

**PHYSICOCHEMICAL AND HEAVY METAL ASSESSMENT OF WATER FROM  
SELECTED BOREHOLES IN KAURA-NAMODA LOCAL  
GOVERNMENT AREA, ZAMFARA STATE, NIGERIA**

**By**

**Chukwuka Clifford ODENIGBO, BSc (UNN) 2000**

**MSc/SCI/8470/2011-2012**

**A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,  
AHMADU BELLO UNIVERSITY, ZARIA**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD  
OF MASTER OF SCIENCE DEGREE IN ANALYTICAL CHEMISTRY**

**DEPARTMENT OF CHEMISTRY,  
FACULTY OF SCIENCE  
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA**

**APRIL, 2015**

## DECLARATION

I declare that the work in this thesis entitled “Physicochemical and Heavy Metal Assessment of Water from Selected Boreholes in Kaura-Namoda Local Government Area, Zamfara State, Nigeria” has been carried out by me in the Department of Chemistry. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma at this or any other institution.

Chukwuka Clifford ODENIGBO

Name of student

-----

Signature

Date

## CERTIFICATION

This thesis titled “PHYSICOCHEMICAL AND HEAVY METAL ASSESSMENT OF WATER FROM SELECTED BOREHOLES IN KAURA NAMODA LOCAL GOVERNMENT AREA, ZAMFARA STATE, NIGERIA” by Chukwuka Clifford ODENIGBO meets the regulations governing the award of degree of Master of science (Analytical Chemistry) of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. (Mrs) E.B Agbaji

Chairman Supervisory Committee

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

Prof. V. O. Ajibola

Member, Supervisory Committee

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

Prof. V. O Ajibola

Head of Department

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

Prof. A.Z. Hassan

Dean, School of Postgraduate Studies

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## **DEDICATION**

This work is dedicated to my dear mother Mrs Ezinne Eunice A. Odenigbo for her love and care for me and my family even now that she is old.

## **ACKNOWLEDEMENT**

I am most grateful to God Almighty for His goodness upon my life and that of my entire family. By His mercy, I was able to carry out this work.

I am also very grateful to my supervisors; Prof. (Mrs.) E.B Agbaji and Prof. V.O Ajibola for their immense contributions towards the success of this work.

To all staff of Chemistry Department, especially those that taught me directly, I say thank you all for what God has used you to do in my life in these two years. My prayer is that God Almighty will reward everybody accordingly.

Special thanks to my dear wife (Dear) and lovely children (Eunice Jr, ThankGod and Victor) for their patience with me as I was always away from them on the course of this study. May God Almighty bless this effort for His glory in Jesus name Amen.

To my friends and classmates at ABU Zaria, Yerima, Victor, Lamis, Abbas, Paul, Juliet, Bawa, Ike, Linus, Dauda, Ebuka, Oshoma, Jonathan, Amina and Philip. I enjoyed every bit of our togetherness. May God Almighty the creator of heaven and earth guide us aright in all our endeavours, Amen.

## **ABSTRACT**

The physicochemical and heavy metal assessment of water from selected boreholes in Kaura Namoda has been studied for the purpose of ascertaining the water quality of the boreholes. Twenty selected boreholes were sampled three times each at two weeks interval between the months of April and May, 2013. Parameters which included temperature, pH, turbidity, electrical conductivity, total dissolved solids (TDS), sulphate, phosphate, nitrate, chloride, fluoride, copper, lead, zinc, cadmium, iron and manganese were determined using standard methods. The results obtained when compared with the WHO, NSDW and USEPA standards for drinking water showed that the parameters which include turbidity, pH, electrical conductivity, TDS, phosphate, nitrate and fluoride had values that were within the maximum permissible limits in all the twenty boreholes sampled while parameters which include sulphate, chloride, cadmium, iron, hardness, lead, manganese and zinc were detected at levels above the permissible limit for drinking water in some of the boreholes sampled. Copper was below detectable level in all the boreholes except in one borehole with value within the maximum permissible limits. Therefore, not all the boreholes investigated had parameters that were in conformity with the WHO 2006, NSDW 2007 and USEPA 2012 recommended permissible limits for drinking water hence possible adverse effect due to consumption of the water containing high level of these parameters may occur among the inhabitants of this study area especially in the cases of the boreholes where lead and cadmium were detected above the permissible limits if they bio-accumulate beyond the tolerable concentrations in the body.

## TABLE OF CONTENTS

<b>TITLE</b>	<b>Pages</b>
Title page	i
Declaration	ii
Certification	iii
Dedication	iv
Acknowledgment	v
Abstracts	vi
Table of Contents	vii
List of Tables	xiv
List of Figures	xv
List of Appendices	xvii
List of Abbreviations	xvii

### CHAPTER ONE

<b>1.0 INTRODUCTION</b>	1
<b>1.1 Background Study</b>	1
<b>1.2 The Importance of Water Quality Assessment</b>	2
<b>1.3 Groundwater Pollution</b>	4
<b>1.4 Justification</b>	6
<b>1.5 Aim and Objectives</b>	7

## CHAPTER TWO

<b>2.0 LITERATURE REVIEW</b>	8
<b>2.1 The Properties of Soil and its Influence on Groundwater</b>	11
<b>2.2 Groundwater and the Aquifer</b>	12
<b>2.3 Factors Affecting the Quality of Groundwater</b>	14
<b>2.4 Sources of Groundwater Pollution</b>	15
2.4.1 Agricultural sources of groundwater pollution	15
2.4.2 Industrial sources of groundwater pollution	19
2.4.3 Domestic of groundwater pollution	21
2.4.4 Natural sources of groundwater pollution	21
<b>2.5 Indicators of Groundwater Quality and their Significance</b>	22
2.5.1 Heavy metals	22
2.5.2 Heavy metals and their significance	23
2.5.3 Some physicochemical indicators of water quality	30

## CHAPTER THREE

<b>3.0 EXPERIMENTAL RESEARCH AND METHODOLOGY</b>	42
<b>3.1 Preamble</b>	42
<b>3.2 Description of the Study Area</b>	42
<b>3.3 Sampling Collection and Preservation</b>	45
<b>3.4 Analysis of Physicochemical Parameters</b>	48
3.4.1 Temperature determination	48
3.4.2 Turbidity determination	48
3.4.3 Potential of hydrogen (pH) determination	48
3.4.4 Electrical conductivity determination	48
3.4.5 Total dissolved solid determination	49
3.4.6 Determination of sulphate, nitrate and phosphate	49
3.4.7 Spectrometric determination of fluoride	49
3.4.8 Determination of chloride	50
3.4.9 Determination of total hardness	51
<b>3.5 Preparation of Samples and Stock Solutions</b>	54
3.5.1 Digestion of water sample for metal analysis	54

3.5.2 Preparation of stock solutions	55
<b>3.6 Atomic Absorption Spectroscopy Analysis and calibration curve</b>	<b>56</b>
<b>3.7 Theory of Atomic Absorption Spectrophotometer (AAS)</b>	<b>57</b>
<b>3.8 Principle of Operation of Photometer</b>	<b>58</b>
<b>3.9 Statistical Analysis</b>	<b>59</b>

## CHAPTER FOUR

<b>4.0 RESULTS</b>	<b>60</b>
<b>4.1 Determination of Physicochemical Parameters</b>	<b>60</b>
4.1.1 Temperature	60
4.1.2 pH	60
4.1.3 Conductivity	60
4.1.4 Total dissolved solids	66
4.1.5 Turbidity	66
<b>4.2 Determination of Chemical Parameters</b>	<b>66</b>
4.2.1 Chloride	66
4.2.2 Fluoride	74

4.2.3 Nitrate	74
4.2.4 Sulphate	74
4.2.5 Phosphate	74
4.2.6 Hardness	74
<b>4.3 Heavy Metals Determination</b>	<b>75</b>
4.3.1 Zinc	75
4.3.2 Manganese	75
4.3.3 Iron	75
4.3.4 Lead	83
4.3.5 Cadmium	83
4.3.6 Copper	83

## **CHAPTER FIVE**

<b>5.0 DISCUSSION</b>	<b>86</b>
<b>5.1 Physicochemical Parameters</b>	<b>86</b>
5.1.1 Temperature	86
5.1.2 pH	86

5.1.3 Conductivity	87
5.1.4 TDS	87
5.1.5 Turbidity	88
5.1.6 Chloride	88
5.1.7 Fluoride	89
5.1.8 Nitrate	90
5.1.9 Sulphate	91
5.1.10 Phosphate	91
5.1.11 Hardness	92
5.2. Heavy Metals	93
5.2.1 Zinc	93
5.2.2 Manganese	94
5.2.3 Iron	94
5.2.4 Lead	95
5.2.5 Cadmium	95
5.2.6 Copper	96

## **CHAPTER SIX**

### **SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS**

<b>6.1 Summary of the Findings</b>	98
<b>6.2 Conclusion</b>	99
<b>6.3 Recommendations</b>	99
<b>References</b>	101
<b>Appendices</b>	109

## LIST OF TABLES

### Table

2.1: Impacts of agricultural activities on water quality	17
2.2: Numerical description of hardness in terms of $\text{mg/cm}^3 \text{CaCO}_3$	41
3.1: Sampling locations and their respective points co-ordinates	45
3.2: Instrumental conditions for AAS determination of metals	56
4.1: Mean and standard deviations for physicochemical parameters	65
4.2: Mean and standard deviations for chemical parameters determination	70
4.3: Mean and standard deviations for the heavy metal determination	77
4.4: Correlation matrix of the physicochemical parameters of the sample	84
4.5: Correlation matrix of the chemical and heavy metals parameters	85

## LIST OF FIGURES

### Figure

3.1: Map of Zamfara State showing where the study area (Kaura-Namoda L.G.A)	43
3.2: Map showing the sampling locations in Kaura-Namoda L.G.A	44
4.1: Comparison of the pH value and WHO, NSDW and USEPA limits	62
4.2: Comparison of conductivity in ( $\mu\text{S}/\text{cm}$ ) and WHO, NSDW and USEPA limits	63
4.3: Comparison of the TDS (mg/l) and WHO, NSDW and USEPA limits	64
4.4: Comparison of the turbidity (NTU) and WHO, NSDW and USEPA limits	65
4.5: Comparison of the chloride in (mg/l) and WHO, NSDW and USEPA limits	68
4.6: Comparison of fluoride in (mg/l) and WHO, NSDW and USEPA limits	69
4.7: Comparison of nitrate in (mg/l) and WHO, NSDW and USEPA limits	70
4.8: Comparison of sulphate in (mg/l) and WHO, NSDW and USEPA.	71
4.9: Comparison of phosphate in (mg/l) and WHO, NSDW and USEPA limits	72
4.10: Comparison of hardness in (mg/l) and WHO, NSDW and USEPA limits	73
4.11: Comparison of zinc in (mg/l) WHO, NSDW and USEPA limits	77
4.12: Comparison of manganese in (mg/l) and WHO, NSDW and USEPA limits	78
4.13: Comparison of iron in (mg/l) and the WHO, NSDW and USEPA limits	79

4.14: Comparison of lead in (mg/l) and WHO, NSDW and USEPA limits	80
4.15: Comparison of cadmium in (mg/l) and WHO, NSDW and USEPA limits	81
4.16: Comparison of copper in (mg/l) and WHO, NSDW and USEPA limits	82

## LIST OF APPENDICES

### Appendix

1	WHO(2006), NSDW (2007) and USEPA (2012) maximum permissible limit in drinking water for some parameters	109
2	One of boreholes sampled for analysis at Kasuwan-Daji (BW11)	110
3	One the boreholes sampled for analysis at Kurya (BW12)	111
4	One of the boreholes sampled for analysis at Sabon-Gari (BW14)	112

## LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
APHA	American Public Health Association
AOAC	Association of Official Analytical Chemist
ASTM	American Society for Testing and Material
BIS	Bureau of Indian Standard
DNA	Deoxyribonucleic acid
EDTA	Ethylenediamine tetraacetate
MDG	Millennium Development Goals
NGO	Non Governmental Organization
NPC	National Population Commission
NSDW	Nigeria Standard for Drinking Water
NTU	Nephelometric Turbidity Unit
RNA	Ribonucleic acid
TDS	Total Dissolved Solid
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
UNESCO	United Nations Educational, Scientific and Cultural Organization
USEPA	United State Environmental Protection Agency
WHO	World Health Organization

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background Study

Water is life and is known to be next to oxygen in the order of importance in the sustenance of life. In fact, about two-thirds of human body is made of water. This colourless, odourless and tasteless liquid is essential for all forms of growth and development and is the basic need for sustaining human economic activities. Not only does water support a wide range of activities, it also plays a central symbolic role in rituals throughout the world and is considered a divine gift by many religions. It is indeed one of the earth's most precious resources (Ayoade and Akintola, 1999; Padma and Namrata, 2009).

Availability of water in the desired quantity and quality, at the right time and place, has been the key to the survival of all civilizations. No other natural resource has had overwhelming influence on human history. As the human population increases, as people express their desire for a better living, as the economic activities continues to expand in scale, the demand for fresh resources continues to grow. Although water is a renewable resource, its availability in space (at a specific location) and time (at different periods of the year) is limited by climate, geographical and physical conditions (Chapman, 1996). Clean water is such scarce resource in the world that only a tiny fraction of the planet's abundant water is available as fresh water. Of the total water on earth only about 97% of it is available as saltwater. More than 2% is

locked up in ice cap or glaciers. Only less than 1% of the earth's total volume of water is available as drinking water. The fresh water we use comes from two sources; surface and groundwater. Precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration is surface water. The subsurface area where all available soil or rock is filled by water is groundwater (Padma and Namrama, 2009).

Although water is essential for human survival, many are denied access to sufficient potable drinking water supply. Globally, about 1.1 billion people rely on unsafe drinking water resources from lakes, rivers and open wells. The majority of these are in Asia (20%) and sub-Saharan Africa (42%). Furthermore, 2.4 billion people lack adequate sanitation worldwide (WHO/UNICEF, 2008). Nevertheless, the key to increase human productivity and long life is good quality drinking water. The provision of good quality water is often regarded as an important means of improving health. In recent time, some parts of the world have been making encouraging progress in meeting the Millennium Development Goals (MDG) on water, but serious disparities remain. Lack of access to improved drinking water is still a serious problem in large portion of Asia and Sub-Saharan Africa (WHO/UNICEF, 2008).

## **1.2 The Importance of Water Quality Assessment**

Water quality assessment process is an evaluation of the physical, chemical and biological nature of a water body in relation to intended uses particularly as it affects human health (Chapman, 1996). The quality of water may be described in terms of concentration and state (dissolved or particulate) of some or all the organic and

inorganic materials present in the water, together with certain physical characteristics of water. It is determined by in-situ measurements and by examination of water samples on site or in laboratory. The main elements of water quality monitoring are, therefore, on-site measurement, the collection and analysis of water samples, the study and evaluation of the analytical results, and the reporting of the findings. The results of analyses performed on a single water sample are only valid for the particular location and time at which the sample is taken (Marky and Raman, 2011).

Unsatisfactory water supply and unwholesome sanitation conditions can result in poor human health. This portends the fact that there are very strong relationship between water and health (WHO/UNICEF, 2004). It is a natural resource whose scarcity or poor quality can cause a chain of unpleasant situations for mankind, especially in developing countries like Nigeria where access to improved drinking water is still a serious problem. There are many ways in which poor water quality and sanitary conditions can give rise to poor health (McJunkin, 1982; WHO, 2008). Water-related diseases are responsible for 80% of all illness/deaths in developing countries, killing more than 5 million people every year (UNESCO, 2007). Water borne diseases, as well as water related diseases which include cholera and other diarrheal diseases, as well as other water related parasitic diseases like schistosomiasis, guinea worm and river blindness are very common (WHO, 2006). In developing countries, thousands of children under the age of five die every day due to drinking of contaminated water (WHO, 2006). Thus lack of safe drinking water supply, basic sanitation and hygienic practice are associated with high morbidity and mortality. In fact, one of the goals of

the United Nations Millennium Development Goals (MDG) is to reduce persistent poverty and promote sustainable development worldwide especially in developing countries through the improvement of drinking water supply and sanitation. The MDG target for water is to half, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation (UNESCO, 2007). The WHO (2008) estimates that if these improvements were to be achieved in Sub-Sahara Africa alone, 434,000 child deaths due to diarrhoea alone would be averted annually.

### **1.3 Groundwater and Pollution**

Groundwater exploitation has been with man way back in the ancient times. The civilizations of the ancient time had its success anchored on water supplies from groundwater as well as surface water. It is reported that in 1183 BC, crusade prisoners in Egypt constructed wells from excavated rocks which they called Joseph's well to ensure the citadels and water supply. The drilling instead of the usual digging of wells began in the 12<sup>th</sup> century with successful drilling of well at Artois of France in 1226 (Osiakwan, 2002).

In the basement rocks, groundwater occurs in the weathered regolith and the fractured zones which sieves as the aquifer zone and usually occurs at depth ranging from 0m to a maximum of 60m. This underground water is protected from surface contamination by a layer of clay and fine grained sediments. The level of groundwater in the borehole may undergo change due to the recharge and discharge. The rate at which a borehole is recharged may vary due to variation in rainfall events, or as influent flows from nearby

streams and rivers. A geological material that stores and transmits groundwater freely is known as an aquifer (Back *et al.*, 1993).

Groundwater, like any other water resource, is not just of public health and economic values (Armon and Kitty, 1994). Water pollution has become a question of considerable public and scientific concern in light of the evidence of their toxicity to human health and biological systems. Heavy metals receive particular concern considering their strong toxicity even at low concentrations (Marcovecchio *et al.*, 2007). Groundwater may contain some impurities or contaminants, which may be above the permissible limit as recommended by WHO even without human activities or disturbances. Natural contaminants can come from many conditions in the water shed or in the ground. This is because water moving through rocks or soil may pick up magnesium, calcium, chlorides, fluorides while some groundwater contain dissolved elements such as arsenic, boron, selenium, lead, cadmium, iron and manganese ( Alloy and Ryres, 2009).

These natural contaminants become a health hazard when they are present in high concentration. Also, groundwater is often polluted by human activities such as the use of fertilizers, animal manure, herbicides, insecticides and pesticides. Other sources of groundwater contamination can originate in the house or other forms such as dormitories, poorly built septic tanks and sewage systems for household wastewater. Leaking or abandoned underground storage tanks and improper disposal or storage waste chemical spills at local industrial sites also contribute to pollution of

groundwater. Abandoned wells that have not been plugged or dismantled provide a potential pathway for water to flow directly from the surface into the groundwater. Open wells can become contaminated by the working fluids such as grease and oil from the pump or contaminants from the surface if the well cap is not tightly closed or if the lining is cracked or corroded (USEPA, 2007).

#### **1.4 Justification**

The major source of drinking water for the inhabitants of Kaura Namoda Local Government Area in recent time is the untreated groundwater obtained from boreholes that are drilled across the entire study area mostly by government agencies and individuals. Most of these boreholes are newly constructed and there is no existing information on their water quality. Meanwhile, the area is known for its intensive agricultural activities and most of these boreholes are located within the vicinities of farm lands and therefore could be contaminated. Also, the area is characterized by massive underlying rocks which could contain minerals capable of impacting on the groundwater. It is on this background that the water quality assessment of these boreholes became necessary so as to ascertain their suitability for drinking purposes by comparing with the WHO, NSDW and USEPA standards for drinking water.

## **1.5 Aim and Objectives of the Study**

The aim of this study was to assess the quality of borehole water sourced from selected boreholes in Kaura Namoda Local Government Area. To achieve this aim, the objectives were as follows:

- i. To determine the level of heavy metals in borehole water which include: zinc (Zn), copper (Cu), iron (Fe), cadmium (Cd), lead (Pb) and manganese (Mn).
- ii. To determine the physicochemical properties of the underground water (borehole) which include: temperature, turbidity, total dissolved solid, electrical conductivity, pH, phosphates, sulphates, nitrates, total hardness, chlorides and fluorides.
- iii. To compare the level of heavy metal and physicochemical parameters obtained from the analysis with the WHO, NSDW and USEPA standards for drinking water to ascertain the suitability of the water for drinking purposes.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

Alexander (2008) investigated the groundwater quality of Mubi town in Adamawa State, Nigeria. Ten groundwater samples from boreholes and dug wells were randomly collected during the raining seasons in the months of June, July and August 2007. The results obtained on analysis showed fluoride as the only physicochemical parameter that was not within the desirable limit for drinking water. From the study, it was concluded that the boreholes and dug well water in Mubi North Local Government Area of Adamawa State were generally suitable for drinking and domestic purposes. The researchers however recommended the need for routine checks of the water quality of the area investigated.

Nkansah and Ephraim (2009) carried out physicochemical analysis of water from selected boreholes in the Bosomtswima-Kanwoma district of Ghana within the month of June, 2008. The results obtained showed variation of the investigated parameters in samples as follow: pH 5.1-6.8, electrical conductivity (EC) 101-111  $\mu\text{S}/\text{cm}$ , turbidity 02-45.0 NTU, colour 5-60, total hardness 3-394mg/l, chloride 9-60mg/l, sulphate 0.5-17mg/l, phosphate 0.1-2.4mg/l, iron 0.1-3.4mg/l, manganese 0.0-0.8mg/l, copper 0.01-0.3mg/l, zinc 0.0-3.3mg/l, cadmium 0.00-0.003mg/l, lead 0.00-0.038mg/l and sodium 6-87mg/l. The study concluded that the water from the region was harmless for house consumption even though there were isolated cases of high level of turbidity and trace metals when compared to the WHO standard for drinking water.

Iyasele and Idiato, (2012) in a study conducted to evaluate the groundwater quality in Edo North of Edo State, Nigeria. Thirty samples of water were collected from thirty boreholes

in different locations and the analysis showed that pH, magnesium and iron on the average had values above the recommended WHO standards for drinking water. While other parameters like the turbidity, ammonium, total hardness, electrical conductivity, total dissolved solid, zinc, lead, cadmium and chloride level were all within the limits as recommended by WHO (2006). It was concluded in the work that the water from the study area needs mild treatment to meet the WHO standard limit for potable water.

Ilechukwu and Okonkwo (2012) carried out an investigation on the heavy metal levels and the physicochemical parameters of borehole water in Nnewi, Anambra State of Nigeria. In the investigation, ten water samples from six randomly selected boreholes were analyzed. The results of the physicochemical analysis were obtained in the following range pH (6.38-8.42), temperature (23-26°C), electrical conductivity (30.22-222.2µS/cm), sodium (0.46-23.0mg/l), potassium (0.07-2.49mg/l), chloride (15.57-36.03mg/l), and hardness (45-275mg/l). The concentrations of heavy metal in the samples were found within the following range; lead (0.02-0.08mg/l), iron (0.02-0.08mg/l), copper (0.03-0.07mg/l), and zinc (ND-0.07). Cadmium was below detectable limit in all of the samples. Apart from lead that was found to be higher than the recommended limit for drinking water by WHO, 2006, all other results obtained were within the recommended limits. The study recommended that potable water sources in the study area should be routinely monitored to ascertain its suitability for drinking purposes.

In another research conducted to evaluate the groundwater quality in villages surrounding Chuka town, Kenya by Ombaka *et al.*, (2013) the results showed that pH, turbidity, fluoride, iron, manganese and lead were all above the recommended level by WHO, 2006

while other parameters investigated were within the required levels of WHO. The study concluded that people using these water resources were at a potential health risk.

Tiimub *et al.*, (2012) investigated the quality of groundwater for drinking at Nkawkaw in eastern region of Ghana. The results obtained included: conductivity (819-1052 $\mu$ S/cm), turbidity (0.59-23.5NTU), manganese (0.038-0.638mg/l), aluminum (0.064-0.47mg/l), total hardness (47.0-56.7mg/l), sulphates (11-15mg/l), fluoride (0.16-1.28mg/l), copper (0.11-0.18mg/l), zinc (0.03 to 0.14mg/l) while arsenic was not detected. The findings concluded that the users of groundwater resources at Nkawkaw were not likely to develop immediate adverse problems as far as the results were concerned but possible defects due to the consumption of water with high levels of conductivity, turbidity, manganese and aluminum which exceeded the WHO, 2006 permissible limit might be encountered if accumulated beyond the tolerable concentrations in the body.

Also, the heavy metal status of boreholes in Calaber South Local Government Area of Cross River, Nigeria has been studied by Njar *et al.*, (2012). Four functional boreholes in the area were sampled in the month of September, 2009. The results obtained showed that the concentrations of iron, zinc and manganese were within WHO maximum permissible limit with mean values of 0.065mg/l, 0.015mg/l and 0.002mg/l respectively. The level of copper, chromium and lead in the sampled boreholes was zero, indicating the absence of detectable limit of these metals in the sampled boreholes. The study recommended that in order to maintain quality status of the boreholes in the area under study, routine monitoring and assessment of borehole should be adopted.

Oruonye and Medjor (2009), investigated the physicochemical composition of borehole water in three resettlement areas of Lake Chad, the results showed that although some of the physical and chemical parameters were within the permissible limits for drinking water, some parameters like nitrates ( $0.70\pm 0.4527$ ) and pH ( $9.13\pm 0.1159$ ) were above the permissible limits. The high concentration of nitrates in all the water samples was of great concern according to the study because of its health implications. The study therefore recommended improved water treatment facilities at the resettlement sites so as to safeguard the people's health.

## **2.1 The Properties of the Soil and Its Influence on Groundwater**

Whenever it rains, some of the water flows on the land surface into the rivers, lakes, streams and some evaporate into the atmosphere while majority seeps into the ground like a glass of water poured on a pile of sand (Clark *et al.*, 1993). The water that eventually gets into the soil is utilized by plant and soil organisms while the water not utilized percolates deeper into spaces in the ground. This water then moves downwards through cracks in the soil and fractures in rocks until it is intercepted by an impermeable layer of clay rock. The water then accumulates in this layer filling up all available spaces until saturation. The top of the saturated zone becomes the water table while the accumulated water below the water table becomes the groundwater. The important properties of soil which determines groundwater contamination are texture, permeability and organic matter content. Soil texture is the relative proportions of sand and clay. Coarse sandy soil allows more water movement by percolation and has less capacity to absorb chemicals than clay. The coarser the texture of the soil, the greater the chances of chemicals reaching the groundwater (Vandre, 1995; Salami, 2003).

Soil permeability is a measure of how fast water moves downwards through the soil. High permeable soils have a greater capacity to lose chemicals to leaching. Applying pesticides or fertilizers to highly permeable soils should be done in such a way that leaching is kept to minimum. Soil organic matter influences soil capacity to hold water and absorb chemicals. The incorporation of organic matter into a soil will increase the capability and reduce the movement of chemicals downwards via leaching (Vandre, 1995).

