



**SCHOOL OF PHYSICAL SCIENCES**

**DEPARTMENT OF CHEMISTRY**

**QUALITY ASSESSMENT OF SOME SELECTED WATER BOREHOLES IN**

**MOGADISHU, SOMALIA**

**BY**

**ABDOLAHI MOHAMED ADAWE**

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FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN ANALYTICAL  
CHEMISTRY OF THE UNIVERSITY OF NAIROBI**

**AUGUST 2015**

## DECLARATION

I declare that this thesis is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.

Sign: ..... Date: .....

Mr. ABDOLAHI MOHAMED ADAWE

This thesis is submitted for examination with our approval as research supervisors.

Supervisors:

Prof. Amir O. Yusuf, Signature..... Date.....

Department of Chemistry,  
University of Nairobi

Dr. John O. Onyatta, Signature.....Date.....

Department of Chemistry,  
University of Nairobi

Mr. Godfrey A. Wafula Signature.....Date.....

Department of Chemistry,  
University of Nairobi

## ABSTRACT

The study was undertaken to assess the fluoride content and other parameters in selected borehole waters in Hodan District area, Southern Mogadishu region, Somalia. Quality water supply is one of the constraints being experienced in Mogadishu city and fluoride content is of particular concern. The study was carried out between September 2014 and March 2015. Water samples were collected from six boreholes in different parts of Hodan District, namely: Rer Mohamed Sheikh, Gorgor, Umu Batula, Cise Qodax, Soonikia (Digfer) and Umu Caisha (Tarabuun). Survey was conducted through a questionnaire to identify the water boreholes for water sample collection. The residents around these water boreholes were interviewed on the water quality and the health effects experienced in the areas. Each water sample was analyzed for pH, fluoride, chloride, nitrate, ammonium, alkalinity, water hardness, electrical conductivity, sodium, total dissolved solids (TDS), cadmium, zinc, lead and E-coli. The results were compared with World Health Organization (WHO). Values were: pH 8.1-8.9; fluoride 0.28-0.596 mg/l ; nitrate 4.27-146.6 mg/l; alkalinity 119.3-158.9 mg/l; electrical conductivity 1.428-3.280 mS/cm; hardness 229.32-501.76 mg CaCO<sub>3</sub>/l; chloride 281.09-888.85 mg/l; total dissolved solids 1339-3428 mg/l; ammonium 0.45-0.7 mg/l; sodium 52.4-149.7 mg/l. Lead, cadmium and zinc were not detected. Hardness, chloride, electrical conductivity, total dissolved solids (TDS) and ammonium values were higher than WHO standard limits. Alkalinity, sodium and fluoride were all below the WHO standard limits. Nitrate values were below the WHO standard limit except for Umu Batula (60.92 mg/l) and Rer M. Sheikh (146.6 mg/l) which were higher. pH values were lower except Cise Qodax (pH= 8.9) which was above WHO value. E-coli was only found in Cise Qodax borehole.

## **DEDICATION**

I dedicate this thesis to my family, wife, supervisors, friends and all those who assisted me to bring my education to this level.

## **ACKNOWLEDGMENT**

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## LIST OF ABBREVIATIONS AND SYMBOLS

ATSDR	Agency for Toxic Substances and Disease Registry
CDTA	Cyclohexanediaminetetraacetic acid
EDTA	Ethylenediaminetetraacetic acid
ET	Eriochrome Black T
F <sup>-</sup>	Fluoride ion
F <sub>2</sub>	Fluorine
g	gram
GPS	Geographic Position System
Kg	kilogram
l	litre
m <sup>3</sup>	Cubic meter
MEWR	Ministry of Energy and Water Resource
mg	milligram
SMEWW	Standard Methods for Examination of Water and Wastewater
SWALIM	Somali Water Land and Information Management
TDS	Total Dissolved Solids
USEPA	United States Environmental Protection Agency
USNRC	United States National Research Council
WHO	World Health Organization



# CHAPTER ONE

## INTRODUCTION

### 1.1 Background

Water is of fundamental importance to human life, animals and plants. It is of equal importance to the air we breathe in maintaining the vital processes of life. It makes up about 60% of body weight in human body. Among the various sources of water, groundwater is the major source of drinking water and accounts for over 94%. Borehole water is known to meet the criteria for quality water and is the most widely used source of water in most African countries, Somalia included. The quality of borehole water is influenced by all the processes and reactions that act on the water from the moment it is condensed in the atmosphere to the time it is discharged by a well or spring which varies from place to place depending on the depth of the water table (Aharm *et al.*, 2004). Borehole waters have unique features, which render them suitable for public water supply as they have excellent natural quality, usually free from pathogens, colorless and non-turbid. These can be consumed directly without treatment.

There are various ways borehole waters may be affected by pollution like land disposal of solid wastes, sewage disposal on land, agricultural activities, urban runoff and polluted surface water. Water supply has been one of the major constraints to human settlement in Mogadishu. To a large extent, the need for water by the inhabitants of the capital city has not changed much from the situation that was there in the late 1960s. Traditionally, supply of water was a commercial activity in Mogadishu. Before independence in 1960, wells provided drinking water to both animals and humans. There were two wells in Mogadishu: Hawl-Wadaag which was managed by Indians while Somalis managed Ceel-Garweyne. These two wells are still in use today. With time, more wells were professionally dug and the quality of the water checked before use.

Initially the local government had minimal control of these wells. However, later they got more involved in assessing water quality and levying taxes (MEWR, 2012).

When another government came to power in October 1969, everything changed. The new regime was intent in modernizing the country and therefore was keen to get full control of the water sector. On 8<sup>th</sup> November 1972, a water agency was established and all commercial wells were placed under the Agency. Many of the wells that were in existence were incorporated and water sellers had to work under the umbrella of the water Agency. However, a place like Medina had no public wells and it heavily relied on the old system (MEWR, 2012). The first major achievement of the water Agency was in 1974 when twenty one (21) wells were put into operation at Km 13 on the road to Balcad, at Ceel-Cirfiid. Their capacity was 240 cubic meters /hour of water. These wells basically supplied the historical centre of Mogadishu. However this was not enough to cope with urban growth and, in 1982 thirty two (32) new wells were commissioned providing an additional 1375 cubic meters/hour. This well was located on the Afgoye Road, about 15 Km from Mogadishu. Two other water towers were also built and are known as 7A (around 12,000 cubic meters per day) near the military academy and 7B (around 10,500 cubic meters per day) near the milk factory. Problems encountered were lack of spare parts for the pumps, and mismanagement of the company.

In 1990, the civil war basically destroyed parts of the infrastructure in some areas; pipes were looted and others were severely damaged, intentionally or otherwise. Pumps and generators were stolen or vandalized. Near Afgoye, the well was controlled by a group of militias who were levying taxes as other state entities like Ministry of Energy and Water Resource controlled the other wells (MEWR, 2012).

After 1991, Old wells were reopened and new ones dug. Currently there are more than 290 wells in the greater Mogadishu city. Unfortunately the water from all these wells are not treated thereby posing human health risk. One of the major health problems being experienced by the use of the ground water for drinking purposes is excess fluoride content. An excess fluoride concentration in drinking water has deleterious effects on human health. It causes a disease known as fluorosis. (Gosselin *et al.*, 1999). Fluoride content higher than permissible limit become toxic and causes clinical and metabolic disturbance in animals and human beings. These ailments include dental, skeletal and non-skeletal fluorosis. Pictures showing the effect of both dental and skeletal fluorosis are given in Figure 1.1 and Figure 1.2.

The main aim of this study was to determine fluoride ion content in selected boreholes in Hodan District, Mogadishu. The study included the determination of pH, chloride, nitrate, ammonium, alkalinity, hardness, total dissolved solids, sodium, cadmium, zinc, lead, E-coli and conductivity.

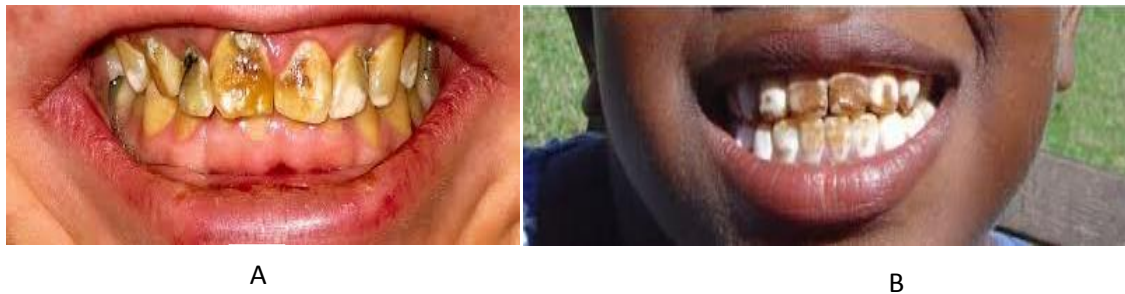


Figure 1.1: Effect of dental fluorosis (<https://www.google.com/wordpress.com>, 2015)



Figure 1.2: Progressive disabilities caused by skeletal fluorosis (Teckle-Haimanot, 2006)

## **1.2 Statement of the Problem**

Somalia is one of the countries thought to have high levels of fluoride in drinking water. The consumption of water with high fluoride level in the long term affects the health of the local population and is the cause of fluorosis. It is suspected that a large number of people residing in Mogadishu are suffering from problems emanating from high fluoride levels in water. The observed teeth problems are a common feature in the country. Hence there is need to assess the fluoride levels in water and to device ways of removing fluoride from drinking water. The WHO guidelines for fluoride in drinking water is 1.5 mg/l (WHO, 2004). Currently there is no data on the fluoride levels in the various boreholes scattered around Mogadishu City. Therefore there was urgent need to generate information on fluoride levels in the borehole waters. The data will help the Government in laying strategies on how to mitigate the consequences of fluorosis. This study therefore will fill the information gap on fluoride content of borehole waters. In addition to fluoride, the study provides fundamental information on other parameters (pH, chloride, nitrate, ammonium alkalinity, hardness, total dissolved solids, sodium, cadmium, zinc, lead, electrical conductivity and E-coli).

## **1.3 Objectives of the Study**

### **1.3.1 Overall objective**

The main objective of this study was to assess the fluoride content in selected borehole waters in Mogadishu, Somalia.

### **1.3.2 Specific objectives**

The objectives of the study were:

- i. To determine the fluoride concentration levels in selected boreholes located in Hodan District in Mogadishu City, Somalia

- ii. To assess other water quality parameters like pH, chloride, nitrate, ammonium, alkalinity, hardness, electrical conductivity, total dissolved solids, sodium, cadmium, zinc, lead and E-coli.
- iii. To compare these experimental data obtained with WHO standard limits for drinking water.
- iv. To interview the residents around these water boreholes to identify the water quality and the health effect experienced in the areas.

#### **1.4 Justification and significance of the study**

The findings of this study will provide a reference data base for fluoride and other parameters that can be used by local residents, local authorities and future researchers. It will create awareness to the local residents on fluoride levels in borehole water in Mogadishu. The local administration can use the generated information in creating awareness during meetings to inform the locals about the water quality. The information on quality of water will enhance service delivery and provide confidence in the use of borehole waters. Further, a code of conduct can be generated using this information to help formulate checklists that can guide water inspectors. The information will also be used in formulation of policies and regulations on drinking water quality. Future researchers will use this study to benchmark their methodologies on fluoride determination in borehole water.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 The Chemistry of fluoride

The fluoride ion is found in the environment and constitutes 0.06- 0.09% of the earth's crust. It is present in water, foods and air. Fluoride has various uses in many industries including toothpaste, ceramics, tiles and bricks. Fluoride is not found naturally in the air in large quantities. Average concentrations of fluoride found in the air are in the magnitude of  $0.5\text{ng/m}^3$  (WHO, 2004). Fluorides are found at significant levels in a wide variety of minerals, including fluor spar, rock phosphate, cryolite, apatite, mica and hornblende (Murray, 1986). Fluorite ( $\text{CaF}_2$ ) is a common mineral of low solubility occurring in both igneous and sedimentary rocks. It is commonly associated with volcanic activity and gases emitted from the earth's crust. Thermal waters, especially those of high pH, are also rich in fluoride. Minerals of commercial importance include cryolite and rock phosphates. Cryolite is used for the production of aluminium (Murray, 1986) and as a pesticide. Rock phosphates which are converted into phosphate fertilizers by the removal of up to 4.2 per cent fluoride (Murray, 1986) are sources of fluoride in some countries. Phosphates are usually added to drinking-water to protect against dental cavities (Reeves, 1994).

##### 2.1.1 Mineral –aqueous fluoride interactions

Ionic compounds of fluoride dissolved in water are believed to be the cause of fluoride released into groundwater. The dissolution of other fluoride bearing aluminosilicate minerals has also been reported. The concentration of fluoride in ground water has been shown to be limited by the presence of  $10^{-3}$  M of calcium. It is therefore the absence of calcium in solution, which allows higher concentrations of fluoride (Reeves, 1994). High fluoride ion concentration may therefore

be expected in groundwater in calcium-poor aquifers and in areas where fluoride bearing minerals are common.

### **2.1.2 Fluoride in water**

Since some fluoride compounds in the earth's upper crust are soluble in water, fluoride is found in both surface and groundwater. In surface water, fluoride concentrations are usually lower than in groundwater because of the shorter contact time between water and rock. According to (Naslund and Snell, (2005), the natural concentration of fluoride depends on the geological, chemical and physical characteristics of the aquifer, the porosity and acidity of the soil and rocks, temperature and the action of other chemical elements. Another reason for high fluoride concentrations in groundwater can be the absorption of rising, subterranean gases containing high levels of fluoride (Fawell, 2003).

### **2.1.3 Distribution of fluoride in the environment**

Fluoride bearing bedrocks and fluoride contaminated water occur in all parts of the world including large parts of Africa, China, the Middle East and Southern Asia. There are two major belts with known high fluoride levels where extensive studies have been carried out (Naslund and Snell, 2005). One belt is the East African Rift from Eritrea to Malawi and the other is the belt which stretches from Turkey through Iraq, Iran, Afghanistan, India and northern Thailand to China. America and Japan have similar belts but with generally lower fluoride levels (Figure 2.1).

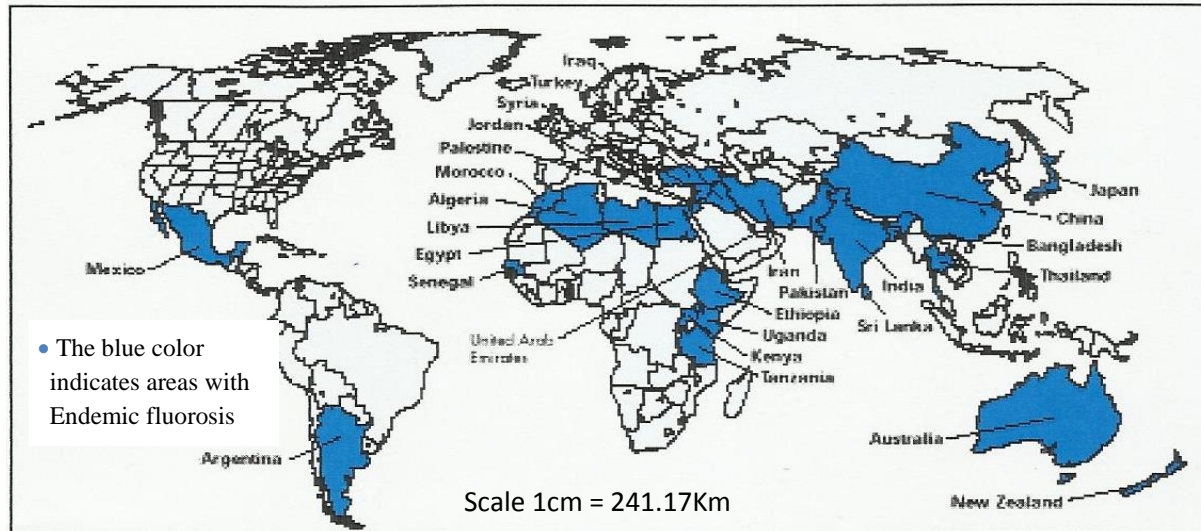


Figure 2.1: Map of countries with endemic fluorosis due to excess fluoride in drinking water (Naslund and Snell, 2005).

Fluoride is often found in higher concentrations in areas where there have been volcanic activities. Many studies on the adverse effects of too high fluoride intake have been carried out and the knowledge of the diseases related to fluoride are well documented (Naslund and Snell, 2005).

#### 2.1.4 Fluoride in air

Fluorides originate from dust, phosphate fertilizer production and coal ash. However, air is typically responsible for only a small fraction of total fluoride exposure (USNRC, 1993). In non-industrial areas, the fluoride concentration in air is typically quite low ( $0.05\text{--}1.90\ \mu\text{g m}^{-3}$  fluoride) (Murray, 1986). In areas where fluoride-containing coal is burned or phosphate fertilizers are produced and used, the fluoride concentration in air is elevated leading to increased exposure to inhalation. High levels of atmospheric fluoride occur in some areas of Morocco and China (Heilman *et al.*, 1999). Studies show that in some provinces of China, fluoride concentrations in indoor air ranged from 16 to  $46\ \mu\text{g m}^{-3}$  owing to the indoor combustion of



high-fluoride coal for cooking, drying and curing food. Indeed, more than ten million people in China are reported to suffer from fluorosis, related in part to the burning of high fluoride coal (Gu *et al.*, 1990).

### **2.1.5 Fluoride in food and beverages**

Vegetables and fruits normally have low levels of fluoride ( $0.1\text{--}0.4\text{ mg kg}^{-1}$ ) and thus are of little health concern. However, higher levels of fluoride have been found in barley and rice (about  $2\text{ mg kg}^{-1}$ ) and taro, yams and cassava have been found to contain relatively high fluoride levels (Holden *et al.*, 2002). The levels of fluoride in meat ( $0.2\text{--}1.0\text{ mg kg}^{-1}$ ) and fish ( $2\text{--}5\text{ mg kg}^{-1}$ ) are relatively low (Jackson *et al.*, 2002). However, fluoride accumulates in bone of fish, such as salmon and sardines, which are eaten by man. Fish protein concentrates may contain up to  $370\text{ mg kg}^{-1}$  fluoride. However, even with relatively high fish consumption in a mixed diet, the fluoride intake from fish alone would seldom exceed  $0.2\text{ mg F}^{-}$  per day (Jackson *et al.*, 2002). Milk typically contains low levels of fluoride, ( $0.02\text{ mg l}^{-1}$  in human breast milk;  $0.02\text{--}0.05\text{ mg l}^{-1}$  in cow's milk) (Holden *et al.*, 2002). Thus milk is usually responsible for only a small fraction of total fluoride exposure. Tea leaves contain high levels of fluoride of up to  $400\text{ mg kg}^{-1}$  dry weight (Murray, 1986).

## **2.2 Instrumentation for analysis**

### **2.2.1 Atomic absorption spectroscopy (AAS)**

When an aspirated sample is passed through a flame of high temperature (temperature range:  $1800\text{--}3100\text{ K}$ ) atomization occurs. When light is passed through the atom, absorption will occur when energy of light is equivalent to the energy difference between two energy levels in

the atoms. The absorbance is proportional to the concentration of sample and path length. This is Beer-Lambert Law (Chatwal and Anand, 2002). Which is expressed as

$$A = \epsilon b c \quad (2.1)$$

Where,

A= absorbance

$\epsilon$  = molar absorptivity coefficient with units of  $M^{-1} \text{ cm}^{-1}$

b= path length (cm)

c= concentration of sample in mole/liter

This instrument consists of source emitting radiation characteristic of element of interest (hollow - cathode lamp), flame or electrically heated furnace, monochromator, detector (photomultiplier) and recorder (Figure 2.2).

