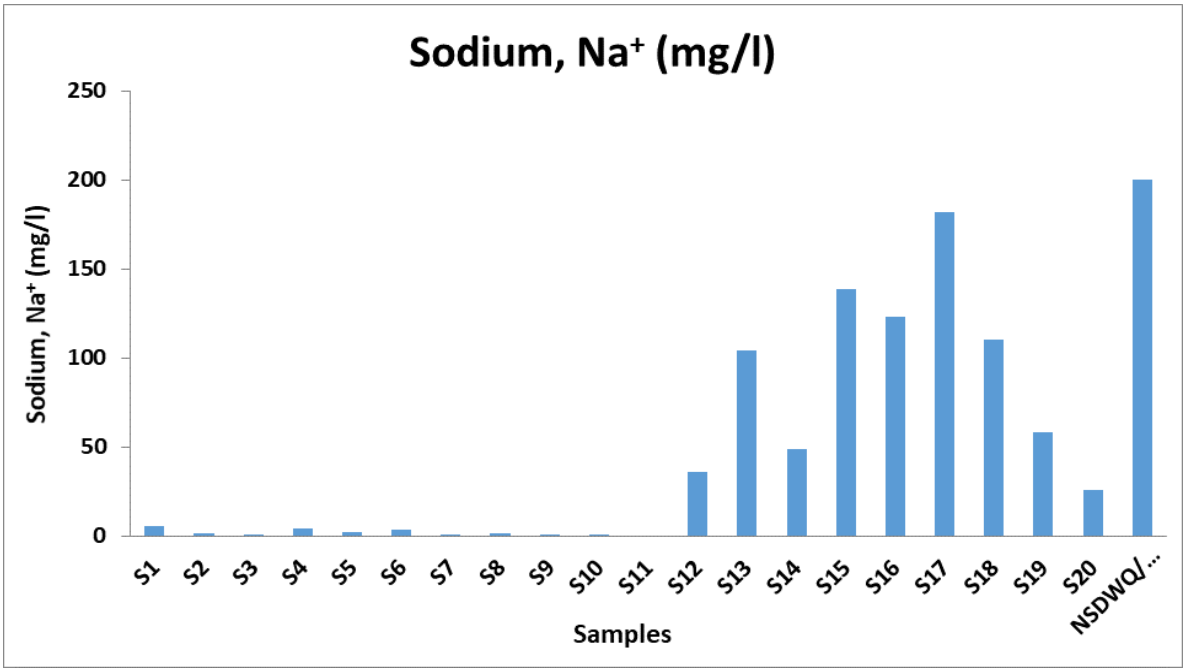
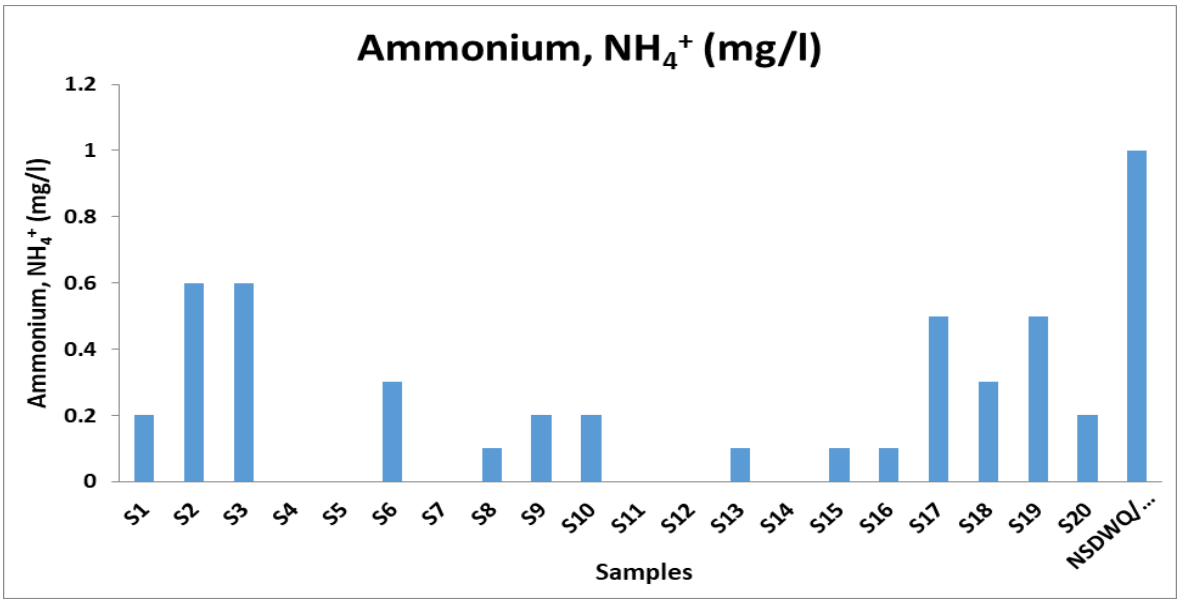
APPENDIX C