## **2.2 Groundwater and the Aquifer**

Groundwater is a complex chemical solution which is in a dynamic state. It is held in the pore space of the sediments such as sands or gravels or in fissures of fractured rock such as crystalline rock and limestone. The body of rocks or sediments containing the water is termed an aquifer and the upper water level in the saturated body is termed the water table. Typically, groundwater has a steady flow pattern and its velocity is governed mainly by the porosity and permeability of the material through which water flows, and is often up to several orders of magnitude less than that of surface waters (Balek, 1977; Obaliagbon and Okiemen, 2007).

Aquifer as an underground formation is of three basic types: hard crystalline rock, consolidated sedimentary formations and unconsolidated sediments. The hard crystalline rocks generally have little or no porosity, and the existence of aquifer depends on fractures and fissures in the rock mass providing porosity and pathways for ground water movement. Consolidated sedimentary formations are often thick and extensive, and sometimes artesian. The permeability of these formations is largely due to fissures (fractures, faults, and bedding planes). Porosity is also significant for the movement and

storage of some pollutants. Dissolution of rock can increase the permeability. The dissolution of carbonates, in particular is responsible for the formation of karsts aquifers, which can have large underground caverns and channels yielding substantial quantities of water. Unconsolidated sediments occur as thin superficial deposits over other rocks or as thick sequences in the major river or lake basins. Porosity and permeability are related to grain size. Sand and gravel deposits can provide important and high-yielding aquifers whereas silts and clays are less productive. In the largest river basins, thick sedimentary deposits may contain many layers of different materials built up over long periods of time, producing important multi-aquifer sequences (Back *et al.*, 1993; Acworth, 2007).

Aquifers may be confined or unconfined. A confined aquifer is overlain by an impermeable layer that prevents recharge or contamination by rainfall or surface water. Recharge of confined aquifer occurs where the permeable rock outcrops at or near the surface, which may be some distance from the area of exploitation. This feature may make control of quality and of pollution more difficult. Unconfined aquifers are overlain by a permeable, unsaturated zone that allows surface water to percolate down to the water table. Consequently, they are generally recharged over a wide area and are often shallow with a tendency for interaction with surface water. The vulnerability of confined aquifer to pollution is generally less than that of the unconfined aquifers and contaminant cannot easily percolate the water table. If contamination does occur, however, it is often difficult to remedy because confined aquifers are usually deep and the number of points where contaminated water may be pumped out is limited. Given the limited outflow, contaminants may also be increasingly concentrated in confined aquifers and this may restrict abstraction of water. The greater vulnerability of unconfined aquifers to

contamination is as a result of the wider area over which they are recharged and in which contamination may enter, and the greater interaction with polluted surface water bodies which may lead to contaminants movement into groundwater. The risk of contamination will depend on the depth of the overlying unsaturated layer, the rate of infiltration to the water table and the land use in areas surrounding groundwater sources (Hem, 1984; Back *et al.*, 1993).

### **2.3 Factors Affecting the Quality of Groundwater**

The quality of groundwater reflects the composition of the recharge water, the interactions between the water and the soil, soil-gas and rocks with which it comes into contact in the unsaturated zone, and in addition, the reaction that occur within the aquifer. As a result, considerable variation can occur in quality of groundwater even in the same general area, especially where rocks of different composition and solubility occur. The major processes influencing water quality in aquifers are physical (dilution, filtration and gas movement), geochemical (complexation, acid-base reactions, oxidation-reduction, precipitation-solution, and biochemical (microbial respiration and decay, cell synthesis) (Nash and McCall, 1994).

Groundwater quality is also influenced by the effects of human activities which include domestic sewages and latrines, municipal solid waste, agricultural waste and manure, industrial wastes which cause pollution at the land surface because most groundwater originates by recharge of rain water infiltrating from surface. The rain water itself may have an increased acidity due to human activity. The unsaturated zone help reduce the concentrations of some pollutants entering groundwater especially micro-organism, but it

can also acts as a store for significant quantities of pollutants such as nitrates, which may eventually be released. Some contaminants of the groundwater enter the groundwater directly from abandoned wells, mines, quarries and buried sewage pipes which by-pass the unsaturated zone (Abbott *et al.*, 1986; Edmund, 2004).

Therefore the vulnerability of aquifer to pollution will depend, in part, on human activity and on land use in the areas where rainfall or surface water may percolate into the aquifer. In these areas, contamination of surface water or of the unsaturated layer above an aquifer is likely to cause groundwater pollution (Chilton, 1996; Edmund, 2004).

## **2.4 Sources of Groundwater Pollution**

Water pollution is a natural or induced change in the quality of water that renders it unsuitable or dangerous for its intended purpose (Daxer, 2010). The principal sources of groundwater pollution are categorized as agricultural, industrial, domestic and natural sources.

### **2.4.1 Agricultural sources of groundwater pollution**

Agriculture is a major cause of degradation of surface and groundwater resources through erosion and chemical run-off. The associated agro- food processing industry is also a significant source of organic pollution in most countries. Aquaculture is now recognized as a major problem in freshwater, estuarine and coastal environments, leading to eutrophication and ecosystem damage (Rhoades, 1993).

Spraying of insecticides, bush burning, fertilizers, herbicides and animal waste applications are agricultural sources of groundwater contamination. The means of agricultural

contamination are varied and numerous. Drainage system is considered by many farmers to be a profitable agricultural practice. So many of them may install drain tiles or drainage wells to a better productivity. These drainages purposefully made to increase productivity will later serve as direct conduct to groundwater for agricultural waste when washed down (Andreoli, 1993).

Also, farming activities generally causes the loosening of soil and rock particles, thereby facilitating the leaching and erosion of component mineral either deeper into the ground system or as washout into the surface water bodies (Andreoli, 1993).

**Table 2.1: Impacts of agricultural activities on water quality**

Agricultural activity.	Surface water	Groundwater.
Tillage/ploughing	Sediment/turbidity: sediments carry phosphorus and pesticides adsorbed to sediment particles; siltation of river beds and loss of habitat, spawning ground, etc.	
Fertilizing	Run-off of nutrients, especially phosphorus, leading to eutrophication causing taste and odour in public water supply, excess algae growth leading to de-oxygenation of water and fish kills.	Leaching of nitrate to groundwater; excessive levels are a threat to public health.
Manure spreading	Carried out as a fertilizer activity; spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen leading to eutrophication and potential contamination.	Contamination of groundwater, especially by nitrogen
Pesticides	Run-off of pesticides leads to contamination of surface water and biota; dysfunction of ecological system in surface waters by loss of top	Some pesticides may leach into groundwater causing human health problems from contaminated wells.

	<p>predators due to growth inhibition and reproductive failure; public health impacts from eating contaminated fish. Pesticides are carried as dust by wind over very long distances and contaminate aquatic systems thousands of miles away (e.g. tropical/subtropical pesticides found in Arctic mammals).</p>	
Feedlots/animal corrals	<p>Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also contamination by metals contained in urine and faeces.</p>	<p>Contamination of the groundwater with metals through leaching.</p>
Irrigation	<p>Run-off of salts leading to salinization of surface waters; run-off of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts.</p>	<p>Enrichment of groundwater with salts, nutrients (especially nitrate).</p>

Clear cutting	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; causes public health problems due to loss of potable water.	Disruption of hydrologic regime, often with increased surface run-off and decreased groundwater recharge; affects surface water by decreasing flow in dry periods and concentrating nutrients and contaminants in surface water.
---------------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

**Source:** Edwin (1996) in Control of Water Pollution from Agriculture.

#### **2.4.2 Industrial sources of groundwater pollution**

A range of hazardous substances may be released to the environment from industrial sites, depending on specific industrial processes. Among these, the mobile compounds reach groundwater. Less mobile compounds may also contaminate groundwater where process wastewaters are discharged through soakage pits. The most common contaminants to reach groundwater in significant quantities from industrial sites are the chlorinated solvents such as trichloroethene (TCE) and perchloroethylene/tetrachloroethene (PCE) but, in specific circumstances, concentrations of many others such as chromium and petroleum constituents may be elevated. Mining can give rise to a range of inorganic contaminants and acid waters, in particular, can result in the accelerated leaching of metals into ground water. However, the most common contaminant for industrial sites is probably oil from machinery and vehicles. In contrast to groundwater contamination from agriculture, larger industrial operations tend to be localized point sources of pollution. This is not the case for

small-scale enterprises, particularly where these are not connected to centralized sewage (Patric *et al.*, 1987; Lerner, 1996).

Also, disposal of waste associated with industrial activities contributes to the contamination of groundwater. Some businesses usually have no access to sewer system relying on shallow underground for waste disposal. They use cesspool dry holes to send the wastewater generated into septic tanks without treating the wastewater leading to contamination of groundwater sources. The waste and waste water disposal practices of certain type of business, such as automobile service stations which makes use of grease, fuel etc, dry cleaners, electrical component or machine manufacturer, photo processors, sludge from chemical industries and metal platters or fabricators are potential contributors to contamination of groundwater because the waste they generate is likely to contain chemical substances capable of contaminating the ground water when washed down. Even low concentration of certain contaminant can accumulate over time to pollute the groundwater (Genereux and Nielsen, 1991).

Underground and above ground tanks holding petroleum products, acids, solvents and chemicals can develop leaks from corrosion, defects, improper installation or mechanical failure of pipes and fittings are possible sources of groundwater contamination. Mining of fuel and non-fuel minerals can create many opportunities for ground water contamination through the mining process itself, disposal of wastes and processing of the ores and the waste it creates (Genereux and Nielsen 1991; USEPA, 2007).

### **2.4.3 Domestic sources of groundwater pollution**

Domestic waste dumped or buried in the ground can contaminate the soil and leach into the groundwater. Improper storing or disposal of household chemicals such as paints, synthetic detergents, solvent, oils, medicine, disinfectants, batteries, and pesticides are potential groundwater contaminants. When stored in basements with floor drains, spills and flooding may induce such contaminants into the groundwater when accumulated over time. Effluents discharged from home and entering a septic system or sewer system may contain detergents from dish washing and laundry, organic compounds from garbage and bacteria, nitrates and sulphates from sewage, grease or oils (Edwin, 1996; USEPA, 2007).

Fertilizers, herbicides, insecticides, fungicides and pesticides applied to the lawn and garden contain hazardous chemicals that can travel through the soil and may contaminate the groundwater when accumulated through time (USEPA, 2007).

### **2.4.4 Natural sources of groundwater pollution**

Naturally, groundwater quality can be affected even when there is no human activity influencing it. This is because groundwater may contain some natural impurities capable of impacting on the water quality. The types and concentrations of natural impurities depend on the nature of the geological materials through which the groundwater moves and the quality of the recharge water (Ward, 1995).

Natural contaminants of groundwater can come from many conditions in the water shed or in the ground. Groundwater moving through rocks or soil may pick up wide range of compounds which may include magnesium, calcium, chloride and fluorides. Some aquifers have high natural concentrations of dissolved constituents such as arsenic, boron, and

selenium. The effect of these natural sources of contamination of groundwater on water quality depends on the type of contaminants and their concentrations in relation to their recommended permissible limit. Other contaminants that can occur naturally may include: aluminum, sodium, barium, chromium, copper, iron, lead, manganese, mercury, zinc, nitrates and sulphates (Ward, 1995; USEPA, 2007).

## **2.5 Indicators of Groundwater Quality and their Significance**

### **2.5.1 Heavy metals**

Heavy metals are a collection term that applies to metals and metalloids with specific gravity 5.0 or greater, especially those ones that are toxic to organisms (Schiele, 1991). Heavy metals are natural components of earth's crust. Therefore, there is a range of normal background concentrations of these elements in the soil, sediments, water and living organism. It is the concentration of the metals relative to the normal background concentration which determines whether or not a substance is polluted. They exist in water in colloidal, particulate and dissolved phases with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments, leaching of ore deposits and volcanic extruded products) or anthropogenic origin (Adepoju *et al.*, 2009). The anthropogenic availability of heavy metals in substances which include water are consequences of several activities like chemical manufacturing, painting and coating, mining, extractive metallurgy, nuclear and other industries. Heavy metals can also enter water supply system through consumer waste or even from acid rain breaking down soils and releasing heavy metals into streams, lakes, rivers and groundwater (Sayar *et al.*, 2008).

Some heavy metals are essential to maintain the metabolism of human body in a small but critical concentration for healthy growth. Examples of such metals include copper, manganese and zinc. However, excess concentration causes toxicity. Some have no known essential biochemical functions and are toxic at concentrations above the tolerance of the organism and examples include arsenic, cadmium, mercury and lead. Heavy metals at excess concentration are dangerous because they to bio-accumulate in the body (Hoidgate, 1979; Zheng *et al.*, 2008).

## **2.5.2 Heavy Metals and their Significance**

### **A. Iron**

Iron is the most abundant heavy metal and the second most abundant metal in the earth's crust. It account for at least 5% of the earth crust. Concentrations of iron in drinking water are normally less than  $0.3\mu\text{g}/\text{dm}^3$  but may be higher in countries where various iron salts are used in coagulating agents in water treatment plants and where cast iron, steel and galvanized iron pipes are used for water distribution (USEPA, 2007). Iron in water may be present in varying quantities depending on the geological area and other chemical components of the water way. Iron contamination of borehole water occurs when rainwater infiltrates the soil and the underlying geological formation dissolves iron causing it to seep into the aquifer that serves as source of groundwater for boreholes (USEPA, 2007).

Iron is mainly present in groundwater in the form of soluble ferrous iron or insoluble ferric iron. Water containing ferrous iron is clear and colourless because the iron is completely dissolved. When exposed to air in the pressure tank or atmosphere the water turns cloudy and a reddish brown substance begins to form. Measurement of iron in water is important

because high concentrations of it affect the taste and odour of the water. High concentration of iron in water also forms oxy-hydroxide precipitate that stains laundry, fixtures and table wares which is difficult to remove (APHA, 1985).

Iron is essential for good health and helps in transporting oxygen in the blood. Iron compounds are employed for medicinal purposes in the treatment of anaemia, when the amount of haemoglobin or the number of red blood corpuscles in the blood is lowered. Limits of  $0.3\text{mg/dm}^3$  of iron is recommended in drinking water (ASTM, 2004). The minimum daily requirement of iron is ranged from about 10 to 50mg per day (WHO, 2008).

## **B. Copper**

Copper may be found in water through the natural process of dissolution of minerals, from industrial discharges, through its use as copper sulphate for controlling biological growth in some reservoirs and distribution system or through corrosion of copper alloy water pipes. Most copper contamination in drinking water happens in the water delivery system as a result of corrosion of copper pipes or fittings (ASTM, 2004).

Copper is an essential substance to human life because it aids in metabolism. The adult daily requirement has been estimated for respiration and it is usually present in most fruits, vegetables and sea foods (Findal, 2008). WHO (2004) reported that copper causes acute gastro-intestinal discomfort, nausea, liver and kidney damage at concentrations above  $3\text{mg/dm}^3$  in water. It also gives rise to staining of sanitary ware and people with Wilson's disease are at a greater risk for health effects from over exposure to the element. Since copper exhibit harmful effects and drinking water may be significant ways exposure to the

element can occur, it is important to know how much copper is in drinking water. A metallic taste is usually found in drinking water before its level is considered high enough to create adverse effect (WHO, 2004).

### **C. Lead**

Lead in the environment arises from both natural and anthropogenic sources. Exposure can occur through drinking water, food, air, soil and dust. It is relatively a minor element in the earth crust. According to Musa (1986) lead contamination of water is primarily as a result of the use of bad pipes, lead-glazed tanks, metallic lead containers, atmospheric pollution or by addition of purifying chemicals during water purification. Contribution of lead may arise from fuel gas (vehicular), coal combustion, burning or attrition of lead painted surface, and industrial processes. Apart from the known case of the addition of lead tetra-ethyl in gasoline, there are other numerous examples which can lead to the contribution of lead to the environment. They include the heavy duty oil which contains lead compounds as additives and many other types of lubricating oil which are usually supplemented with lead compounds (Csuros and Csuros, 2002).

Except in related cases, lead is probably not a major problem in drinking water although it potentially exists in cases where lead pipes are still used. In humans, exposure to it can result in a wide range of biological effects depending on the level and duration of exposure. High levels of exposure may result in toxic biochemical effect in humans which in turn causes problems in the synthesis of haemoglobin, effects on the kidneys gastrointestinal tract, joints and reproductive system, acute or chronic damage to the nervous system. Lead accumulates in tissues and bones and these causes their destruction

(Sridhar *et al.*, 2000). The presence of lead in the body is indicated by lead blood levels, expressed as micrograms of lead per deciliter of blood ( $\mu\text{g}/\text{dl}$ ). Blood lead level of  $10\mu\text{g}/\text{dl}$  and higher may contribute to decreased cognition, nervous system damage and stunted growth (Schwart and Otto, 1987).

Acute toxicity from lead is not usual, as lead is relatively insoluble cumulative poison. Reported symptoms include fatigue, sleep disturbance, and constipation, followed by colic, anaemia and neuritis (Csuros and Csuros, 2002). Lead interacts with a number of other metals. A typical detoxification treatment involves chelating of lead with calcium ethylenediamine tetraacetate (EDTA). Repeated treatment removes lead out of bone tissue. Lead arthralgia (joint pains) is lead induced gout caused by its interference with uric acid excretion by the kidneys. Lead toxicity affects the kidney and causes tubular dysfunction or nephrotoxicity. It is associated with the depression of many endocrine functions, particularly the adrenal glands (Csuros and Csuros, 2002).

#### **D. Manganese**

Manganese is an essential element occurring in concentration hardly toxic to the environment. It is available in plants and animal cells in high levels especially in mitochondria where it helps in the activation of some enzymes (Schiele, 1991). Manganese deficiency causes disorders in menstrual cycle, still birth, and low birth weight as well as growth impairments in rats, mice, cow (Matrone *et al.*, 1977). Manganese deficiency is manifested by dermatitis, pigment changes, deficiencies in hair growth, hypolipidemia, and prothrombin deficiency (Doisy, 1972). Manganese also acts as a catalyst in the formation of chlorophyll and increases the availability of calcium, magnesium and phosphorus in

soils. It is a troublesome element in water even when present in small quantities. Manganese is less commonly found in appreciable quantities in natural waters. It occurs naturally in both surface and groundwater, as a result of weathered and solubilized manganese from soil and bedrock. In the presence oxygen or when chlorine is added, it tends to deposit out from water thereby coating the interior of pipes as black slime. The slime eventually gets detached from the pipe walls and is conveyed through the service pipes to the consumer's premises where it is most objectionable (Edward, 2010).

Measurement of manganese in water is important because it impacts a purple or brown colour to water and laundered plumbing fixtures. It also impacts a taste of coffee and tea to water (Edward, 2010). Manganese is often associated with iron in water and has a behavior which is similar, except that the deposits are cumulative. High quantities of manganese are toxic but it is seldom accumulated to such level. It is often regarded as one of the least toxic metals by the oral route because homeostasis limits the gastrointestinal absorption (Schiele, 1991). However, there is increasing evidence of neurotoxicity by the oral route especially in infants. They have a more sensitive nervous system than adults, and their homeostasis is not fully developed. While breast milk generally contains low manganese concentrations, significant amount can be found in infant formula. Moreover, because infant formula is normally sold in powdered form, the manganese concentration of the water with which the formula is mixed may contribute significantly to the infant's manganese exposure. Generally, a less amount of manganese can be tolerated in a supply system than iron because, although deposition of manganese is slow, it is continuous and the onset of serious troubles may not be apparent for several of years (Twort *et al.*, 1974).

The current edition of the WHO guidelines for manganese in drinking-water quality was published in 2006 and presented a health based guideline value of 0.4mg/l (WHO, 2006).

#### **E. Cadmium.**

Cadmium is found in low concentrations in most rocks. Its deposit occurs as traces and can serve as sources of cadmium in groundwater or surface water. It is produced as a by-product of zinc and lead mining and smoldering. Cadmium is discarded as used batteries in some cases. It may exist in water as hydrated ions or as inorganic complexes such as carbonates, hydroxides, chlorides or sulphates or as organic complexes with humic acid (Asolkar *et al.*, 2002).

Cadmium may enter drinking water via weathering of soils and bedrocks, corrosion of galvanized pipes, atmospheric decomposition of direct discharge from industrial operations, leakages from landfills and contaminated sites and the dispersive use of sludge and fertilizer in agriculture. Much of the cadmium entering fresh waters from industrial source may rapidly adsorbed by particulate matter and thus sediment may be a significant sink for cadmium emitted to the aquatic environment (WHO, 2004; Asolkar *et al.*, 2002). Rivers containing excess cadmium can contaminate surrounding land, either through irrigation for agricultural purposes, dumping of dredged sediments or flooding. It has been revealed that rivers can transport cadmium for considerable distances up to 50km from source (WHO, 2004).

Cadmium derives its toxicological properties from its chemical similarity to zinc. In human, it is found to be potentially toxic especially in long term exposure. High exposure can lead to renal dysfunction, obstructive lung disease, lung cancer, vomiting, diarrhoea,

sensory disturbance, muscle cramps, convulsion and liver injury. It also produces bone defects in human and animals. It often accumulates in aquatic life, adding to the danger of fish that may have been exposed to high levels of cadmium (Evangeton, 1998; USEPA, 2007).

## **F. Zinc**

Zinc is found in some natural water most frequently in areas where it is mined. The concentration of zinc in natural waters is generally low, but on some occasion, high levels have been reported. High levels of zinc are always found in waters flowing in through a bedrock system containing zinc deposits. The principal zinc ores are sulphides such as sphalerite and wurtzite. Zinc is mainly used in galvanizing; hence its high concentration in drinking water can be traced to the use of galvanized pipe or plumbing materials (Shelton and Scibila, 1998). In natural surface water the concentration of zinc is usually below  $10\mu\text{g}/\text{dm}^3$  and  $10\text{-}40\mu\text{g}/\text{dm}^3$  in some groundwater. Measurement of zinc in water is important because it is essential in trace amounts for plants and animal growth. In mammals, it plays a vital role in the biosynthesis of nucleic acids, RNA polymerases, and DNA polymerases and thus, is involved in the healing processes such of tissues in the body. Other physiological processes such as hormone metabolism, immune response, stabilization of ribosome and membranes also require zinc. Clinical manifestations of zinc deficiency in animals include growth retardation, testicular atrophy, skin changes, and poor appetite. Zinc is ubiquitous in the environment and its deficiency in humans and animals may be considered an unlikely problem. Nevertheless, zinc deficiency and related problems have been reported in humans, birds, and plants (Shelton and Scibila, 1998). Concentration above  $4\text{mg}/\text{dm}^3$  can render water unpalatable causing a bitter astringent

taste. Test indicates that 5% of a population could distinguish between zinc-free water and water containing zinc as zinc sulphate at level of  $4\text{mg/dm}^3$  (UNEP and WHO, 2008).

### **2.5.3. Some Physicochemical Indicators of Water Quality**

#### **A. Temperature**

Temperature has effect on properties such as alkalinity, electrical conductivity and solubility of gases. Temperature is primarily an important aesthetic criterion for drinking water. Generally, cool water is more palatable than warm water and the drinking water treatment efficiency is temperature dependent (WHO, 2008). The turbidity and colour of filtered water may be indirectly affected by temperature, as low water temperatures tends to decrease the efficiency of water processes by affecting floc formation rates and sedimentation efficiency. Chemical reaction rates increases with temperature, and this can lead to greater corrosion of pipes and fittings in closed systems. Scale formation in hard water will also increase with greater temperature and high water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems (Metcalf and Eddy, 2009).

#### **B. Electrical conductivity (EC)**

Conductivity is defined as the ability of a solution to carry electric current. It depends on the total concentration, mobility, valence and temperature of ions in solution. Electrolytes in solution dissociate into cations and anions and impact conductivity. Most dissolved inorganic substances are in the ionized form in water and contribute to conductance. The measurement of conductance of drinking water sample gives rapid and practical estimate of the variation in dissolved mineral of water supply (WHO, 2006). The electrical

conductivity of water increases with the concentration of dissolved solid. Electrical conductivity can be used as a fast method of indirect measure of total dissolved solid (TDS), but the factor used to convert EC to TDS will depend on the type of dissolved solid present in the water (Metcalf and Eddy, 2009).

### **C. pH**

pH is the negative logarithm to base ten of hydrogen concentration in the solution. It is the measure of acidity or basicity of solution. Natural water often has a pH of 4 to 9 and is slightly basic as a result of bicarbonates and carbonates of the alkali and alkaline earth metals. The content of  $H^+$  ions in natural water is mainly related to the quantitative ratio of carbonic acid and its ions. Therefore, dissolved carbon dioxide ( $CO_2$ ) increases the acidity of natural water. Shelton and Scibila (1998) reported that high degree of mineralization associated with alkaline water, will result in the encrustation of water pipes and water using appliances.

The determination of pH involves the activity of hydrogen ions by potentiometric measurement using a standard hydrogen electrode and a reference electrode. The measurement of pH is influenced by temperature in two ways. These include the mechanical effect caused by changes in the properties of the electrode and the chemical effects caused by the equilibrium changes (Marky and Raman, 2011).

### **D. Turbidity**

Turbidity is the term used to describe suspended matters in the water body. It is most common in surface waters and usually uncommon in groundwater except in shallow wells. Turbidity of natural water is caused by the presence of foreign matters such as clay, mud,

organic matter, bacteria, and algae. Higher turbidity levels are often associated with high level of disease-causing micro-organisms such as viruses, parasites and bacteria. It may also be due to the presence of inorganic particulate matter in some groundwater or sloughing of bio film within the distribution system. It expresses the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample (WHO, 2008).

Turbidity causes the staining of sinks and fixtures as well as the staining of fabrics. Usually turbidity is measured in NTU (Nephelometric turbidity units) and typical drinking water has turbidity level of 0 to 1 NTU. Turbidity can also be measured in ppm (parts per million) and its size is measured in microns. Turbidity can be particles in the water consisting of finely divided solids ranging from 0.001 to 0.150mm (1 to 150 microns). Typically, turbidity can be reduced to 75microns with a cyclone separator, then reduced down to 20microns with standard back washable filter and can be reduced further to as low as 10microns using a multimedia filter (USEPA, 2007).

#### **E. Total dissolved solids**

Total dissolved solid (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in water. It is the solids that are in dissolved state in solution and can pass through a 2.0 micrometer or smaller nominal average pore size while suspended solids are those ones that do not pass the filtration. The amount of dissolved solids also termed filterable residue is the difference between the total solids and the suspended solid contents of a water sample. The principal constituents are usually calcium, magnesium, sodium and potassium cations. Other constituents in the form of anions

include carbonates, hydrogen carbonates, chlorides, sulphates and nitrates (Marky and Raman, 2011).