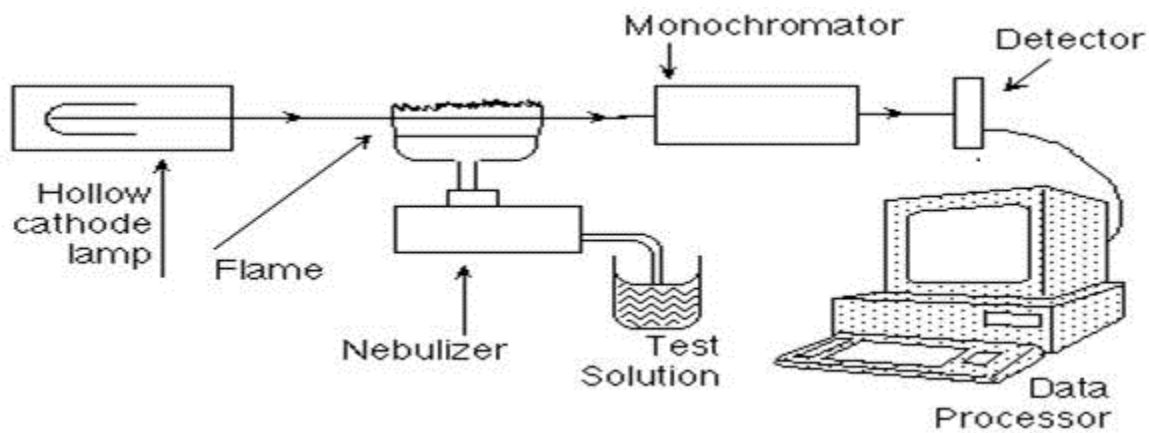


Figure 2.2: Schematic representation of the atomic absorption spectrophotometer

(<https://www.google.com>, 2015)

The light source, which is usually a hollow cathode lamp, emits line radiation of the same wavelength as that absorbed by the element under study. Beer-Lambert's law is applied to correlate absorption and concentration of the metal in the sample. Each element has a characteristic absorption spectra relating to specific, quantized transitions of atoms to excited

states. The locations of the absorption peaks are unique to each element, and their intensities are directly proportional to the concentration of the sample. In order to measure the electronic transitions the sample to be analyzed must be atomized using a flame atomizer which employs air-acetylene flame. When aerosols of the analytes are aspirated through the flame, they evaporate fast and leave behind pure particles of the analyte, which are heated into gaseous phase. This is the most widely used technique for the quantitative determination of metals at trace levels (0.1 to 100 ppm), which are present in various materials. It utilizes Beer –Lambert's Law for the analysis and a standard calibration graph is obtained by plotting absorbance versus concentration of the samples taken. The usual procedure is to prepare a series of standard solutions over a concentration range suitable for the sample to be analyzed. The standards and samples are then separately aspirated into the flame, and the absorbances are read from the instrument. The plot will give the useful linear range from which the concentrations of the samples can be determined.

### **2.2.2 Flame photometer**

Flame photometry relies upon the fact that the compounds of the alkali and alkaline earth metals can be thermally dissociated in a flame and that some of the atoms produced will be further excited to a higher energy level. When these atoms return to the ground state they emit radiation which lies mainly in the visible region of the spectrum (Chatwal and Anand, 2002). The emission wavelengths at which the alkali and alkaline earth metals are found and provided in Table 2.1.

**Table 2.1: Emission wavelength and flame color for the determination of metals**

Metal	Emission Wavelength (nm)	Flame Color
Sodium (Na)	589	Yellow
Potassium (K)	766	Violet
Barium (Ba)	554	Lime Green
Calcium (Ca)	622	Orange
Lithium (Li)	670	Red

Over certain ranges of concentration the intensity of the emission is directly proportional to the number of atoms returning to the ground state. This is in turn proportional to the absolute quantity of the species volatilized in the flame, i.e. light emitted is proportional to sample concentration. It can be seen that if the light emitted by the element at the characteristic wavelength is isolated by an optical filter and the intensity of that light measured by a photo-detector, then an electrical signal can be obtained proportional to sample concentration. Such an electrical signal can be processed and the readout obtained in an analogue or digital form. This instrument consists of the following basic components (Figure 2.3). a) The burner: a flame that can be maintained in a constant form and at a constant temperature. b) Nebulizer and mixing chamber: a means of transporting a homogeneous solution into the flame at a steady rate. c) Simple color filters (interference type): a means of isolating light of the wavelength to be measured from that of extraneous emissions. d) Photo-detector: a means of measuring the intensity of radiation emitted by the flame.

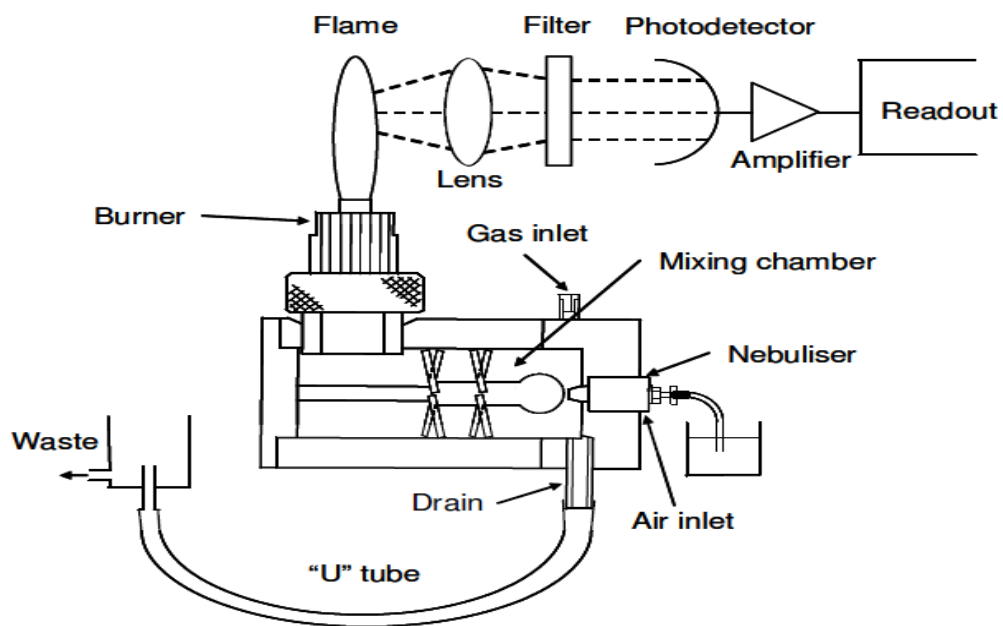


Figure 2.3: Schematic diagram showing the component parts of a flame photometer

(<https://www.google.com>, 2015)

The analysis of alkali and alkaline earth metals by flame photometry has two major advantages:

- I. Their atoms reach the excited state at a temperature lower than that at which most other elements are excited.
- II. Their characteristic wavelengths are easily isolated from those of most other elements due to wide spectral separation.

Intensity of emission is very sensitive to changes in flame temperature. Usually, spectral interference and self-absorption are also encountered which affects the precision of the measurement. Further, a linear plot of absorbance against concentration is not always obtained. Flame photometer is used exclusively in the quantitative determination of metals in solution, especially alkali and alkaline earth metals in the given samples. The principle is similar to that of

atomic absorption. Qualitative determination is also possible as each element emits its own characteristic line spectrum.

### **2.2.3 Ultraviolet-visible Spectrophotometer**

The instrument which measures the ratio of the intensity of two beams of light in the ultraviolet-visible region is called ultraviolet-visible spectrophotometer. UV-Visible spectrophotometer is one of the most frequently employed techniques in pharmaceutical analysis. It involves measuring the amount of ultraviolet or visible radiation absorbed by a substance in solution. Color is an important property of a substance and is related to its absorptivity or reflectivity. The human eye sees the complementary color to that which is absorbed. It can determine the absorption spectrum of anions like nitrate, ammonium ion among others. For the concentrations of these anions to be determined, one has to color the sample using specific reagent for each anion. A solution which is more concentrated will absorb more light than a less concentrated one. Ultraviolet-visible spectra generally show only a few broad absorbance bands, compared to techniques such as infrared spectroscopy, which produces many narrow bands. Ultraviolet-visible gives broad bands (Davidson, 2002). In qualitative analysis, organic compounds can be identified by use of spectrophotometer. If any recorded data is available then quantitative spectrophotometric analysis can be used to ascertain the quantity of molecular species absorbing the radiation. Spectrophotometric technique is simple, rapid, moderately specific and applicable to small quantities of compounds. It operates by passing light from a lamp through a monochromator that separates the light into individual wavelength. Using an adjustable slit, light of a single wavelength is allowed to get into the sample which is placed in a transparent cuvette. A photoelectric tube which is placed on the other side of the cuvette, measures the amount of

light that pass through the sample. Amount of light transmitted can be converted to absorbance (Figure 2.4).

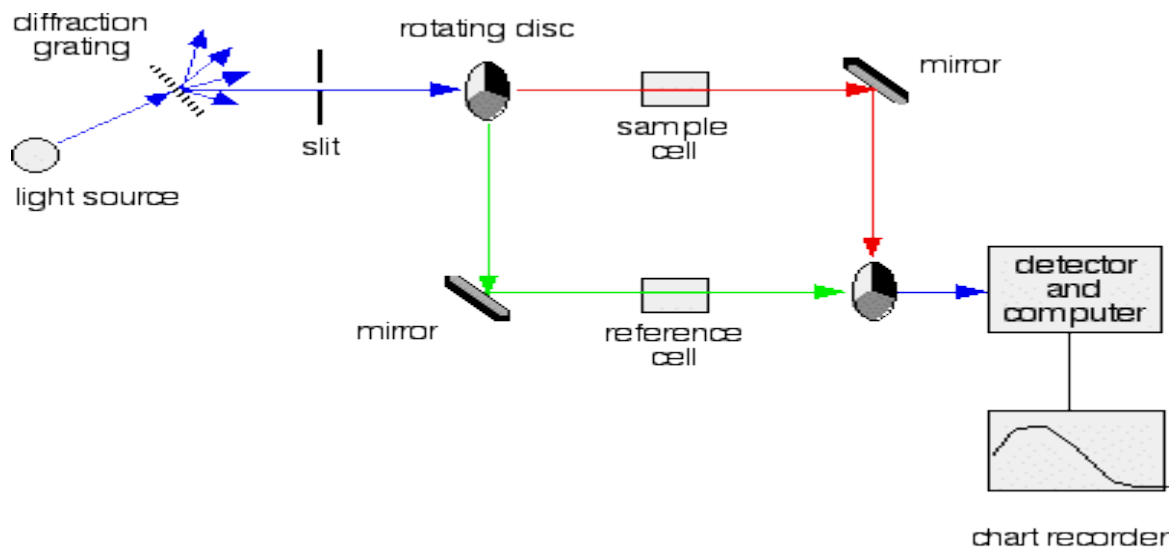


Figure 2.4: Schematic diagram showing the component parts of uv-visible spectrophotometer

(<https://www.google.com>, 2015)

The concentration of the unknown solution can be determined in two ways. The first method is to generate a standard calibration curve which is a graph of absorbance versus concentration of standard solution whose concentration is known. The absorbance of the unknown solution is then compared to the standard. The second method is by using Beer-Lambert's law where the wavelength ( $\lambda_{\max}$ ) at which a substance absorbs best is determined and a standard calibration curve showing a linear relationship between absorbance and concentration is drawn (Behera *et al.*, 2012). Extinction coefficient which is used to find the concentration of that substance under similar instrumental conditions can then be calculated. Extinction coefficient relates absorbance to concentration using Beer-Lambert's law. With the advancement in technology, most of the recent spectrophotometers determine the concentration of solutions automatically.

#### **2.2.4 Potentiometric determination of fluoride**

Potentiometry is one of the methods that have been used to determine fluoride using a fluoride electrode in conjunction with a standard single junction sleeve-type reference electrode and pH meter with an expanded millivolt scale or selective ion meter having a direct concentration scale for fluoride. The fluoride electrode consists of a lanthanum fluoride crystal across which a potential is developed by fluoride ions, (USEPA, 1979). The cell may be represented by Ag/AgCl.Cl<sup>-</sup>(0.3M), F<sup>-</sup>(0.001M) LaF/test solution/SCE/.

#### **2.3 pH measurements**

In pure water there are an equal number of H<sup>+</sup> ions and OH<sup>-</sup> ions. The amount or number of H<sup>+</sup> ions to OH<sup>-</sup> ions determines the pH of a substance on whether the substance is acidic, basic or neutral. This information can be obtained from the pH scale which ranges from 0 to 14, where 0 is the pH of very strong acids and 14 is the pH of very strong bases (Peden and Skowron, 1978). Pure water has a pH of 7 and is a neutral solution, which means it is neither acidic nor basic and has an equal number of H<sup>+</sup> ions and OH<sup>-</sup> ions. The lower the pH of a solution the more acidic it is and the higher the pH of a solution the more basic it is. The pH is of major importance in determining the corrosive nature of water. The guideline value of 6.5 to 8.5 is based on the need to control corrosion and scaling. When the pH falls below 6.5 (acidic) metal corrosion can become a problem. Above 8.5 (Alkaline) scaling of pipes may occur. pH values above 9.5 can cause a bitter taste and may promote skin irritation. The pH of water can be adjusted by the addition of acid or alkali, but care needs to be taken to avoid excessive addition.



## **2.4 Alkalinity**

Alkalinity comes from rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges (e.g. detergents and soap based products are alkaline). If an area's geology contains large quantities of calcium carbonate ( $\text{CaCO}_3$ , limestone), water bodies tend to be more alkaline (Thomas and Schiettecatte, 2008). Alkalinity of water is its acid-neutralizing capacity. It is the sum of all the titratable bases. The measured value may vary significantly when the end point pH is used. Alkalinity is a measure of an aggregate property of water to neutralize acids and can be interpreted in terms of specific substances only when the chemical composition of the sample is known. Alkalinity in excess of alkaline earth metal concentration is significant in determining the suitability of water for irrigation hence the need to determine the alkalinity of water. Alkalinity measurements are used in the interpretation and control of water treatment processes.

## **2.5 Water hardness**

Originally, water hardness was understood to be a measure of the capacity of water to precipitate soap. Soap is precipitated chiefly by the calcium and magnesium ions present in water (Marque *et al.*, 2003). Hard water is formed when water passes through limestone or chalk areas and calcium and magnesium ions dissolve in water. The hardness is made up of two parts: temporary (carbonate) and permanent (non-carbonate) hardness. In conformity with current practice, total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as calcium carbonate, in milligram per liter. When hardness is numerically greater than the sum of carbonate and bicarbonate alkalinity, that amount of hardness that is equivalent to the total alkalinity is called carbonate hardness; while the amount of hardness in excess of this is called non-carbonate hardness. When the hardness is numerically equal to or less than the sum of

carbonate and bicarbonate alkalinity, then there is no hardness. Hardness should not exceed 200 mg/L as calcium carbonate. Soft water, where hardness is less than 60 mg/L, may cause corrosion problems. There is no evidence that high hardness may have any adverse health effects. Hardness can be removed from water by ion-exchange systems, and these are available commercially as water softening units. High levels of hardness can cause problems with some plants if spray irrigation is used.

## **2.6 Electrical conductivity**

Electrical conductivity reflects the capacity of water to conduct electrical current, and is directly related to the concentration of salts dissolved in water. It depends on the water temperature; the higher the temperature, the higher the electrical conductivity which increases by approximately 2-3% per degree Celsius. Electrical conductivity (EC) is a measure of the concentration of ions in solution. International convention dictates that the measurements are to be standardized to 15°C, which is known as specific conductivity. The electrical conductivity of sea water is 55-60 mS/cm.

## **2.7 Total dissolved solids (TDS)**

Total dissolved solids (TDS) are those solids that pass through a filter with a pore size of 2.0 micron (or smaller) nominal pore size under specified conditions. Waters with high dissolved solids are generally of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer hence it is important to determine total dissolved solids (TDS). A limit of 500 mg /L is desirable for drinking water. Generally water with less than 500 mg/L is regarded as good quality water but values of up to 1000 mg/L can be tolerated. Corrosion may also become a problem with high TDS levels. TDS is related to electrical conductivity (EC) of

the water and high electrical conductivity normally produces high total dissolved solids (TDS). There is no health effects associated with high TDS but the components which make up the TDS may cause problems.

## **2.8 Chloride**

Chloride, in the form of  $\text{Cl}^-$ , is one of the major anions, in saltwater and freshwater. It originates from the dissociation of salts, such as sodium chloride or calcium chloride, in water. In drinking water, the salty taste produced by chloride depends upon the concentration of the chloride ion. Water containing 250 mg/L of chloride may have a detectable salty taste if the chloride came from sodium chloride. High chloride levels in water are usually caused by high salt (sodium chloride) levels. High chloride is not thought to cause health problems but high sodium levels that usually accompany it may cause health effects. If the water is used for agricultural purposes then chloride ion enhance the release of heavy metals (Kaushal *et al.*, 2005). The recommended maximum of 250 mg/L is based on taste considerations.

## **2.9 Ammonium**

Ammonium is extremely soluble in water. It is the natural product of decay of organic nitrogen compounds. Ammonium gets into water supplies most frequently as runoff in agricultural areas where it is applied as fertilizer and it easily finds its way into underground aquifers from animal feedlot runoff. It is commonly found in surface and rain water. The level of ammonium in surface water varies regionally and seasonally and can be affected by localized anthropogenic influences, such as runoff from agricultural fields or industrial or sewage treatment discharges. The ammonium concentrations in rivers and bays are usually less than 6 mg/L; higher levels may indicate anthropogenic pollution (Bouwer and Crowe, 1988). Groundwater generally contains

low concentrations of ammonium; natural levels are usually below 0.2 mg/L. However, deep wells affected by some geological formations have been shown to have high concentrations of ammonium (Schilling, 2002). Ammonium ion is in equilibrium with the ammonia in water. This equilibrium is highly dependent on pH and, to a lesser extent, temperature. The equilibrium favours the ammonium ion in acidic or neutral waters. If present in surface waters, ammonium can be converted to ammonia in basic media. This phenomena is affected by pH, temperature, wind speed and the atmospheric ammonia concentration. Ammonium present in air can readily dissolve in rainwater as a result of its high water solubility. Ammonium can be removed by microbial processes or adsorbed by sediment and suspended organic material.

#### **2.10 Nitrate**

Nitrates are naturally occurring ions that are part of the nitrogen cycle. The nitrate ion ( $\text{NO}_3^-$ ) is the stable form of combined nitrogen for oxygenated systems. Although chemically unreactive, it can be reduced by microbial action. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity, from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. The guideline value of 50 mg/L is established to protect bottle-fed infants less than three months of age. Up to 100 mg/L can be safely consumed by adults and children over three months. Nitrate can be removed by use of special ion-exchange plants. (Avery, 1999).

#### **2.11 Sodium**

For many years sodium ion has been washed out from rocks and soil, ending up in oceans. Seawater contains approximately 11,000 ppm sodium, while river contains only about 9 ppm. Therefore the possibility of sodium ion reaching ground water is high. Drinking water usually

contains about 50 mg/l sodium. This value is clearly higher for mineral water. In soluble form sodium always occurs as ions. The guideline value of 200 mg/L is based primarily on taste. However medical practitioners treating people with severe hypertension or congestive heart failure should be aware if the sodium concentration exceeds 20 mg/L. Sodium is usually present in water as sodium chloride. Hence there is need to determine sodium in borehole water used for drinking.