Bar Chart 4.2.7



Bar Chart 4.2.8



NSDWQ: Nigerian Standard for Drinking Water Quality

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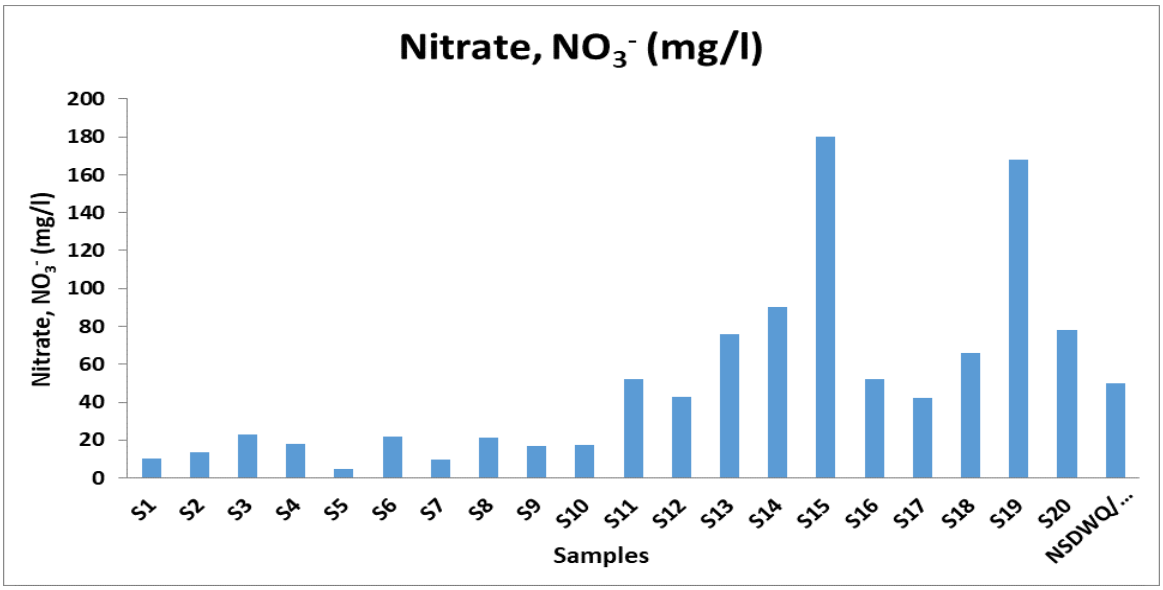
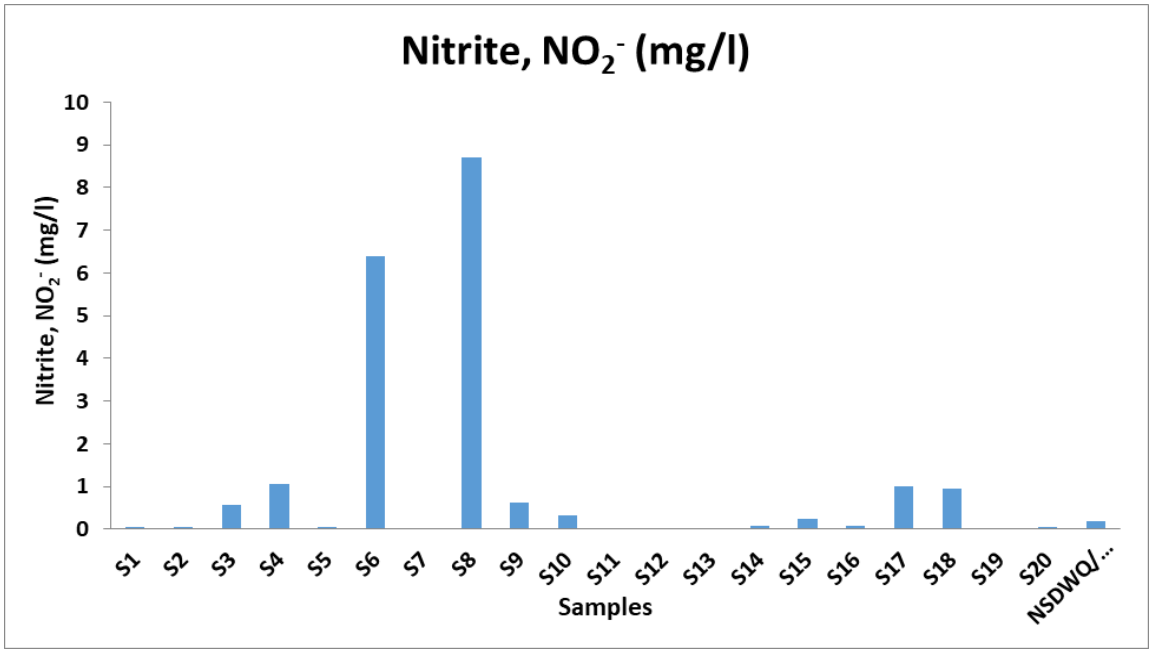
APPENDIX C