Water with high dissolved solids is generally of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer. The palatability of drinking water has been rated by panel of tasters in relation to its TDS level as follows:

1. Less than 300mg/l \_\_\_\_\_ Excellent.
2. 300 to 600mg/l \_\_\_\_\_ Good.
3. 600 to 900mg/l \_\_\_\_\_ Fair.
4. 900 to 1200mg/l \_\_\_\_\_ Poor.
5. Greater than 1200mg/l \_\_\_\_\_ Unacceptable (APHA, 1989).

However, water containing extremely low concentrations of TDS may be unacceptable because of its insipid taste (Bruvold and Ongerrh, 1969).

Total dissolved solids in water originate from natural sources, sewages, urban and agricultural run- off and industrial waste water. Certain components of TDS such as chlorides, sulphates, magnesium, calcium and carbonates affect corrosion or encrustation in water distribution systems and household appliances. Such scaling can shorten the service life of these appliances. Water with concentrations of 500mg/l of TDS is usually acceptable to consumers (WHO, 2008).

## **F. Nitrates**

Nitrate occurs naturally in mineral deposits such as sodium or potassium nitrate in soil, sea water, fresh water, biota and atmosphere. Nitrate concentration in natural water is usually

in minute quantities but can reach high levels as a result of pollution from chemical fertilizers applications, drainage from livestock feeds, as well as domestic and industrial source. In general, vegetables are the main source of nitrate intake when the level in drinking water is below 10mg/l. When nitrate level in drinking water exceeds 50mg/l, such drinking water becomes the main source of total nitrate intake for the consumer (Makhijani and Manohara, 1999).

High levels of nitrate in excess of 50mg/l in water cause methemoglobinemia (blue baby syndrome), a condition found especially in infants less than six months. The stomach acid of an infant is not strong as in older children or adults. This causes an increase in bacteria that readily convert nitrate to nitrite ( $\text{NO}_2^-$ ). This nitrite then oxidizes haemoglobin in the blood stream to methemoglobin, thus limiting the ability of the blood to carry oxygen. Severe methemoglobinemia can result in brain damage and death. Another health effect of nitrate in drinking water is shortness of breath. (Somaini and Quirindongo, 2004; WHO, 2004). Reverse osmosis will remove 92-95% nitrate. Anion exchange resin will also remove nitrate as well as distillation. The WHO standard for nitrate in drinking water is 50mg/l for short time exposure (WHO, 2004).

### **G. Sulphate**

Sulphate is an ion that is found in natural water. Most sulphate compounds originate from the oxidation of sulphur containing ores, the presence of shale and the existence of industrial waste. Minerals that contain sulphates include magnesium sulphate (Epsom salt), sodium sulphate and calcium sulphate (gypsum). As water moves through the soil and rock formations that contain sulphate minerals, some of the sulphate dissolves in the water into

the groundwater. Also, as animals die, sulphides produced are oxidized to sulphate naturally though some may escape to the air as odorous material (Makhijani and Manohara, 1999; USEPA, 2007).

It do not adversely affect the health of human consumers at concentration below the recommended standard but high concentrations in drinking water above 500mg/l causes laxative effect when combined with calcium and magnesium, the two most common components of hard water. The effect of sulphate depends largely on the body mass of an animal - the smaller the animal, the greater the effect. Increased sulphate levels causes deficiencies in trace minerals which can contribute to a depressed growth rate and infertility in herd. The most serious is thiamine deficiency. The major physiological effect resulting from the ingestion of large quantities of sulphate leads to catharsis, dehydration, and gastrointestinal irritation. Water containing magnesium sulphate at levels above 600 mg/l acts as a purgative in humans. The presence of it in drinking water can also result in a noticeable taste (USEPA, 2007). Sulphate ion is precipitated in an acid medium with barium chloride to form barium sulphate. Light absorbance of barium sulphate suspension by uv-visible spectrophotometer at 420nm is used to determine the sulphate concentration. This is done by comparing with the calibration curve (APHA, 1989). A maximum permissible limit of 250mg/l recommended for sulphate in drinking water was established, based on taste considerations. However, because of the gastrointestinal effects resulting from ingestion of drinking-water containing high sulphate levels, it was recommended that health authorities be notified of sources of drinking-water that contain sulphate concentrations in excess of 500 mg/l. The presence of sulphate in drinking-water may also

cause noticeable taste at concentrations above 250mg/l and may contribute to the corrosion of distribution systems (WHO, 2006).

## **H. Phosphate.**

Phosphorus is an essential nutrient for micro-organisms and exists in water bodies as both dissolved and particulate species. Phosphates exist in three forms and they include orthophosphates, metaphosphates (polyphosphates) and organically bound phosphate. Each compound contains phosphorous in a different chemical formula. Changes between these forms occur continuously due to the decomposition and synthesis of organically bound and oxidized inorganic forms (WHO/UNICEF, 2008).

Natural sources of phosphates include the weathering of phosphorus bearing rocks and the decomposition of organic matter. Domestic wastewaters particularly those containing detergents, industrial effluents, breakdown organic pesticides which contain phosphates and fertilizer run-off contribute to elevated levels of phosphates. Rainfall can cause varying amounts of phosphates to wash from farm soil into nearby waterways, leaching into groundwater. Phosphate stimulates the growth of plankton and aquatic plants which provides food for fishes. Phosphates may not be toxic to human and animals except when the recommended level is exceeded. Digestive problems could occur from high levels of phosphates. Phosphorus is an essential component of the biological cycle in water bodies, and phosphate determination is often included in basic water quality survey and monitoring. High concentration of phosphate indicates pollution. The phosphate level in drinking water is not regulated but the World Health Organization has provided a maximum safe level of 5.0mg/l and daily amount intake not to exceed 800mg per day (WHO/UNICEF, 2008; Makhijani and Manohara, 1999).

## **I. Chlorides.**

Chloride (Cl<sup>-</sup>) is one of the anions found in water and is generally combined with calcium, magnesium or sodium. Some common chlorides include sodium chloride (NaCl) and magnesium chloride (MgCl<sub>2</sub>). Chlorides are present in natural waters from soil, atmospheric deposition (sea salt), sewage effluents and industrial waste containing salts. They may get into surface water from several sources including rocks containing chlorides, agricultural run-off, waste water from industries, oil well wastes and effluent waste water from waste water treatment plants (Shaw, 1994).

In combination with a metal such as sodium, it becomes essential for life. Small amounts of chlorides are required for normal cell functions in plants and animal lives. Environmental impacts of chlorides are usually not harmful to human health; however, prolonged exposure to excess of it above the permissible limit had been linked to heart and kidney diseases (Shaw, 1994). Chloride in drinking water though not considered as being source of harm to human health has maximum permissible level of 250mg/l which is as a result of the objectionable salty taste produced in drinking water. Sodium chloride may impact a salty taste at 250mg/l; but other chloride salts like calcium and magnesium chloride salty taste are not usually detected until levels of 1000mg/l are reached. High chloride content has a deleterious effect on metallic pipes as well as agricultural plants. Excessive chloride concentration increases rates of corrosion metals in distribution system and this could lead to increase in concentration of metals in supply (USEPA, 2007).

## **J. Fluorides.**

Amongst the various elements, fluorine is thirteenth in the order of abundance in the earth's crust. Fluorine gas is the most electronegative of all known elements with electronegativity value of 4.0 and the most reactive (Pauling, 1960). It rarely occurs free in nature, therefore in minerals, fluorine is generally found as the fluoride ion ( $F^-$ ). Occurrence of fluoride in groundwater has drawn worldwide attention due to its considerable impact on human physiology (Kundu *et al.*, 2001). Fluorine occurs mainly as free fluoride ion in natural waters, though fluoride complexes of Al, Be, B and Si are also encountered under specific conditions (Kundu *et al.*, 2001).

Up until the 1960s, the ingestion of fluoride from water (whether natural or supplemented) probably represented the bulk exposure for both adults and children in most populations (Murray *et al.*, 1991). Since then however, the availability of fluoride from sources has changed significantly and fluoride in drinking water is now recognized as just one component of an individual's total fluoride intake. For example, in 1970s, fluoride started to be added to toothpastes and by 1978, 96% of toothpastes on the market contained fluoride, usually at concentrations of 1000 to 1500ppm (though lower fluoride toothpastes containing about 500ppm fluoride are now available for use by children (WHO, 2008).

Fluoride ion has a dual significance in water supplies. High concentration of fluoride ion causes dental fluorosis. Dental fluorosis is a form of defect of tooth enamel. It presents a hypo-calcification effect, while clinically it ranges from barely visible white striations on the teeth through gross defects and staining of enamel. There are about 90 different causes of enamel defects, of which three or four causes are common. Minor forms of dental

fluorosis are not aesthetically troublesome and may even enhance the appearance of dental enamel (Jenkins, 1978; Periakali *et al.*, 2001).

Generally, ingestion of water having fluoride concentrations above 1.5 to 2.0 mg/l may lead to dental motting, an early sign of dental fluorosis which is characterized by opaque white patches on teeth. In advanced stages of dental fluorosis, teeth display brown to black staining followed by pitting of teeth surfaces (Pillai and Stanley, 2002; Hamilton, 1992). However, concentrations less than 0.8mg/l result in dental caries. Hence it is important to maintain the fluoride concentrations between 0.8 and 1.0 mg/l in drinking water. The assimilation of fluoride into the human body from potable water at the level of 1mg/l enhances bone development and prevents dental caries. The maximum tolerance limit of fluoride in drinking water specified by the World Health Organization is 1.5mg/l (Henderson 1982; WHO, 2008).

#### **K. Total hardness.**

Total hardness is defined as the sum of the calcium and magnesium concentration expressed as calcium carbonate in mg/l or ppm. It is traditionally a measure of the capacity of water to react with soap, requiring considerably more soap to produce lather. It is not caused by a single substance but a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, although other cations, such as barium, iron, manganese, strontium and zinc can also contribute to water hardness (APHA, 1985). Hardness is mostly expressed as milligrams of calcium carbonate equivalent per litre and water containing less than 60mg of calcium carbonate equivalent per litre is generally

being considered as soft water .The hardness of water is derived largely from weathering of minerals such as limestone, dolomite, gypsum, run-off soils, seepage and industrial waste products. Hardness varies considerably from place to place depending on the nature of geological formation of a place (WHO, 2004).

The results of a number of studies have suggested that water hardness may protect against diseases (Degremont, 1991). In some studies, an inverse relationship between the hardness of drinking water and cardiovascular disease at elevated hardness has been reported (WHO, 2006). Some data suggested that very soft water, with a hardness of less than  $75\text{mg/dm}^3$  may have an adverse effect on mineral balance in the body (Periakali *et al.*, 2001). Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately  $200\text{mg/dm}^3$  may cause scale deposition in the distribution system, as well as increased soap consumption. In contrast, soft water, with hardness less than  $100\text{mg/dm}^3$ , has greater tendency to cause corrosion of pipes, resulting in the presence of certain heavy metals such as cadmium, copper, lead and zinc in drinking water (WHO, 2004). Table 2.2 shows how description may be related to the numerical value of hardness in common unit of mg equivalent of  $\text{CaCO}_3/\text{l}$ .

**Table 2.2: Numerical description of hardness in terms of CaCO<sub>3</sub> content.**

Description of hardness	Hardness in terms of mg equivalent of CaCO <sub>3</sub> /l
Soft	< 50
Moderately soft	50-100
Slightly hard	100-150
Moderately hard	150-200
Hard	200-300
Very hard	>300

Source: (APHA, 1989).

## CHAPTER THREE

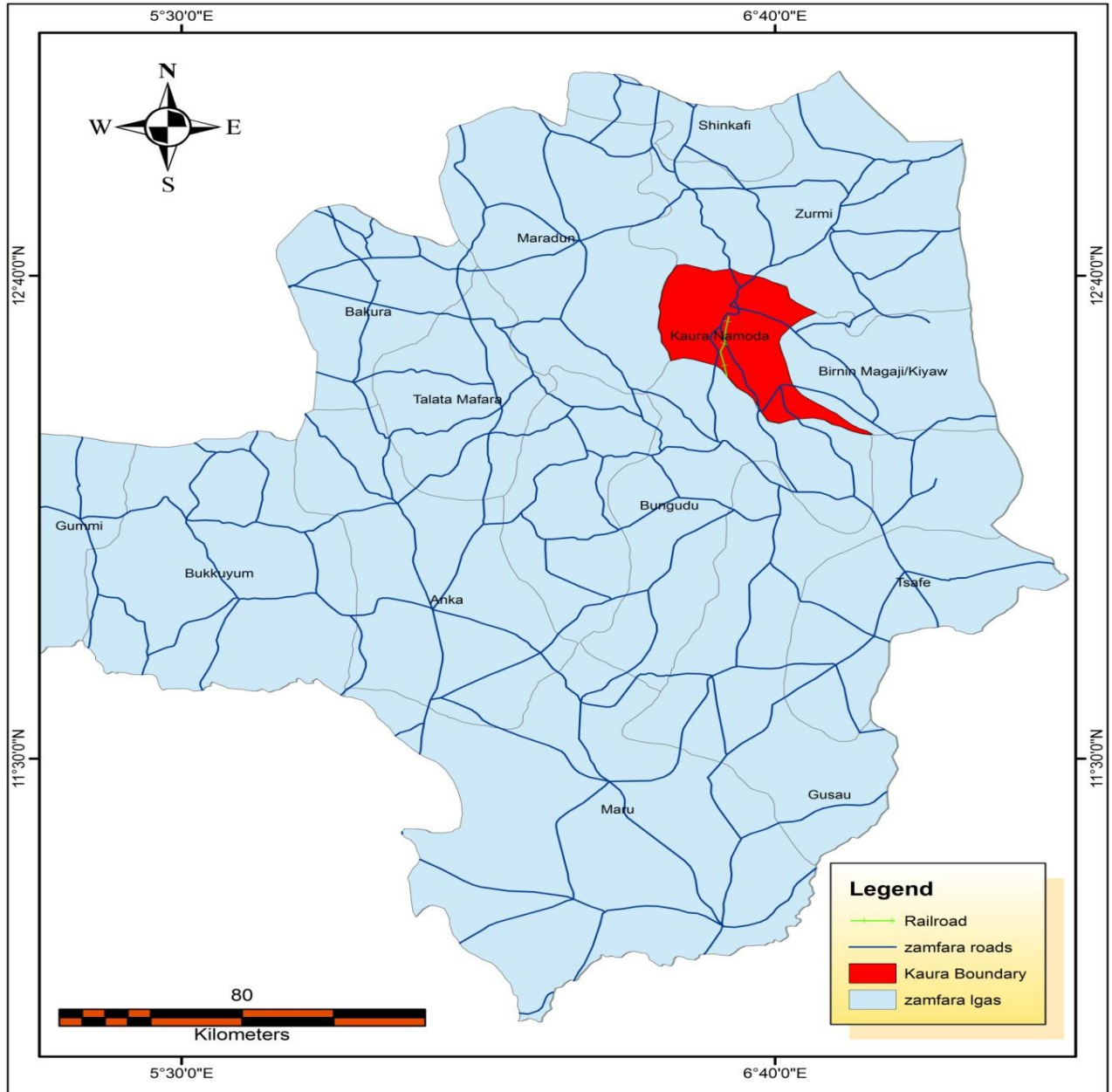
### MATERIALS AND RESEARCH METHOD

#### 3.1 Preamble

In the preparation of reagents, chemicals of analytical grade and distilled water were used. All glassware were washed with detergents and rinsed properly with distilled water before use.

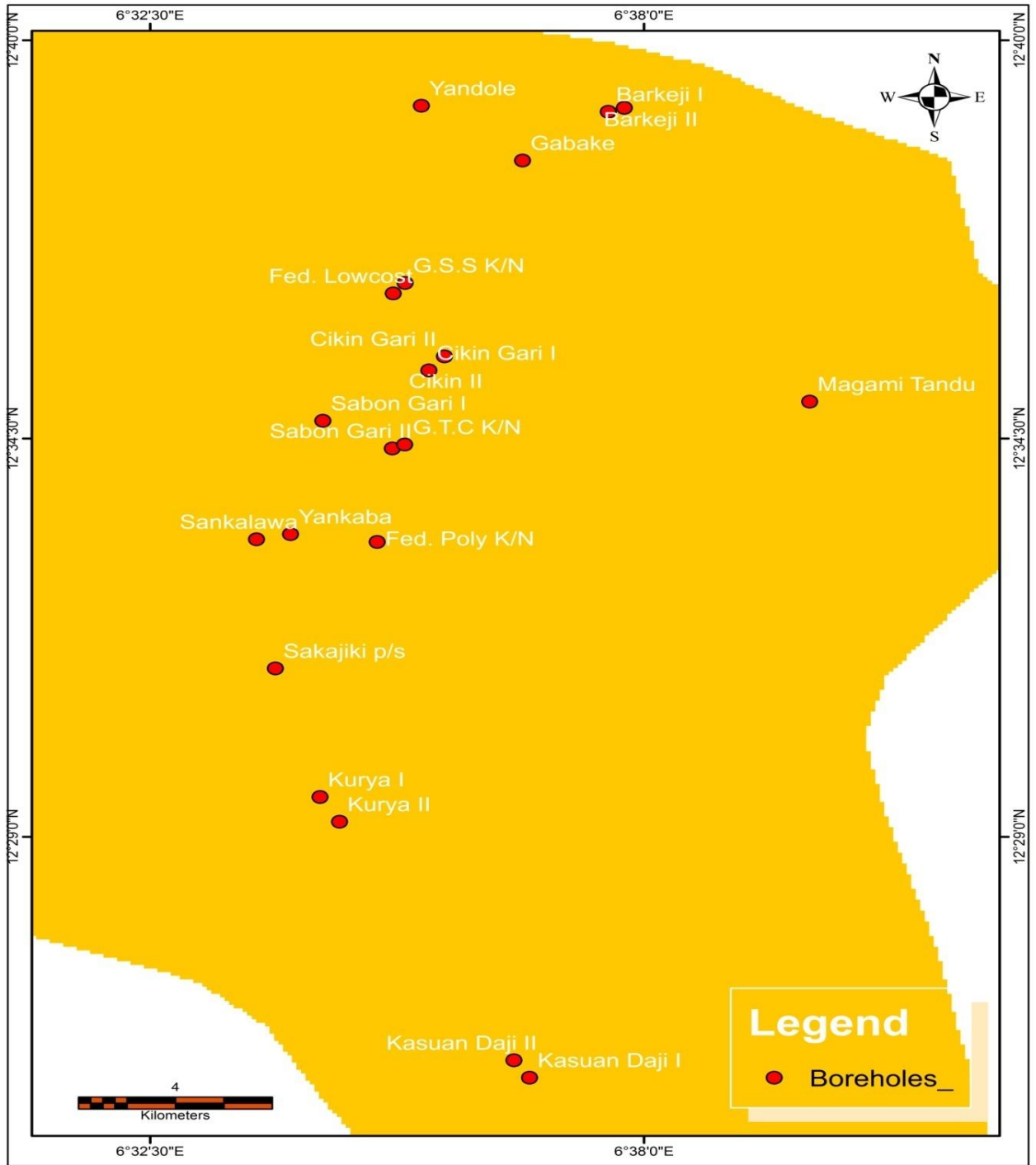
#### 3.2 Description of the Study Area

Kaura - Namoda local Government Area in Zamfara State of Nigeria is located between latitude  $12^{\circ} 16' 43.56''$  to  $12^{\circ} 41' 4.48''$ N and longitude  $6^{\circ} 25' 34.87''$  to  $6^{\circ} 51' 53.92''$ E. It is bounded in the north by Zurmi Local Government Area, in the south by Bungudu Local Government Area, in the east by Birnin Magagi Local Government Area and in the west by the Maradum Local Government Area (Figure 3.1 and 3.2) and has its headquarter located in the town of Kaura-Namoda. It has an area of  $868\text{km}^2$  and a population of 281,367 at the 2006 NPC census. The inhabitants of the area are predominantly farmers that engage in commercial crops and animal production. The major source of their water in recent time is the groundwater in the form of boreholes which are being drilled across the entire study area mostly as government projects and in some cases by individuals.



**Source:** Adopted and modified from administrative map of Zamfara State.

**Figure 3.1:** Map of Zamfara State where the study area (Kaura-Namoda Local Government Area) is located (red colour).



**Source:** Adopted and modified from administrative map of Zamfara State.

**Figure 3.2:** Map showing the distributions of the various sampling locations.

### 3.3 Sample Collection/Preservation

The co-ordinates points of all the boreholes sampled were taken using a global positioning system (GPS) (model N20230 etrex Garmin) (Table 3.1). Borehole water samples were collected three times (fortnightly) between the months of April and May, 2013 according to standard procedures by (APHA, 1998). The study comprises of 20 selected sampling points (boreholes) (Table 3.1) that were sampled three times each. Parameters with low stability such as pH and temperature were determined *in-situ* during each sampling period. The sampling containers were rinsed with the borehole water and each borehole was allowed to operate for at least five minutes before sample collection was made. All the samples were collected in pre-cleaned one litre polythene plastic bottles and acidified with analar grade of concentrated nitric acid to about pH 2.0 except in samples separately collected and without acidification for the purpose of nitrate determination. Samples were respectively labeled according to the sampling points and were taken to the laboratory for analysis

**Table 3.1: Sampling locations and their respective point co-ordinates**

S/no	Point Coordinates	Sample locations	Designation
1	12°38'20.5" N 6°36'38.8" E	Gabake Mesa borehole (By dispensary centre).	BW1
2	12°35'007" N 6°39'50.7" E	Magami Tandu borehole (By dispensary centre).	BW2
3	12°39'00.6" N 6°37'36.11" E	Barkeji I borehole (By dispensary health centre).	BW3

4	12°39'03.9" N 6°37'46.9" E	Barkeji II borehole (By district head residence).	BW4
5	12°39'05.7" N 6°35'31.3" E	Yandole primary school borehole.	BW5
6	12°33'04.2" N 6°35'01.6" E	Fed. Poly. Kaura borehole (Near main mosque Yankaba road).	BW6
7	12°33'10.7" N 6°34'03.7" E	Yankaba primary school borehole.	BW7
8	12°35'26.6" N 6°34'03.7" E	Kurya II (By the road side) borehole.	BW8
9	12°29'33.1" N 6°34'23.5" E	Kurya 1(Government Secondary School kurya borehole).	BW9
10	12°25'40.4" N 6°36'43.5" E	Kasuwan-Daji I. (By District head residence borehole)	BW10
11	12°25'54.7" N 6°36'33.1" E	Kasuwan Daji II (General hospital borehole).	BW11
12	12°29'12.4" N 6°36'48" E	Cikin Gari I (forestation II project borehole)	BW12
13	12°31'19.7" N 6°33'53.6" E	Sakajiki Primary School borehole.	BW13

14	12°34'21.7" N 6°35'11.6" E	Sabon-gari I (By the old bridge) Kaura borehole.	BW14
15	12°38'44.9" N 6°34'25.4" E	Sabon-gari II (By Kunkurki ward) Kaura borehole.	BW15
16	12°36'38.7" N 6°35'20.4" E	Government Secondary School, Kaura Namoda borehole.	BW16
17	12°36'30.2" N 6°35'12.6" E	Federal low-cost Kaura borehole (By Federal Poly. Primary school).	BW17
18	12°35'38.5" N 6°36'46.8" E	Cikin-gari II (By Ecobank Kaura Namoda).	BW18
19	12°35'26.7" N 6°35'20.4" E	Government Technical College, Kaura Namoda.	BW19
20	12°38'20.5" N 6°36'38.8" E	Sankalawa (By Sakajiki roadside).	BW20

### 3.4 Analysis for Physicochemical Parameters

The working conditions of all field meters and equipment were checked and they were calibrated according to the manufacturer's specifications. The pH meter was standardized with two reference buffer solution of 4.0 and 10.0. A spectrophotometer ( HANNA multi-parameter H183200 model) for anions like phosphates, sulphates, nitrates determination

were checked to ascertain its working condition by passing standard solutions of all the parameters to be measured. Blank samples made with deionized water were also passed in between every three measurements of the sample as check for a possible contamination and malfunctioning of the equipment. The following physicochemical parameters were determined:

**3.4.1. Temperature determination:** This was determined *in-situ* using mercury in glass thermometer (APHA, 1998).

**3.4.2. Turbidity determination:** The turbidity of the water sample was determined using turbidity meter (APHA, 1998).

**3.4.3. Determination of pH (Ademoroti, 1996)**

The pH values of the water samples were determined *in-situ* using a portable digital pH meter (model lab. Tec.3320). The meter was switched on and allowed to warm for about five minutes. It was then standardized with two reference buffer solutions of pH of 4.0 and 10.0. The electrode of the meter was thoroughly rinsed with distilled water after every sample pH determination. The pH values of the samples were displayed on the unit of the meter and were recorded accordingly.

**3.4.4. Conductivity determination (AOAC, 1998)**

The conductivity of the samples was determined using digital conductivity meter (model HACH CEL/890). The power key and the conductivity key of the conductivity meter were switched on and allowed to warm for about fifteen minutes. The temperature of the meter was adjusted and then standardized with 0.001M KCl to give a conductivity value of

14.7 $\mu$ S/cm at 25°C. The electrode was thoroughly rinsed with distilled water and then immersed directly into water sample and each measurement was taken. The probe was thoroughly rinsed with distilled water after each measurement.

#### **3.4.5. Total dissolved solid determination (AOAC, 1998)**

The total dissolved solid was obtained by immersing the probe of model HACH CEL/890 sensing portable multi-parameter meter in a mixed water sample. The probe was rinsed thoroughly with distilled water after each measurement.

#### **3.4.6. Determination of sulphate, nitrate and phosphate (Greenberg et al., 1992)**

The HANNA multi parameter logging spectrophotometer (HI 83200) was used to digitally determine the nitrate, phosphates and sulphate levels of the samples. The spectrophotometer was checked for malfunctioning by passing standard solutions of all parameters to be measured. Blank samples (deionized water) were passed between every three measurements of water samples to be sure of the accuracy of equipment. Nitrate as nitrogen was determined by the cadmium method 8036. The cadmium metal in the added reagent reduced the nitrate to nitrite while sulphate was determined by the use of sulfa Ver methods 8051. Phosphate was determined using direct reading from HI 83200 HANNA multi-parameter spectrophotometer.