### **2.12 Cadmium**

Cadmium is a metal which can exist with an oxidation state of +2. It is chemically similar to zinc and occurs naturally with zinc and lead in sulfide ores. Cadmium metal is used mainly as an anticorrosive, electroplated onto steel. Cadmium sulfide and selenide are commonly used as pigments in plastics. Cadmium compounds are used in electric batteries, electronic components and nuclear reactors. The solubility of cadmium compounds in water is influenced to a large degree by its acidity. Suspended or sediment-bound cadmium may dissolve when there is an increase in acidity. In natural waters cadmium is found mainly in bottom sediments and suspended particles. (Adebisi *et al.*, 2013). Cadmium concentrations in unpolluted natural waters are usually below 1 µg/l. Contamination of drinking-water may occur as a result of the presence of cadmium as an impurity in the zinc of galvanized pipes or cadmium-containing solders in fittings, water heaters, water coolers and taps. According to World Health Organization guidelines (WHO, 2011), the maximum permissible concentration of cadmium in drinking water is 0.003 mg/l. Tolerable daily intake of cadmium is 57 to 72 µg per day. Normal cadmium content in rice is about 29 ppb. (Nduka and Orisakwe, 2007).

### **2.12.1 Toxic effects of cadmium on human health**

The main sources of cadmium in the air are the burning of fossil fuels such as coal and the incineration of municipal waste. The cadmium in the soil is based on the divalent cation ( $\text{Cd}^{2+}$ ). The hydrated free cation is the main species of cadmium in soil solution, but it is also known to form complex ions with chloride, hydroxyl groups and bicarbonate. The acute (short-term) effects of cadmium in humans through inhalation exposure consist mainly of effects on the lung, such as pulmonary irritation. Chronic (long-term) inhalation or oral exposure to cadmium leads to a build-up of cadmium in the kidneys that can cause kidney disease. Eating food or drinking water with very high cadmium levels severely irritates the stomach, leading to vomiting and diarrhoea, and sometimes death. Taking higher levels of cadmium over a long period of time can lead to a build-up of cadmium in the kidneys. If the build-up is high enough, it will damage the kidneys. Exposure to lower levels of cadmium for a long time can also cause bones to become fragile and break easily. The U.S. Department of Health and Human Services (DHHS) has reported that cadmium and cadmium compounds are known human carcinogens. The International Agency for Research on Cancer (IARC) has also reported that cadmium is carcinogenic to humans (ATSDR, 2012).

### **2.13 Lead**

Lead is a toxic metal that has been used for many years in products found in and around homes. Even at low levels, lead may cause a range of health effects including behavioral problems and learning disabilities. Children six years old and under are most at risk because this is when their brain is developing. The primary source of lead exposure for most children is lead-based paint in older homes. Lead in drinking water can add to that exposure intake by human beings. Lead is used in the manufacture of pipes, pottery, alloys, paints, pigments, varnishes and pesticides.

Main sources of lead pollution are mining, smelting of lead ores, emission from automobile exhausts and effluents from storage battery industries (Kaur, 2008). Lead is present in tap water to some extent as a result of its dissolution from natural sources, but primarily from household plumbing systems in which the pipes solder, fittings or service connections to homes contain lead. Polyvinyl chloride (PVC) pipes also contain lead compounds that can be leached and result in high lead concentrations in drinking-water. The amount of lead dissolved from the plumbing system depends on several factors, including the presence of chloride and dissolved oxygen, pH, temperature, water softness and standing time of the water. According to World Health Organization guidelines (WHO, 2011), the maximum permissible concentration of lead in water is 0.01 mg/l.

### **2.13.1 The health effects of lead**

The human body contains approximately 120 mg of lead. About 10-20% of lead is absorbed by the intestines. Symptoms of over-exposure to lead include colics, skin pigmentation and paralysis. Generally, effects of lead poisoning are neurological or teratogenic. Organic lead cause necrosis of neurons and are absorbed faster, and therefore pose a greater risk. Organic lead derivates may be carcinogenic and women are generally more susceptible to lead poisoning than men (Ezenwaji and Otti, 2013). It causes menstrual disorder, infertility and spontaneous abortion, and it increases the risk of stillbirth. Children may absorb a larger amount of lead per unit body weight than adults (up to 40%) (Akoteyson *et al.*, 2011).

## **2.14 Zinc**

Zinc in its elemental form is a bluish-white metal. It is found naturally at low concentrations in many rocks and soils principally as sulphide ores and to a lesser degree as carbonates (Akoteyson *et al.*, 2011). Zinc can be introduced into water naturally by erosion of minerals from rocks and soil; however, zinc ores are only slightly soluble in water and is only dissolved at relatively low concentrations (Kaur, 2008). High level of zinc in water is usually associated with higher concentrations of other metals such as lead and cadmium. Most zinc is introduced into water by artificial pathways such as by-products of steel production or coal-fired power stations, or from the burning of waste materials. Zinc is also used in some fertilizers that may leach into groundwater. Older galvanized metal pipes are coated with zinc that may dissolve in soft, acidic waters. The average zinc concentration in seawater is 0.6-5 ppb. Rivers generally contain between 5 and 10 ppb. Algae contains 20-700 ppm, sea fish and shells (3-25 ppm), oysters (100-900 ppm) and lobsters (7-50 ppm). According World Health Organization guidelines (WHO, 2011), the maximum permissible concentration of zinc in drinking water is 3 mg/l.

### **2.14. 1 Health effects of zinc**

Zinc is a trace element that is essential for human health. When people absorb too little zinc they can experience loss of appetite, decreased sense of taste and smell, slow wound healing and skin sores. Zinc-shortage can cause birth defects. Although humans can handle proportionally large concentration of zinc, high zinc content can cause eminent health problems, such as stomach cramps, skin irritation, vomiting, nausea and anemia. High zinc level can damage the pancreas and disturb the protein metabolism and cause arteriosclerosis. Extensive exposure to zinc chloride can cause respiratory disorders. In the work environment zinc contagion can lead to flu-



like condition known as metal fever. This condition will pass after two days and is caused by over sensitivity. Zinc can be a danger to unborn and newborn children. When their mothers absorb large concentrations of zinc, the children may be exposed to zinc through blood or milk (Ezenwaji and Otti, 2013). In view of the above health concerns of zinc, it is necessary that its content in the borehole water is monitored.

### **2.15 Escherichia Coli**

Escherichia coli is a taxonomically well defined member of the family enterobacteriaceae, and is characterized by possession of the enzymes  $\beta$ - galactocidase and  $\beta$ -glucuronidase. It grows at 44-45°C on complex media, ferments lactose and mannitol with the production of acid and gas and produces indole from tryptophan. However, some strains can grow at 37°C but not at 44-45°C, and some do not produce gas. E-coli is abundant in human and animal faeces, and in fresh faeces where it may attain concentrations of  $10^9$  per gram (Dombek *et al.*, 2000). It is found in sewage, treated effluents, and all natural waters and soils subject to recent faecal contamination, whether from humans, wild animals, or agricultural activity. The detection of E-coli in water from treatment works is of the same significance as any other coliform organisms present in water. Its absence does not necessarily indicate that pathogens have been eliminated. E-coli are indicative of recent faecal contamination, which can cause severe illness like bloody diarrhoea and abdominal cramps.

### **2.16 Statistical analysis**

The data obtained from the respondents during the survey period and collection of water borehole samples from Hodan District were analyzed and calculated statistically. All statistical analyses were computed using SPSS software version 20.

**CHAPTER THREE**  
**MATERIALS AND METHODS**

**3.1 Study Area**

The research was conducted within Hodan district, Mogadishu which is located at 02°02' S latitude and 45°19'E longitude. Hodan district borders Afgoye to the West, Deynile to the north, Howlwadag to East, Wabari to the south and Wadajir to the southwest.

The map of the study area where sampling was conducted is shown in Figure 3.1. In this study six sampling points were selected in Hodan District .The sampling points were Rer M. Sheikh, Gorgor, Umu Batula, Cise Qodax, Soonikia (Digfer) and Umu Caisha (Tarabuun). Table 3.1 shows the coordinates of the sampling points.

**Table 3.1: Coordinates and depths of the sampling points in Hodan District**

Sampling point	Longitude	Latitude	Depth (meters)
Rer M.Sheikh	045:19.142°E	02:02.208°S	43
Gorgor	045:18.750°E	02:02.478°S	86
Umu Batula	045:18.691°E	02:03.036°S	85
Cise Qodax	045:18.479°E	02:02.412°S	90
Soonikia (Digfer)	045:17.886°E	02:02.557°S	90
Umu Caisha (Tarabuun)	045:18.573°E	02:02.511°S	93

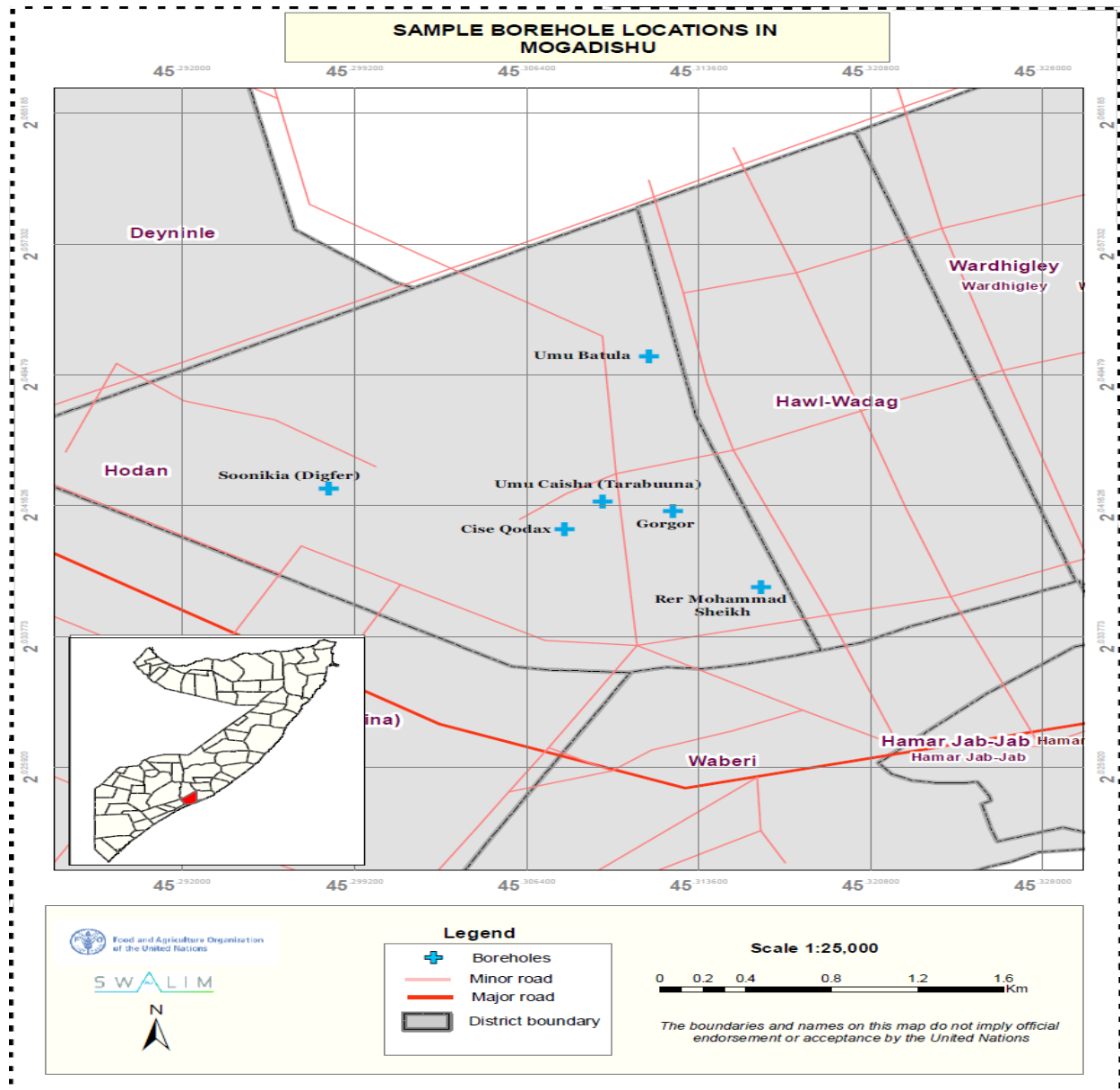


Figure 3.1: A map of the sampling points in Hodan District (Source: SWALIM, 2015 Nairobi, Kenya)

### 3.2 Description of the sampling points

Rer M. Sheikh (Fig.3.2) is located at the Ahmed Gurey wards (waax) of the district behind Imam Shafi University. This borehole is surrounded by garages where car washing and maintenance of

vehicles take place. This borehole has a water tower and provides water to about one hundred and fifty (150) households (MEWR, 2012).



Figure 3.2: Water sampling at Rer M. Sheikh borehole

Gorgor (Fig. 3.3) is located at the October wards (waax) of the district, behind district administration office. The borehole is surrounded by residential houses. It provides water to around two hundred (200) households (MEWR,2012).



Figure 3.3: Water sampling at Gorgor borehole site



Umu Batula (Fig. 3.4) is located near the military hospital. This borehole has a water tower that provides water to around 600 households (MEWR, 2012).



Figure 3.4: Water sampling at Umu Batula borehole

Cise Qodax (Fig. 3.5) is located at the October wards (waax) of the district opposite Digfer hospital. This borehole serves water to around 680 households (MEWR, 2012).



Figure 3.5: Water sampling at Cise Qodax Borehole

Soonikia (Digfer) (Fig. 3.6) is located at the October wards (waax) of the district near Gahayr University. This place is home to refugees who were displaced from their homes. This place has a restaurant, petrol station and shops. This borehole provides water to around 1500 households (MEWR, 2012).



Figure 3.6: Water sampling at Soonikia (Digfer) Borehole

The water borehole at Umu Caisha (Tarabuun) in Hodan district (Fig. 3.7) is located at the October wards (waax) of the district along the Tarabuun Road, near a garage where car washing and car maintenance activities are conducted. Other business premises are also located here. This borehole serves water to around 2235 households (MEWR, 2012).



Figure 3.7: Water sampling at Umu Caisha (Tarabuun) Borehole

### **3.3 Equipment and chemicals**

The following equipment and chemicals were used in the study.

**3.3.1 Equipment:** Atomic absorption spectrophotometer (AAS-6300, Shimadzu, Japan), ultraviolet-visible spectrophotometer model UV-1700, Shimadzu, Japan), flame photometer model 410 (Sherwood), EC/ pH meter model 15, (Fisher Scientific), pH meter model MI306 (Apps Enterprises Ltd, Australia), fluoride ion selective electrode ion, analytical balance ,digital balance, pipette (10 ,25 ml), burette (50 ml), beaker (200 ml) , Kjeldahl flask (800 ml), volumetric flask (100, 250 ml), hot plate, conical flask (125 ml)and filter paper No.1.

**3.3.2 Chemicals:** Nessler's reagent, distilled water, lead nitrate, zinc nitrate, cadmium nitrate, standard potassium chloride solution with conductivity 12.88ms/cm, calcium carbonate, nitric acid, methyl red indicator, litmus paper indicator, phenolphthalein indicator, oxalic acid dihydrate, disodium ethylenediamminetetraacetatedihydrate,1M hydrochloric acid, 1M sodium hydroxide, borate buffer , Eriochrome black-T indicator, ammonium chloride, ammonia / ammonium chloride buffer, potassium chromate, sodium fluoride, sodium nitrate, sodium chloride, nitric acid and potassium nitrate.

### **3.4 Sample collection and storage**

Water sampling was carried out in the different boreholes in Hodan District, Mogadishu, Somalia, in December 2014. Hot water was used to sterilize the plastic containers before collection of the samples. At each sampling borehole, 3L and 1L plastic containers were rinsed twice with borehole water from the tap which was then allowed to run for two minutes before collecting the samples. Plastic containers were carefully filled with the water and recapped. The water samples were acidified with concentrated nitric acid to  $\text{pH} < 2$  for total metal analysis and



then transported to the laboratory and preserved at a temperature of 4 °C for bacteriological analysis. All the reagents that were used were of analytical grade.

### **3.5 Experimental procedure**

#### **3.5.1 Determination of electrical conductivity (EC) and pH**

The EC/pH meter was standardized at room temperature (25°C) using a solution of KCl with a conductivity of 12.88mS/cm. After standardization the electrical conductivity and pH were measured by dipping the EC/pH meter directly into the water sample. One measures by changing mode from pH to electrical conductivity appropriately

#### **3.5.2 Determination of total dissolved solids (TDS)**

A 100ml of water sample was filtered into a pre-weighed beaker. The filtered sample in the beaker was oven dried at 105°C for 5 to 6 hours. The beaker was then removed and placed in a desiccator to cool. The weight of beaker and sample was then determined.

#### **3.5.3 Determination of alkalinity**

##### **3.5.3.1 Standardization of sodium hydroxide with 0.05M oxalic acid**

A sample of oxalic acid dihydrate ( $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ) (0.1579g) was weighed and transferred into a 1000 ml volumetric flask. Distilled water (25ml) was added to dissolve the oxalic acid dihydrate. The solution was then diluted to the mark with distilled water. An aliquot of the oxalic solution (25ml) was pipetted into a clean conical flask and bromocresol green indicator (2 drops) was added and the solution was then titrated with sodium hydroxide solution. The titration was repeated four times. The result obtained was used to calculate the actual concentration of sodium hydroxide.

### **3.5.3.2 Standardization of hydrochloric acid with standard 0.097M sodium hydroxide**

An aliquot of hydrochloric acid solution (25 ml) was drawn by a pipette into a clean conical flask and phenolphthalein indicator (2 drops) added. The solution was then titrated with the standard 0.097M sodium hydroxide. The titration was repeated four times. The result obtained was used to calculate the concentration of the hydrochloric acid.

### **3.5.3.3 Alkalinity determination**

An aliquot of borehole water sample (25 ml) was pipetted into a clean 250 ml conical flask and bromocresol green indicator (3 drops) added. The solution was titrated with the standard hydrochloric acid until end-point. The titration was repeated four times. The results obtained for each borehole was recorded separately.

### **3.5.3.4 Bicarbonate determination**

An aliquot of borehole water (25ml) was pipetted into a clean 250 ml conical flask. Standard sodium hydroxide solution (25 ml) was added to the conical flask. The conical flask was shaken to mix. 10% (w/w) barium chloride solution (5 ml) was measured using a graduated cylinder and added to the conical flask. The mixture was shaken well to precipitate barium carbonate. Phenolphthalein indicator (3 drops) was added and the mixture was immediately titrated with standard hydrochloric acid. This titration was repeated four times. The result obtained in each borehole was recorded separately.

### **3.5.4 Determination of hardness**

#### **3.5.4.1 Preparation of standard 0.0109M calcium solution**

0.2738g of calcium carbonate was weighed and transferred into a 250 ml volumetric flask and dissolved using drops of concentrated HCl. It was then mixed with about 20 ml of distilled water. The solution was then heated to remove CO<sub>2</sub> and boiled gently until the volume was reduced, then cooled. A few drops of 1M NaOH were reacted with calcium solution using methyl orange indicator. The color of solution changed to yellow then gradually to red using drops of methyl orange indicator. The solution was then diluted to the mark with distilled water (ASTM, 1976).

#### **3.5.4.2 Standardization of EDTA with 0.0109M calcium solution**

A 25ml aliquot of the calcium solution was drawn from a pipette into a clean conical flask and Eriochrome black-T indicator (10 drops) and 2ml of the ammonia-ammonium chloride buffer added. The solution was then titrated with EDTA until the initial wine red color changed to sky blue. The titration was repeated four times. The result obtained was used to calculate the concentration of EDTA.