Bar Chart 4.2.9



Bar Chart 4.2.10



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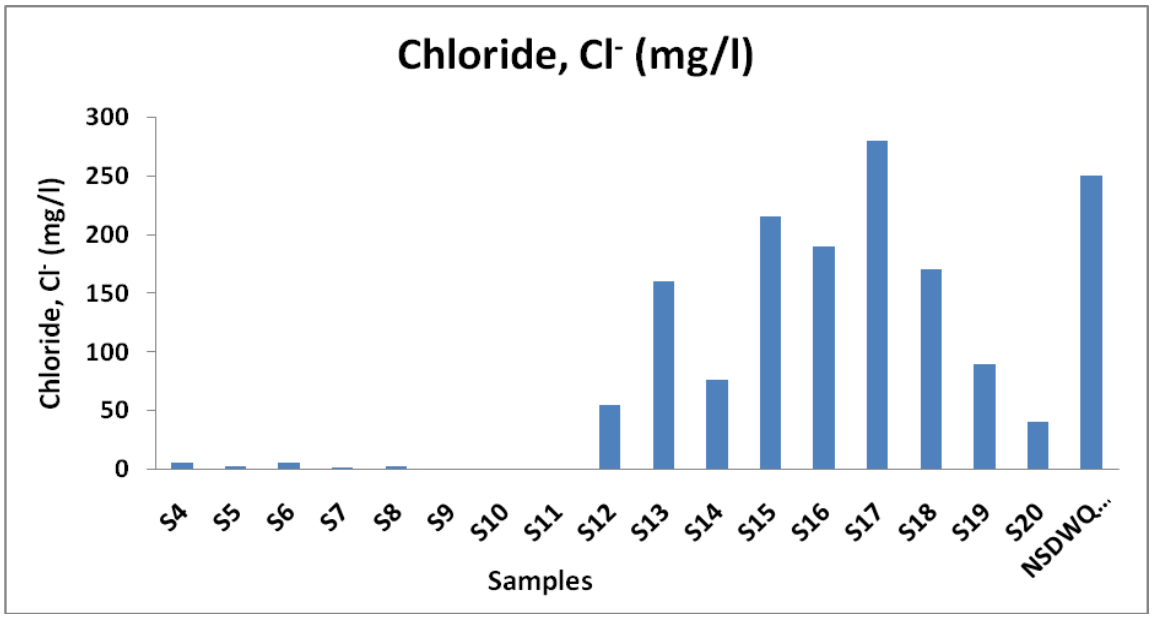
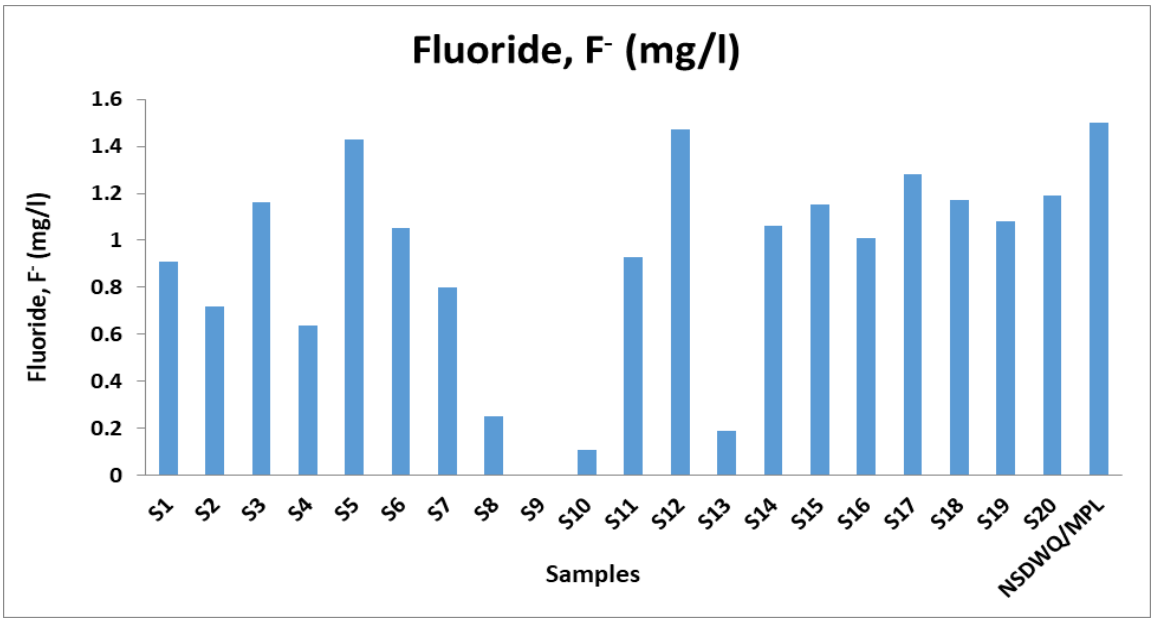
APPENDIX C