#### **3.4.7. Spectrometric determination of fluoride content in water**

A given volume of water sample (1cm<sup>3</sup>) was carefully transferred into a sample cuvette, 4 drops of alizarin and 4 drops zirconyl acid were then added and the solution made up to the mark of the cuvette. The blank solution was prepared in the same way but without the

water sample. The cuvette caps were then replaced and inverted several times to mix properly. The fluoride content was then determined using the HI 83200 multi-parameter bench photometer.

#### **3.4.8. Determination of chloride using Mohr's argentometric method**

##### **Reagents and their preparations**

- a. Standard silver nitrate titrant (0.014M) prepared by dissolving 2.396g  $\text{AgNO}_3$  in distilled water and made up to mark in a  $1000\text{cm}^3$  volumetric flask. The solution was standardized against 0.014M NaCl.
- b. Standard NaCl (0.014M) prepared by dissolving 0.8249g NaCl previously dried at  $140^\circ\text{C}$  and made up to mark in a  $100\text{cm}^3$  volumetric flask.
- c. Potassium Chromate indicator solution prepared by dissolving 5g of potassium chromate in a little distilled water and made up to mark in a  $100\text{cm}^3$  volumetric flask,  $\text{AgNO}_3$  (0.1M) solution was added to it until definite red precipitate was formed. It was left for to stand for about 12 hours and then filtered and made up to mark in a  $1000\text{cm}^3$  volumetric flask.
- d. Sodium hydroxide (0.1M) was prepared by dissolving 4g of sodium hydroxide pellet in little distilled water and made up to mark in a  $1000\text{cm}^3$  volumetric flask.

**Procedure:** The borehole water sample of volume  $50\text{cm}^3$  was taken in a conical flask and titrated against 0.014M standard silver nitrate solution. An indicator of potassium chromate (5%) of volume  $1\text{cm}^3$  was added. Samples were titrated in the pH range of 7.0 to 10.0 directly ( samples below pH of 7.0 were adjusted with sodium hydroxide as in the case of some of the samples analyzed that had pH less than 7.0). In each sample, the titration was

carried out until the colour of water sample with indicator changed from yellow to brick red. The titre value of each titration was recorded and the chloride concentration was calculated by using the formula:

$$Cl^{-} \left( \frac{mg}{dm^3} \right) = \frac{A-B \times M \times 35450}{cm^3 (Sample Volume)} \dots\dots\dots (3.1)$$

Where;

A = Volume of AgNO<sub>3</sub> used for titrating the sample.

B = Volume of AgNO<sub>3</sub> used for titrating the blank.

M = Molarity of AgNO<sub>3</sub> solution.

**3.4.9. Determination of total hardness using the titration method (Ademoroti, 1996)**

**Procedure:** The sample was shaken thoroughly and 25cm<sup>3</sup> was taken into a conical flask and diluted to 50cm<sup>3</sup> with distilled water. Buffer solution (1cm<sup>3</sup>) and two to three drops of Eriochrome Black-T indicator were added to the titrating flask. The buffer maintains the pH of the solution at about 10. The mixture was then titrated with 0.01M EDTA until the colour changed from wine red to blue indicating the end point. The procedure was repeated two times to obtain the average titre value. The reactions are as follows:

Metal Cation + EDTA = (Metal Cation-EDTA) Complex.

The success of the use of EDTA for hardness determination lies in having suitable indicator, Erichrome Black T, which shows when EDTA is present in excess or when all the cations causing hardness have been complexed. The colour of this indicator is blue but when a small quantity of it is added to a sample of water, it combines with  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  in the water to form a weak complex which is wine red in colour as shown below:

Cation + Erichrome Black T. = Cation-Erichrome Black T (Wine red complex).

During titration, the EDTA and hardness causing cations are complexed finally disrupting the weak complex originally formed as above. This is because the EDTA and the cations form more stable complexes to give a reaction as shown below:

Cation-Erichrome Black T. + EDTA = Cation-EDTA complex + Erichrome Black T.  
(Wine red complex) (Blue colour)

This reaction as above frees the Erichrome Black T indicator and the red wine colour changes to a distinct blue colour, indicating the end point of the titration.

#### **Reagents:**

- a. Buffer solution prepared by mixing dissolved 40g of borax (disodium tetraborate-10-water)  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$  in about 800ml of distilled water and a mixture of dissolved 10g of sodium hydroxide with 5g sodium sulphide in 100ml of distilled water. The two solutions were allowed to cool before mixing and the mixture made up to one litre with distilled water.
- b. Erichrome Black –T indicator: This was prepared by mixing 0.5g of Erichrome Black T and a mixture of 3 parts triethanol-amine and 1 part of methylated spirit.

- c. Standard calcium solution of 0.01M was prepared by weighing 1.00g of CaCO<sub>3</sub> analytical grade into 250cm<sup>3</sup> conical flasks in which 50%HCl was added till all the CaCO<sub>3</sub> was dissolved completely. Distilled water of 200cm<sup>3</sup> was added and boiled to expel carbon dioxide. The solution was cooled and a few drops of methyl orange indicator added. The intermediate methyl orange color was adjusted by addition of drops of 3M NH<sub>4</sub>OH solution. The solution was transferred to a litre flask and made up to mark with distilled water.

The total hardness was calculated using the relationship below

$$\text{Total hardness in mg/l CaCO}_3 = \frac{A \times B \times 100}{\text{Volume of the sample}} \text{-----}3.2$$

Where;           A = Volume of EDTA used for the titration.

                      B = Molarity of the EDTA titrant.

### **3.5. Preparation of Sample and Aqueous Stock Solutions for AAS Analysis**

#### **3.5.1. Digestion of water sample for metal analysis (APHA, 1998)**

**Procedures:** The steps involved in the digestion process are listed below:

1. 100cm<sup>3</sup> of the water sample was measured into a 250 cm<sup>3</sup> beaker and 10 cm<sup>3</sup> of concentrated HNO<sub>3</sub> added.

2. The mixture was placed on a hot plate and boil until the color of the solution become colorless, clear and the volume has reduced to about 30 cm<sup>3</sup> of volume, making certain that the sample does not boil.
3. The mixture was filtered and transferred into a 100 cm<sup>3</sup> sample bottle, and made up to 100cm<sup>3</sup> mark with deionized water for metal analysis using an AAS machine.

### **3.5.2. Preparation of aqueous stock solutions.**

All chemicals used were of analytical grade. All solutions used for this analysis were prepared by dissolving appropriate amounts in deionized distilled water. Deionized distilled water was used for solution preparations.

**Alizarin solution:** Alizarin red of 0.70g was weighed and dissolved in about 700cm<sup>3</sup> distilled water using 1000cm<sup>3</sup> volumetric flask. The solution obtained was shaken and made up to mark.

**ZirconylAcid:** Zirconyl acid of 0.354g was weighed into a 1000 cm<sup>3</sup> volumetric flask containing 800ml distilled water, 33.3 cm<sup>3</sup> conc. H<sub>2</sub>SO<sub>4</sub> was added slowly with stirring and made up to mark with distilled water.

#### **Cadmium solution**

The solution was prepared by dissolving 2.744g Cd(NO<sub>3</sub>)<sub>2</sub>.4H<sub>2</sub>O in 5.00cm<sup>3</sup> concentrated HNO<sub>3</sub>. The solution was made up to 1000 ml with distilled water in a volumetric flask giving 1000mg/dm<sup>3</sup> of cadmium solution.

### **Iron stock solution**

The solution was prepared by dissolving 0.483g of  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  in  $100\text{cm}^3$  of distilled water using  $1000\text{cm}^3$  volumetric flask which was made up to mark giving  $1000\text{mg}/\text{dm}^3$  of iron solution.

### **Copper stock solution**

This was prepared by dissolving 3.803 g of  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  in 5ml concentrated  $\text{HNO}_3$  and made up to  $1000\text{cm}^3$  with distilled water giving  $1000\text{ mg}/\text{dm}^3$  copper solution.

### **Zinc stock solution**

This was prepared by dissolving 1.244 g of  $\text{ZnO}$  in 5 ml of water then 25 ml concentrated  $\text{HNO}_3$  was added and made up to  $1000\text{cm}^3$  with distilled water giving  $1000\text{mg}/\text{dm}^3$  of zinc solution.

### **Manganese stock solution**

This was prepared by dissolving 4.058g  $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$  in  $5.00\text{cm}^3$  of water,  $1\text{cm}^3$  concentrated  $\text{H}_2\text{SO}_4$  was then added and the solution made up to  $1000\text{cm}^3$  with distilled water giving  $1000\text{mg}/\text{dm}^3$  of manganese solution.

### **Lead stock solution.**

This was prepared by dissolving 1.599g of Lead nitrate ( $\text{PbNO}_3$ )<sub>2</sub> in  $20\text{cm}_3$  1% v/v  $\text{HNO}_3$  and made up to  $1000\text{cm}^3$  with distilled water giving  $1000\text{mg}/\text{dm}^3$  of lead solution.

### 3.6 Atomic Absorption Spectroscopy Analysis and Preparation of Calibration Curves

Six working standards were prepared in triplicates for each metal by serial dilution of stock solutions. These standards and the blank solutions were aspirated in a Varian AA240FS atomic absorption spectrophotometer. Then the calibration curves of absorbance versus concentrations of the samples were plotted.

The digested sample solution was also aspirated into the flame and the absorbance values recorded. The metal concentration was calculated from the calibration curve. The instrumental conditions used are given in Table 3.2 below:

**Table 3.2 Instrumental conditions for AAS determination of metals with Varian AA240FS sequential Atomic Absorption Spectrometer**

<b>Element</b>	<b>Wavelength (nm)</b>	<b>Band pass (nm)</b>	<b>Flame type</b>	<b>Fuel flow rate L/Min</b>
<b>Cd</b>	228.8	0.5	Air/C <sub>2</sub> H <sub>2</sub>	1.2
<b>Pb</b>	217.0	0.5	Air/C <sub>2</sub> H <sub>2</sub>	1.1
<b>Zn</b>	213.9	1.0	Air/C <sub>2</sub> H <sub>2</sub>	1.1
<b>Cu</b>	341.5	0.5	Air/C <sub>2</sub> H <sub>2</sub>	1.1
<b>Fe</b>	217.0	0.5	Air/C <sub>2</sub> H <sub>2</sub>	1.1
<b>Mn</b>	279.5	0.2	Air/C <sub>2</sub> H <sub>2</sub>	1.1

### **3.7. Theory of Atomic Absorption Spectrophotometer (AAS)**

The atomic absorption spectrophotometer is a form of optical machine that is used primarily for detecting the presence of metals. It relies on the absorption of light by atoms in an excited state to allow the determination of the concentration of atoms in the sample. The liquid samples are nebulized and the resulting aerosol passes through a flame which vaporizes the solvent, leaving a cloud of atoms. The light is beamed at a particular wavelength by a hollow cathode lamp specific for the element of interest. The light beam passes through the hotter part of the flame and the amount of light absorbed by the excited atom cloud is detected by the instrument and the concentration of atoms present can be measured. The absorption follows the Beer's law. That is, the absorbance is directly proportional to the path length in the flame and to the concentration of atomic vapour in the flame. Both of these variables are difficult to determine, but path length can be held constant and the concentration of the atomic vapour is directly proportional to the concentration of the analyte in the solution being aspirated. The procedure used is to prepare a calibration curve of concentration in the solution versus absorbance. Atomic absorption spectrophotometer gives accurate measurement of very small amounts of elements (typically 1mg/l detection limit for flame mode). The great advantage of the method over other procedures is its high degree of freedom from interference from its environment (i.e. by the presence of other elements). The major disadvantage of making measurement with atomic absorption is that it can only measure the atoms specific to the cathode lamp used and therefore a different source is required for each element (Gary, 2004; Vogel, 1996).

### 3.8. Principles of Operation of HI 83200, Photometer

HI 83200 is a multi-parameter bench photometer used for laboratory analysis. The principle behind its operation is also based on Beer-Lambert law below:

$$-\log I/I_0 = \epsilon_\lambda cd \quad \text{or } A = \epsilon_\lambda c d \quad \text{-----}(3.3)$$

Where:

$-\log I/I_0 = \text{Absorbance (A)}$

$I_0 = \text{intensity of incident light beam}$

$I = \text{intensity of light beam after absorption}$

$\epsilon_\lambda = \text{molar extinction coefficient at wave length } \lambda$

$c = \text{molar concentration of the substance}$

$d = \text{optical path through the substance}$

Therefore the concentration of the analyte can be calculated from the absorbance of the substance as other factors are known. Photochemical analysis is based on the possibility to develop an absorbing compound from a specific chemical reaction between sample and reagent. The optical system of HI 83200 is based on special subminiature tungsten lamps and narrow-band interference filters to guarantee both high performance and reliable results. Five measuring channels allow a wide range of tests. A microprocessor controlled special tungsten lamp emits radiation which is first optically conditioned and beamed through the sample contained in the cuvette. The optical path is fixed by the diameter of the cuvette. Then the light is spectrally filtered to a narrow spectral bandwidth, to obtain a light beam of intensity  $I_0$  or  $I$ . the photoelectric cell collects the radiation  $I$  that is not

absorbed by the sample and converts it into an electric current, producing a potential in the mV range. The microprocessor then uses this potential to convert the incoming value into the desired measuring unit and to display it on the Liquid Crystal Display (LCD) (Vogel, 1996).

**3.9. Statistical Analysis.** Statistical analysis was carried out using SPSS 20 Version to correlate the heavy metals and the physicochemical parameters under investigation. Also, the mean values of the parameters obtained over three sampling periods for the various sampled boreholes were presented in charts in comparison with WHO (2006), NSDW (2007) and USEPA (2012) standards for drinking water.

## CHAPTER FOUR

### RESULTS

#### 4.1 Determination of Physicochemical Parameters.

The results for physicochemical determinations are presented in Table 4.1 and the comparison of results with the standards for drinking water in Figures 4.1-4.4. The results of physicochemical parameters as presented in Table 4.1 were described below:

##### 4.1.1. Temperature

The values of temperature obtained ranged from  $28.50 \pm 0.06$  to  $29.60 \pm 0.15^\circ\text{C}$  (Table 4.1). The minimum value of  $28.50^\circ\text{C}$  and the maximum value of  $29.60^\circ\text{C}$  were obtained from the boreholes designated as BW8 and BW16 respectively.

##### 4.1.2. pH

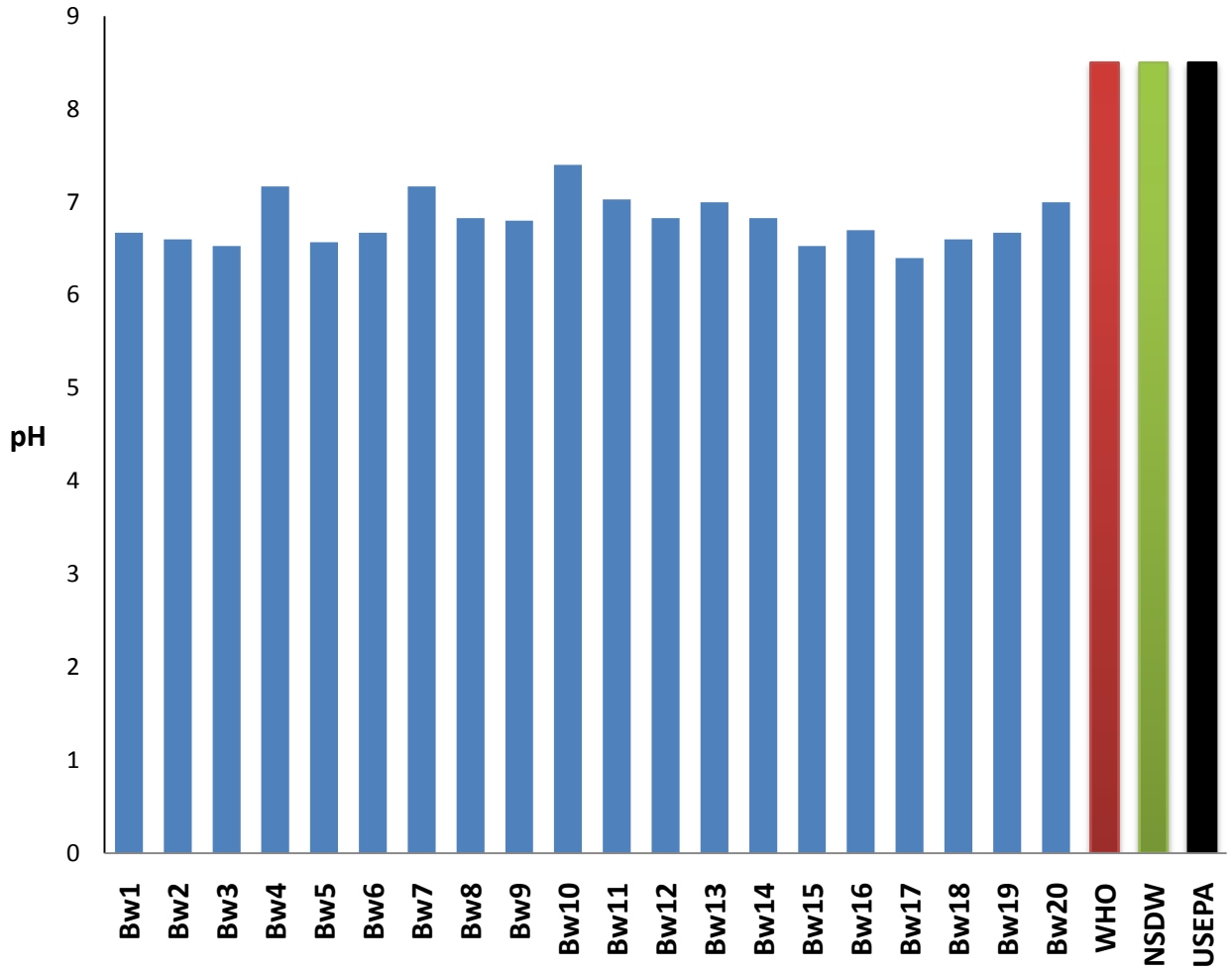
The values of pH obtained in all the sampled boreholes ranged from  $6.4 \pm 0.10$  to  $7.40 \pm 0.10$  (Table 4.1). The maximum value of 7.40 was recorded at the borehole designated BW10 while the minimum pH value of 6.4 was recorded at borehole water with designation BW17.

##### 4.1.3. Conductivity

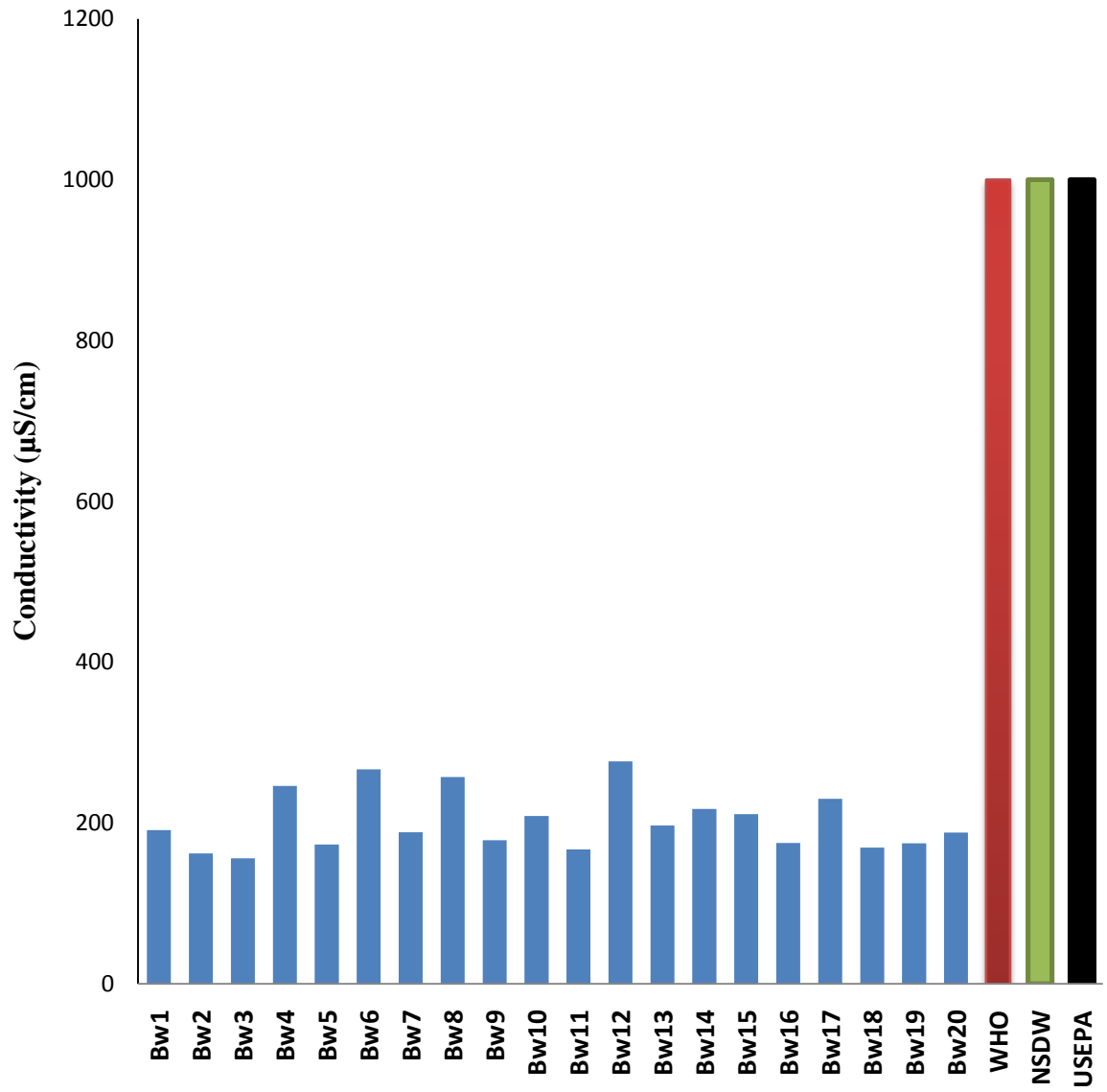
The values of electrical conductivity obtained ranged from  $156.0 \pm 5.3$  to  $276.7 \pm 14.7 \mu\text{S/cm}$  (Table 4.1). The highest value of  $276.7 \pm 14.7 \mu\text{S/cm}$  and the lowest value of  $156 \pm 5.3 \mu\text{S/cm}$  were recorded from the borehole water designated as BW12 and BW3 respectively.

**Table 4.1: Mean and Standard Deviation Values of Physicochemical Parameters of the Three Sampling Periods for all the Sampled Boreholes**

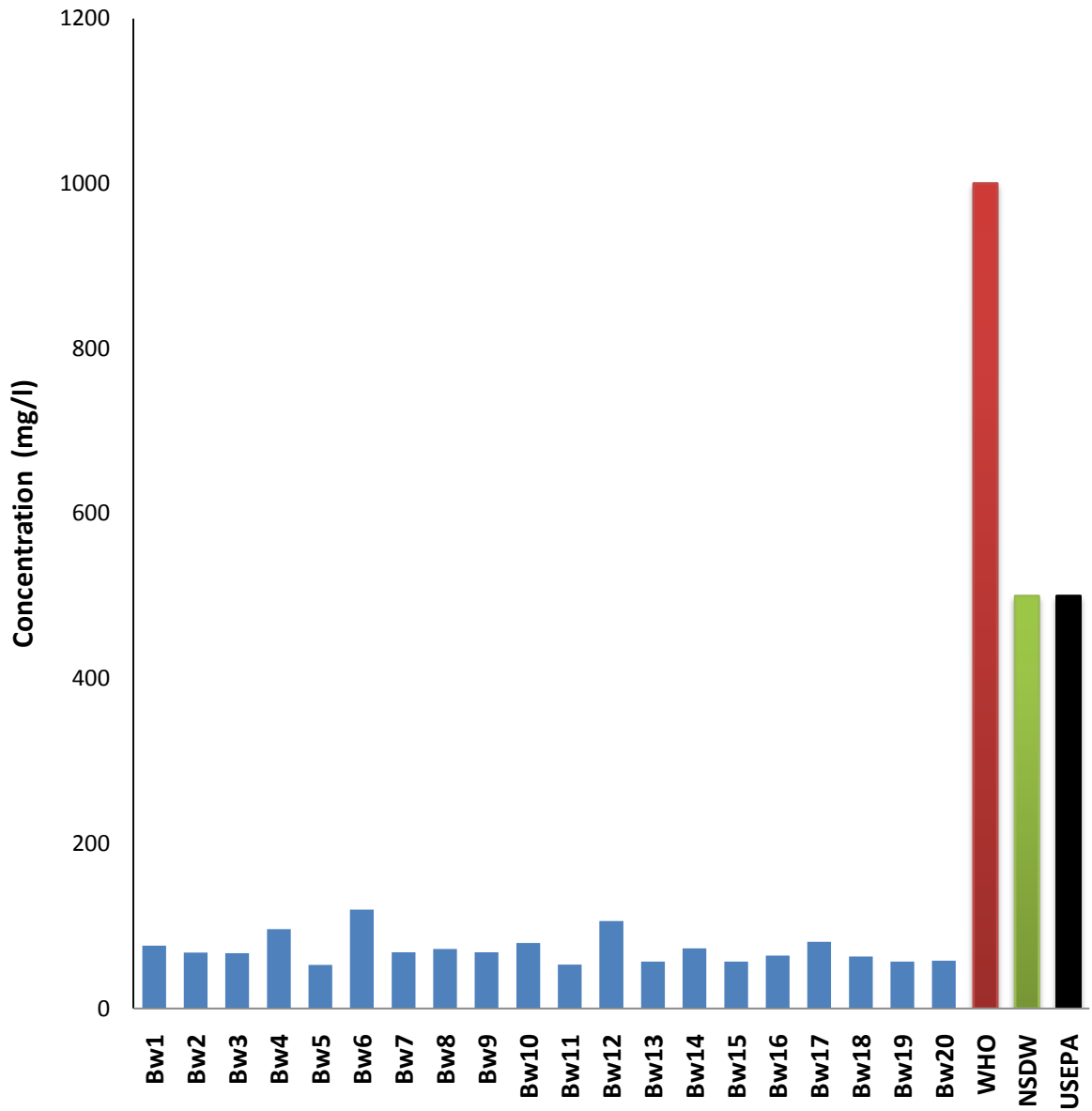
<b>Sample</b>	<b>Temperature (°C)</b>	<b>pH</b>	<b>Turbidity (NTU)</b>	<b>EC(µS/cm)</b>	<b>TDS (mg/l)</b>
BW1	28.90± 0.06	6.67± 0.11	1.04± 0.30	191.3± 2.30	76.3± 8.10
BW2	29.60 ± 0.15	6.60± 0.10	0.88± 0.20	162.3± 2.50	67.7± 7.10
BW3	29.70± 0.05	6.53± 0.05	0.49± 0.30	156.0± 5.30	67.0± 7.00
BW4	28.90± 0.06	7.17± 0.15	2.65± 0.30	246.0± 5.20	96.0± 5.30
BW5	28.60± 0.06	6.57± 0.11	0.21± 0.12	173.3± 13.30	53.3± 5.70
BW6	28.80± 0.05	6.67± 0.12	1.90± 0.12	266.7± 11.70	119.7± 11.06
BW7	29.60± 0.10	7.17± 0.15	0.05± 0.01	188.3± 7.80	68.3± 3.30
BW8	28.50± 0.06	6.83± 0.06	0.27± 0.06	257.3± 7.80	72.3 6.80
BW9	28.90± 0.10	6.80± 0.06	0.06± 0.01	178.6± 6.10	68.3± 3.30
BW10	29.00± 0.05	7.40± 0.10	0.10± 0.01	208.7± 14.70	79.3± 3.10
BW11	28.90± 0.10	7.03± 0.15	0.43± 0.11	167.3± 3.10	53.3± 6.10
BW12	29.00± 0.05	6.83± 0.06	0.75± 0.04	276.7± 14.70	106.0± 9.20
BW13	29.00± 0.10	7.00± 0.10	1.24± 0.16	196.6± 16.00	56.7± 8.10
BW 14	28.70± 0.06	6.83± 0.05	0.15± 0.01	217.3± 8.10	73.0± 6.60
BW15	28.70± 0.15	6.53± 0.11	0.29± 0.01	211.0± 20.10	86.7± 4.20
BW16	29.60± 0.15	6.70± 0.10	0.22± 0.02	175.3± 10.30	64.0± 4.40
BW17	28.90± 0.10	6.40± 0.10	1.03± 0.02	230.0± 11.10	81.0± 8.90
BW18	28.90± 0.15	6.60± 0.10	2.61± 0.01	169.3± 11.70	63.0± 6.60
BW19	28.70± 0.10	6.67± 0.15	0.26± 0.02	174.7± 5.00	57.0± 6.60
BW20	29.20± 0.15	7.06± 0.21	0.44± 0.04	188.0± 7.20	58.0± 5.40