#### **3.5.4.3 Hardness**

An aliquot of borehole water sample (10 ml) was drawn from a pipette into a clean 250ml conical flask and Eriochrome black-T indicator (10 drops) and 2 ml of the ammonia-ammonium chloride buffer added. The solution was titrated with the standard EDTA until the initial red color changed to blue. The titration was repeated four times. The result obtained in each borehole was recorded in separate tables.

## 3.6 Determination of anions

### 3.6.1 Fluoride

The reagents for determination of fluoride concentration were prepared as follows:

**3.6.1.1 Buffer solution:** Approximately 500 ml of distilled water was transferred into a 1 liter beaker. 57 ml of glacial acetic acid, 58g of sodium chloride and 4g of cyclohexanediaminetetraacetic acid (CDTA) were added. Mixture was stirred then cooled to room temperature. The pH of solution was adjusted to between 5.0 and 5.5 with 5M sodium hydroxide (about 200 ml). The solution was then transferred to a 1- liter volumetric flask and diluted to the mark with distilled water.

**3.6.1.2 Sodium fluoride, stock solution:** 0.2210 g of sodium fluoride was weighed and transferred into a 1-liter volumetric flask and dissolved in distilled water and diluted to a volume of 1000 ml to make 1000 ppm fluoride. From 1000 ppm, dilution was made to give 100 ppm using dilution formula  $c_1v_1=c_2v_2$  where c and v are concentration and volume respectively. From 100 ppm a series of dilutions were done to give working standards: 0.5 ppm, 1.00 ppm, 2.00 ppm, 4.00 ppm, 8.00 ppm, 10.00 ppm, 20.00 ppm, 30.00 ppm, 40.00 ppm, 50.00 ppm, 60.00 ppm, 70.00 ppm, 80.00 ppm, and 100.00 ppm, fluoride using dilution formula  $c_1v_1=c_2v_2$ . The instrument was then calibrated. The samples were analyzed using fluoride electrode.

### 3.6.2 Chloride

The reagents for the determination of chloride concentration were prepared as follows:

**3.6.2.1 Potassium chromate solution:** 1.0g of  $K_2CrO_4$  was dissolved in 20ml of distilled water for use during the chloride analysis.

**3.6.2.2 0.1M Sodium chloride solution:** 0.5843g of NaCl was weighed and transferred to 1-litre volumetric flask and dissolved in about 100 ml of distilled water. The resulting solution was made to volume (Kaur, 2008).

**3.6.2.3 Standardization of silver nitrate solution with 0.1M NaCl:** 16.987g of  $AgNO_3$  was weighed and transferred into a 500 ml volumetric flask and made up to the mark with distilled water.  $AgNO_3$  solution was standardized by placing 10 ml of NaCl solution in a conical flask and 2ml of chromate solution was added then the solution was titrated with  $AgNO_3$  solution until reddish coloration appeared. The amount of  $AgNO_3$  solution used was recorded and the titration repeated four times. The results obtained were recorded in separate tables and used to calculate the concentration of  $AgNO_3$ .

**3.6.2.4 Determination of chloride concentration:**

An aliquot of borehole water sample (25 ml) was drawn into a clean 250 ml conical flask using a pipette and 2 ml of  $K_2CrO_4$  indicator was added. The solution was titrated with the standard  $AgNO_3$  solution until reddish coloration appeared. The titration was repeated four times. The results obtained were recorded (Kaur, 2008).

### 3.6.3 Ammonium

The reagents for the determination of ammonium concentration in the borehole water sample were prepared as follows:

**3.6.3.1 Nessler reagent:** 100g of mercuric iodide and 70g of potassium iodide were accurately weighed and transferred into 1-liter volumetric flask. Small amount of distilled water was added and the mixture stirred. To this was slowly added a cooled solution of 160 g of sodium hydroxide in 1-liter volumetric flask which was dissolved in 500 ml of distilled water. This was then diluted to 1 liter with distilled water (SMEWW, 1975). The reagent was stored in a Pyrex bottle out of direct sunlight.

**3.6.3.2 Borate Buffer:** Approximately 88 ml of 0.1M NaOH solution was added to 500 ml of 0.025M sodium tetra borate in a 1-liter volumetric flask ( borate was prepared by weighing 9.5g of  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ . This was then dissolved in distilled water then diluted to 1 liter in a volumetric flask).

**3.6.3.3 Sample preparation:** 500 ml of distilled water was added to 800 ml Kjeldahl flask containing boiling chips (which had previously been treated with dilute concentration of NaOH). To 400 ml of sample was added a few drops of 0.1M NaOH to adjust the pH to 9.5. The sample with adjusted pH of 9.5 was transferred to 800 ml Kjeldahl flask and 25 ml of borate buffer added. 300 ml of distilled water was added at the rate of 6-10ml/min into 50ml of 1M HCl contained in a 500 ml Erlenmeyer flask. The extension of the condenser tip was extended below the level of the hydrochloric acid solution (SMEWW, 1975). The distillate was then diluted to

500 ml with distilled water and an aliquot Nesslerized to obtain an approximate value of the ammonium ion concentration.

**3.6.3.4 Ammonium chloride, stock solution:** A 3.821 g of ammonium chloride was weighed and transferred into a 1 liter volumetric flask and dissolved in distilled water and diluted to a volume of 1286 ml to make 1286 ppm ammonium ion. From 1286 ppm dilution was made to give 129 ppm using dilution formula  $c_1v_1 = c_2v_2$  where c and v are concentration and volume respectively. From 129 ppm a series of dilutions were done to give working standards of: 0.13 ppm, 0.26 ppm, 0.39 ppm, 0.51 ppm, 0.64 ppm, 0.77 ppm, 0.9 ppm, 1.03 ppm, 1.16 ppm, and 1.29 ppm of ammonium. The instrument was then calibrated. The absorbance values for the standards were determined and recorded. The samples were run using uv-vis spectrophotometer at wavelength 425 nm.

### **3.6.4 Nitrate**

Nitrate ion in borehole water samples were determined using phenol sulphonic acid method

#### **3.6.4.1 Principle**

Nitrate reacts with phenol sulphonic acid to produce a nitro derivative, which in alkaline solution develops a yellow color. The development of yellow color is attributed to rearrangement in the structure of the nitro derivative. The color is proportional to the concentration of  $\text{NO}_3^-$  present in the water sample according to Beer's law. The concentration of  $\text{NO}_3^-$  is determined using a uv-vis spectrophotometer.

**3.6.4.2 Preparation of nitrate standard:** 1.6470 g of potassium nitrate was weighed and dissolved in about 10 ml water and diluted to 1000 ml to make 1000 ppm.

**3.6.4.3 Preparation of stock solution:** A calibration curve was prepared from standard potassium nitrate ( $\text{KNO}_3$ ) solution. 2 ml of standard 1000 ppm  $\text{KNO}_3$  solution was taken in separate 100 ml beaker and dried in an oven at  $120^\circ\text{C}$  for 4 to 7 hours to evaporate the entire solution. 2 ml of phenol sulphonic acid was added to dissolve the residue. 7 ml of conc.  $\text{NH}_4\text{OH}$ , (to develop color) was added and diluted to 100 ml standard volumetric flasks to obtain a concentration of 20 ppm. From 20 ppm a series of dilutions were done to give working standards of: 1.0 ppm, 2.0 ppm, 3.0 ppm, 4.0 ppm, 5.0 ppm, 6.0 ppm, 7.0 ppm, 8.0 ppm, 9.0 ppm, and 10.0 ppm nitrate using dilution formula  $c_1v_1 = c_2v_2$ . Contents were mixed well and the solutions from each of the standard flasks were transferred to a cuvette. The absorbance was measured at 410 nm using uv-visible spectrophotometer. A calibration curve was drawn by plotting absorbance versus concentration of  $\text{NO}_3^-$ .

**3.6.4.1.2 Sample preparation:** 100 ml of each water sample was taken in six separate beakers and dried in an oven at  $120^\circ\text{C}$  for 6 to 8 hours to evaporate the entire water sample. The beaker was then removed and kept in a desiccator and left to cool. The residue retained in the beaker was treated and the following addition was done: beaker (1) 17 ml of 0.1M  $\text{AgNO}_3$  and 8 ml of distilled water ; beaker (2) adding 23 ml of 0.1M  $\text{AgNO}_3$  and 2 ml of distilled water; beaker (3) 15 ml of 0.1M  $\text{AgNO}_3$  and 10 ml of distilled water; beaker (4) 7 ml of 0.1M  $\text{AgNO}_3$  and 18 ml of distilled water; beaker (5) 9 ml of 0.1M  $\text{AgNO}_3$  and 16 ml of distilled water; beaker (6) 11 ml of 0.1M  $\text{AgNO}_3$  and 14 ml of distilled water. All were warmed using a heater then filtrated. The filtrates were then dried in an oven at  $120^\circ\text{C}$  for 6 to 8 hours. The beakers were removed again



and placed in a desiccator. 2 ml of phenol sulphonic acid was added to each beaker and 7 ml of  $\text{NH}_4\text{OH}$  added. This was then transferred into 25 ml volumetric flask then diluted to the mark. Yellowish color was formed. A blank solution was prepared by excluding the water sample. The water samples were diluted ten times except Rer. M. Sheikh which was diluted twenty times then using the calibration curve, the concentration of  $\text{NO}_3^-$  in the water samples were determined.

### **3.7 Determination of the concentration of heavy metals in borehole water samples**

#### **3.7.1 Digestion procedure**

50 ml of water sample was transferred to a 150 ml conical flask and added 5 ml con. $\text{HNO}_3$  and few boiling chips then boiled slowly and evaporated on a hot plate to the lowest volume possible (about 10 ml before precipitation occurs). The heating was continued by adding conc.  $\text{HNO}_3$  until digestion was completed and gave a light- colored, clear solution. The flask wall was washed down with distilled water and then filtered and filtrate transferred to a 100 ml volumetric flask and left to cool. It was then diluted to the mark then mixed thoroughly. A portion of this solution was taken for required metal determinations.

#### **3.7.2 Lead**

Lead nitrate ( $\text{Pb}(\text{NO}_3)_2$ ) (1.6146g) was accurately weighed and dissolved in 50 ml of distilled water in a volumetric flask. It was then diluted with distilled water to a volume of 1000 ml to make 1000 ppm lead. From 1000 ppm, dilutions were made to give other concentrations using dilution formula  $c_1v_1=c_2v_2$  where c and v are concentration and volume respectively. From 100ppm a series of dilutions were done to give working standards: 0.00 ppm, 0.5 ppm, 1.00 ppm, 1.5 ppm, 2.0 ppm, 2.5 ppm and 3.00 ppm of lead.

### 3.7.3 Zinc

Zinc nitrate ( $\text{Zn}(\text{NO}_3)_2$ ) (2.9550g) was accurately weighed and placed in a 1-liter volumetric flask. Distilled water was then added to dissolve it then made to volume of 1000 ml to make 1000 ppm zinc. From 1000 ppm a dilution was made to give 100 ppm using dilution formula  $c_1v_1=c_2v_2$  where c and v are concentration and volume respectively. Other dilutions made were: 0.00 ppm, 0.5 ppm, 1.00 ppm, 1.5 ppm, 2.00 ppm, 2.5 ppm and 3.00 ppm of zinc.

### 3.7.4 Cadmium

Cadmium nitrate ( $\text{Cd}(\text{NO}_3)_2$ ) (2.1461g) was accurately weighed and placed in 1-liter volumetric flask. This was dissolved in distilled water and made to a volume of 1000 ml to make 1000 ppm of cadmium. From 1000 ppm dilution was made to give 100 ppm using dilution formula  $c_1v_1=c_2v_2$  where c and v are concentration and volume respectively. Other dilutions were made to give: 0.00 ppm, 0.5 ppm, 1.00 ppm, 1.5 ppm, 2.00 ppm, 2.5 ppm and 3.00 ppm of cadmium.

The working conditions of the atomic absorption spectrophotometer for the analysis of heavy metals were summarized in table 3.2.

**Table3.2: Conditions of the atomic absorption spectrophotometer**

Element	Lamp current	Wave length	slit width	Fuel	oxidant	detection limit
Lead	10mA	217.00nm	1.00nm	acetylene	Air	0.5 ppm
Zinc	5mA	213.9nm	1.00nm	acetylene	Air	0.5 ppm
Cadmium	4mA	228.8nm	0.5 nm	acetylene	Air	0.5 ppm

### **3.8 Determination of the concentration of sodium ion in borehole water Samples**

#### **3.8.1 Sodium**

Sodium nitrate ( $\text{NaNO}_3$ ) (3.7517g) was accurately weighed and placed in a 1-liter volumetric flasks and distilled water added. It was made to volume to make 1000 ppm of sodium. From 1000ppm a dilution was made to give 100ppm using dilution formula  $c_1v_1=c_2v_2$  where c and v are concentration and volume respectively. From 100 ppm a series of dilutions were made to give: 0.00 ppm, 2.0 ppm, 4.0 ppm, 6.0 ppm, 8.0 ppm , 10.0 ppm and 12.00 ppm of sodium using dilution formula  $c_1v_1= c_2v_2$ . The dilutions were used to calibrate the flame photometer. The water samples were diluted twenty (20) times and then the samples were analyzed using flame photometer.

The working condition of the flame photometer for the analysis of sodium was as follows: The burner: a flame, emission wavelength (589 nm), color (yellow), low temperature (1500-2000°C), fuel mixture (propane/air and natural gas) and detection limit for sodium (0.2 ppm).

### **3.9 Microbial determination of borehole water samples**

#### **3.9.1 Media preparation**

All the media used were prepared in Applied Biology Laboratory of University of Nairobi. Sterilization was done by the use of an autoclave, which provided heat to kill the organisms present. Sterilizations of glassware and media were done at a temperature of 121°C for 15 minutes. Workbenches were sterilized using ethanol.

### **3.9.2 Preparation of macConkey broth purple**

8g of the MacConkey broth powder was weighed and dissolved in 200 ml of distilled water then heated until the media completely dissolved. The media solution was placed into test tubes with inverted durham's tube. Sterilization was done by autoclaving at 121°C for 15 minutes. For presumptive test 10 ml of lactose broth was put in a test tube which had durham's tube and inoculated with sample of water then incubated at 37°C for 24 to 48 hours.

### **3.9.3 Presumptive coliform tests result**

Positive tubes turned from purple to yellow with gas produced at the durham vials. The numbers of tubes showing acid and gas were noted and recorded.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Hydrogen ion concentration (pH)

pH indicates the intensity of acidic or basic character at a given temperature. Measurement of pH is one of the most important and most frequently used tests in determining water quality. Every phase of water treatment and water supply like acid-base neutralization, water softening, precipitation, coagulation, disinfection and corrosion control are pH dependent. The pH of the water samples were found in the range 8.1 to 8.9 i.e. slightly alkaline (figure 4.1). The maximum value of pH was recorded at Cise Qodax (8.9) and the minimum pH value was recorded at Gorgor (8.1). The maximum permissible limit of pH according to WHO is 6.5 to 8.5. pH of all boreholes were within the WHO (6.5-8.5) except Cise Qodax (8.9). (Figure 4.1)

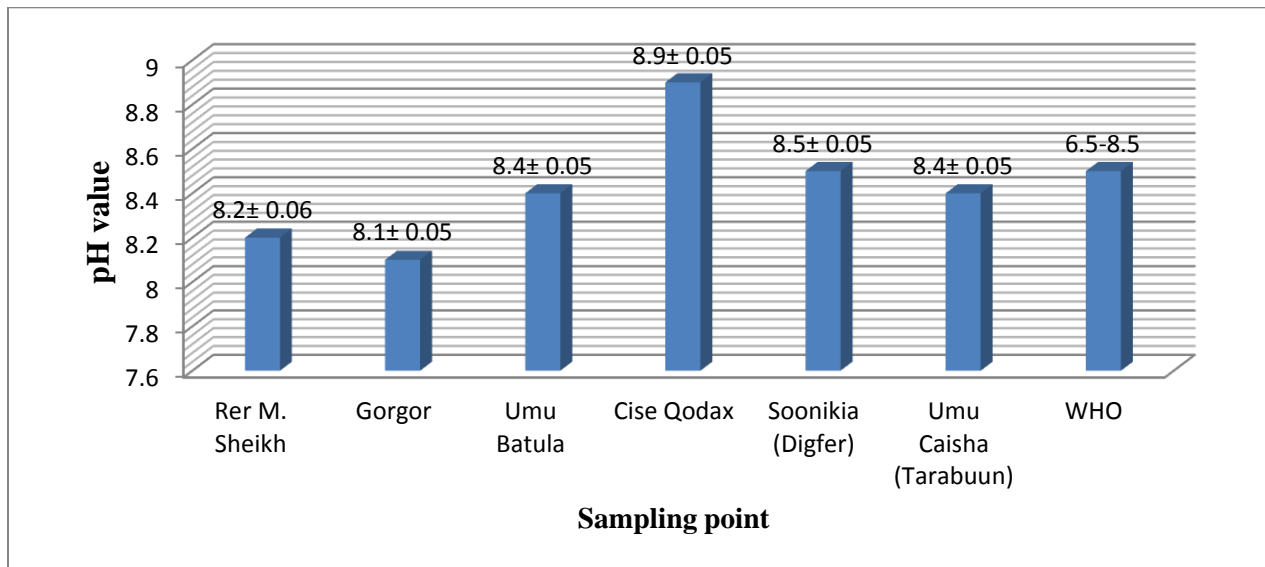


Figure 4.1: The pH of the water samples at the various sampling sites

## 4.2 The electrical conductivity

Electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current. It depends on the presence of ions, their total concentration, mobility and temperature. Higher value of conductivity shows higher concentration of dissolved ions. Conductivity of water samples were in the range 1.428 to 3.28 mS /cm (Figure 4.2), which is slightly above the WHO standards (0.25mS /cm). Highest was Rer M. Sheikh (3.28 mS/cm) and lowest was at Soonikia (Digfer) (1.428 mS /cm).