Bar Chart 4.2.11



Bar Chart 4.2.12



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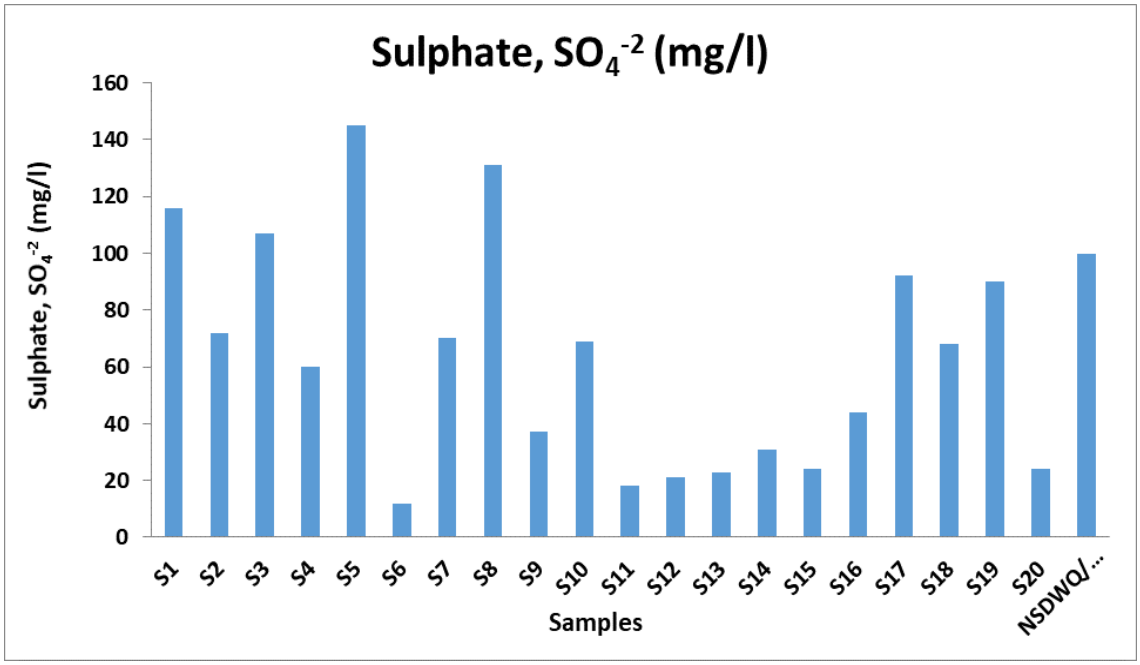
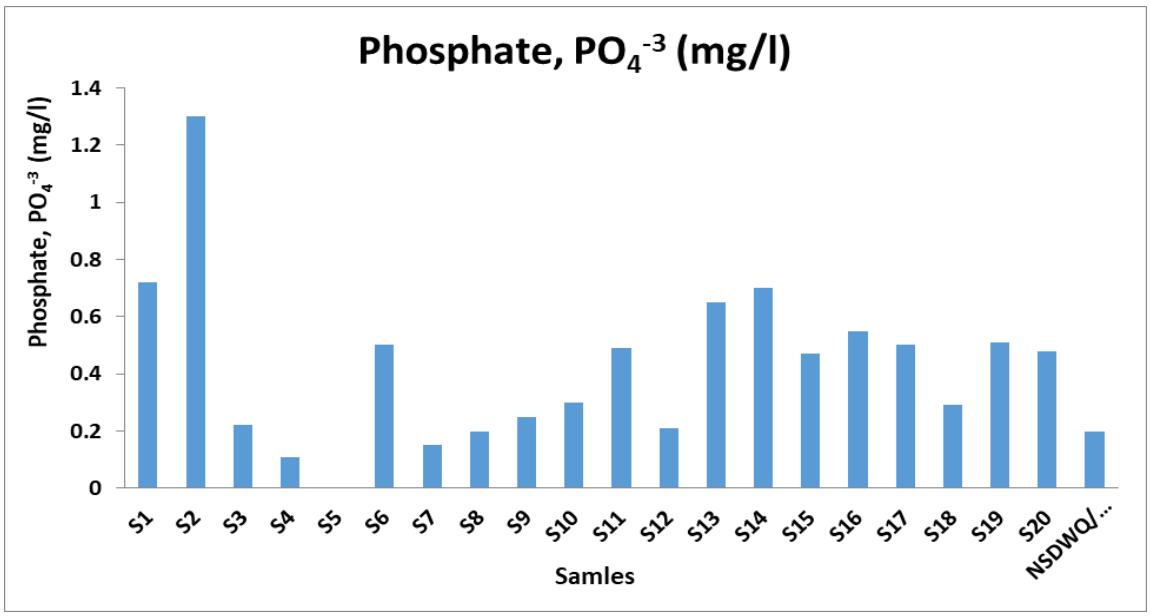
APPENDIX C