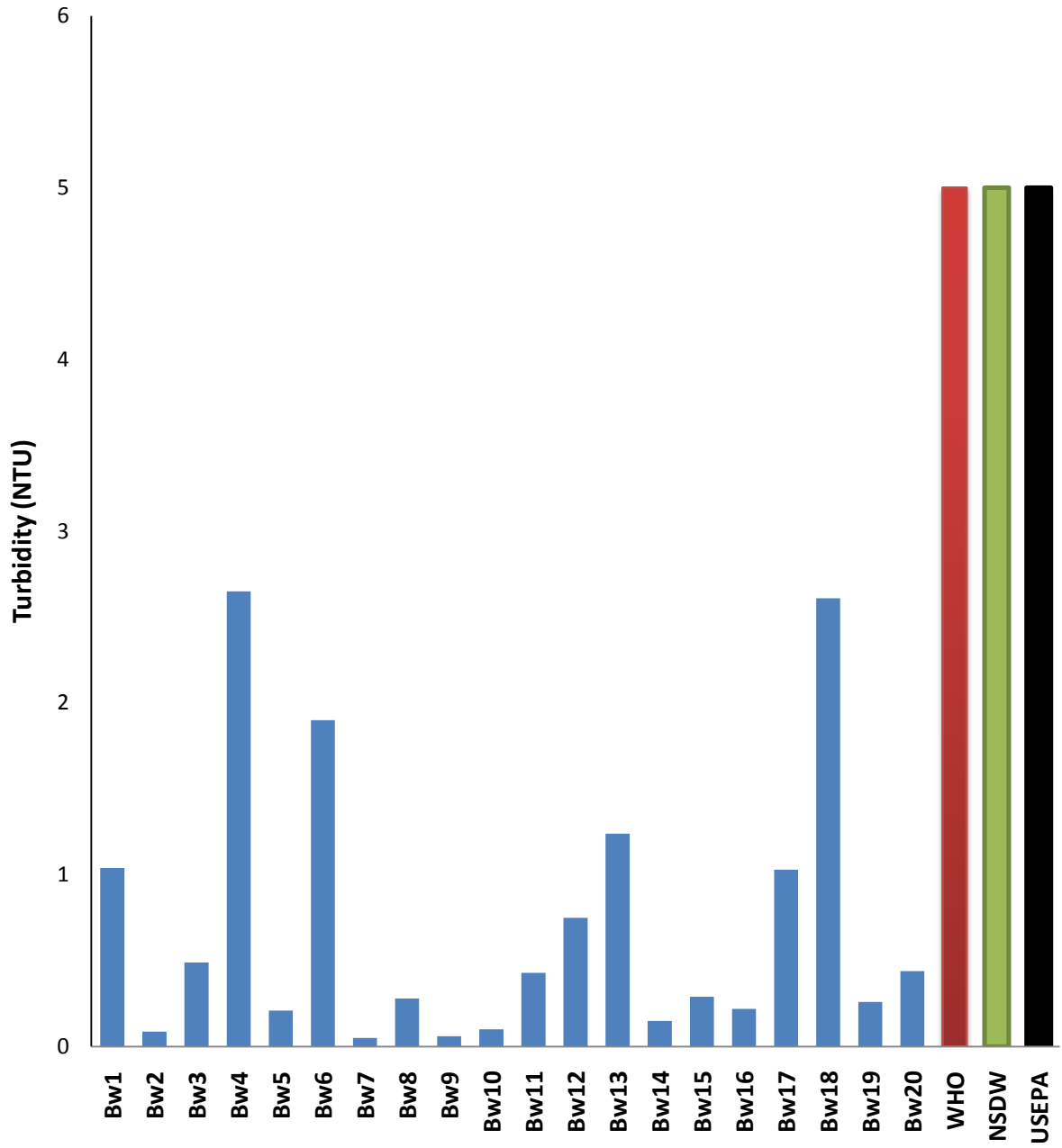
**Figure 4.1: Comparison of the pH Values of the Water Samples and the Maximum Permissible Limits Set by WHO, NSDW and USEPA.**



**Figure 4.2: Comparison of the Conductivity Values of the Water Samples and the Maximum Permissible Limits Set by WHO, NSDW and USEPA.**



**Figure 4.3: Comparison of the TDS Values of the Water Samples and the Maximum Permissible Limits Set by WHO, NSDW and USEPA.**



**Figure 4.4: Comparison of the Turbidity Values of the Water Samples with the Maximum Permissible Limits Set by WHO, NSDW and USEPA.**

#### **4.1.4. Total dissolved solids (TDS)**

The values of the total dissolved solid obtained in the sampled water ranged from  $53.3\pm 5.7$  to  $119.7\pm 11.6$ mg/l (Table 4.1). The minimum value of 53.3mg/l was obtained at boreholes designated as BW5 and BW11 while the maximum value of 119.7mg/l was obtained at the borehole designated as BW6.

#### **4.1.5. Turbidity**

The turbidity values ranged from  $0.05\pm 0.01$  to  $2.65\pm 0.30$  NTU (Table 4.1). The minimum value of 0.05NTU was obtained from the borehole water designated as BW7 while the maximum value of 2.65NTU was obtained at the borehole water designated as BW4.

### **4.2. Determination of Chemical Parameters**

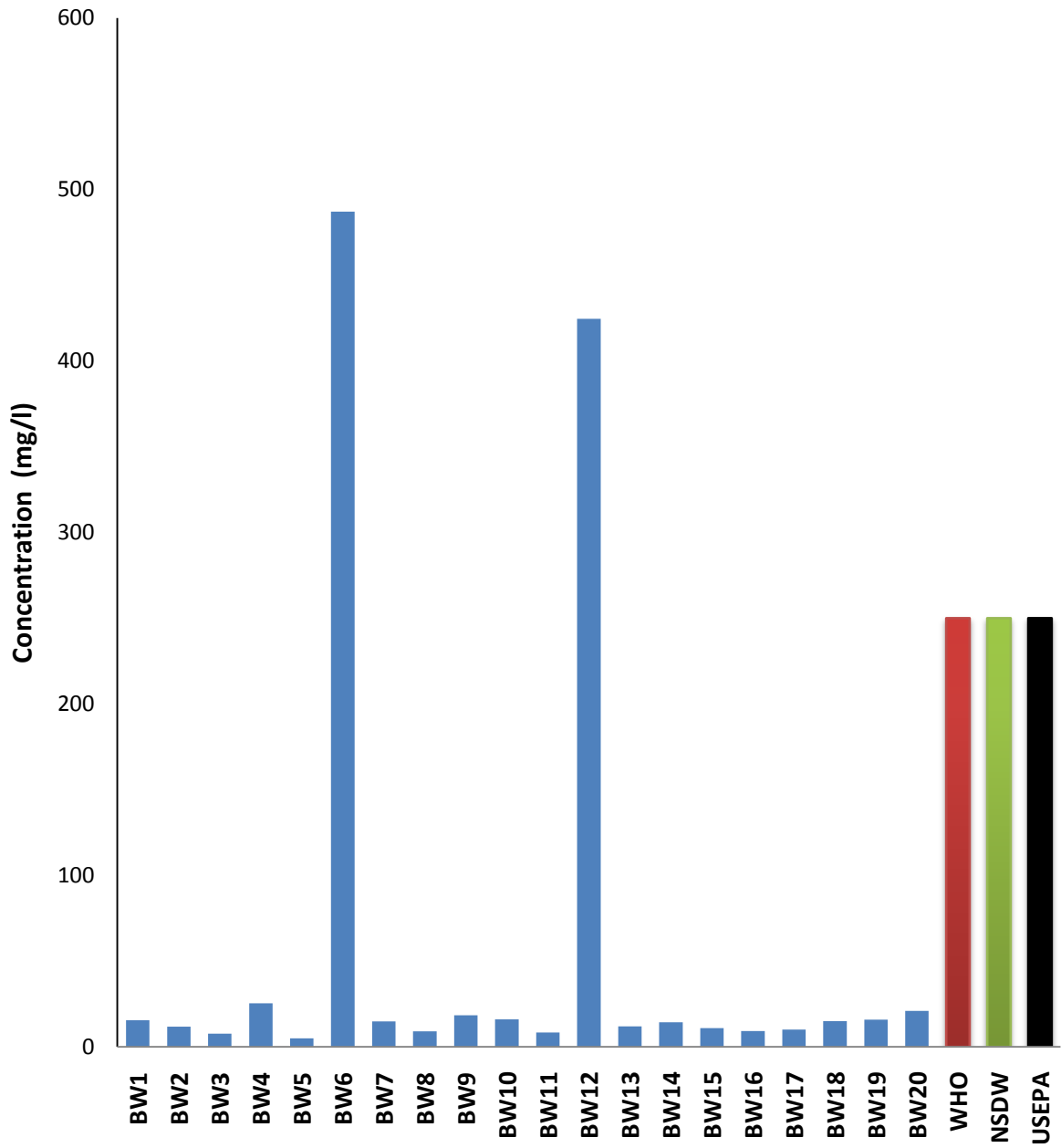
The results of the chemical parameters determinations are presented in (Table 4.2) and the comparison of results with standards for drinking water in Figures 4.5-4.10. The results of chemical parameters as presented in Table 4.2 were described below:

#### **4.2.1. Chloride**

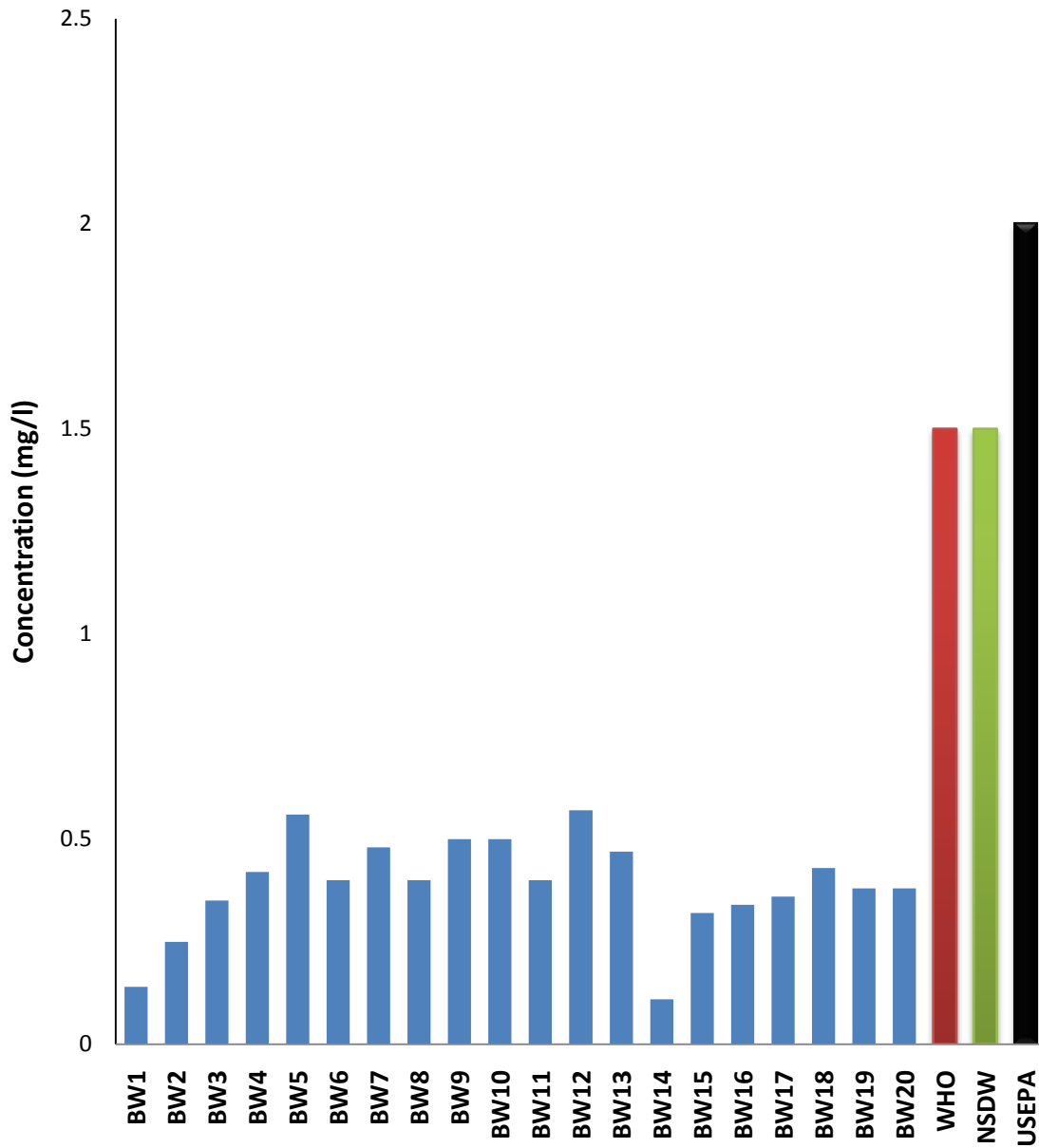
Chloride values obtained ranged from  $7.66\pm 1.04$  to  $487.01\pm 9.40$ mg/l (Table 4.2). The minimum value of 7.66mg/l was obtained from the borehole water designated as BW3 while the maximum value of 487.01mg/l was obtained from the borehole water designated as BW6.

**Table 4.2: Mean and Standard Deviation Values of Chemical Parameters of the Three Sampling Periods in all the Sampled Boreholes**

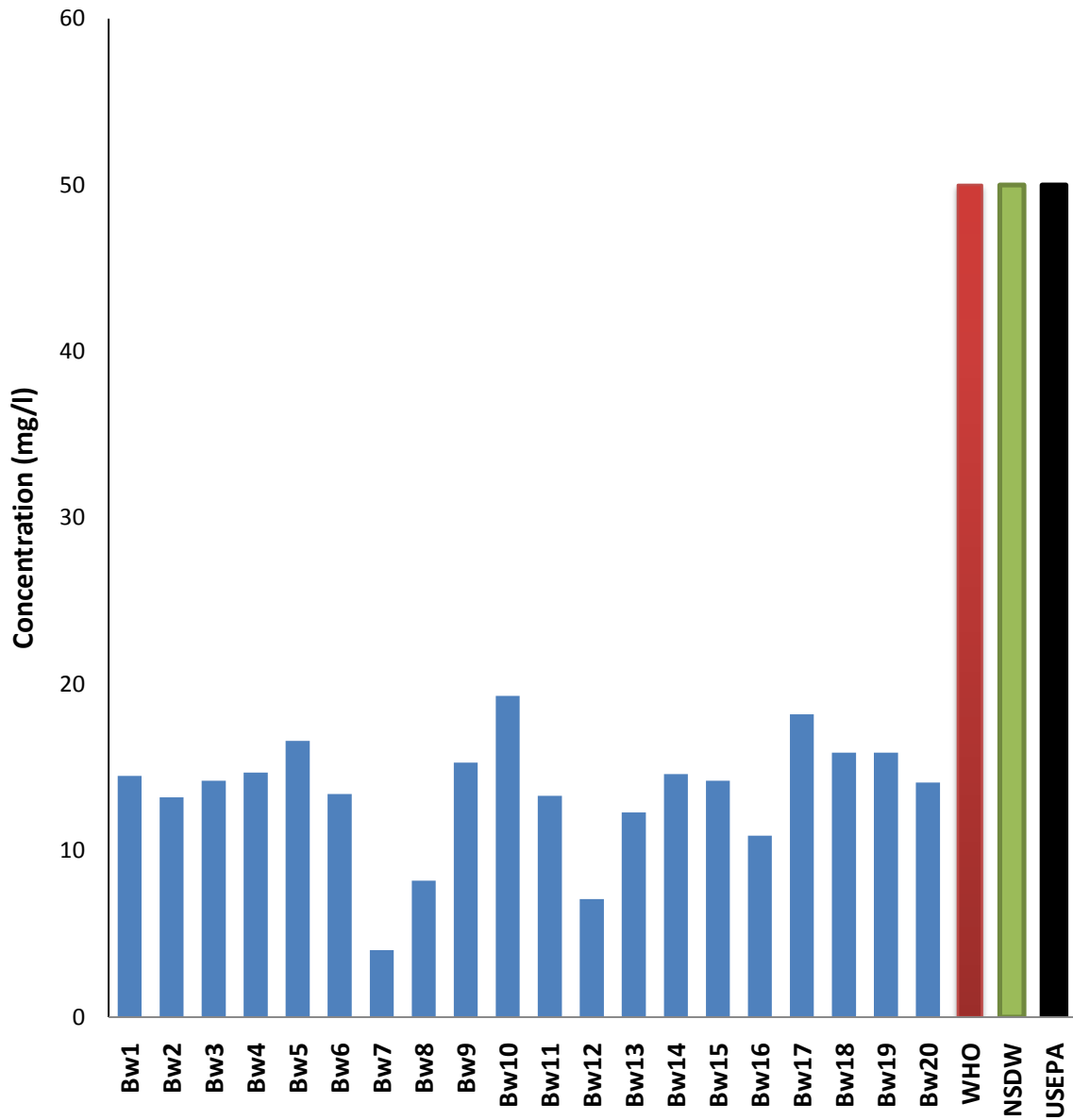
Sample	Chloride (mg/l)	Fluoride (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	Hardness (mg/l)
BW1	15.50±0.87	0.14±0.02	14.53±1.70	236.7±5.80	1.49±0.28	441.0±36.50
BW2	11.83±1.89	0.25±0.03	13.23±0.84	225.0±5.00	0.56±0.21	420.8±30.90
BW3	7.66±1.04	0.35±0.03	14.23±0.15	210.0±10.00	1.16±0.13	801.5±57.50
BW4	25.46±0.55	0.42±0.01	14.67±0.41	285.0±5.00	0.37±0.01	663.2±29.20
BW5	4.99±0.76	0.56±0.01	16.60±2.88	296.7±4.40	0.71±0.23	273.0±45.70
BW6	487.01±9.40	0.40±0.01	13.40±0.66	343.3±6.60	0.47±0.22	690.2±5.80
BW7	14.83±1.26	0.48±0.01	4.03±0.06	345.0±5.00	0.46±0.10	457.9±46.00
BW8	8.99±1.29	0.40±0.01	8.23±3.70	293.3±4.60	0.30±0.07	198.6±31.00
BW9	18.32±1.75	0.50±0.02	15.30±0.36	256.7±9.30	0.42±0.14	205.4±21.00
BW10	15.99±0.49	0.50±0.02	19.33±1.62	338.3±5.80	0.67±0.21	387.2±32.60
BW11	8.33±2.57	0.40±0.03	13.33±0.81	291.6±2.90	0.36±0.06	447.8±30.90
BW12	424.61±8.78	0.57±0.01	7.13±0.32	300.0±5.00	0.23±0.11	400.6±15.40
BW13	11.99±0.50	0.47±0.02	12.30±1.15	310.0±10.00	0.34±0.05	195.0±6.10
BW14	14.33±3.40	0.11±0.02	14.57±0.57	323.3±5.80	0.35±0.20	188.7±29.00
BW15	10.83±2.07	0.32±0.02	14.17±1.00	298.0±2.90	0.28±0.10	280.0±31.40
BW16	9.16±2.08	0.34±0.01	10.86±0.06	263.4±5.30	0.24±0.05	212.1±10.10
BW17	9.99±2.28	0.36±0.01	18.20±0.34	281.6±7.60	0.22±0.11	393.3±10.50
BW18	15.00±2.78	0.43±0.01	15.90±0.98	316.7±5.80	0.29±0.04	218.5±5.60
BW19	15.83±1.89	0.38±0.01	15.90±0.17	265.0±7.80	0.24±0.04	205.3±21.00
BW20	21.00±3.04	0.38±0.01	14.06±0.23	266.7±11.60	0.24±0.05	225.6±30.90



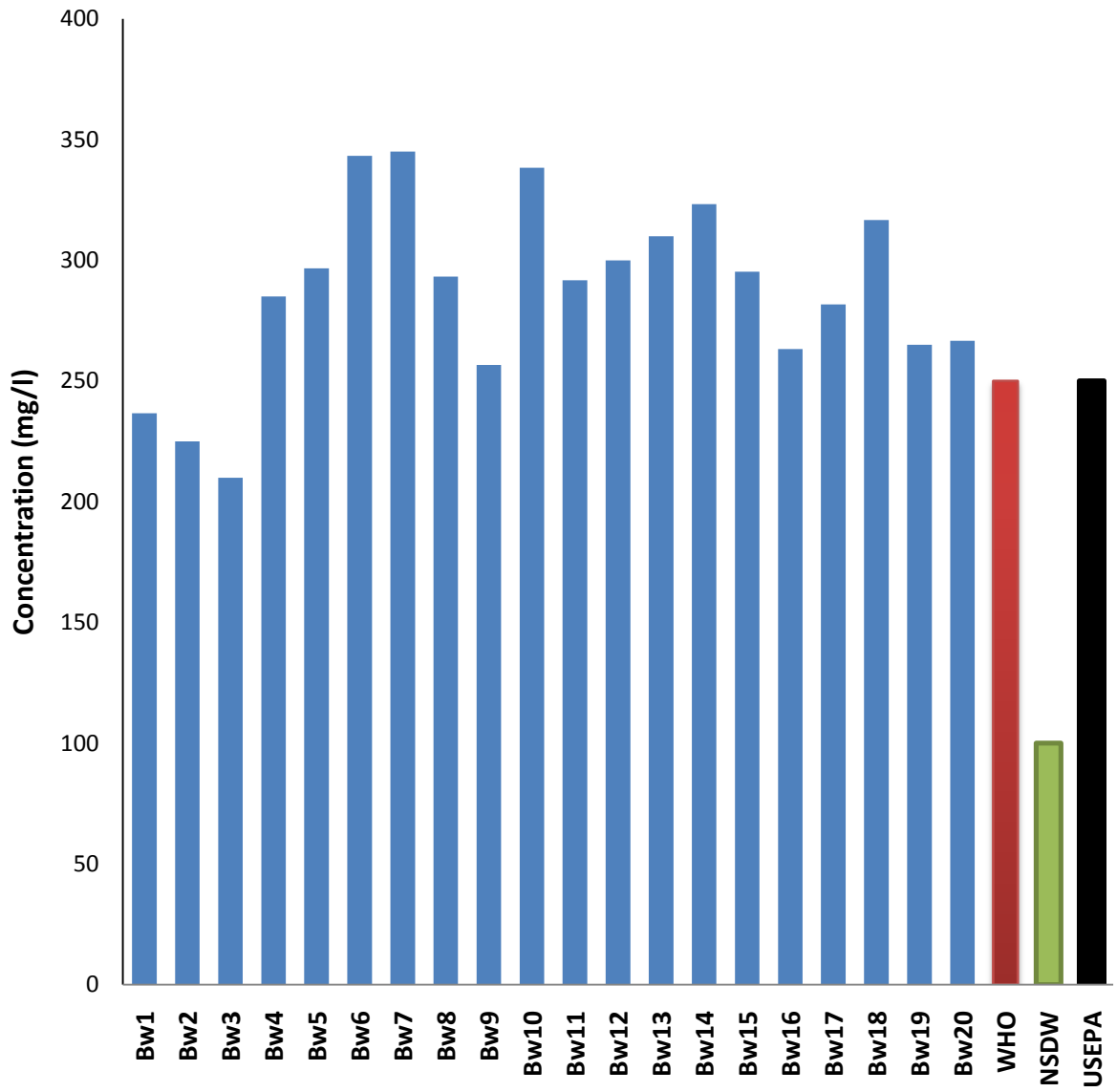
**Figure 4.5: Comparison of the Chloride Values of Water Samples with the Maximum Permissible Limits Set by WHO, NSDW and USEPA.**