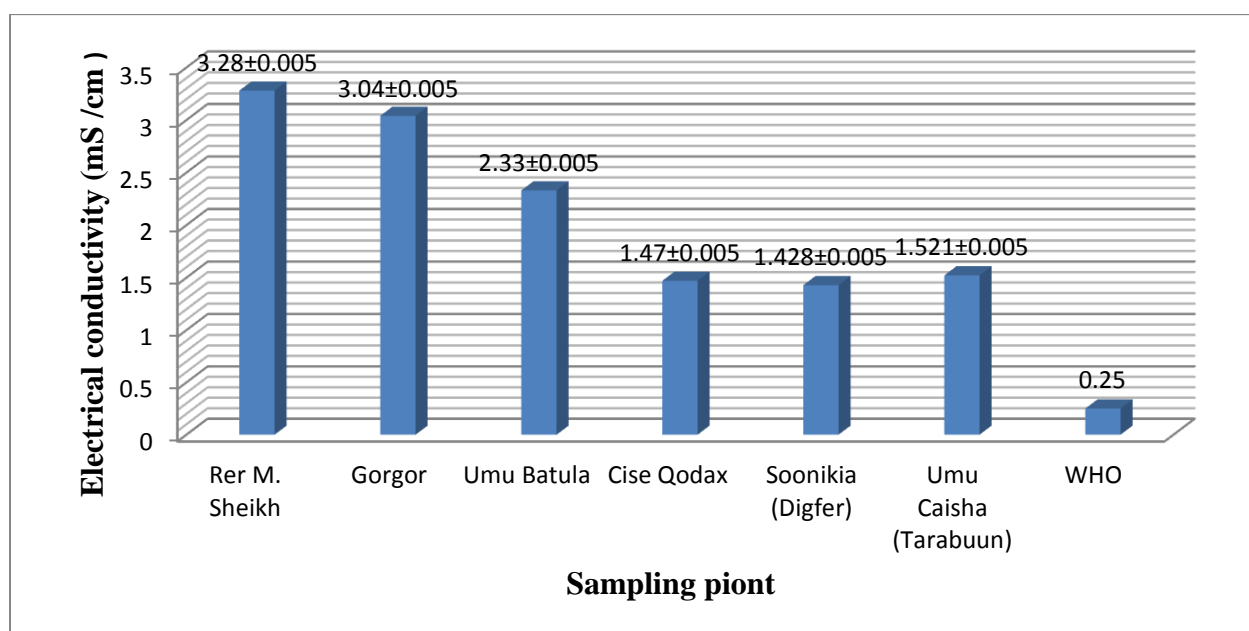


Figure 4.2: Electrical conductivity (mS /cm) at various sites

## 4.3 Alkalinity

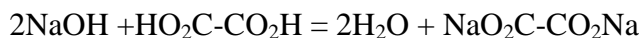
### 4.3.1 Standardization of sodium hydroxide with 0.05M oxalic acid

Oxalic acid dihydrate was standardized using sodium hydroxide as shown in Table 4.1

**Table 4.1: Standardization of sodium hydroxide with 0.05M oxalic acid dihydrate**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	0.00	0.00	0.00
Final burette reading (ml)	25.9	25.4	25.5	25.8
Volume of NaOH used	25.9	25.4	25.5	25.8
Average volume of NaOH used	$= \frac{25.9+25.4+25.5+25.8}{4} = 25.65 \text{ ml} \pm 0.2062$			

Then moles of oxalic acid dihydrate ( $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ) reacted with sodium hydroxide is according to scheme 4.1



Scheme 4.1 Reaction between sodium hydroxide and oxalic acid

$$\text{Moles of oxalic acid dihydrate} = \frac{\text{Mass used}}{\text{Molecular weight}} = \frac{0.1579\text{g}}{126.32\text{g/mole}} = 1.25 \times 10^{-3} \text{ mole}$$

$$\text{Molarity of oxalic acid dihydrate} = \frac{1000 \text{ ml} \times 0.00125 \text{ mole}}{25 \text{ ml}} = 0.05\text{M}$$

$$\text{Moles of sodium hydroxide} = 2 \times 1.25 \times 10^{-3} \text{ mole} = 2.5 \times 10^{-3} \text{ mole.}$$

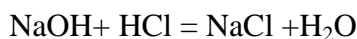
$$\text{Therefore molarity of NaOH} = \frac{0.0025 \text{ mole} \times 1000 \text{ ml}}{25.65 \text{ ml}} = 0.097\text{M}$$

### 4.3.2 Standardization of hydrochloric acid with standard 0.097M sodium hydroxide solution

**Table 4.2: Standardization of hydrochloric acid with standard 0.097M sodium hydroxide**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	0.00	0.00	0.00
Final burette reading (ml)	24.6	24.4	24.4	24.4
Volume of NaOH used	24.6	24.4	24.4	24.4
Average volume of NaOH used	$= \frac{24.6+24.4+24.4+24.4}{4} = 24.45 \text{ ml} \pm 0.0866$			

Reaction stoichiometry between acid and base is shown in scheme 4.2



Scheme 4.2: Reaction of base and acid

$$\text{Moles of sodium hydroxide} = \frac{MV}{1000 \text{ ml}} = \frac{0.097 \times 24.45 \text{ ml}}{1000 \text{ ml}} = 2.372 \times 10^{-3} \text{ mole}$$

$$\text{Moles of hydrochloric acid} = 2.372 \times 10^{-3} \text{ mole.}$$

$$\text{Therefore molarity of HCl} = \frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of acid used}} = \frac{0.002372 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.09488 \text{ M}$$

### 4.3.3 Alkalinity of Rer M. Sheikh borehole

**Table 4.3: Total alkalinity of Rer M. Sheikh borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	17	0.00	17.00
Final burette reading (ml)	17.6	33.2	16.3	33.2
Volume of HCl used	17.6	16.2	16.3	16.2
Average volume of HCl used	$= \frac{17.6+16.2+16.3+16.2}{4} = 16.575 \text{ ml} \pm 0.5932$			



Volume of acid used = 16.575 ml

$$\text{Moles of acid} = \frac{MV}{1000 \text{ ml}} = \frac{0.09488M \times 16.575 \text{ ml}}{1000 \text{ ml}} = 1.573 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of}$$

sample

$$\text{Therefore molarity of OH}^- \text{ in 25 ml of sample} = \frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001573 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}}$$

$$= 0.06292M$$

#### 4.3.4 Bicarbonate content

**Table 4.4: Bicarbonate content of Rer M. Sheikh borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	0.00	18.00	32.00
Final burette reading (ml)	12.1	13.3	31.7	45.6
Volume of HCl used	12.1	13.3	13.7	13.6
Average volume of HCl used	$= \frac{12.1+13.3+13.7+13.6}{4} = 13.175 \text{ ml} \pm 0.6379$			

Volume of acid used = 13.175 ml

$$\text{Moles of acid} = \frac{MV}{1000 \text{ ml}} = \frac{0.09488M \times 13.175 \text{ ml}}{1000 \text{ ml}} = 1.25 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of}$$

sample.

Excess mole of NaOH that reacted with HCl =  $1.25 \times 10^{-3}$  mole

$$\text{Moles of NaOH added to the water sample} = \frac{0.097M \times 25 \text{ ml}}{1000 \text{ ml}} = 2.425 \times 10^{-3} \text{ mole.}$$

A mole of NaOH that reacted with  $\text{HCO}_3^-$  was calculated thus;

$$= (\text{Original mole of NaOH} - \text{Excess moles of NaOH}) =$$

$$= (2.425 \times 10^{-3} \text{ mole} - 1.25 \times 10^{-3} \text{ mole}) = 1.175 \times 10^{-3} \text{ mole} = \text{moles of HCO}_3^- \text{ in 25 ml of sample.}$$

Moles of  $\text{HCO}_3^-$  that reacted with  $\text{NaOH} = 1.175 \times 10^{-3}$  mole

$$\text{Molarity of } \text{HCO}_3^- \text{ in 25 ml of sample} = \frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001175 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.047 \text{ M}$$

$$\text{Total alkalinity} = [\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}] \quad (1)$$

From equation (1) carbonate ion concentration was calculated:

$$0.06292 \text{ M} = 0.047 \text{ M} + 2x [\text{CO}_3^{-2}] \quad (2)$$

$$[\text{CO}_3^{-2}] = \frac{0.06292 \text{ M} - 0.047 \text{ M}}{2} = 0.00796 \text{ M of } \text{CO}_3^{-2}$$

Therefore concentration of carbonate ion in 25 ml of sample = 0.00796 M.

Since it was assumed that the sample contained a mixture of carbonate and bicarbonate:

$$\text{ppm of compound} = \text{molarity} \times (\text{molecular weight}) \times (\text{Av. vol. of sample used}) \times (1000 \text{ mg/1 g})$$

$$\text{ppm } \text{CaCO}_3 = (0.00796 \text{ mole/1000 ml}) \times (100.0869 \text{ g/mole}) \times (25 \text{ ml}) \times (1000 \text{ mg/1 g}) = 19.9 \text{ mg/l}$$

$$\text{ppm } \text{KHCO}_3 = (0.047 \text{ mole/1000 ml}) \times (100 \text{ g/mole}) \times (25 \text{ ml}) \times (1000 \text{ mg/1 g}) = 117.5 \text{ mg/l}$$

$$\text{Therefore alkalinity} = [\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}] = 117.5 \text{ mg/l} + (2 \times 19.9 \text{ mg/l})$$

$$= 117.5 \text{ mg/l} + 39.8 \text{ mg/l} = 157.3 \text{ mg/l}$$

### 4.3.5 Alkalinity of Gorgor borehole

Table 4.5 and 4.6 gave results for Gorgor borehole which were then used to calculate alkalinity as done in 4.3.3 and 4.3.4.

**Table 4.5: Total alkalinity of Gorgor borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	15	0.00	15.00
Final burette reading (ml)	14.7	29.4	14.5	29.7
Volume of HCl used	14.7	14.4	14.5	14.7
Average volume of HCl used	$= \frac{14.7+14.4+14.5+14.7}{4} = 14.575 \text{ ml} \pm 0.1299$			

**Table 4.6: Bicarbonate content of Gorgor borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	13.00	0.00	13.00
Final burette reading (ml)	12.6	25.2	12.6	25.6
Volume of HCl used	12.6	12.2	12.6	12.6
Average volume of HCl used	$= \frac{12.6+12.2+12.6+12.6}{4} = 12.5 \text{ ml} \pm 0.1732$			

$$\text{Alkalinity} = [\text{HCO}_3^-] + 2x[\text{CO}_3^{2-}] = 123.9 \text{ mg/l} + (2 \times 7.21 \text{ mg/l})$$

$$= 123.9 \text{ mg/l} + 14.42 \text{ mg/l} = 138.32 \text{ mg/l}$$

See calculation in Appendix BI

### 4.3.6 Alkalinity of Umu Batula borehole

The procedures 4.3.3 and 4.3.4 were applied for Umu Batula borehole water samples and alkalinity (mg/l) calculated. The results for Umu Batula are given in table 4.7 and 4.8.

**Table 4.7: Total alkalinity of Umu Batula borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	16.00	0.00	17.00
Final burette reading (ml)	16.00	32.1	16.6	33.1
Volume of HCl used	16.00	16.1	16.6	16.1
Average volume of HCl used	$= \frac{16+16.1+16.6+16.1}{4} = 16.2 \text{ ml} \pm 0.2345$			

**Table 4.8: Bicarbonate content of Umu Batula borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	14.00	0.00	25.00
Final burette reading (ml)	13.7	25.8	13.00	38.6
Volume of HCl used	13.7	11.8	13.00	13.6
Average volume of HCl used	$= \frac{13.7+11.8+13+13.6}{4} = 13.025 \text{ ml} \pm 0.7562$			

$$\text{Alkalinity} = [\text{HCO}_3^-] + 2x[\text{CO}_3^{2-}] = 118.9 \text{ mg/l} + (2 \times 17.42 \text{ mg/l})$$

$$= 118.9 \text{ mg/l} + 34.84 \text{ mg/l} = 153.74 \text{ mg/l}$$

See calculation in Appendix BII

### 4.3.7 Alkalinity of Cise Qodax borehole

Table 4.9 and 4.10 gives data for Cise Qodax that were used in alkalinity calculation as done in procedures 4.3.3 and 4.3.4.

**Table 4.9: Total alkalinity of Cise Qodax borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	18.00	18.00	0.00
Final burette reading (ml)	16.7	34.6	34.6	17.1
Volume of HCl used	16.7	16.6	16.6	17.1
Average volume of HCl used	$= \frac{16.7+16.6+16.6+17.1}{4} = 16.75 \text{ ml} \pm 0.2062$			

**Table 4.10: Bicarbonate content of Cise Qodax borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	10.00	19.00	28.00
Final burette reading (ml)	9.3	18.5	27.4	36.4
Volume of HCl used	9.3	8.5	8.4	8.4
Average volume of HCl used	$= \frac{9.3+8.5+8.4+8.4}{4} = 8.65 \text{ ml} \pm 0.3775$			

$$\begin{aligned} \text{Alkalinity} &= [\text{HCO}_3^-] + 2[\text{CO}_3^{2-}] = 160.4 \text{ mg/l} + (2 \times 0.75 \text{ mg/l}) \\ &= 160.4 \text{ mg/l} - 1.5 \text{ mg/l} = 158.9 \text{ mg/l} \end{aligned}$$

See calculation in Appendix BIII

#### 4.3.8 Alkalinity of Soonikia (Digfer) borehole

The procedures 4.3.3 and 4.3.4 were applied for calculation of alkalinity of Soonikia (Digfer) borehole water samples using data in table 4.11 and 4.12.

**Table 4.11: Total alkalinity of Soonikia (Digfer) borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	13.00	0.00	13.00
Final burette reading (ml)	12.9	25.4	12.4	25.6
Volume of HCl used	12.9	12.4	12.4	12.6
Average volume of HCl used	$= \frac{12.9+12.4+12.4+12.6}{4} = 12.575 \text{ ml} \pm 0.2046$			

**Table 4.12: Bicarbonate content of Soonikia (Digfer) borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	0.00	13.00	13.00
Final burette reading (ml)	12.3	12.3	24.7	25.3
Volume of HCl used	12.3	12.3	11.7	12.3
Average volume of HCl used	$= \frac{12.3+12.3+11.7+12.3}{4} = 12.15 \text{ ml} \pm 0.2598$			

$$\begin{aligned} \text{Alkalinity} &= [\text{HCO}_3^-] + 2x[\text{CO}_3^{2-}] = 127.2 \text{ mg/l} + (2 \times 3.95 \text{ mg/l}) \\ &= 127.2 \text{ mg/l} - 7.9 \text{ mg/l} = 119.3 \text{ mg/l} \end{aligned}$$

See calculation in Appendix BIV

#### 4.3.9 Alkalinity of Umu Caisha (Tarabuun) borehole

Procedures 4.3.3 and 4.3.4 were repeated for Umu Caisha (Tarabuun) borehole water samples and alkalinity (mg/l) calculated using data in table 4.13 and 4.14.

**Table 4.13: Total alkalinity of Umu Caisha (Tarabuun) borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	15.00	0.00	15.00
Final burette reading (ml)	14.2	31.5	14.2	29..2
Volume of HCl used	14.2	16.5	14.2	14.2
Average volume of HCl used	$= \frac{14.2+16.5+14.2+14.2}{4} = 14.775 \text{ ml} \pm 0.9959$			

**Table 4.14: Bicarbonate content of Umu Caisha (Tarabuun) borehole**

Experiment No:	1	2	3	4
Initial burette reading (ml)	0.00	13.00	0.00	13.00
Final burette reading (ml)	12.6	25.2	12.4	25.2
Volume of HCl used	12.6	12.2	12.4	12.2
Average volume of HCl used	$= \frac{12.6+12.2+12.4+12.2}{4} = 12.35 \text{ ml} \pm 0.1658$			

$$\text{Alkalinity} = [\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}] = 125.3 \text{ mg/l} + (2 \times 7.46 \text{ mg/l})$$

$$= 125.3 \text{ mg/l} + 14.92 \text{ mg/l} = 140.22 \text{ mg/l}$$

See calculation in Appendix BV

The results of the six water borehole samples indicated that alkalinity in all boreholes had values below the WHO acceptable levels (600 mg/l) for domestic water. It ranged from 119.3 mg/l to 158.9 mg/l. The highest value was obtained at Cisse Qodax (158.9 mg/l) while Soonikia (Digfer) borehole had the lowest value (119.22mg/l). (Figure 4.3)

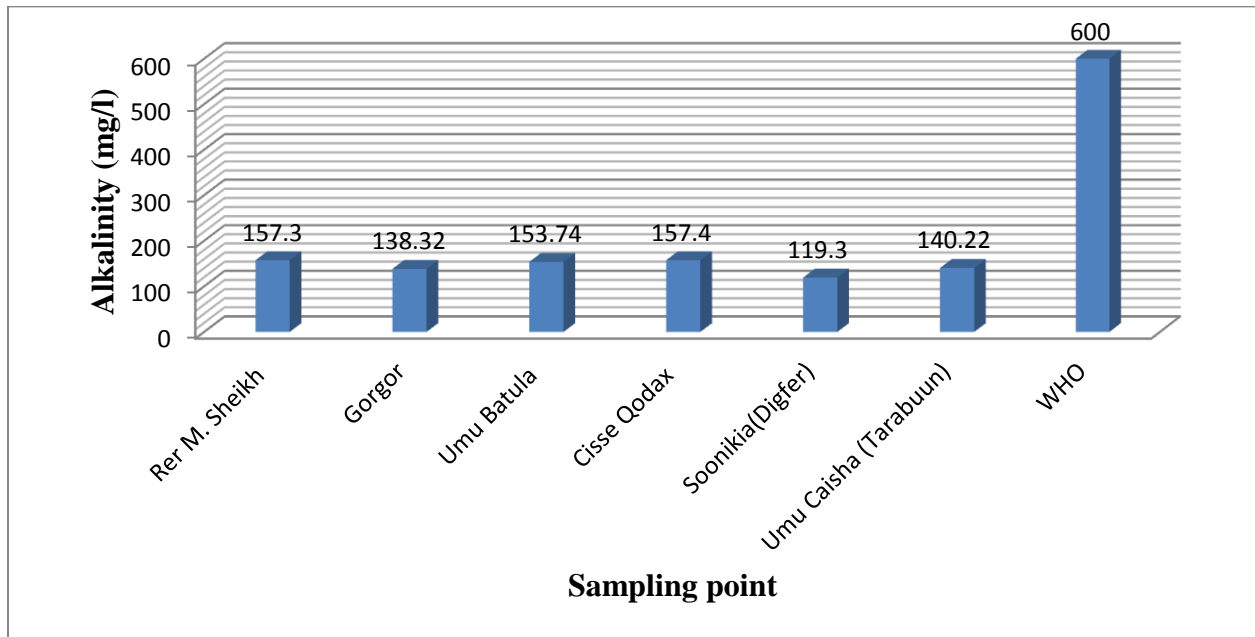


Figure 4.3: The alkalinity values (mg/l) of water samples for the various sites

## 4.4 Hardness

### 4.4.1 Standard calcium solution

In this case standard calcium solution was prepared and then calculated as follows:

$$\text{Mole of CaCO}_3 = \frac{0.2738g}{100.09g/mole} = 0.00274 \text{ mole of Ca}^{2+},$$

$$\text{Molarity of Ca}^{2+} = \frac{0.00274 \text{ mole Ca}^{2+}}{0.250L} = 0.0109M \text{ Ca}^{2+}$$



#### 4.4.2 Standardization of EDTA with 0.0109M calcium solution

Table 4.15 gives titration values in standardization of EDTA

**Table 4.15: Standardization of EDTA with 0.0109M calcium solution**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.6	0.5	0.00	0.00
Final burette reading (ml)	29.5	27.6	27.6	27.5
Volume of EDTA used	28.9	27.1	27.6	27.5
Average volume of EDTA used	$= \frac{28.9+27.1+27.6+27.5}{4} = 27.775 \text{ ml} \pm 0.6759$			

$$\text{Mole of Ca}^{2+} = \frac{\text{volume in ml} \times \text{molarity}}{1000 \text{ ml}} = \frac{25 \text{ ml} \times 0.0109\text{M}}{1000 \text{ ml}} = 2.725 \times 10^{-3} \text{ mole}$$

$$\text{Moles of EDTA} = 2.725 \times 10^{-3} \text{ mole}$$

$$\text{Therefore molarity of EDTA} = \frac{0.0002725 \text{ mole} \times 1000 \text{ ml}}{27.775 \text{ ml}} = 0.0098 \text{ mole/l.}$$

#### 4.4.3 Hardness of Rer M. Sheikh borehole water

Table 4.16 gives data for Rer. M. Sheikh borehole that were used in calculating hardness.

**Table 4.16: Titration of Rer M. Sheikh borehole water with EDTA**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	12.00	23.00	0.00
Final burette reading (ml)	11.7	22.9	33.9	10.9
Volume of EDTA used	11.7	10.9	10.9	10.9
Average volume of EDTA used	$= \frac{11.7+10.9+10.9+10.9}{4} = 11.1 \text{ ml} \pm 0.3464$			

At all times, 10 ml of the borehole sample was used.