Bar Chart 4.2.13



Bar Chart 4.2.14



NSDWQ: Nigerian Standard for Drinking Water Quality

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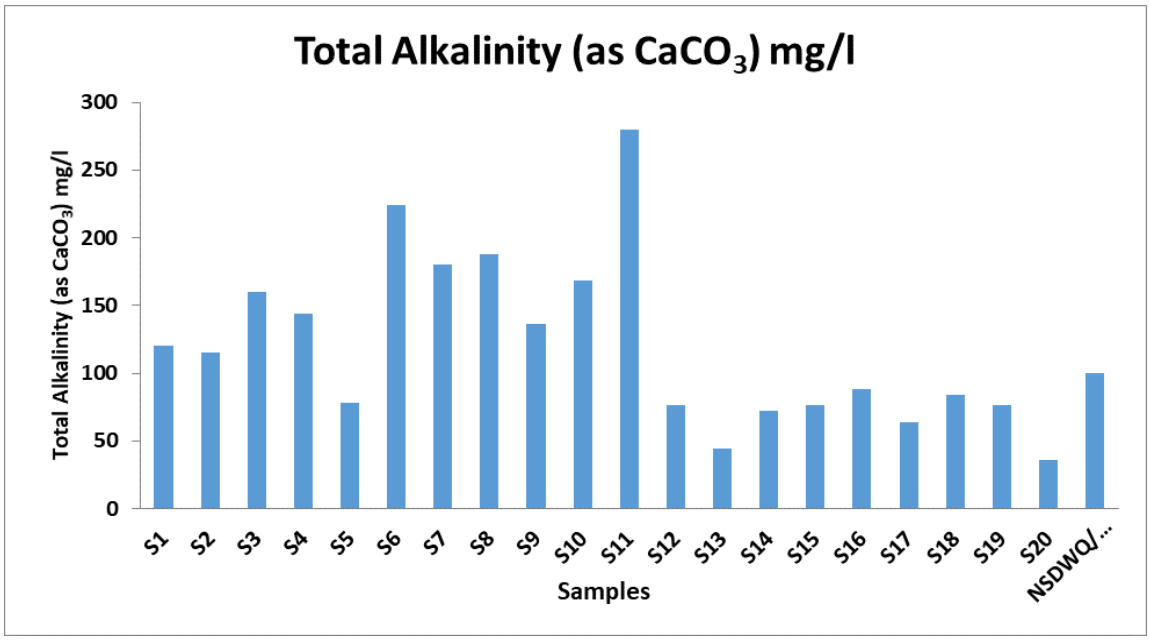
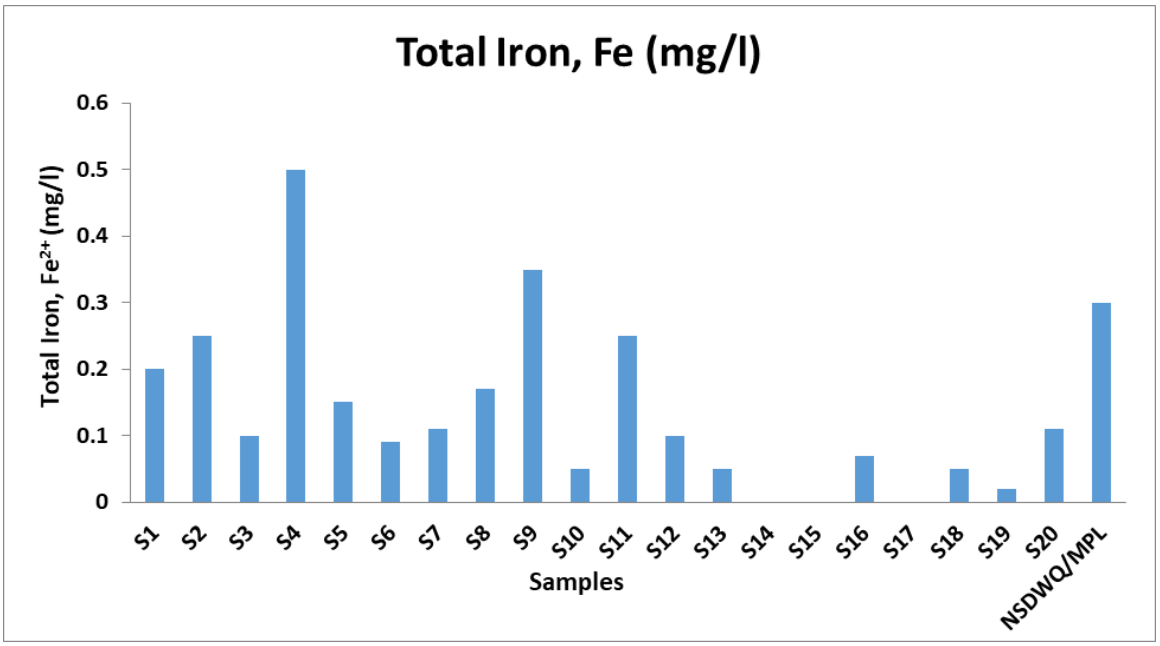
APPENDIX C