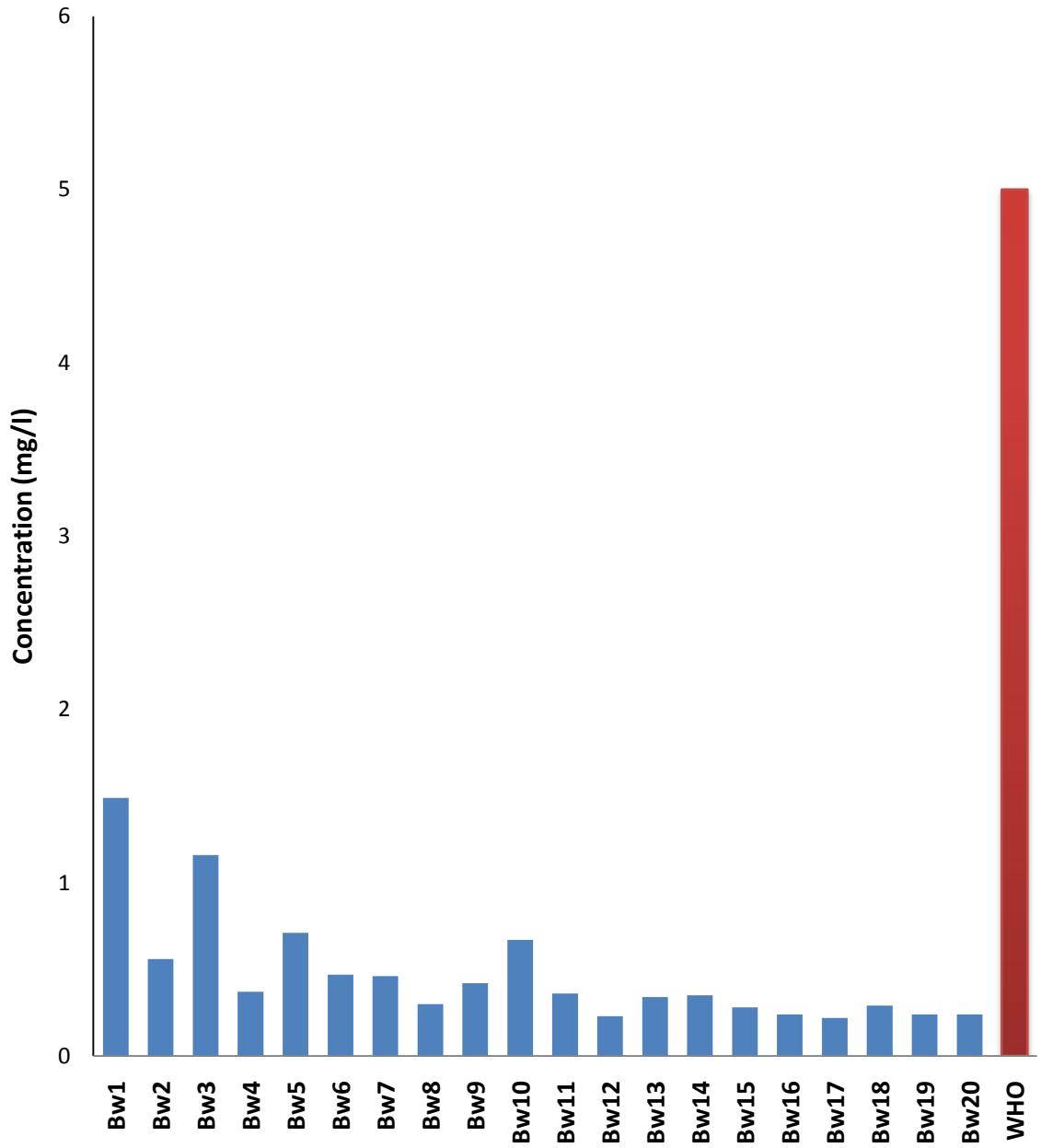
**Figure 4.6: Comparison of the Fluoride Values of the Water Sample with the Maximum Permissible Limits Set by WHO, NSDW and USEPA.**



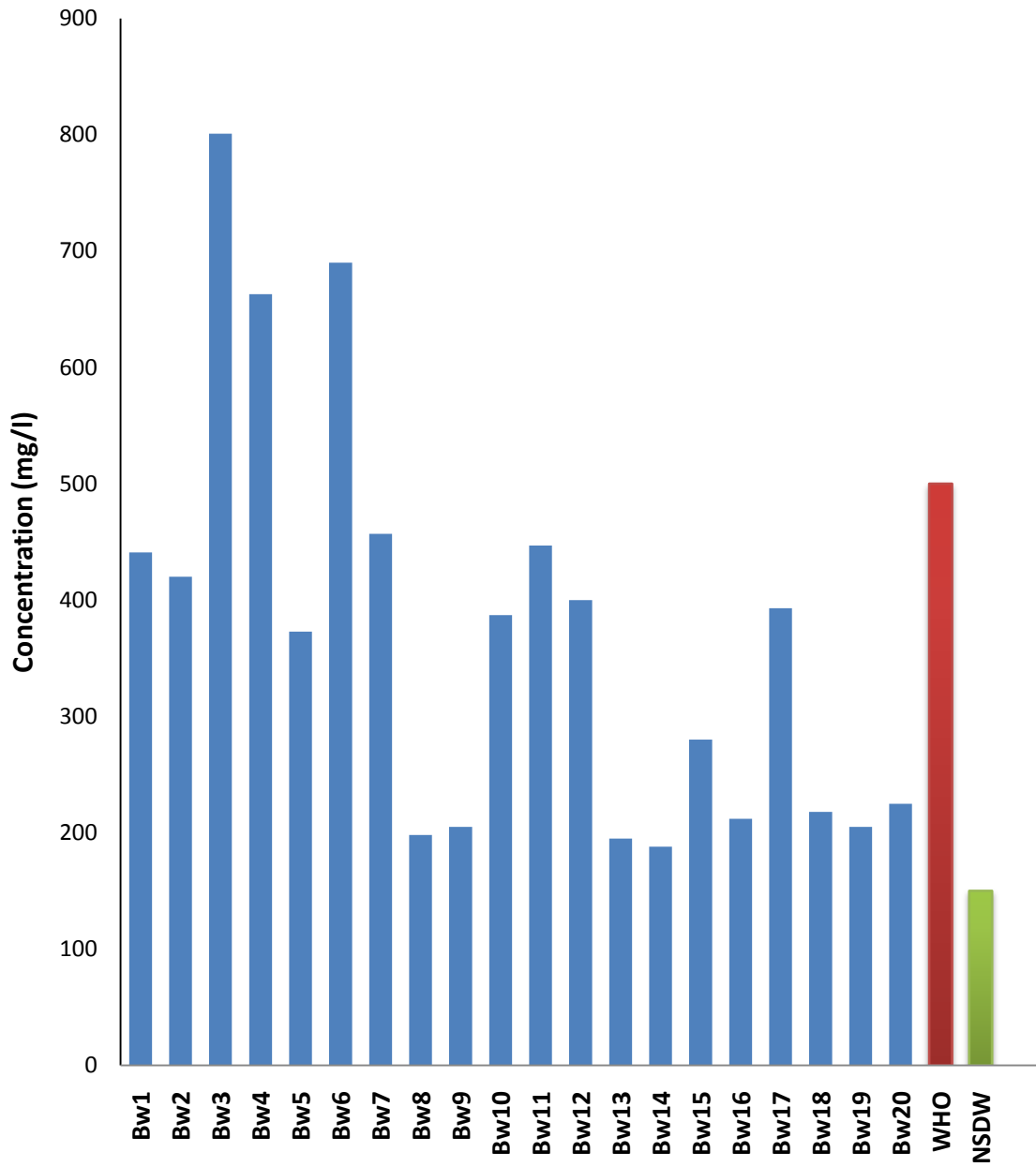
**Figure 4.7: Comparison of the Nitrate Values of the Water Samples with the Maximum Permissible Limit Set by WHO, NSDW and USEPA.**



**Figure 4.8: Comparison of the Sulphate Values of the Water Samples with the Maximum Permissible Limit Set by WHO, NSDW and USEPA.**



**Figure 4.9: Comparison of the Phosphate Values of the Water Sample with the Maximum Permissible Limit Set by WHO.**



**Figure 4.10: Comparison of the Hardness Values of the Water Samples with the Maximum Permissible Limit Set by WHO and NSDW.**

#### **4.2.2. Fluoride**

Fluoride values obtained ranged from  $0.11\pm 0.02$  to  $0.57\pm 0.01$ mg/l (Table 4.2). The minimum value of 0.11mg/l was obtained from the borehole designated as BW14 and the maximum value of 0.57mg/l was obtained from the borehole designated as BW12.

#### **4.2.3. Nitrate**

Nitrate values obtained ranged from  $4.03\pm 0.06$  to  $19.33\pm 1.62$ mg/l (Table 4.2). The minimum value of 4.03mg/l was obtained from borehole designated as BW7 while the maximum value of 19.33mg/l was obtained from the borehole designated as BW10.

#### **4.2.4. Sulphate**

Sulphate values obtained ranged from  $210.0\pm 10.0$  to  $345.0\pm 5.0$ mg/l (Table 4.2). The minimum value of 210mg/l was obtained from the borehole designated as BW3 while the maximum value of 345mg/l was recorded at the borehole designated as BW7.

#### **4.2.5. Phosphate**

Phosphate values obtained ranged from  $0.22\pm 0.11$  to  $1.49\pm 0.28$ mg/l (Table 4.2). The minimum value of 0.22mg/l was obtained from the borehole designated as BW17 while the maximum value of 1.49mg/l was obtained from the borehole with designation BW1.

#### **4.2.6. Total hardness**

Total hardness of water values obtained ranged from  $188.7\pm 29.0$  to  $801.5\pm 57.5$ mg/l (Table 4.2). The minimum value of 188.7mg/l was obtained from the borehole designated

as BW14 and the maximum value of 801.5mg/l was obtained from the borehole water with designation BW3.

### **4.3 Determination of Heavy Metals**

The results of the heavy metal determinations are presented in Table 4.3 and the comparison of results with the standards for drinking water in Figures 4.11-4.16. The results of heavy metal parameters as presented in Table 4.3 were described below:

#### **4.3.1. Zinc**

Zinc values obtained ranges from  $37\pm 16$  to  $3500\pm 14\mu\text{g/l}$  (Table 4.3). The minimum value of  $37\mu\text{g/l}$  was obtained from the borehole water designated as BW1 while the maximum value of  $3500\mu\text{g/l}$  was recorded at the borehole water designated as BW6.

#### **4.3.2. Manganese**

Manganese values recorded ranged from  $30\pm 18$  to  $282\pm 104\mu\text{g/l}$  (Table 4.3). The minimum value of  $30\mu\text{g/l}$  was obtained at the borehole designated as BW10 while the maximum value of  $282\mu\text{g/l}$  was recorded at borehole designated as BW3.

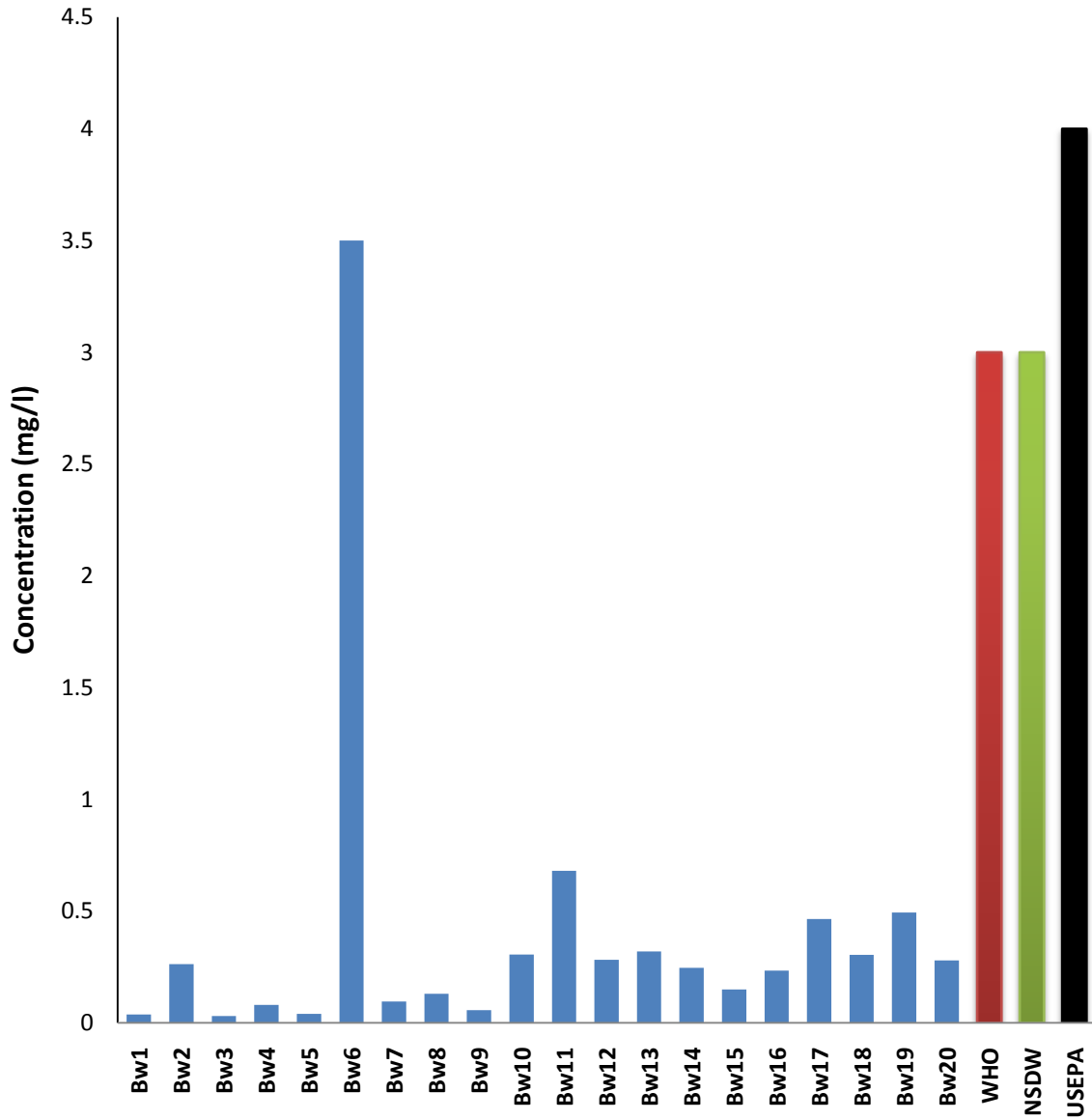
#### **4.3.3. Iron**

Iron values obtained of the sampled water ranged from  $88\pm 15$  to  $1856\pm 271\mu\text{g/l}$  (Table 4.3). The minimum value of  $88\mu\text{g/l}$  was obtained from the borehole water designated as BW5 while the maximum value of  $1856\mu\text{g/l}$  was obtained from the borehole water with designation of BW17.

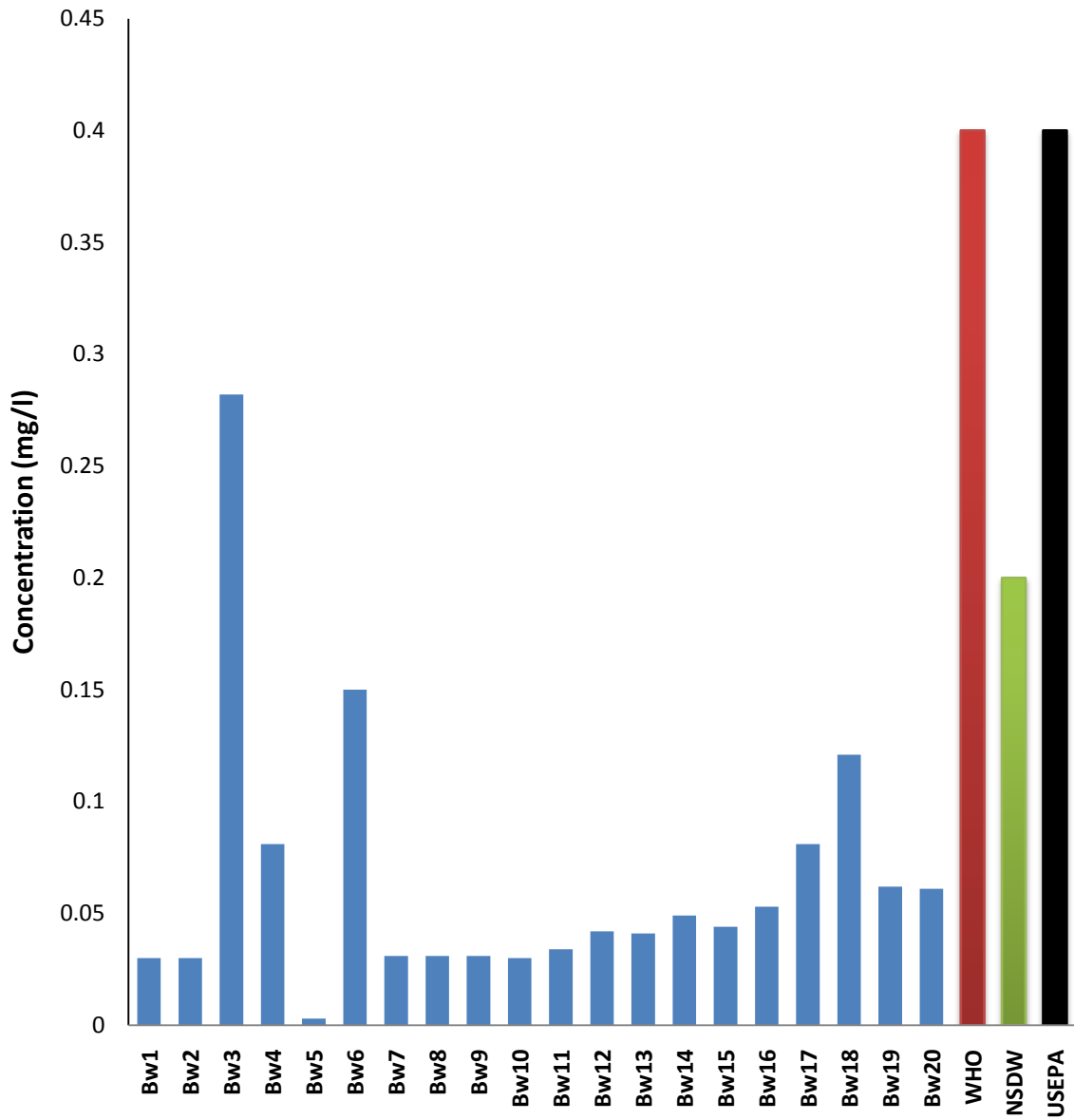
**Table 4.3: Mean and Standard Deviation Values of Heavy Metals of the Three Sampling Periods in all the Sampled Boreholes**

Samp- Le	Zn( $\mu\text{g/l}$ )	Pb( $\mu\text{g/l}$ )	Mn( $\mu\text{g/l}$ )	Fe( $\mu\text{g/l}$ )	Cd( $\mu\text{g/l}$ )	Cu( $\mu\text{g/l}$ )
BW1	37 $\pm$ 16.0	7 $\pm$ 2.0	61 $\pm$ 1.0	149 $\pm$ 7.0	2.5 $\pm$ 0.7	ND
BW2	263 $\pm$ 18.0	8 $\pm$ 1.0	18 $\pm$ 2.0	228 $\pm$ 1.0	2.5 $\pm$ 0.2	ND
BW3	300 $\pm$ 70.0	23 $\pm$ 7.0	282 $\pm$ 104.0	141 $\pm$ 1.0	2.3 $\pm$ 0.8	91 $\pm$ 56.0
BW4	80 $\pm$ 28.0	8 $\pm$ 1.0	81 $\pm$ 27.0	312 $\pm$ 27.0	2.5 $\pm$ 0.3	ND
BW5	40 $\pm$ 14.0	8 $\pm$ 1.0	66 $\pm$ 1.0	88 $\pm$ 15.0	2.0 $\pm$ 1.0	ND
BW6	3500 $\pm$ 14.0	7 $\pm$ 2.0	150 $\pm$ 63.0	1214 $\pm$ 4.0	3.0 $\pm$ 1.0	ND
BW7	95 $\pm$ 17.0	9 $\pm$ 4.0	62 $\pm$ 1.0	95 $\pm$ 9.0	2.5 $\pm$ 0.9	ND
BW8	130 $\pm$ 19.0	7 $\pm$ 3.0	61 $\pm$ 1.0	703 $\pm$ 431.0	4.0 $\pm$ 1.0	ND
BW9	57 $\pm$ 14.0	21 $\pm$ 8.0	62 $\pm$ 1.0	320 $\pm$ 4.70	3.0 $\pm$ 0.2	ND
BW10	306 $\pm$ 158.0	6 $\pm$ 2.0	30 $\pm$ 18.0	95 $\pm$ 60.0	2.5 $\pm$ 0.1	ND
BW11	680 $\pm$ 339.0	18 $\pm$ 2.0	34 $\pm$ 18.0	163 $\pm$ 32.0	2.5 $\pm$ 0.1	ND
BW12	282 $\pm$ 88.0	9 $\pm$ 6.0	42 $\pm$ 13.0	808 $\pm$ 13.0	3.0 $\pm$ 1.0	ND
BW13	320 $\pm$ 29.0	10 $\pm$ 3.0	41 $\pm$ 22.0	265 $\pm$ 26.0	3.0 $\pm$ 1.0	ND
BW14	246 $\pm$ 19.0	8 $\pm$ 3.0	49 $\pm$ 16.0	257 $\pm$ 35.0	3.0 $\pm$ 1.0	ND
BW15	150 $\pm$ 40.0	15 $\pm$ 6.0	44 $\pm$ 17.0	123 $\pm$ 29.0	4.0 $\pm$ 1.0	ND
BW16	234 $\pm$ 20.0	14 $\pm$ 7.0	53 $\pm$ 13.0	592 $\pm$ 103.0	3.0 $\pm$ 1.0	ND
BW17	465 $\pm$ 181.0	16 $\pm$ 4.0	81 $\pm$ 1.0	1856 $\pm$ 271.0	4.0 $\pm$ 0.1	ND
BW18	304 $\pm$ 202.0	20 $\pm$ 6.0	121 $\pm$ 9.0	237 $\pm$ 28.0	7.0 $\pm$ 3.0	ND
BW19	494 $\pm$ 274.0	13 $\pm$ 2.0	62 $\pm$ 11.0	57 $\pm$ 14.0	4.0 $\pm$ 0.1	ND
BW20	279 $\pm$ 16.0	16 $\pm$ 1.0	61 $\pm$ 12.0	170 $\pm$ 92.0	4.0 $\pm$ 1.0	ND

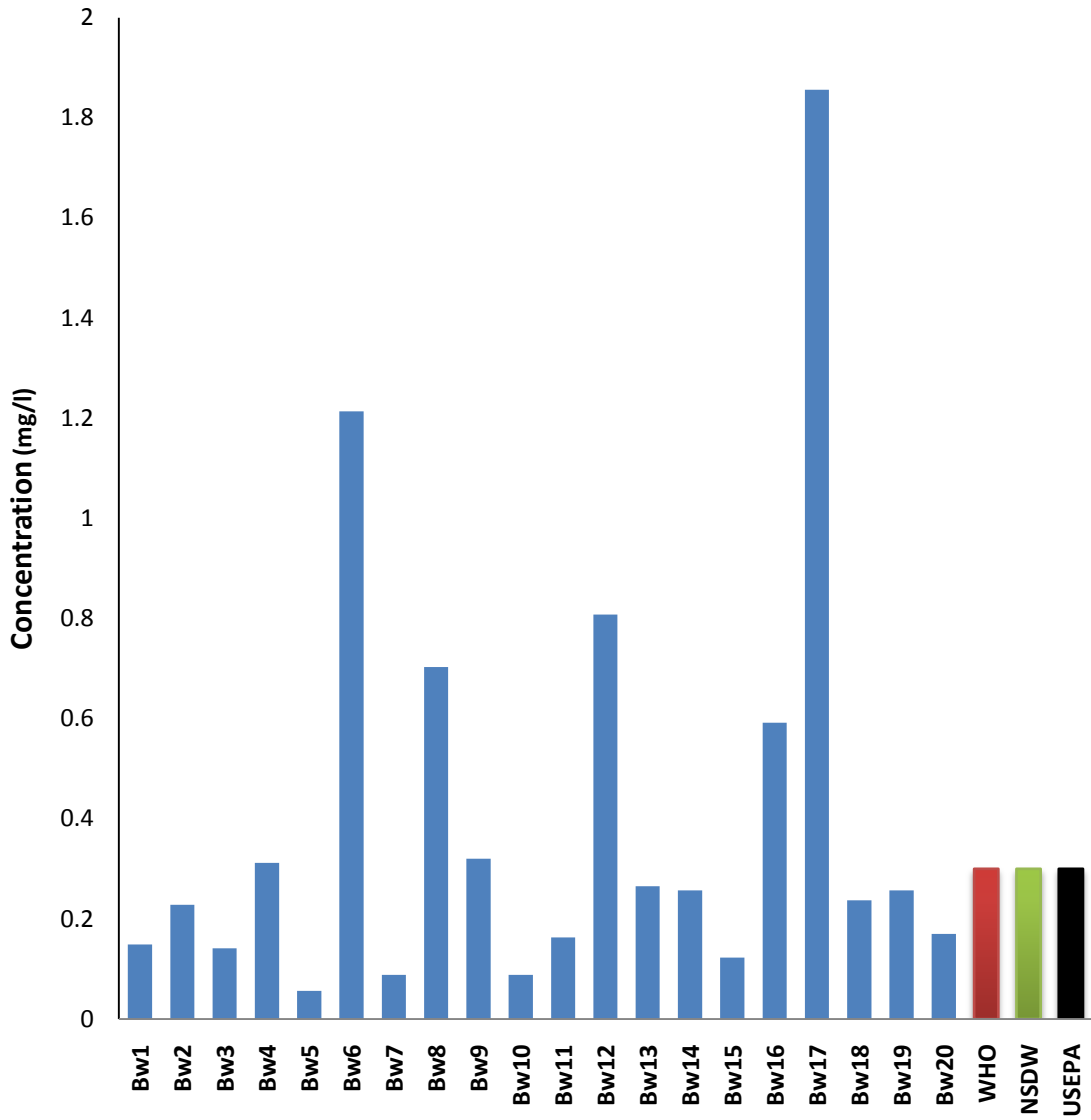
ND (Not Detected).