If 1000 ml of EDTA contained 0.0098 mole  $\text{Ca}^{2+}$ , so for 11.1ml of EDTA contained

$$= \frac{0.0098\text{M} \times 11.1\text{ml}}{1000 \text{ ml}} = 1.0878 \times 10^{-4} \text{mole } \text{Ca}^{2+}, \text{ since the reaction ratio of EDTA: } \text{Ca}^{2+} = 1:1, \text{ mole}$$

of EDTA that reacted with  $\text{Ca}^{2+} = 1.0878 \times 10^{-4}$ .

$$\text{ppm } \text{Ca}^{2+} = (1.0878 \times 10^{-4} \text{mole}) \times (40\text{g/mole}) \times (1000\text{mg/1g}) \times (1/0.01\text{L}) = 435.12 \text{ mg/l}$$

#### 4.4.4 Hardness of Gorgor borehole water

The same procedure as done in 4.4.3 was applied for Gorgor borehole water samples. Table 4.17 gives titration values that were used to calculate hardness.

**Table 4.17: Titration of Gorgor borehole water with EDTA**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	13.00	0.00	13.00
Final burette reading (ml)	12.7	26.3	12.4	25.8
Volume of EDTA used	12.7	13.3	12.4	12.8
Average volume of EDTA used	$= \frac{12.7+13.3+12.4+12.8}{4} = 12.8 \text{ ml} \pm 0.324$			

$$\text{ppm } \text{Ca}^{2+} = (0.0098\text{mole}) \times (12.8\text{ml}/1000\text{ml}) \times (40\text{g/mole}) \times (1000\text{mg/1g}) \times (1/0.01\text{L}) = 501.76 \text{ mg/l}$$

#### 4.4.5 Hardness of Umu Batula borehole water

The same procedure as 4.4.3 was applied for Umu Batula borehole water samples and hardness (mg/l) calculated using data given in Table 4.18.

**Table 4.18: Titration of Umu Batula borehole water with EDTA**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	11.00	21.00	31.00
Final burette reading (ml)	9.1	20.4	30.9	41.1
Volume of EDTA used	9.1	9.4	9.9	10.1
Average volume of EDTA used	$= \frac{9.1+9.4+9.9+10.1}{4} = 9.625\text{ml} \pm 0.3961$			

$$\text{ppm Ca}^{2+} = (0.0098\text{mole}) \times (9.625\text{ml}/1000\text{ml}) \times (40\text{g}/\text{mole}) \times (1000\text{mg}/1\text{g}) \times (1/0.01\text{L}) = 377.3 \text{ mg/l}$$

**4.4.6 Hardness of Cise Qodax borehole water**

The same procedure as 4.4.3 was applied for Cise Qodax borehole water samples and hardness (mg/l) calculated using data in table 4.19.

**Table 4.19: Titration of Cise Qodax borehole water with EDTA**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	8.00	14.00	20.00
Final burette reading (ml)	5.9	13.9	19.7	25.9
Volume of EDTA used	5.9	5.9	5.7	5.9
Average volume of EDTA used	$= \frac{5.9+5.9+5.7+5.9}{4} = 5.85 \text{ ml} \pm 0.0866$			

$$\text{ppm Ca}^{2+} = (0.0098\text{mole}) \times (5.85\text{ml}/1000\text{ml}) \times (40\text{g}/\text{mole}) \times (1000\text{mg}/1\text{g}) \times (1/0.01\text{L}) = 229.32 \text{ mg/l}$$

#### 4.4.7 Hardness of Soonikia (Digfer) borehole water

The same procedure as 4.4.3 was applied for Soonikia (Digfer) borehole water samples and hardness (mg/l) calculated using data in table 4.20.

**Table 4.20: Titration of Soonikia (Digfer) borehole water with EDTA**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	7.00	1.00	8.00
Final burette reading (ml)	6.7	13.9	7.6	15.2
Volume of EDTA used	6.7	6.9	6.6	7.2
Average volume of EDTA used	$= \frac{6.7+6.9+6.6+7.2}{4} = 6.85 \text{ ml} \pm 0.2291$			

$$\text{ppm Ca}^{2+} = (0.0098\text{mole}) \times (6.85\text{ml}/1000\text{ml}) \times (40\text{g}/\text{mole}) \times (1000\text{mg}/1\text{g}) \times (1/0.01\text{L}) = 268.52 \text{ mg/l}$$

#### 4.4.8 Hardness of Umu Caisha (Tarabuun) borehole water

The same procedure as 4.4.3 was applied for Umu Caisha (Tarabuun) borehole water samples and hardness (mg/l) calculated using data in table 4.21.

**Table 4.21: Titration of Umu Caisha (Tarabuun) borehole water with EDTA**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	8.00	16.00	23.00
Final burette reading (ml)	7.1	14.5	22.1	29.0
Volume of EDTA used	7.1	6.5	6.1	6.00
Average volume of EDTA used	$= \frac{7.1+6.5+6.1+6.00}{4} = 6.425\text{ml} \pm 0.4323$			

$$\text{ppm Ca}^{2+} = (0.0098\text{mole}) \times (6.42\text{ml}/1000\text{ml}) \times (40\text{g}/\text{mole}) \times (1000\text{mg}/1\text{g}) \times (1/0.01\text{L}) = 251.86 \text{ mg/l.}$$

Hardness of water indicates water quality mainly in terms of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  expressed as  $\text{CaCO}_3$ . The total hardness was found to be in the range of 229.32 mg/l to 501.76mg/l. The lowest was at Cise Qodax (229.32/l) while Gorgor had the highest (501.76mg/l). The main sources of calcium in natural water are various types of rocks, industrial wastes and sewage. The results for water hardness are presented in Figure 4.4.

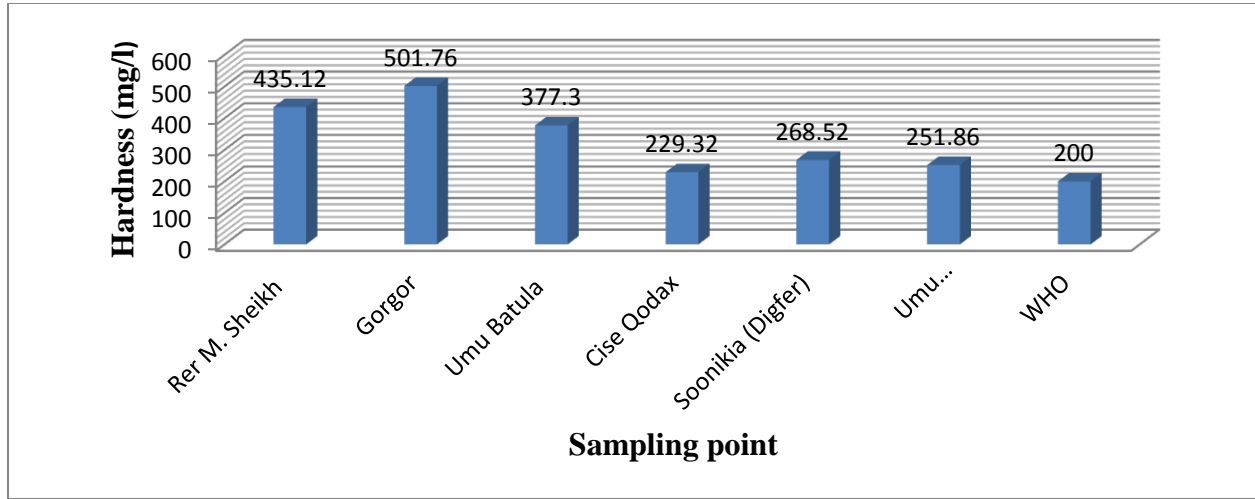


Figure 4.4: The levels of hardness as  $\text{CaCO}_3$  (mg/l) for the various sampling sites

#### 4.5 Total Dissolved Solids (TDS):

##### 4.5.1 TDS of Rer M. Sheikh borehole water

Table 4.22 gives data that was used to calculate TDS of water sample from Rer. M. Sheikh borehole water.

**Table 4.22: TDS of Rer M. Sheikh borehole water**

Experiment No:	1	2	3	Average
Weigh of empty beaker in (g)	51.8727	52.4208	53.1223	52.4719
Weigh of beaker +residue in (g)	52.1887	52.7412	53.4391	52.7896
Difference obtained in (g)	0.3160	0.3204	0.3168	0.3177g $\pm$ 0.0019

The TDS is expressed in mg/l and the following formula was used to calculate it:

$$\text{TDS, mg/l} = \frac{(A-B) \times 1000}{C} = \frac{(52.7896 - 52.4719) \times 1000}{100 \text{ml} / 1000 \text{ml}} = \frac{(0.3177 \times 1000 \text{mg})}{0.1 \text{L}} = 3177 \text{ mg/l}$$

Where:

A= weight of beaker and residue in g

B= weight of empty beaker in g

C= volume of sample in ml = 100

#### 4.5.2 TDS of Gorgor borehole water

Same procedure as applied in 4.5.1 was used in calculating TDS in mg/l. Table 4.23 gives data that were used in its calculation.

**Table 4.23: TDS of Gorgor borehole water**

Experiment No:	1	2	3	Average
Weigh of empty beaker in (g)	51.9592	53.3338	52.0501	52.4477
Weigh of beaker +residue in (g)	52.3017	53.6773	52.3927	52.7905
Difference obtained in (g)	0.3425	0.3435	0.3426	0.3428g ± 0.0005

The TDS result of Gorgor obtained was:  $\frac{0.3428 \times 1000}{0.1} = 3428 \text{ mg/l}$

#### 4.5.3 TDS of Umu Batula borehole water

Procedure as 4.5.1 was used in the calculation of TDS. Data in table 4.24 were used for the calculation.

**Table 4.24: TDS of Umu Batula borehole water**

Experiment No:	1	2	3	Average
Weigh of empty beaker in (g)	52.2917	52.4888	52.4007	52.3937
Weigh of beaker +residue in (g)	52.5238	52.7204	52.6314	52.6252
Difference obtained in (g)	0.2321	0.2316	0.2307	0.2315g ±0.0006

The TDS result of Umu Batula obtained was:  $\frac{0.2315 \times 1000}{0.1} = 2315 \text{ mg/l}$

#### 4.5.4 TDS of Cise Qodax borehole water

The same procedure 4.5.1 was applied for Cise Qodax borehole and the TDS (mg/l) calculated using data in Table 4.25.

**Table 4.25: TDS of Cise Qodax borehole water**

Experiment No:	1	2	3	Average
Weigh of empty beaker in (g)	52.3017	53.6773	52.3927	52.7906
Weigh of beaker +residue in (g)	52.4345	53.8119	52.5272	52.9245
Difference obtained in (g)	0.1328	0.1346	0.1345	0.1339g ± 0.0008

TDS result of Cise Qodax obtained was:  $\frac{0.1339 \times 1000}{0.1} = 1339 \text{ mg/l}$

#### 4.5.5 TDS of Soonikia (Digfer) borehole water

Procedure 4.5.1 was applied for Soonikia (Digfer) borehole and TDS (mg/l) calculated using data in Table 4.26.

**Table 4.26: TDS of Soonikia (Digfer) borehole water**

Experiment No:	1	2	3	Average
Weigh of empty beaker in (g)	52.5238	52.7204	52.6314	52.6252
Weigh of beaker +residue in (g)	52.7792	52.9797	52.8794	52.8794
Difference obtained in (g)	0.2554	0.2593	0.248	0.2542g ± 0.0047

TDS result of Soonikia (Digfer) obtained was:  $\frac{0.2542 \times 1000}{0.1} = 2542 \text{ mg/l}$

**4.5.6 TDS of Umu Caisha (Tarabuun) borehole water**

Procedure as 4.5.1 was applied for Umu Caisha (Tarabuun) borehole and TDS (mg/l) calculated using data in Table 4.27.

**Table 4.27: TDS of Umu Caisha (Tarabuun) borehole water**

Experiment No:	1	2	3	Average
Weigh of empty beaker in (g)	52.1887	52.7412	53.4391	52.7897
Weigh of beaker +residue in (g)	52.3397	52.8934	53.5842	52.9391
Difference obtained in (g)	0.1510	0.1522	0.1451	0.1494g ± 0.0031

The TDS result of Umu Caisha (Tarabuun) obtained was:  $\frac{0.1494 \times 1000}{0.1} = 1494 \text{ mg/l}$

The high concentrations of the total dissolved solids could be attributed to the dissolved organic and inorganic compounds associated with underground water. Total dissolved solids (TDS) values were above the acceptable WHO limits of 1000mg/l for domestic water with a range of 1339 mg/l to 3428 mg/l. The highest concentration of TDS was obtained at Gorgor (3428 mg/l) and lowest at Cise Qodax (1339 mg/l). TDS is not a health hazard although high levels may lead



to scale build up in pipes and aesthetic problems such as salty or bitter taste in water. Figure 4.5 gives a summary of TDS values in all the six boreholes.

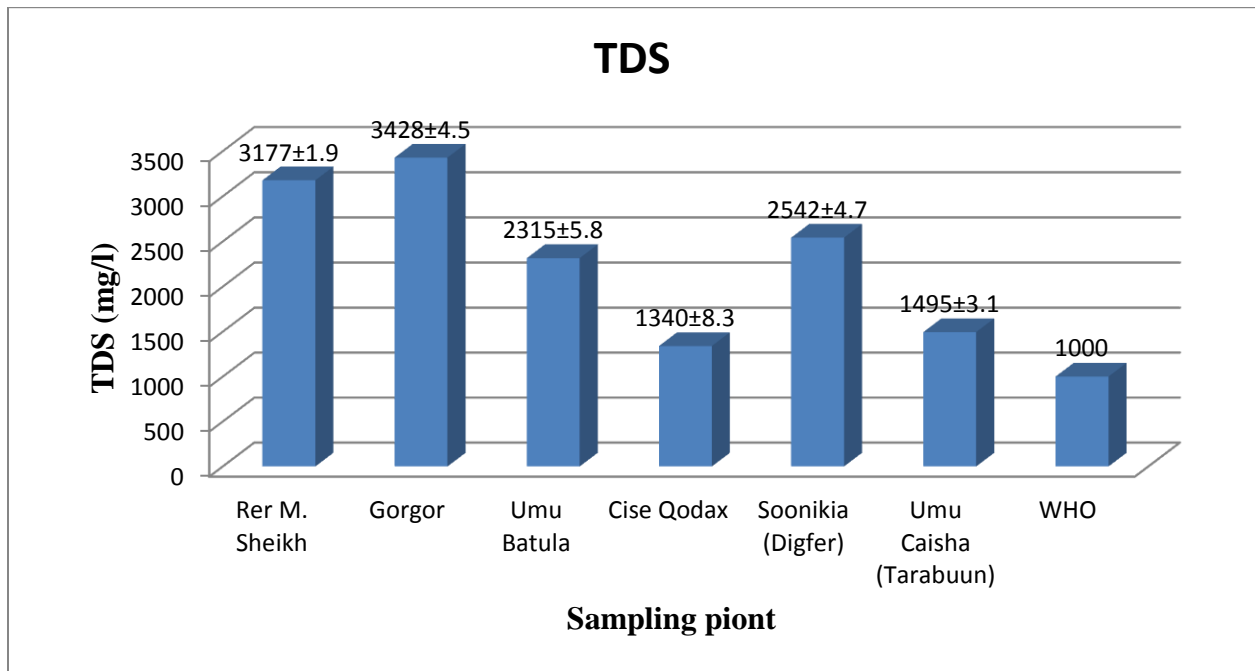


Figure 4.5: The levels of TDS (mg/l) in water samples at the various sampling sites

#### 4.6 Fluoride

Fluoride was determined directly using fluoride ion selective electrode and the result obtained from the instrument was plotted as milliVolt versus concentration. Table 4.28 shows data used to plot mV versus log of concentration

**Table 4.28: Plot of mV versus log of concentration of standard fluoride solutions**

Concentration, c (ppm)	Log C,(where C=concentration)	milliVolt (mV)
0.50	-0.30103	125.1
1.00	0	112.2
2.00	0.30103	96.1
4.00	0.60206	80.0
8.00	0.90301	62.1
10.00	1	55.6
20.00	1.30103	39.0
30.00	1.47712	28.6
40.00	1.60206	21.8
50.00	1.69897	16.8
60.00	1.77812	11.6
70.00	1.84509	7.0
80.00	1.90309	4.9
100.00	2	-1.00

The values in Table 4.28 were used to plot figure 4.6. The gradient of the plot is -56 with y intercept located at 111.5.

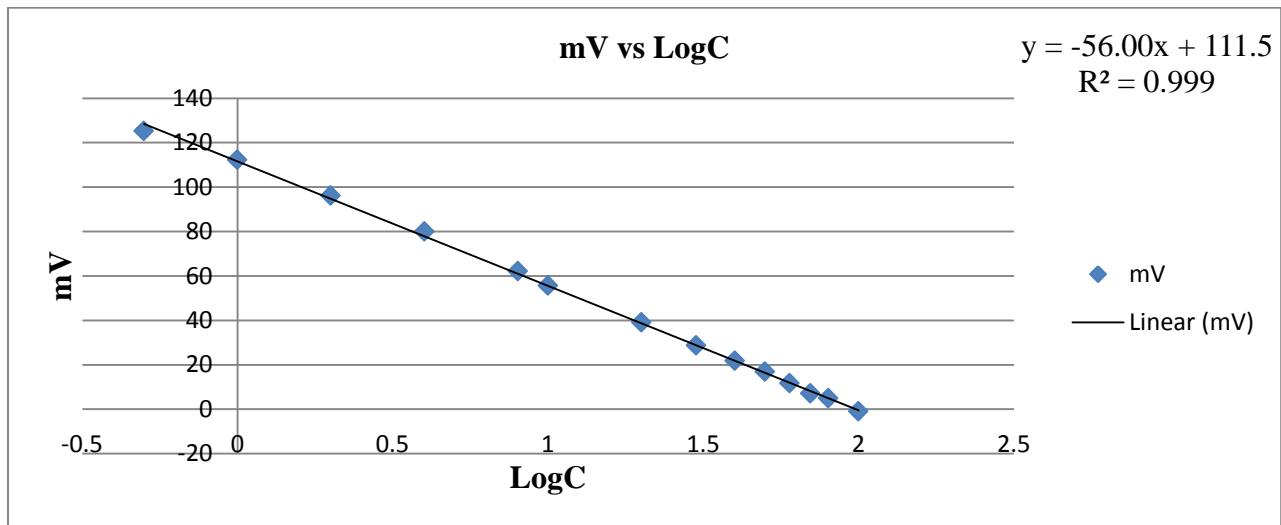


Figure 4.6: Calibration graph for Fluoride

Table 4.29 shows sample readings in mV. The corresponding logC was found directly from the graph or from the linear equation,  $y = -56x + 111.5$ .