Bar Chart 4.2.15



Bar Chart 4.2.16



NSDWQ: Nigerian Standard for Drinking Water Quality

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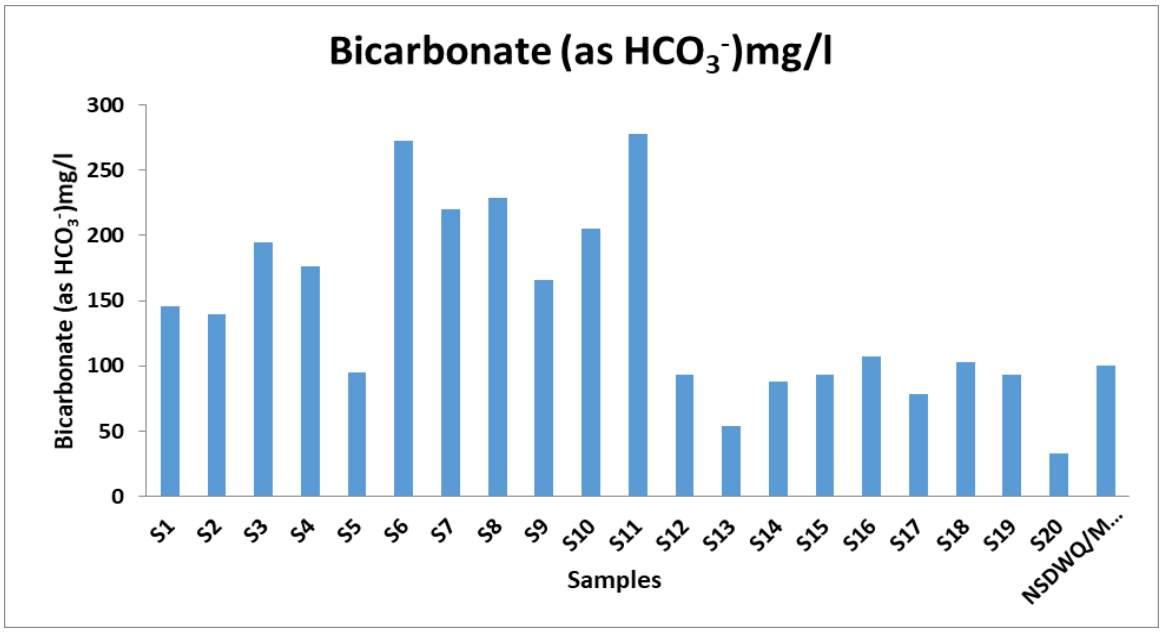
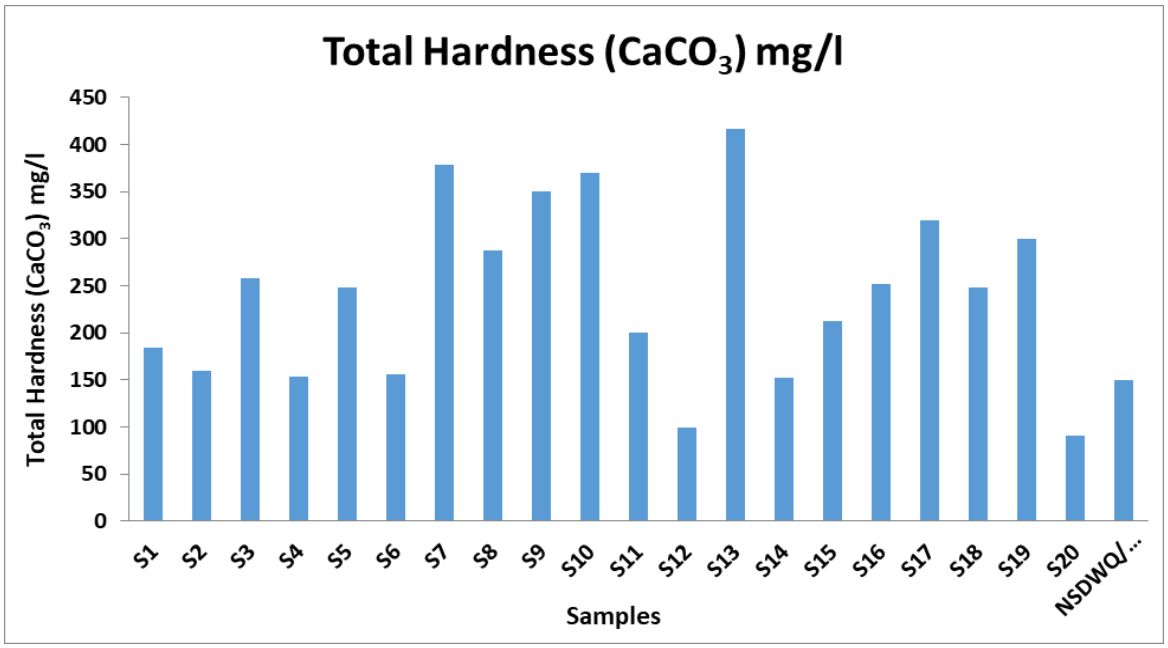
APPENDIX C