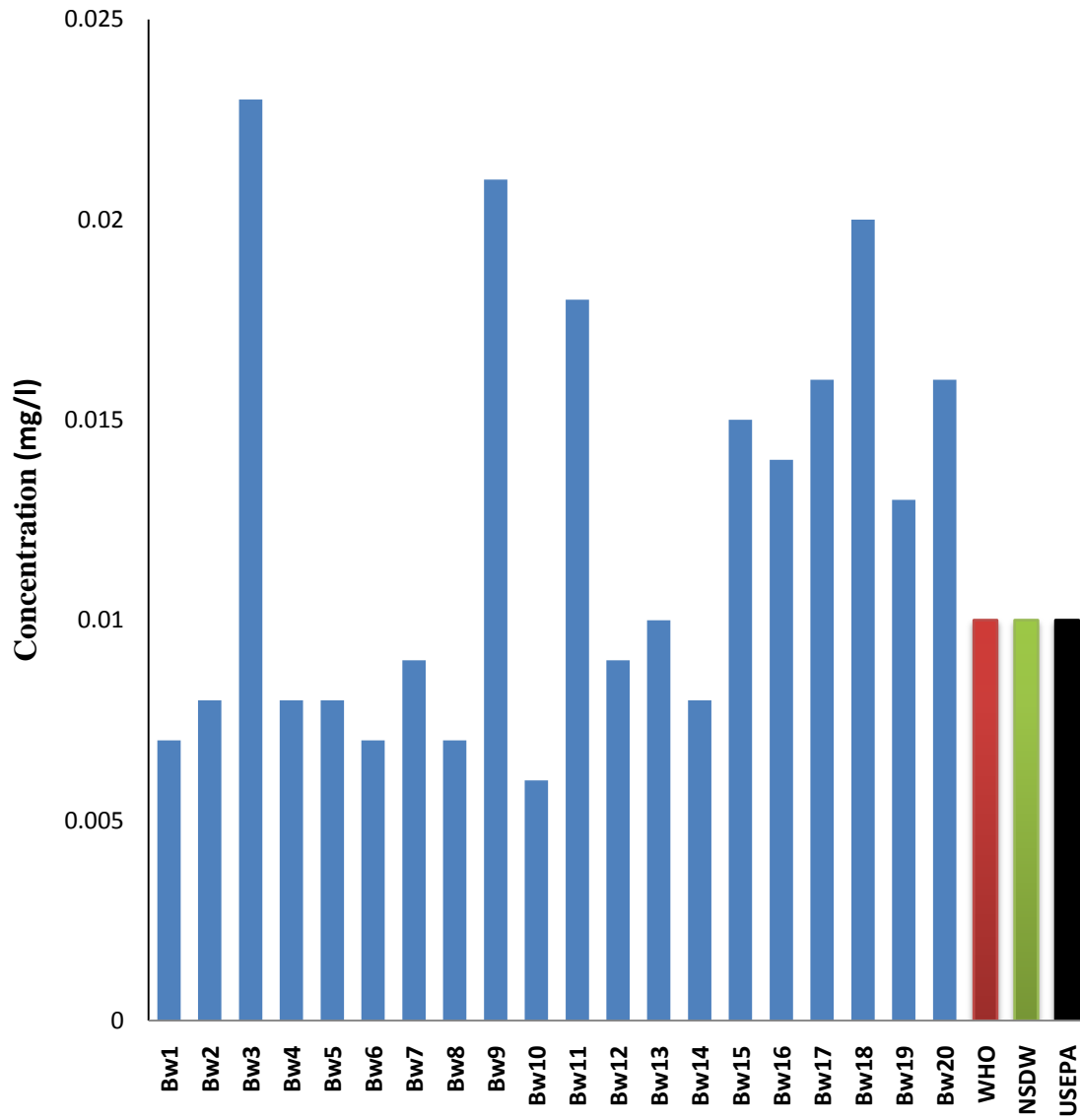
**Figure 4.11: Comparison of the Concentration in mg/l of Zinc obtained with the Maximum Permissible Limit Set by WHO, NSDW and USEPA.**



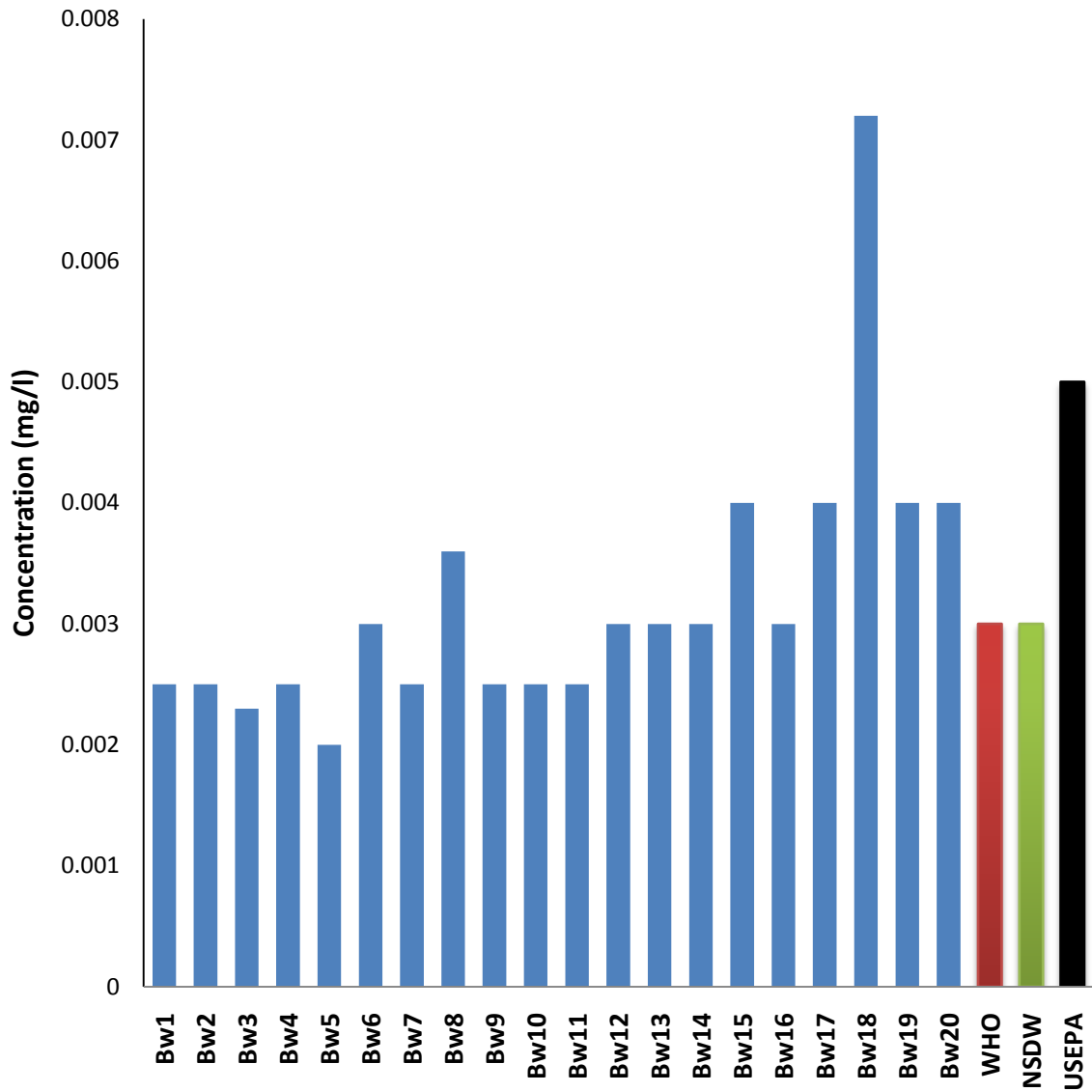
**Figure 4.12: Comparison of the Concentration in mg/l of Manganese with the Maximum Permissible Limit Set by WHO, NSDW and USEPA.**



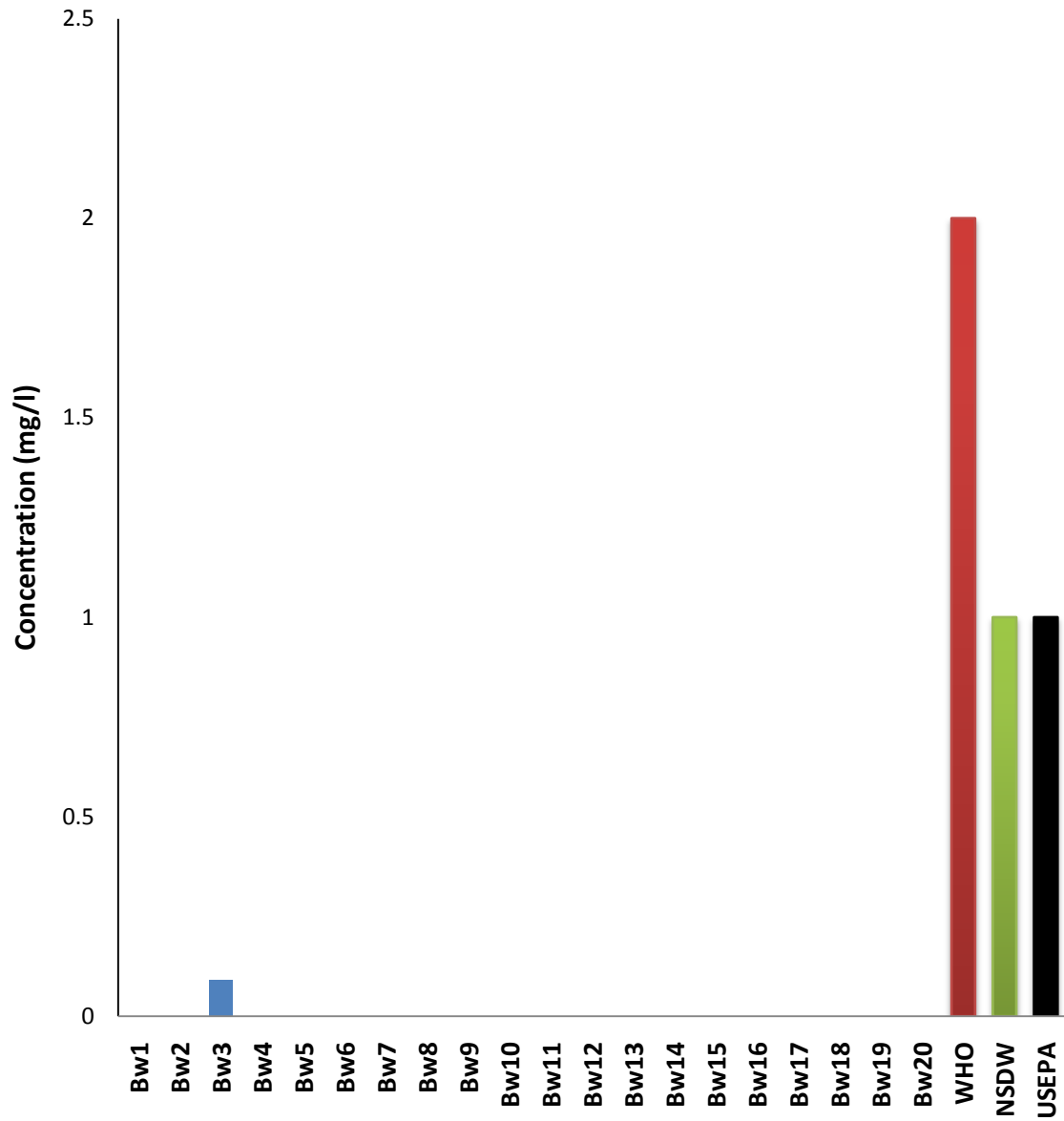
**Figure 4.13: Comparison of the Concentration in mg/l of Iron obtained with the Maximum Permissible Limit Set by WHO, NSDW and USEPA.**



**Figure 4.14: Comparison of the Concentration in mg/l of Lead obtained with the Maximum Permissible Limit Set by WHO, NSDW and USEPA.**



**Figure 4.15: Comparison of the Concentration in mg/l of Cadmium obtained with the Maximum Permissible Limits set by WHO, NSDW and USEPA.**



**Figure 4.16: Comparison of the Concentration in mg/l of Copper obtained with the Maximum Permissible Limit Set by WHO, NSDW and USEPA.**

#### **4.3.4. Lead**

Lead values obtained on the analysis of the sampled water ranged from  $6\pm 2$  to  $23\pm 7\mu\text{g/l}$  (Table 4.3). The minimum value of  $6\mu\text{g/l}$  was obtained at borehole water designated as BW10 while the maximum value of  $23\mu\text{g/l}$  was obtained at the borehole water designated as BW3.

#### **4.3.5 Cadmium**

Cadmium values obtained ranged from  $2\pm 1.0\mu\text{g/l}$  to  $7\pm 3.0\mu\text{g/l}$  (Table 4.3). The minimum value of  $2\mu\text{g/l}$  was obtained from the borehole water designated as BW5 while the maximum value of  $7\mu\text{g/l}$  was obtained from the borehole water with designation BW18.

#### **4.3.6. Copper**

Copper was only detected in the borehole water designated as BW3 with the mean value of  $91\pm 56\mu\text{g/l}$  (Table 4.3).

**Table 4.4: Correlation Matrix of the Physicochemical Parameters Obtained from the Borehole Water Samples Analyzed.**

	Temp.	pH	TDS	Fluoride	Phosphate	Turbidity	Conductivity	Chloride	Nitrate	Sulphate	Hardness
Temp	1.000										
PH	0.302*	1.000									
TDS	.205	-.035	1.000								
Fluoride	.196	.288*	.035	1.000							
Phosphate	.019	-.083	-.005	-.266*	1.000						
Turbidity	.136	-.145	.158**	.201	-.204	1.000					
Conductivity	.164	.128	.760**	.120	-.256*	.101**	1.000				
Chloride	.170	-.057	.731**	.448*	-.112	.128**	.641**	1.000			
Nitrate	.214	-.145	-.103	-.139	.429**	-.273*	-.233	-.255*	1.000		
Sulphate	.095	.334**	.227	.489*	-.344**	.218	.357**	.499*	-.143	1.000	
Hardness	-.001	.006	.462**	-.004	-.414**	.227	.146	.348**	-.036	-.104	1.000

**\*\*.** Correlation is significant at the 0.01 level (2-tailed).

**\*.** Correlation is significant at the 0.05 level (2-tailed).

**Table 4.5: Correlation Matrix of the Chemical and Heavy Metal Parameters  
Obtained from the Borehole Water Sample Analyzed.**

	Zn	Fe	Cd	Mn	Pb	Fluoride	phosphate	chloride	nitrate	Sulphate	Hardness
Zn	1.000										
Fe	.489**	1.000									
Cd	-.040	.088	1.000								
Mn	.280	.150	.088	1.000							
Pb	.069	-.084	-.075	.751**	1.000						
Fluoride	.090	.100	.086	-.158	-.216	1.000					
Phosphate	-.198	-.272	-.106	-.176	-.222	-.266*	1.000				
Chloride	-.087	.102	.531**	.046	.043	.448*	-.112	1.000			
Nitrate	.017	-.039	-.056	-.020	-.041	-.139	.429**	-.255*	1.000		
Sulphate	.007	-.029	.072	-.257	-.123	.489*	-.344**	.499*	-.143	1.000	
Hardness	.201	.106	.171	.089	.120	-.004	-.414**	.348**	-.036	-.104	1.000

**\*\*.** Correlation is significant at the 0.01 level (2-tailed).

**\***. Correlation is significant at the 0.05 level (2-tailed).

## CHAPTER FIVE

### DISCUSSION

#### 5.1 Physicochemical Parameters

##### 5.1.1. Temperature

The relatively low sampling temperature recorded could be attributed to the time of collection of the samples which was in the morning. The temperature of drinking water is often not a major concern to consumers especially in terms of the quality. The quality of water with respect to temperature is usually left to the individual taste and preference and there are no set guidelines for drinking water temperature. Nkansah and Ephraim, 2009 reported low temperature in the physicochemical analysis of water in Ghana which they attributed to the time of sampling.

##### 5.1.2. pH

The pH values of all the sampled borehole water tested were within the WHO 2006, NSDW 2007 and USEPA 2012 acceptable range of 6.5 to 8.5 except for the BW17 with the pH of value of  $6.40 \pm 0.10$ . Although the values indicated that most of the water samples were slightly acidic and few slightly basic, the consumers of the water are not at any health risk due to pH. Ilechukwu and okonkwo, 2012, reported pH of range of 6.38 to 8.42 and concluded that the consumers of such water in that pH range are not at any health risk due to pH.

### **5.1.3. Conductivity**

Electrical conductivity gives an account of all the dissolved ions in solution. All the values obtained were below the WHO 2006, NSDW 2007 and USEPA 2012 maximum permissible limit of 1000 $\mu$ S/cm for drinking water (Figure 4.2) and therefore, the electrical conductivity values recorded from the samples do not have any potential health risk to the consumers. Electrical conductivity is considered to be a good and rapid measure of determining total dissolved solids as reported by Quaitto, (1996). A very strong positive correlation between conductivity and TDS (Table 4.4) is in line with this existing relationship between the two parameters and this could mean that they have the same source and therefore are dependent on each other. Also, the positive correlation between conductivity and other parameters like chloride and sulphate could also mean that the ions of those parameters were responsible for the electrical conductivity of the water.

### **5.1.4. Total dissolved solids (TDS).**

All the TDS values obtained were below the 500mg/l maximum permissible limit as recommended by USEPA 2012 and NSDW 2007 and also below 1000mg/l maximum permissible limit as recommended by WHO 2006 (Figure 4.3). Therefore, the TDS in the water have no any potential health risk to the consumers. The strong positive correlation (Table 4.4) between chloride and TDS could be a suggestion that chloride is partly responsible for the total dissolved solids in the sampled water. Bruvold and Ongerrh, (1969) reported components of TDS to include chlorides, sulphates, nitrates, magnesium, potassium, calcium and carbonates. The report added that water containing extremely low concentration of TDS may be unacceptable because of its insipid taste and that water with

TDS above the upper limit of 1000mg/l as recommended by WHO is generally unacceptable due to its inferior palatability and may induce an unfavorable physiological reaction in the transient consumer. TDS of the water under investigation with range 53.3 to 119.7 is acceptable due to its moderate concentration and therefore no health risk is associated with the water due to total dissolved solids.

#### **5.1.5. Turbidity**

Turbidity is an indication of the clarity the water. The turbidity values as recorded in all the boreholes sampled were below the WHO 2006, NSDW 2007 and USEPA 2012 maximum permissible limit of 5NTU (Figure 4.4) and therefore do not have any potential health risk to the consumers. Generally, borehole water usually have low turbidity value since surface water that percolate as groundwater would have undergone natural filtration through the soil as it percolates into the aquifer. However, the significant values obtained in some of the borehole analyzed signified a possible clay and groundwater interaction in some aquifers which is capable of influencing the clarity of the water. Tiimub *et al.*, 2012, reported turbidity of 0.59-23.3 in underground water analysis and attributed it to clay and underground water interaction.

#### **5.1.6. Chloride**

All the values obtained for the boreholes analyzed were below the WHO 2006, NSDW 2007 and USEPA 2012 maximum permissible of 250mg/l except for the water from BW6 and BW12 which recorded mean value of 487.01mg/l and 424.61mg/l (Figure 4.5). However, the guideline value of 250mg/l as above was established for chloride based on taste consideration not on health reason since human exposure to chloride is the addition of

salt to food, and the intake from this source is usually greatly in excess of that from drinking water (WHO,2006). The high chlorides in these two boreholes could probably be as a result of rock containing chlorides which may be underlying the area and when in contact with the water in the aquifer dissolves into the groundwater or probably the location of the borehole BW6 and BW12 close to a dumping site where refuse leachate can influence the groundwater with chloride. Masona, (2009) reported high chloride above WHO permissible limit and attributed it to the nature of the rocks underlying the study area which interacts with the underground water. There is a positive correlation between chlorides and sulphate (Table 4.4) which could mean that they have the same origin in the sampled water and is probably from the interaction of rocks containing the salts of the anions and water in the aquifer. The negative correlation between chlorides with nitrates and phosphates (Table 4.4) may also indicate that nitrates and phosphates may have different origin in the water sample and this could be linked to originate from agricultural activities (fertilizer and organic manure application) that are common in the study area.

#### **5.1.7. Fluoride**

Fluoride was detected in all boreholes analyzed, however, the values obtained were below the WHO 2006 and NSDW 2007 maximum permissible limit of 1.5mg/l and USEPA 2012 permissible limit of 2mg/l. Therefore, the consumers of the water are not likely to suffer from dental fluorosis as a result of the water. Also, the present of the fluoride (0.11-0.58mg/l) is also importance to the consumers because moderate concentration of about 0.8mg/l prevents dental carries. Hence it is important to maintain the fluoride concentration between 0.8 to 1.0 mg/l in drinking water (Pillai and Stanley, 2002). The presence of fluoride recorded in all the sampled water may be attributed to the presence of inorganic

compounds containing fluoride in the underlying rocks in the aquifer that interact with underground water. The variations in the values across the analyzed boreholes could occur especially where rocks of different composition exist. McDonghet *et al.*, (2004) and Dibala, (2012) reported high concentrations of fluoride in groundwater and they attributed it to the presence of inorganic compounds containing fluoride that interact with the groundwater.

#### **5.1.8. Nitrate**

All the borehole water analyzed showed appreciable levels of nitrates which were still below the WHO 2006, NSDW 2007 and USEPA 2012 maximum permissible limit of 50mg/l (Figure 4.7) and therefore do not pose adverse health risk to consumers. The adverse effect of nitrate can only occur at elevated level above 50mg/l, especially in children causing methemoglobinemia blue baby syndrome (WHO, 2004). The availability of nitrate in appreciable quantities in all the boreholes analyzed signified a common possible source of nitrates in the entire sample which is suspected to originate from the farming practices that are common in the study area. All the boreholes analyzed were within the vicinity of farm lands that involved the application of organic manure and inorganic fertilizers. Mancy, (2012) reported availability of nitrate in the analyzed water sample and identified agricultural activities which included fertilizer and organic manure application as the possible sources of contamination.

#### **5.1.9. Sulphate**

All the samples analyzed showed high sulphate concentration that were above the maximum permissible limit of 250mg/l for WHO 2006 and USEPA 2012 except for

boreholes designated as BW1, BW2 and BW3 with 236.7mg/l, 225mg/l and 210mg/l respectively (Figure 4.8). Sulphate can only adversely affect the health of human consumers in high concentration above 500mg/l and causes laxative effect when combine with calcium and magnesium, the two most common components of hard water. The guideline values of 250mg/l (WHO and USEPA) as above were established for sulphates based on taste consideration not on health reason. Therefore, sulphates do not pose adverse health risk to the consumers of the sampled water since all samples recorded values below 500mg/l which is limit that has health implication. The positive correlation of sulphate with chloride and fluoride (Table 4.4) could suggest a possible common source of contamination resulting from rocks containing the salts of the anions and water interactions in the aquifer while negative correlation of sulphate with nitrate and phosphate (Table 4.4) may also suggest that both phosphate and nitrate could have another common source of contamination which could be linked to the agricultural activities in the study area. Mancy, (2012) reported high sulphate and suggested the geological formation of the study area as the possible source of contamination.

#### **5.1.10. Phosphates**

The phosphate concentrations of the samples analyzed were all within the WHO, 2006 acceptable limit of 5.0mg/l and therefore do not pose any health risk to the consumers. The presence of phosphate in all the borehole water analyzed could be an indication that the source of phosphate in water samples may be of the same origin. Also, the positive correlation of phosphate with nitrate (Table 4.4) may suggest a common source of contamination and could be linked to the intensive agricultural practices like fertilizers and organic manure application. Phosphate like any other nutrient is harmless in lower

concentrations but becomes harmful only when maximum permissible limit is exceeded. Higher concentrations of phosphate are known to interfere with digestion in both human and animals (USEPA, 2007). Therefore, the intensive farming practices in the study area did not contribute to elevated level of phosphate concentration in the groundwater above the WHO 2006 permissible limit and hence no adverse health risk is associated with nitrate for consuming the sampled water.

#### **5.1.11. Total hardness**

All the borehole water analyzed recorded different degrees of hardness that were still within the WHO 2006 maximum permissible limit of 500mg/l except for boreholes designated as BW3, BW4, and BW6 with the hardness of 801.50mg/l, 663.25mg/l and 690.23mg/l respectively (Figure 4.10 ). NSDW 2007 provided a permissible limit of 150mg/l though not on health based but on the acceptability to consumers in terms of taste and scale deposition. The hardness recorded in all the boreholes analyzed could be attributed to the nature of geological formation since hardness is derived largely from weathering of minerals such as limestone, dolomite and gypsum (WHO, 2004). Ombaka *et al.*, (2013) reported high levels of hardness in the groundwater and suggested the weathering of minerals that varied considerably from place to place depending on the nature of geological formation as the source of the hardness. The results of a number of studies have suggested that water hardness may protect against disease (Degremont, 1991). There exist, an inverse relationship between the hardness of drinking water and cardiovascular disease at elevated hardness (WHO, 2006). Some data suggested that very soft water, with a hardness of less than 75mg/dm<sup>3</sup> may have an adverse effect on mineral balance in the body (Manky and Ramam, 2011). Depending on the interaction of other

factors, such as pH and alkalinity, water with hardness above approximately 200mg/l may cause scale deposition in the distribution system, as well as increased soap consumption (WHO, 2006). Therefore, the inhabitants of the study area are not at risk of water hardness related cardiovascular disease but scale deposition in distribution system and increased soap consumption are likely to occur in the study area due to the concentration range of hardness obtained.

## **5.2. Heavy Metals**

### **5.2.1. Zinc**

All the borehole water analyzed had values below the maximum permissible limit of 4.0mg/l as recommended by the USEPA 2012 and also below the permissible limit of 3.0mg/l as provided by WHO 2006 and NSDW 2007 except for BW6 with 3.50mg/l. The presence of zinc in all the samples analyzed could mean that the source of contamination is the same and is probably the dissolution of minerals of zinc in the underground water depending on the rock composition of a particular place. The high zinc concentration in the borehole water designated as BW6 is probably as a result of the piping system that was newly constructed with galvanized pipes which is capable of influencing the water with zinc. Shelton and Scibila, (1998) reported high zinc in drinking water and attributed it to galvanized pipes. Measurement of zinc in water is important because it is essential in trace amounts for plants and animal growth. However, concentration above 4mg/dm<sup>3</sup> can render the water unpalatable causing a bitter astringent taste (WHO, 2006). Therefore, the water quality in study area in reference to zinc concentration is acceptable.

### **5.2.2. Manganese**

All the values obtained in all the water samples were below the WHO 2006 and USEPA 2012 maximum permissible limit of 0.4mg/l (Figure 4.12). However, NSDW 2007 provided permissible limit of 0.2mg/l for manganese. The detectable levels of manganese in all the samples analyzed could mean that the source of contamination is common to all the boreholes and is probably due to the dissolution of minerals of manganese in the underground water. Manganese occurs as a result of weathered and solubilized manganese from soil and bedrock (Ward, 1995). Tiimub, *et al.*, (2012) reported high level of manganese in groundwater analysis with range 0.038mg/l to 0.638mg/l and attributed it to the probable interaction of groundwater with rock layers or soil minerals and concluded that manganese as an essential element is of great important in living organism provided that the recommended limit is not exceeded. Hence the concentration of manganese in the water sample obtained from the study area is acceptable since it is below the maximum permissible limit as above.