**Table 4.29: mV readings of the samples**

Borehole name	mill volt (mV) (y)	$x = \text{LogC} = \frac{y-111.5}{-56}$	Concentration (C)
Rer M. Sheikh	124.1	-0.225	0.596
Gorgor	141.7	-0.5393	0.289
Umu Batula	140.9	-0.525	0.299
Cise Qodax	132.4	-0.3732	0.42
Soonikia (Digfer)	137.1	-0.4571	0.349
Umu Caisha(Tarabuun)	142.1	-0.5464	0.284

The value of fluoride was in the range of 0.284 mg/l to 0.596 mg/l. The maximum value was 0.596 mg/l and minimum value was 0.284 mg/l of fluoride recorded at Rer M. Sheikh and Umu Caisha (Tarabuun) respectively. The values are within the permissible limit as recommended by WHO (1.5mg/l). A fluoride concentration of approximately 1.0 mg/l in drinking water effectively reduces dental caries without harmful effects on the health. Fluoride may occur naturally in water or it may be added in controlled amounts. Some fluorosis may occur when the fluoride level exceeds the recommended limit. (Figure 4.7)

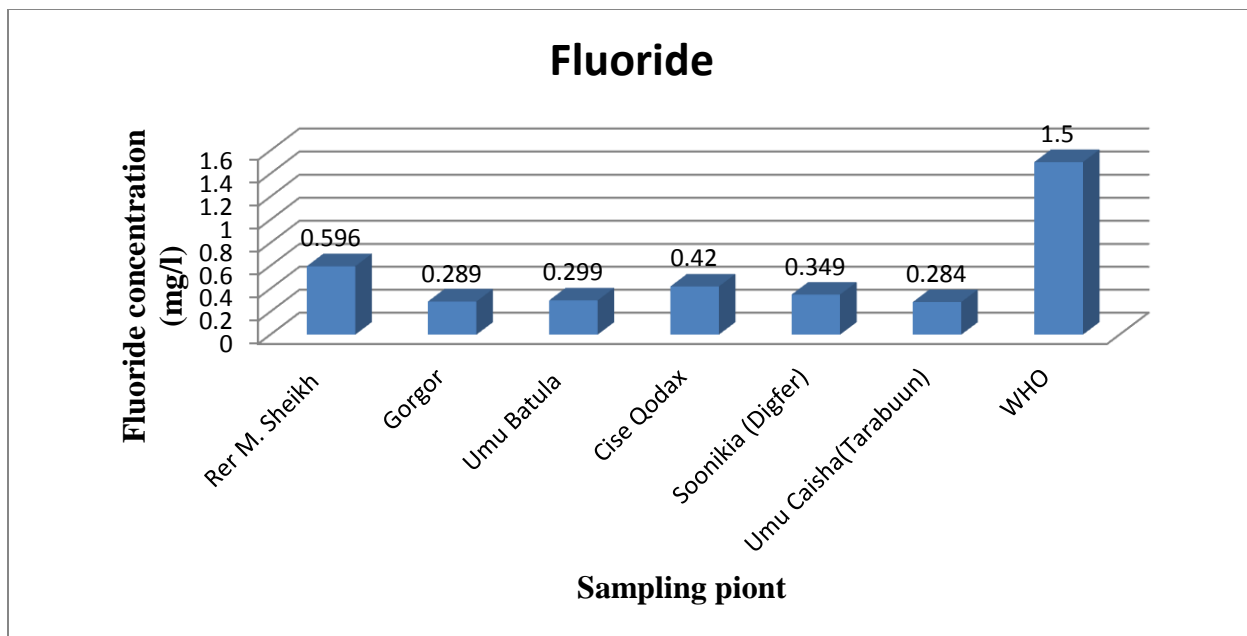


Figure 4.7: The levels of fluoride ion (mg/l) at the sampling sites

#### 4.7 Chloride

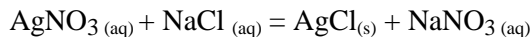
##### 4.7.1 Standardization of silver nitrate solution with 0.1M NaCl

Table 4.30: Standardization of AgNO<sub>3</sub> with 0.1M NaCl

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	11.5	20.00	28.7
Final burette reading (ml)	11.4	20.0	28.7	37.4
Volume of AgNO <sub>3</sub> used	11.4	8.5	8.7	8.7
Average volume of AgNO <sub>3</sub> used	$= \frac{11.4+8.5+8.7+8.7}{4} = 9.325 \text{ ml} \pm 1.2007$			

The volume of 0.1M NaCl used was 10 ml

Reaction stoichiometry between two salts is shown in scheme 4.3



Scheme 4.3: Reaction of silver nitrate with sodium chloride

Then moles of silver nitrate reacted with sodium chloride was calculated using the following formula:

$$\text{Number of moles of sodium chloride} = \frac{\text{Mass used}}{\text{Molecular weight}} = \frac{0.58730\text{g}}{58.44\text{g/mole}} = 0.01\text{mole}$$

$$\text{Molarity of NaCl} = \frac{1000 \times \text{mole}}{\text{Volume in ml}} = \frac{1000 \text{ ml} \times 0.01 \text{ mole}}{100 \text{ ml}} = 0.1\text{M}$$

$$\text{Moles of NaCl in 10 ml} = \frac{\text{volume in ml} \times \text{mole}}{1000 \text{ ml}} = \frac{10 \text{ ml} \times 0.1 \text{ mole}}{1000 \text{ ml}} = 0.001\text{mole.}$$

Since the reaction ratio between silver nitrate and sodium chloride = 1:1, then the moles of silver nitrate reacted with sodium chloride was 0.001mole.

$$\text{Therefore molarity of AgNO}_3 = \frac{0.001\text{mole} \times 1000 \text{ ml}}{9.325\text{ml}} = 0.107\text{M}$$

## 4.7.2 Determination of chloride concentration

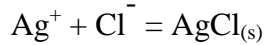
### 4.7.2.1 Concentration of chloride in Rer M. Sheikh borehole

Table 4.31 gives the titration data used in the calculation of chloride concentration.

**Table 4.31: Rer M. Sheikh borehole sample titration using 0.107M AgNO<sub>3</sub>**

Titration. No:	1	2	3	4
Initial burette reading (ml)	0.00	4.7	9.4	14.2
Final burette reading (ml)	4.7	9.4	14.2	19.1
Volume of AgNO <sub>3</sub> used	4.7	4.7	4.8	4.9
Average volume of AgNO <sub>3</sub> used	= $\frac{4.7+4.7+4.8+4.9}{4} = 4.775 \text{ ml} \pm 0.0829$			

Reaction taking place during titration is



Scheme 4.4: Reaction of silver ion and chloride ion

$$\text{Moles of AgNO}_3 = \frac{M \times V}{1000} = \frac{0.107\text{M} \times 4.775\text{ml}}{1000\text{ ml}} = 5.109 \times 10^{-4} \text{ mole} = \text{moles of Cl}^- \text{ in 25 ml of sample}$$

$$\text{Molarity of Cl}^- = \frac{\text{Mole} \times 1000 \text{ ml}}{\text{volume in ml}} = \frac{0.0005109 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.02044\text{M}$$

$$\text{Concentration of Cl in mg/l} = (\text{molarity}) \times (\text{molecular weight of chloride}) \times (1000\text{mg/1g})$$

$$= (0.02044 \text{ mole/l}) \times (35.5 \text{ g/ mole}) \times (1000\text{mg/1g})$$

$$= 725.62 \text{ mg/l}$$

General equation is:  $\text{Cl (mg/l)} = (\text{Molarity AgNO}_3) \times (\text{Average volume of AgNO}_3 \text{ used}) \times (\text{M.w of Cl}) \times (40)$

#### 4.7.2.2 Concentration of chloride in Gorgor borehole

The same procedure as 4.7.2.1 was used for Gorgor borehole water samples and chloride (mg/l) calculated using data given in Table 4.32.

**Table 4.32: Gorgor borehole sample titration using 0.107M AgNO<sub>3</sub>**

Titration. No:	1	2	3	4
Initial burette reading (ml)	19.1	24.4	0.00	17.8
Final burette reading (ml)	24.4	30.9	5.8	23.6
Volume of AgNO <sub>3</sub> used	5.3	6.5	5.8	5.8
Average volume of AgNO <sub>3</sub> used	$= \frac{5.3+6.5+5.8+5.8}{4} = 5.85 \text{ ml} \pm 0.4272$			

$$\text{Cl, mg/l} = 0.107 \times 5.85 \times 35.5 \times 40 = 888.85 \text{ mg/l}$$

Chloride concentration (mg/l) obtained in Gorgor borehole was = 888.85 mg/l

#### 4.7.2.3 Concentration of chloride in Umu Batula borehole

The same procedure 4.7.2.1 was applied for Umu Batula borehole water samples and chloride (mg/l) calculated using data in Table 4.33.

**Table 4.33: Umu Batula borehole sample titration using 0.107M AgNO<sub>3</sub>**

Titration. No:	1	2	3	4
Initial burette reading (ml)	23.6	27.4	30.8	35.3
Final burette reading (ml)	27.4	30.8	35.3	39.00
Volume of AgNO <sub>3</sub> used	3.8	3.4	4.5	3.7
Average volume of AgNO <sub>3</sub> used	$= \frac{3.8+3.4+4.5+3.7}{4} = 3.85 \text{ ml} \pm 0.4031$			

$$\text{Cl, mg/l} = 0.107 \times 3.85 \times 35.5 \times 40 = 584.97 \text{ mg/l}$$

Chloride concentration (mg/l) obtained in Umu Batula borehole was: 584.97 mg/l

#### 4.7.2.4 Concentration of chloride in Cise Qodax borehole

Procedure 4.7.2.1 was applied for Cise Qodax borehole water samples and chloride (mg/l) calculated using data in Table 4.34.

**Table 4.34: Cise Qodax borehole sample titration using 0.107M AgNO<sub>3</sub>**

Titration. No:	1	2	3	4
Initial burette reading (ml)	6.00	7.8	9.7	11.4
Final burette reading (ml)	7.8	9.7	11.4	13.4
Volume of AgNO <sub>3</sub> used	1.8	1.9	1.7	2.00
Average volume of AgNO <sub>3</sub> used	$= \frac{1.8+1.9+1.7+2}{4} = 1.85 \text{ ml} \pm 0.1118$			

$$\text{Cl, mg/l} = 0.107 \times 1.85 \times 35.5 \times 40 = 281.09 \text{ mg/l}$$

Chloride concentration (mg/l) obtained in Cise Qodax borehole was: 281.09 mg/l

#### 4.7.2.5 Concentration of chloride in Soonikia (Digfer) borehole

Procedure 4.7.2.1 was applied for Soonikia (Digfer) borehole water and chloride (mg/l) calculated using data in Table 4.35.

**Table 4.35: Soonikia (Digfer) borehole sample titration using 0.107M AgNO<sub>3</sub>**

Titration. No:	1	2	3	4
Initial burette reading (ml)	5.6	7.1	9.8	11.8
Final burette reading (ml)	7.1	9.8	11.8	13.9
Volume of AgNO <sub>3</sub> used	1.5	2.7	2	2.1
Average volume of AgNO <sub>3</sub> used	$= \frac{1.5+2.7+2+2.1}{4} = 2.075 \text{ ml} \pm 0.4264$			

$$\text{Cl, mg/l} = 0.107 \times 2.075 \times 35.5 \times 40 = 315.28 \text{ mg/l}$$

Chloride concentration (mg/l) obtained in Soonikia (Digfer) borehole was: 315.28 mg/l

#### 4.7.2.6 Concentration of chloride in Umu Caisha (Tarabuun) borehole

The same procedure 4.7.2.1 was applied for Umu Caisha (Tarabuun) borehole water samples and chloride (mg/l) calculated using data in Table 4.36.

**Table 4.36: Umu Caisha (Tarabuun) borehole sample titration using 0.107M AgNO<sub>3</sub>**

Titration. No:	1	2	3	4
Initial burette reading (ml)	13.9	15.9	18.2	20.4
Final burette reading (ml)	15.9	18.2	20.4	22.8
Volume of AgNO <sub>3</sub> used	2.0	2.3	2.2	2.4
Average volume of AgNO <sub>3</sub> used	$= \frac{2+2.3+2.2+2.4}{4} = 2.225 \text{ ml} \pm 0.1479$			



$$\text{Cl, mg/l} = 0.107 \times 2.225 \times 35.5 \times 40 = 338.07 \text{ mg/l}$$

Chloride concentration (mg/l) obtained in Umu Caisha (Tarabuun) borehole was: 338.07 mg/l.

The concentration of chloride in all boreholes was high. Chloride values were above the acceptable WHO limits of 250 mg/l for domestic water. The range of chloride in the water samples was 281.09 to 888.85mg/l. The highest concentration of chloride was recorded at Gorgor (888.85 mg/l) and the lowest at Cise Qodax (281.09 mg/l). This could be due to contamination by the chloride arising from, anthropogenic activities and intrusion of sea water and other saline water. It is widely distributed in nature in form of sodium, phosphate and calcium salts. There is no health –based guidelines on the values that are recommended for chloride in drinking water; however, chloride concentration in excess of about 250 mg/l can give rise to a detestable taste in water. Figure 4.8 gives a summary of chloride content in borehole water samples.

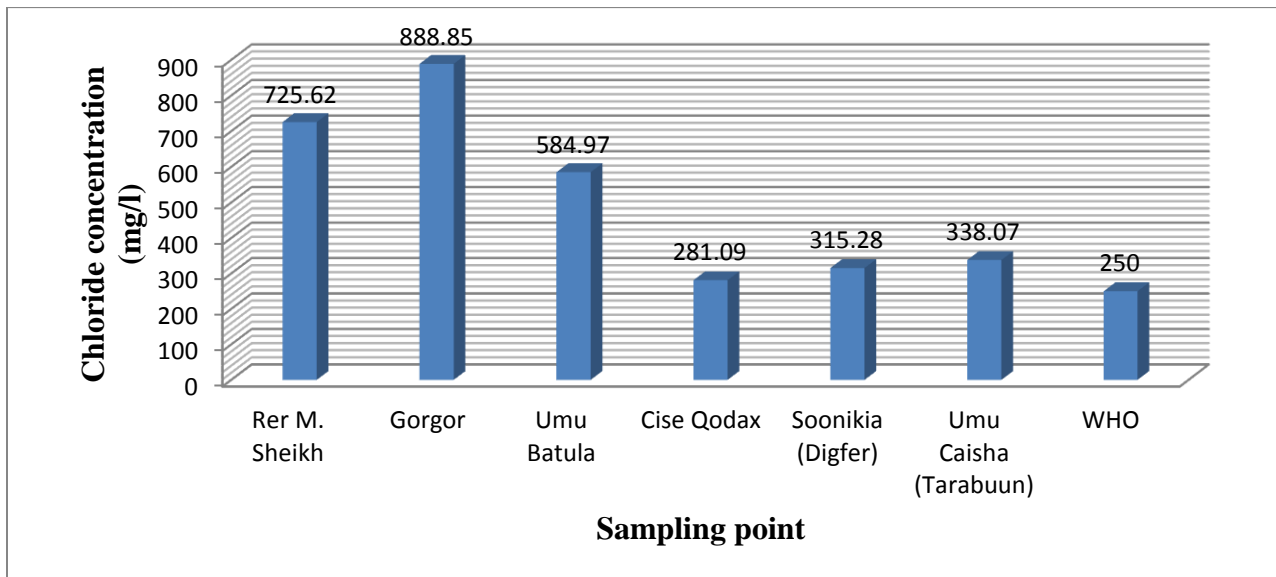


Figure 4.8: Chloride ion concentration in water samples

## 4.8 Nitrate

Nitrate was determined using UV-Visible spectrophotometer and the result obtained used to plot absorbance versus concentration. Table 4.37 shows the data for the absorbance versus concentration for nitrate standards.

**Table 4.37: Absorbance values versus concentration for nitrate**

Concentration (ppm)	Absorbance
0.00	0.00
1.0	0.081
2.0	0.216
3.0	0.335
4.0	0.501
5.0	0.617
6.0	0.783
7.0	0.759
8.0	0.974
9.0	1.164
10	1.302

Table 4.37 values were used to plot the graph in Figure 4.9. The gradient of the slope in figure 4.9 is 0.131 with the Y- intercept (absorbance intercept) occurring at -0.052 and concentration intercept at 0.397 ppm. The equation,  $y = 0.131x - 0.052$  was used to calculate the concentration of the borehole samples in Table 4.38.

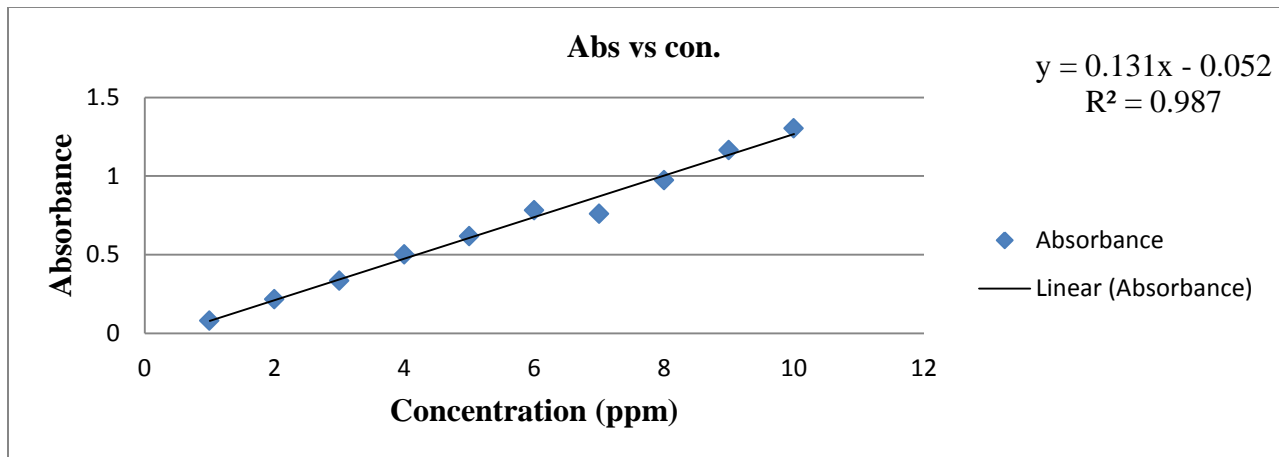


Figure 4.9: Calibration graph for the nitrate standards

Rer M. Sheikh was diluted twenty times while others were diluted ten times

**Table 4.38: Absorbance readings of the samples**

Borehole name	Absorbance (y)	Concentration (ppm) $x = \frac{y+0.052}{0.131}$	Original concentration (ppm)
Rer M. Sheikh	0.9085	7.33	$7.33 \times 20 = 146.6$
Gorgor	0.132	1.405	$1.405 \times 10 = 14.05$
Umu Batula	0.746	6.09	$6.09 \times 10 = 60.92$
Cise Qodax	0.004	0.427	$0.427 \times 10 = 4.27$
Soonikia (Digfer)	0.037	0.679	$0.679 \times 10 = 6.79$
Umu Caisha (Tarabuun)	0.233	2.17	$2.17 \times 10 = 21.7$

All nitrate values were lower than WHO (50mg/l) except Umu Batula (60.92 mg/l) and Rer M. Sheikh (146.6 mg/l) (Figure 4.10).