Bar Chart 4.2.17



Bar Chart 4.2.18



NSDWQ: Nigerian Standard for Drinking Water Quality

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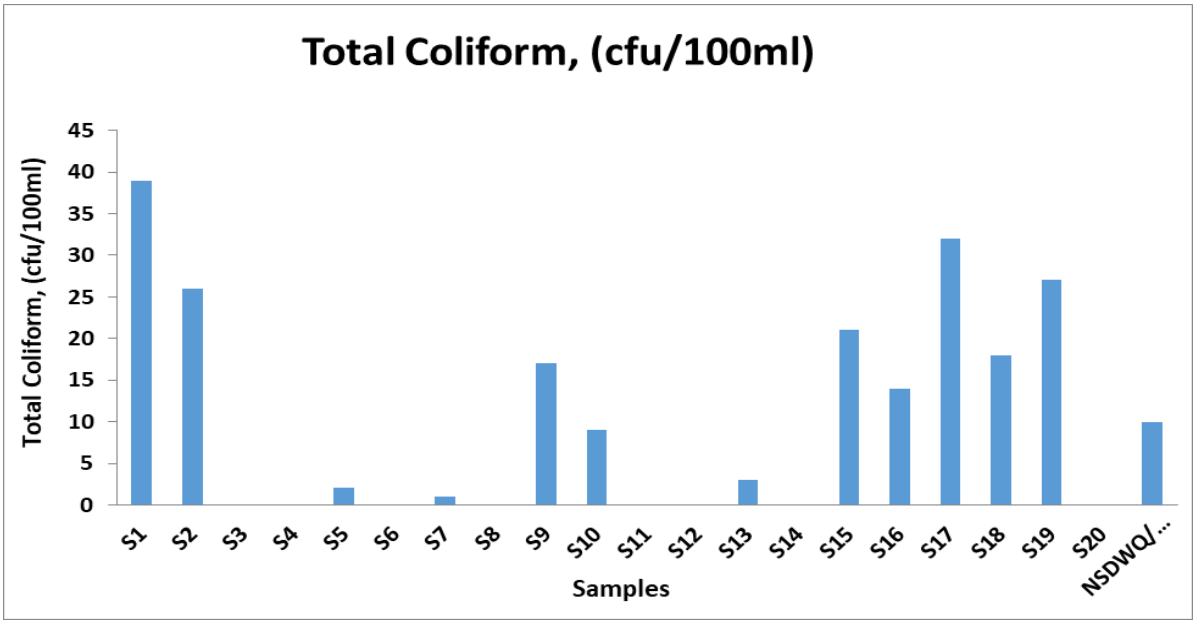
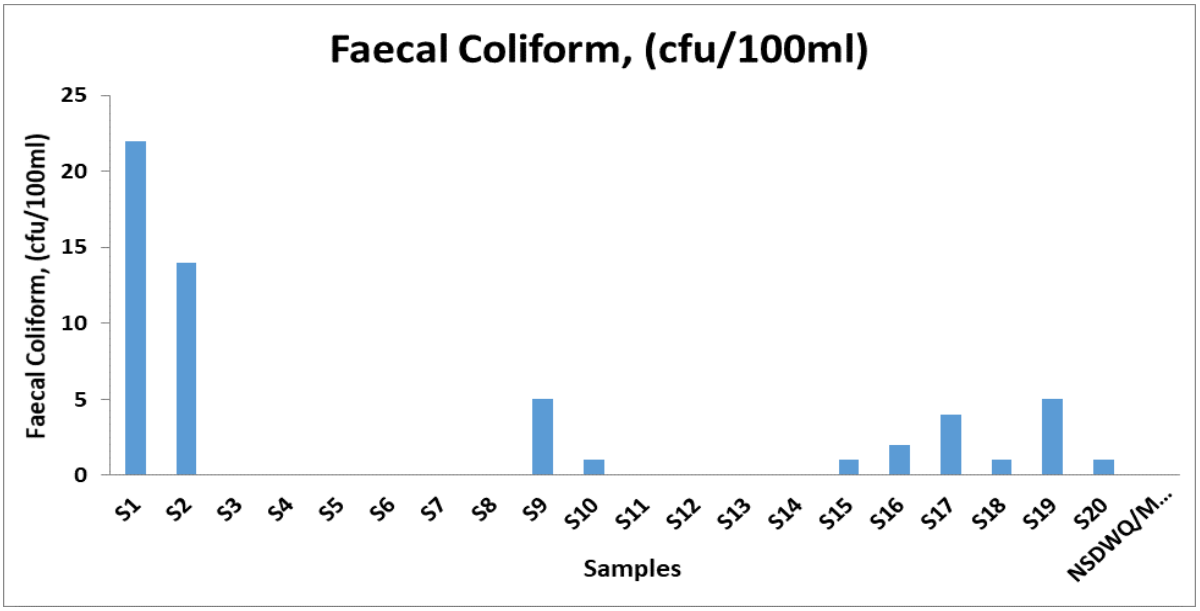
APPENDIX D

Bar Chart 4.3.1



Bar Chart 4.3.2



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