### **5.2.3. Iron**

All the borehole water analyzed had iron concentration below the WHO 2006, NSDW 2007 and USEPA 2012 maximum permissible limit of 0.3mg/l except for borehole designated as BW6, BW8, BW12, BW16 and BW17 with values of 1.214mg/l, 0.703mg/l, 0.808mg/l, 0.592mg/l, and 1.856mg/l respectively (Figure 4.13). The appreciable quantity of iron detected in all the samples may be as result of common source of contamination which is probably from the iron bearing minerals in the rocks as they interact with the underground water. The pipes used in the construction of the boreholes could also be a

possible source of contamination. Akoto and Adiyiah, (2007) reported a range of 0.05mg/l to 0.85mg/l iron in drinking water which they linked to probable interaction of the groundwater with rocks layers or soil minerals. Iron is essential for good health and helps in transporting of oxygen in the blood but at high concentrations above the recommended levels affect the taste and the odour of the water. Also, high concentrations of iron in water forms oxy-hydroxide precipitate that stains laundry, fixtures and utensils which is difficult to remove (APHA, 1985).

#### **5.2.4. Lead**

Nine out of the twenty boreholes analyzed showed high lead values that were above the WHO 2006, NSDW 2007 and USEPA 2012 maximum permissible limits of 0.01mg/l (Figure 4.14) and therefore can pose adverse health risk to the consumers especially when accumulated over a long period of time. In humans, exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure (Sridhar *et al.*, 2000). The recorded high level of lead in the sampled water signified a possible rock mineral and groundwater interaction. The underlying rocks may contain minerals of lead composition capable of impacting lead on the groundwater. Odunola *et al.*, (2013) reported high level of lead in groundwater above WHO recommended limit and suggested the possible source of contamination from the nature of the rock underlying the study area.

#### **5.2.5. Cadmium**

All the samples analyzed recorded values below the USEPA 2012 maximum permissible limit of 0.005mg/l except for the borehole water with designation BW18 that recorded 0.007mg/l while BW8, BW15, BW17, BW18, BW19 and BW20 recorded values above

0.003mg/l maximum permissible limit as provided by WHO 2006 and NSDW 2007 (Figure 4.15). The detectable level of cadmium in all the samples analyzed could also mean that the source of contamination is common to all sample locations though at different degrees. This source of contamination may be attributed to the interaction of the groundwater and the rock layers or soil minerals. Cadmium correlated strongly with manganese and this could be an indication that both may have the same origin of contamination. Contamination of groundwater with cadmium can also be possible through the application of fertilizer that is common in the study area. According to Asolkar *et al.*, (2002), cadmium may also enter drinking water via weathering of soil and bedrock, corrosion of galvanized pipes, atmospheric decomposition of direct discharge from industrial operation, leakages from landfills and from the use of fertilizers. In human, cadmium is found to be potentially toxic especially in long term exposure (USEPA, 2007). Hence the consumers of water in those boreholes found to have cadmium value above permissible level are at adverse health risk. The intensive farming practices in the study area that involves application of fertilizers or probably the nature of underlying rocks in study area may be responsible for cadmium presence in the water sample.

#### **5.2.6. Copper**

Copper was only detected in the borehole water designated as BW3 with the mean value of  $0.091 \pm 0.056$ mg/l (Table 4.3). The WHO 2006 recommended permissible limit for copper in drinking water is 2.0mg/l while 1.0mg/l was recommended by NSDW 2007 and USEPA 2012. Therefore the value obtained in BW3 is still within the acceptable limit of copper in drinking water. Copper may be found in water through the natural process of dissolution of minerals, industrial discharge, through its use as copper sulphate for controlling biological

growth in some reservoirs and distribution system or through copper corrosion of copper alloy water pipes but most copper contamination in drinking water happens in the water delivery system as a result of corrosion of copper pipes or fittings (ASTM, 2004). The absence of copper in detectable levels in the 95% of samples analyzed may be an indication that the rocks underlying the study area do not have detectable copper influence on the groundwater.

## CHAPTER SIX

### 6.0. SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

#### 6.1. Summary of the Findings

The results obtained from the twenty boreholes investigated showed that the physicochemical parameters which include turbidity, TDS, electrical conductivity, pH, phosphate, fluoride, manganese and nitrate had values that were within the WHO (2006), NSDW (2007) and USEPA (2012) permissible limits for drinking water. However, parameters which include chloride was detected at the level within the acceptable limit of 250mg/l except in two boreholes BW6 (487.01mg/l) and (BW12 474.61mg/l) while hardness had all values still within the recommended limit of 500mg/l for hardness in drinking water by WHO 2006 and USEPA 2012 except in three boreholes BW3 (801.5mg/l), BW4 (663.2mg/l) and BW6 (690.2mg/l) that recorded above the recommended limit. Sulphate was found to have values above the permissible limit of 250mg/l as recommended by WHO 2006 and USEPA 2012 in all boreholes investigated except in three boreholes BW1 (236.7mg/l), BW2 (225.5mg/l) and BW3 (210.0mg/l).

Also, the results obtained showed that the heavy metals which include zinc were detected at level within the acceptable limits of 3.0mg/l by WHO 2006 and NSDW 2007 for drinking water in all the boreholes except for one borehole (BW6) that record 3.5mg/l for zinc. Cadmium had values that were within the acceptable limits of 0.003mg/l in all the boreholes except in six boreholes which included BW6, BW8, BW15, BW17, BW18, BW19 and BW20 in the range 0.004-0.007mg/l while iron also had values within the acceptable limit of 0.3mg/l in all the boreholes except five boreholes which included BW6,

BW8, BW12, BW16, BW17 at concentration range of 0.592-1.856mg/l. Copper was below detectable limit in all the boreholes except in one borehole (BW3) where it was detected in the concentration of 0.091mg/l which is still within the acceptable limit of 2mg/l by the WHO regulatory body while lead had values above the acceptable limits of 0.05mg/l by the WHO regulatory body in the following nine boreholes BW3, BW9, BW11, BW15, BW16, BW17, BW18, BW19 and BW20 at the concentration range of 0.013-0.023mg/l.

Correlation of the parameters investigated suggested agricultural activities and the nature of the rocks underlying the study area as the possible sources of contamination of the underground water (borehole water) studied.

## **6.2 Conclusion**

Based on the findings, it is evident that not all the boreholes investigated had parameters that were in conformity with the WHO 2006, NSDW 2007 and USEPA 2012 recommended permissible limits for drinking water. Therefore, possible adverse effect due to consumption of the water containing high levels of these parameters may occur among the inhabitants of this study area especially in the cases of lead and cadmium if they bio-accumulates beyond the tolerable concentrations in the body.

## **6.3 Recommendation**

Based on the outcome of the study, the following recommendations are made: Sampled boreholes in the study area that their parameters measured were not in conformity with standards for drinking water (especially in the cases of lead and cadmium) should undergo treatment before consumption.

Relevant authorities should ensure that the inhabitants of the study area are educated on the needs not to sight boreholes close to farm lands so as to avoid contamination resulting from farming activities.

Water quality assessment should be carried out on the boreholes in the study area at least once every three years. This will ensure that incidence of contaminations are noticed earlier for remedial actions to be taken.

## REFERENCES

- Abbott, M. B., Bathrust, J. C., Cunge, J. A., O'Connell, P. E. and Rasmussen, J. (1986). An introduction to European Hydrological System. *Journal of Hydrology*, 87:45-77.
- Acworth, R. I. (2007). Measurement of vertical environmental-head profile in unconfined sand aquifers using a multi-chemical manometer board. *Hydrogeology Journal*, 15: 1279-1289.
- Ademoroti, C.M.A. (1996). Standard Method for Water and Effluent Analysis. Foludex press Ltd, Ibadan, pp. 28-29, 40-43.
- Adepoju, A. A., Ojomolade, O. O., Ayoola, G. A. and Cooker, H. A. B. (2009). Quantitative analysis of some toxic metals in domestic water obtained from Lagos metropolis. *The Nigeria Journal PHARM.*, 42(1): 57-60.
- Akoto, O. and Adiyiah A. (2007). Chemical analysis of drinking water from some communities in the Brong Ahafo region. *International Journal Environ. Sci. Tech.* 4(2): 211-214.
- Alexander, P. (2008). Evaluation of Ground water quality of Mubi town in Adamawa, Nigeria. *African Journal of Biotechnology*, 7(11): 1712-1715.
- Alloy, B. J. and Ryres, D. C. (2009). *Chemical Principles of Environmental Pollution*. 2<sup>nd</sup> ed., University of London, United Kingdom. Pp. 44-46.
- Andreoli, C. V. (1993). The influence of agricultural on water quality. In: prevention of water pollution by agricultural and related activities. Proceedings of the FAO Expert Consultation, Santiago, Chile, 20-23 Oct., 1992. Water Report 1. FAO, Rome. Pp. 53-60.
- AOAC, (1998). Official methods of analysis of the Association of Official Analytical Chemist Alexandria, V. A: Association of Official Analytical Chemist, Pp 432-444.
- APHA. (1985). Standard methods for the examination of water and waste water. 16<sup>th</sup> ed., America Public Health Association inc. New York, pp.130-145.
- APHA. (1989). Standard methods for the examination of water and waste water. 17<sup>th</sup> ed., Washington, DC. pp. 1269.
- APHA. (1998). Standard methods for the examination of waste water. 20<sup>th</sup> ed. American Public Health Association, Washington, DC. pp. 45-60.
- Armon, R. and Kitty, D (1994). *The Health Dimension of Groundwater Contamination*. Mercel Dekker, New York, USA, Pp. 122-140.

- Asolker, S. R., Sridhar, T. and Joshi, S. G. (2002). Pollution effect in drinking water. *Journal IAEM*, 25: 66-70.
- ASTM (2004). American society for testing materials Annual book of Standard Water and environmental technology. Vol. 11 Pp 22-132.
- Ayoade, Y. O. and Akintola, F. O. (1999). *Water and Man, a Handbook of Geography Teaching for Schools and Colleges*, Heineman Education and Books, Ibadan. Pp.58-64.
- Back, W., Baedecker, M. J. and Wood, W. W. (1993). *Scales in Chemical Hydrology: a Historical Perspective*. W. M. Alley and Van Nostrand Reinhold, New York. Pp, 111-120.
- Balek, J. (1977). *Hydrology and Water Resources in Tropical Africa*. Elsevier Amsterdam, pp,128-140.
- Bruvoid, W. H. and Ongerrh, H. J. (1969). Taste quality of mineralized water. *Journal of the American water works Association*, 61:170.
- Chapman, D. (1996). *Water quality Assessment: A guide to the use of Biota, Sediments and Water in Environmental Monitoring*. 2<sup>nd</sup> edition, Chapman and Hall, London
- Chilton, J. (1996). *Groundwater*. In: D. Chapman (Ed) *Water Quality Assessment. A guide to the use of biota, sediments and water in environment monitoring*. 2<sup>nd</sup> edition. Chapman and Hall, London, Pp.320-326.
- Clark, B., Koning N. and Roos J. C. (1993). The Continued Influence of Organic Pollution in Water Quality of the Turbid Modder River South Africa. *African Journal*, 25(2):285-292
- Csuros, M. and Csuros, C. (2002). *Environmental Sampling and Analysis for Heavy Metals*. Lewis publishers, pp. 13-40, 221-231.
- Daxer, M. (2010). *Environmental Pollution*. John Wiley and sons. New York. Pp. 78-84.
- Degremont, J. (1991). *Water Treatment Handbook*. (6<sup>th</sup> Ed) Lavoisier, Paris, pp 10-15.
- Dibala, H. (2012). The environment and the consequences of fluoride in human. *Journal Agric Food Chem.*, 30: 704-710.
- Doisy, E. A. (1972). *Trace Substances in Environmental Health*. University of Missouri, Columbia Missouri, pp. 193-199.
- Edmund, W. M. (2004). Groundwater quality international union of geological science. *Geoindicator*, 4: 1-3.

- Edward O. U. (2010). Practical information and problems. In: The chemistry of water Bulletin No 1237, Johnson Wells screens overseas Ltd, Northern Ireland, pp. 3000-306.
- Edwin, D. O. (1996). *Control of Water Pollution from Agriculture*. FAO Flat Paris Rome, pp. 10-11.
- Evangelon, V. P. (1998). *Enviromental Soil and Water Chemistry, Principles and Application*. John Wileyand sons, New York, pp. 484-486.
- Findal, O.A (2008) Analysis of drinking water from some communities in the Bostawa region. *International Journal Environ. Sci. Tech.* 4(2): 228-234.
- Gary, D. C. (2004). *Analytical Chemisty*. 6<sup>th</sup> edition. John Wiley and sons (Asian). Ltd., Singapore. Pp 525-531.
- Genereux, D. P. and Nielsen, D. M. (1991). *Practical handbook of ground water monitoring*. Lewis publishers Inc. pp. 186-198.
- Greenberg, A. E., Clesceri, L. S. and Eaton, A. D. (1992). Standard mehod for the examination of water and waste water. 15<sup>th</sup> Edition. American water works association and water environmental federation, Washington, D. C., pp. 432-434.
- Hamilton, J. (1992). Chemical quality of water. *Journal of Environ. Health*, 54: 27-32.
- Hem, J. D. (1984). Study and interpretation of the chemical quality of natural water, 3<sup>rd</sup> edition. Water supply paper 2254, united state human geological survey, Washington D. C., pp.560-566.
- Henderson, L. (1982). *Inorganic Chemistry*. Pergamon press, Oxford, pp.211-218.
- Holgate, M. W. (1979). *A Perspective of Environmental Pollution*. Cambridge academic press, Cambrige, Pp. 200-202.
- Ilechukwu, I. and Okonkwo. O. (2012). Heavy metal level and physiocochemical parameters of potable water in Nnewi, Anambra State. *Archives of applied science research*, 4(5): 2094-2097.
- Iyasale, J. and Idiata, D. J. (2012). Determination of the boreholes water quality in Edo South and Edo North of Edo state. *Research journal in engineering and applied science*, 1(4): 209-213
- Jenkins, S. P. (1978). *The Physiology and Biochemistry of the Mouth*. Blackwell oxford pp. 220-224.

- Kundu, N., Pamgrahi, M. K., Tripathy, S., Munnshi, S., Powell, M. A. and Haul, B. R. (2001). Geochemical appraisal of fluoride contamination of ground water in the Nayagarh district of Orissa, India, *Environmental Geology* 41: 451-460
- Lerner, D. N. (1996). Urban groundwater and asset for sustainable city. *European Water Control*, (6):43-51
- Makhijani, S.D and Manohara A. (1999). Nitrate pollution problem in drinking water sources. Morning and surveillance. Paper presented in the workshop water quality field test kits for arsenic, fluoride and nitrate held from 8-9<sup>th</sup> sept.1999 at ITRS, Lucknow.
- Mancy J.W (2012). The Environmental Impact of Agricultural Nitrogen and Phosphorus Use. *Journal Agric Food Chem.*, 30: 804-810.
- Marcovecchio, J. E., Botte, S. E. and Freije, R. H. (2007). Heavy metals, major metals, trace metals. In: Hand book of water analysis. L. M. Wollet, (Ed). 2<sup>nd</sup> Edn. London: CRC Press; 275-311.
- Manky, J. W and Ramam, S. (2011). Heavy metal in natural water, applied monitoring and impact assessment. *Springer-veriag*, New York, 59(4): 493-497.
- Mason V.L (2009). "Evaluation of Groundwater Quality in the selected boreholes located in Kwanwoma District of Ghana" *African Journal of Biotechnology* 7(11) pp 1200 - 1209.
- Matrone, G., Jenne, E.A., Kubota, J., Mena, I. and Newberne, P.M (1977). Geochemistry and environment. *National Academy of Sciences*, 1(11): 29-39.
- McDonghet, M., John, C., Michael.P. (2004).Systematic Review of water fluoridation. *British Medical Journal* 321 (7265): 855-859.
- McJerkin, F. E. (1982). United State Agency for Development, Washington, D. C. Retrieved from <http://www.whglibdoc.int/publications/2007/9241546964.eng.pdf>
- Merian, E. (1991). *Metals and their Compounds in the Environment Occurrence, Analysis and Biological Relevance*, UCH Weinleim, New York, pp. 208-220.
- Metcalf M. and Eddy D. (2009). *Waste Water Engineering Treatment and Reuse*. 4<sup>th</sup> ed., Mc Graw-Hill companies, New York, pp. 1231-1272.
- Murray, J. J., Rugg-Gunn and Jerkins, G. N. (1991). Fluorides in caries prevention. 3<sup>rd</sup> ed. Uttrworth-Heineman, Oxford. Pp. 27-32
- Musa H. (1986). Limit test for lead in food and drugs. (Unpublished thesis) Ahmadu Bello University, Zaria, Nigeria.

- Nash, H. and McCall, J. G. H. (1994). *Groundwater Quality*. Chapman and Hal, London, pp. 230-238.
- Njar, G. N., Iwera, A. I., Offiong, R. A. and Deckor, T. D. (2012). The heavy metal status of boreholes in Calabar south local government area, Cross river State, Nigeria. *Ethiopian journal of environmental studies and management*, 5(1): 86-91.
- Nkansah, M. A. and Ephraim, J. H. (2009). Physicochemical studies of water from selected boreholes in Bosomtwi-Atwima-Kwanwoma district of Ghana. *Pacific Journal of Science and Technology* 10(2):643-648.
- NSDW (2007). Nigeria Standard for Drinking Water. A publication of Standard Organisation of Nigeria. Retrieved from [www.unicef.org/nigeria/ng.publication](http://www.unicef.org/nigeria/ng.publication).
- Obaliagbon K. O. and Okiemen C. O. (2007). Comparison of the levels of some toxic heavy metals in underground water from shallow well and deep well in Niger Delta; a case study of warm Nigeria. *Journal Chem. Society Nigeria* 1(32): 28-31.
- Odunola, O.A., Gbadegesini, M.A., Owumi S.E., Akinwumi, K.A., and Ogunbiyi, B. (2013). Physicochemical parameters and selected heavy metal assessment of drinking water at the students residence of Nigeria Premier University, *Academia Journals*, 7(10):203- 209.
- Ombaka, O., Gichumbi, J. M. and Kibara, D. (2013). Evaluation of groundwater and Tap water quality in villages surrounding Cluks town, Kenya. *Journal of Bio.phy.science*, 3(2): 1551-1563.
- Orunye, E. D. and Medjor, W. O. (2009). Physicochemical analysis of borehole water in the three resettlement areas of Lake Chad Region of Nigeria, *Nigerian Journal of Microbiology* 23(1):1846-1851.
- Osiakwan, G. M. (2002). Baseline studies into the ground water resources in the Bosomtwi-Atwima-kwanwoma District of Ashanti Region (published thesis) Nkrumah university of Science and Technology, Kumasi, Ghana. Pp. 23-26.
- Padma, V. and Namrata, P. (2009). *Drawn Water Quality*. Indian institute of Tech. Delhi, India, pp.76-82.
- Patric, R., Ford, E. and Quarles, T. (1987). *Groundwater Contamination in the United States*, Philadelphia, University of Philadelphia press, USA, pp 112-120.
- Pauling, L. (1960). *The Nature of the Chemical Bond*, 3<sup>rd</sup> edition. Cornell University Press, New York, pp. 98-101.

- Periakali, P., Subramnians, Eswaraworth, S., Arul, B., Rajeswa, R. N., Sridher (2001). Distribution of fluoride in the ground water of saloon and warmakkai distrits, Tam Nadu. *Journal of Applied Geochemical*, 3(2):120-132.
- Pillai, K. S. and Stanley, V. A. (2002). Implication of fluoride and endless uncertainty. *Journal of Environ. Boil.* 1(23): 81-87.
- Price M. (1985). *Introducing Groundwater*. U.K George Allen and Unwin publisher ltd pp 167-169.
- Quaitto, W.A (1996). *Ultimate Chemistry*. Pixelimage Accra, pp. 105-110.
- Rhoades, J. D. (1993). Reducing salinization of soil and water by irrigation and drainage management. In: prevention of water pollution by agricultural and related activities. Proceedings of the FAO expert Consultation, Santiago, Chile, 20-23 Oct., 1992. Water Report 1. FAO, Rome. Pp. 291-300.
- Salami, A. W. (2003). Assessment of the level of water pollution along Aso river channel, Ilorin, Kwara State Nigeria. *Nigerian Journal pure of and Applied Science*, 18: 1423- 1429.
- Sayar, A.S., Hamoudi A. and Yangi. Y (2008). Applications of expanded malodorous silica removal of heavy metal caption sand organic pollutants from waste water. *Chem. Matter*, 2: 212-216.
- Schwart, Z.J and Oho D. (1987). Blood lead, hearing thresholds, and neurobehavioral development in children and youth, *Archives of environmental health*, 42: 153-160.
- Shaw, M. E. (1994). *Hydrology in Perspective*, T. S. international Ltd, London, pp. 133-162.
- Shelton, T. B. and Scibila, S. L. (1998). Interpreting drinking water quality analysis 5<sup>th</sup> edition Rutgers cooperative extension, New Jersey Agricultural Experiment Station, New Brunswick, New Jersey. Retrieved from <http://www.n.gov/dep/pwteaddress.htm> 04.07.2013
- Schiele, R. (1991). *Metals and their Compounds in the Environment*. Verlags geselschaft mbH, Wemheim New York, pp.1032-1040.
- Somaini, A. and Quirindongo M. (2004). The Hidden Danger. Environmental health threats in the latino community. National resources defense council, pp. 50-55. Retrieved from <http://www.epa.gov/nrmrl/pubs/625r97009/625r97009.pdf>
- Sridhar, T., Asolker S. R. and Joshin, S. G. (2000). Trace pollutants in Drinking water. *Journal IAEM*, 27: 16-24

- Tiimub, B. M., Kuffour, R. A., Aeratia, G. A. (2012). Quality determination of ground water for drinking at Nkawkaw in Eastern region of Ghana. *Civil and environmental research*, 2 (9): 2852-2860.
- Twort, A. C., Hoather, R. C. and Law, F. M. (1974). *Water Supply*. 2<sup>nd</sup> edition, Edward Arnold press, London, p.191.
- UNEP and WHO (2008). Water quality assessment: a guide to biota, sediments and water in the environment monitoring. 2<sup>nd</sup> ed. University press, Cambridge, UK P. 43.
- UNESCO (2007). Water portal newsletter. No 161; water related diseases. Retrieved from [www.unesco.org/water/newsletter/161.shtml](http://www.unesco.org/water/newsletter/161.shtml) 08.07.2013
- USEPA (2007). Drinking water microbiology committee on challenges of modern society. Wato/ccm drinking water pilot project series. Edition by D. A. Uiver and R. A. Newman EPA, Washinton D. C. Retrieved from [www.unesco.org/water/newsletter/161.shtml](http://www.unesco.org/water/newsletter/161.shtml) 04.06.2014
- USEPA (2012). Drinking water standards and health advisories. Retrieved from <http://www.epa.gov/waterscience/>.water.epa.gov/./dwstandards2012.pdf
- Vandre, W. (1995). *How Groundwater Contamination Occurs*. University of Alaska, Fairbank, pp.88-93.
- Vogel, I. A. (1996). *A Textbook of Qualitative Analysis and Instrumentations*. Chapman and Hall; London U.K. pp 84-90.
- Ward, N. I. (1995). *Environmental Analytical Chemistry*, Blackie Academic and professional. Chapman and Hall; London U.K., pp.121-127.
- WHO (1984). International Standard for Drinking Water Quality. Health criteria and other supporting information. World health organization, Geneva Switzerland, vol. 2.
- WHO (2004). Guidelines for drinking water quality. Recommendation (2<sup>nd</sup> ed. Vol.1) AUBS publishers New Delhi pp. 122-143.
- WHO (2006). Guidelines for drinking water quality. Recommendation (4<sup>nd</sup> ed. Vol.1) AUBS publishers New Delhi pp. 234-243.
- WHO (2008). Guidelines for drinking water quality. WHO publications, Geneva, Switzerland. Retrieved from <http://www.whglibdoc.who.int/publications/2008/9241546964.eng.pdf> 20.05.2013

- WHO/UNICEF, (2004). Meeting the MDG Drinking water and sanitation; A mid-term assessment of progress. Geneva: WHO/UNICEF. ISBN 9241562781. Retrieved from <http://www.who.int/whr/en/> 12.08.2013
- WHO/UNICEF (2008). Progress on drinking water and sanitation. Retrieved from <http://www.who/unit/publications/index.htm/> 04.08.2013
- Zheng, N., Zheougzhul, L. and Dongunci, Z. (2008). Characterization of heavy metal contaminations in sediment and water from Huludaocity, North East China. *Environmental pollution in press*, 2(3): 122-130.

## APPENDIX 1

		<b>WHO (2006)</b>	<b>NSDW(2007)</b>	<b>USEPA (2012)</b>
1	Temperature	Ambient	Ambient	Ambient
2	Turbidity	5.0NTU	5.0NTU	5.0NTU
3	TDS	1000mg/l	500mg/l	500mg/l
4	pH	6.5-8.5	6.5-8.5	6.5-8.5
5	Conductivity	1000µS/cm	1000µS/cm	1000µS/cm
6	Copper	2.0mg/l	1.0mg/l	1.0mg/l
7	Cadmium	0.005mg/l	0.003mg/l	0.003mg/l
8	Zinc	4mg/l	3mg/l	3mg/l
9	Iron	0.5mg/l	0.3mg/l	0.3mg/l
10	Manganese	0.4mg/l	0.2 mg/l	0.4 mg/l
11	Lead	0.01mg/l	0.01mg/l	0.01mg/l
12	Chloride	250mg/l	250mg/	250mg/l
13	Fluoride	1.5mg/l	1.5 mg/l	2.0 mg/l
14	Phosphate	5mg/l	Not specified	Not specified
15	Sulphate	250mg/l	100mg/l	250mg/l
16	Nitrate	50mg/l	50mg/l	50mg/l
17	Total hardness	500mg/l	150mg/l	Not specified

WHO (2006), NSDW (2007) and USEPA (2012) maximum permissible limit for drinking water of some parameters

## Appendix 2



One of boreholes sampled for analysis at kasun-daji designated as BW11

### Appendix 3



One the boreholes sampled for analysis at kurya designated as BW12

#### Appendix 4



One of the boreholes sampled for analysis at Sabon-gari designated as BW14