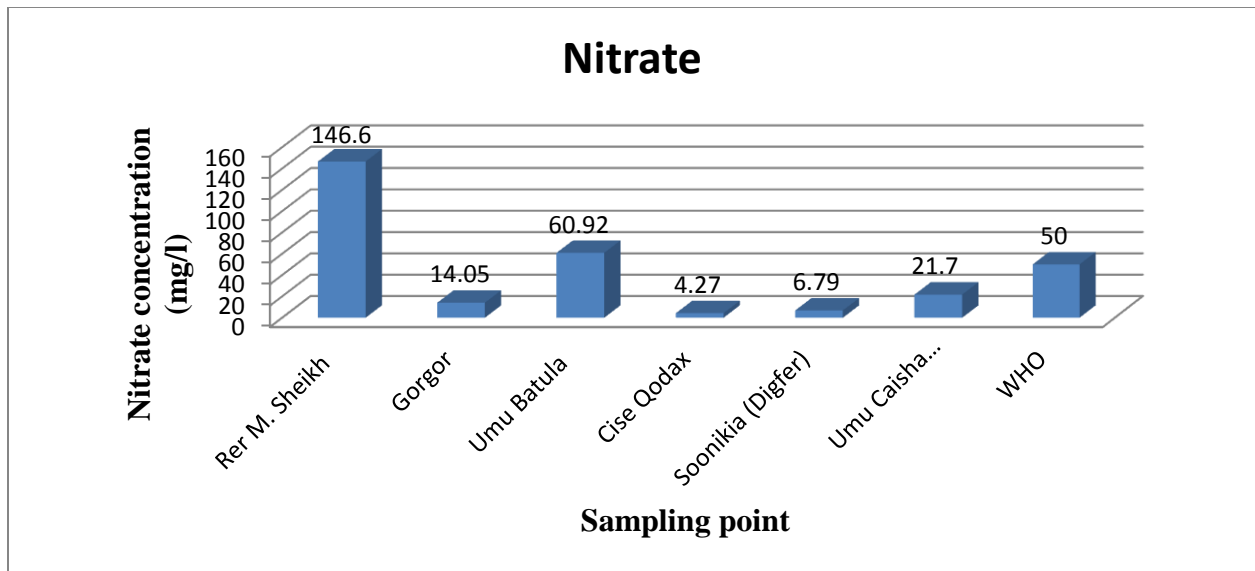


Figure 4.10: The nitrate ion concentration (mg/l) at the various sampling sites

#### 4.9 Ammonium

Ammonium was also determined using UV-Visible spectrophotometer and the result obtained used to plot absorbance versus concentration. Table 4.39 shows the absorbance value for ammonium standards, which were then used to plot the graph in Figure 4.11.

**Table 4.39: Absorbance values versus concentration for ammonium**

Concentration (ppm)	Absorbance
0.00	0.00
0.13	-0.043
0.26	-0.030
0.39	0.085
0.51	-0.003
0.64	0.010
0.77	0.025
0.9	0.034
1.03	0.049
1.16	0.065
1.28	0.085

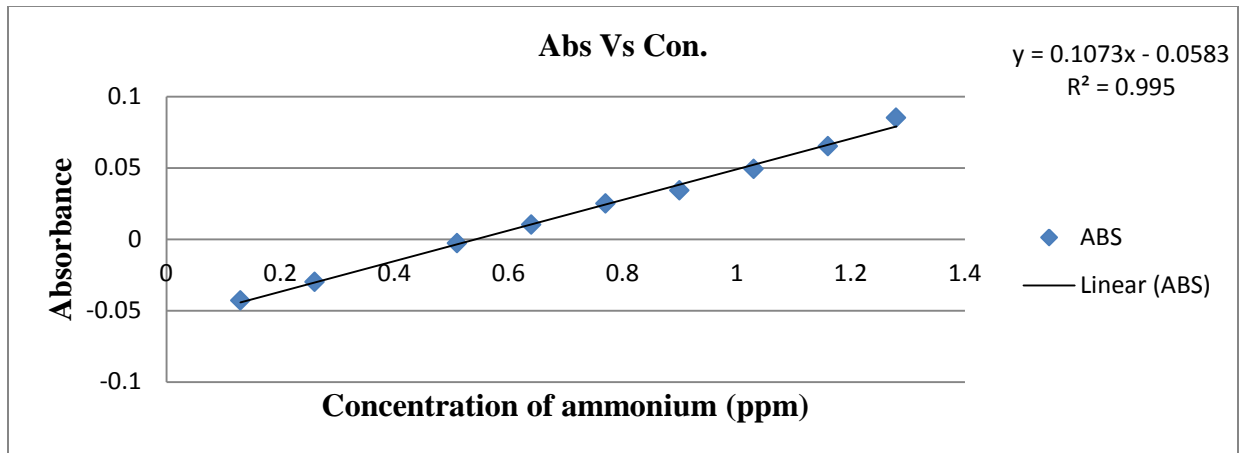


Figure 4.11: Calibration graph for ammonium standards

From the equation,  $y = 0.1073x - 0.0583$ , the gradient was 0.1073. This equation was used to calculate the concentration of samples by inserting absorbance value in Table 4.40.

Table 4.40 shows sample readings got from the instrument

**Table 4.40: Absorbance readings of the samples**

Borehole name	Absorbance (y)	Concentration (ppm) $x = \frac{y + 0.0583}{0.1073}$
Rer M. Sheikh	0.01	0.64
Gorgor	0.018	0.71
Umu Batula	-0.001	0.53
Cise Qodax	-0.01	0.45
Soonikia (Digfer)	-0.001	0.53
Umu Caisha(Tarabuun)	-0.003	0.52

All values were higher than WHO (0.2 mg/l). The highest value was given by Gorgor (0.71 mg/l) and lowest by Cise Qodax (0.45 mg/l) (figure 4.12). This might be due to organic compounds that are formed during decomposition of proteins, manure and urine wastes. Because of its solubility, excessive soil ammonium may penetrate into deeper soils and eventually reach groundwater. In some soils part of the ammonium may be converted to nitrites and nitrates before or after it reaches groundwater.

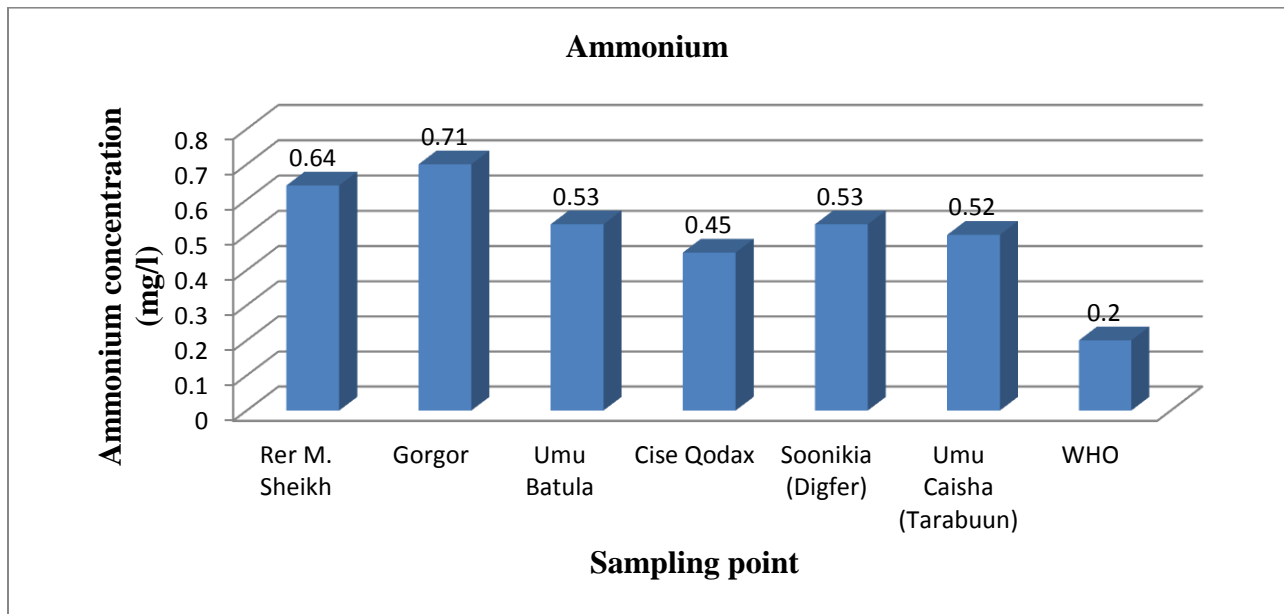


Figure 4.12: The concentration of ammonium (mg/l) at the various sampling sites.

#### 4.10 Sodium

Sodium was run in flame photometer and the results obtained used to plot emission versus concentration of samples. Table 4.41 shows the emission values for sodium standards, which were used to plot emission versus concentration in figure 4.13.

**Table 4.41: Emission values for the sodium standards**

Concentration (ppm)	Emission
0.00	0.00
2.00	4.7
4.00	9.9
8.00	19
10.0	24
12.0	28.6

This gave a linear plot fitting equation,  $y = 2.383x + 0.063$ . This equation was therefore used to calculate concentrations of samples from emission values in Table 4.42.

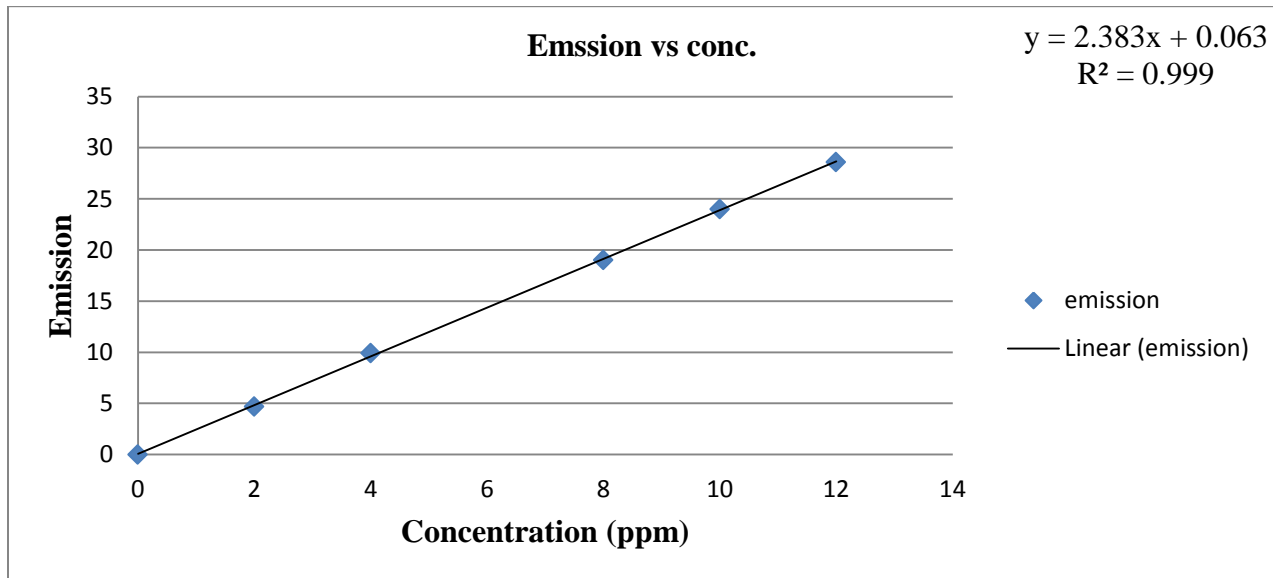


Figure 4.13: A linear calibration graph for the sodium standards

Table 4.42 shows sample readings got from the instrument. The samples were diluted twenty (20) times.

**Table 4.42: Emission readings of the samples**

Borehole name	Emission (y)	Concentration (ppm) $x = \frac{y-0.063}{2.383}$	Original concentration (ppm)
Rer M. Sheikh	17.9	7.485	$7.485 \times 20 = 149.7$
Gorgor	13	5.43	$5.43 \times 20 = 108.6$
Umu Batula	12.5	5.22	$5.22 \times 20 = 104.4$
Cise Qodax	8.6	3.58	$3.58 \times 20 = 77$
Soonikia (Digfer)	6.3	2.62	$2.62 \times 20 = 52.4$
Umu Caisha(Tarabuun)	7	2.91	$2.91 \times 20 = 58.2$

The concentrations of sodium in all were observed to be low (Figure 4.14). Its concentration in all the sampling points were below the WHO guideline of 200 mg/l for domestic water. The values ranged between 52.4 to 149.7 mg/l. The highest value was at Rer. M. Sheikh (149.7 mg/l) and the lowest as Soonikia (Digfer) (52.4 mg/l).

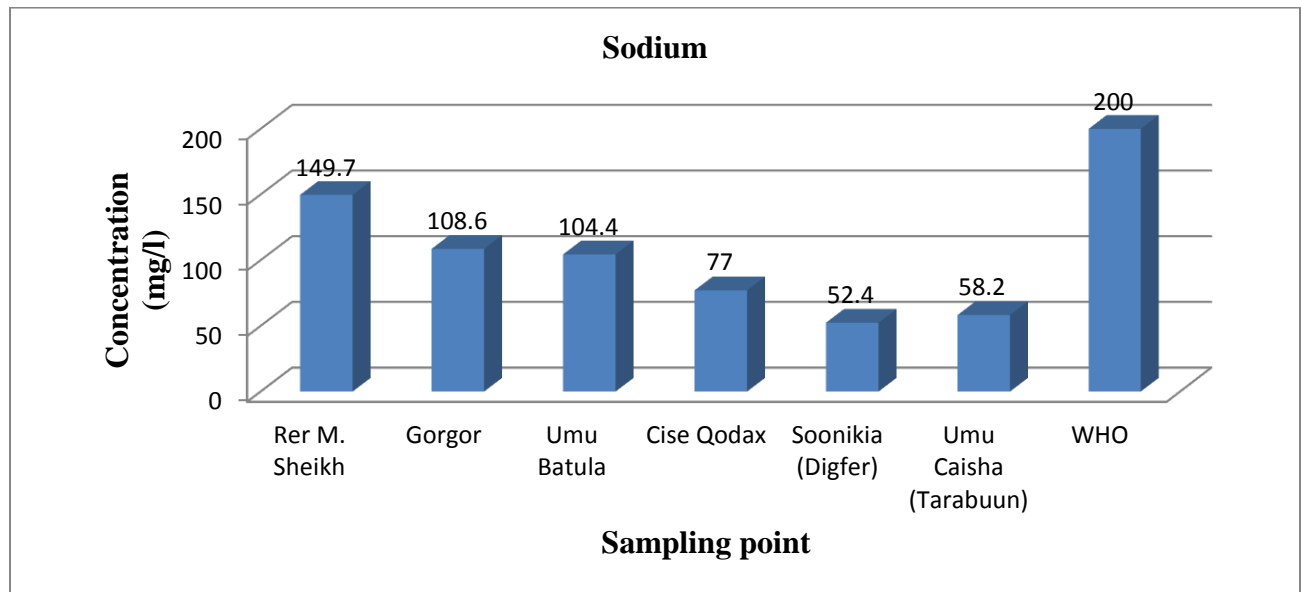


Figure 4.14: The concentration of sodium ion (mg/l) at the various sampling sites



## 4.11 Heavy metals

### 4.11.1 Cadmium

Cadmium standards in Table 4.43 were used to plot absorbance versus concentration in figure 4.15.

**Table 4.43: Absorbance versus concentration of cadmium standards**

Concentration (ppm)	Absorbance
0.5	0.1444
1	0.2345
1.5	0.3618
2	0.4392
2.5	0.5187
3	0.59

The equation fitting the plot in Figure 4.15 was,  $y = 0.180x + 0.065$ .

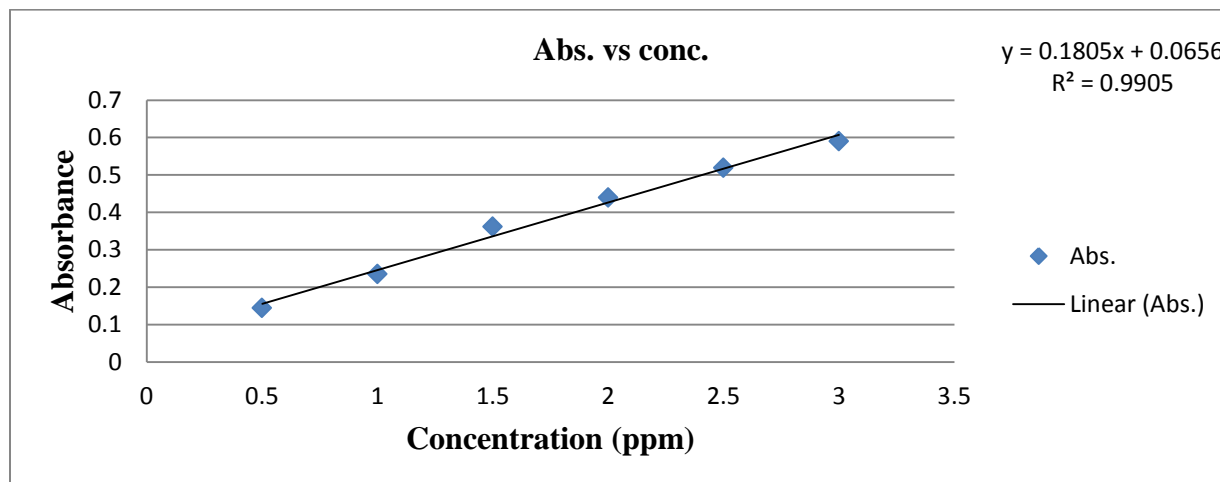


Figure 4.15: Calibration graph for cadmium standards

The equation was used in Table 4.44 to calculate the concentration of cadmium in the samples.

**Table 4.44: Absorbance readings of the samples**

Borehole name	Absorbance (y)	x= Concentration (ppm) $x = \frac{y-0.065}{0.180}$
Rer M. Sheikh	-0.0006	-0.364
Gorgor	-0.0002	-0.362
Umu Batula	0	-0.361
Cise Qodax	0.0003	-0.359
Soonikia (Digfer)	-0.0003	-0.363
Umu Caisha(Tarabuun)	0.0004	-0.3588

Cadmium was not detected in all sampling points. The concentration could have been below detection limit, which was 0.5 mg/l. The acceptable level of cadmium according WHO limit is 0.003mg/l for domestic water.

#### 4.11.2 Lead

The lead values in Table 4.45 were used to plot absorbance versus concentration as given in figure 4.16. This gave a linear equation,  $y = 0.003x-0.001$ .

**Table 4.45: Absorbance versus concentration of lead standards**

Concentration (ppm)	Absorbance
0.5	0.0007
1	0.0019
1.5	0.0036
2	0.0053
2.5	0.0073

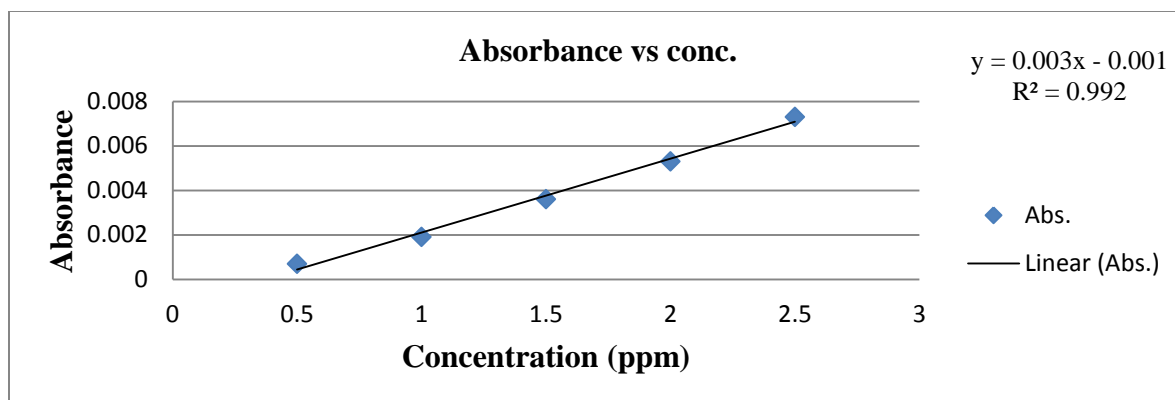


Figure 4.16: Calibration graph for lead standards

The linear equation was used to calculate concentrations of the samples in table 4.46.

**Table 4.46: Absorbance readings of the samples**

Borehole name	Absorbance (y)	x= Concentration (ppm) $x = \frac{y+0.001}{0.003}$
Rer M. Sheikh	-0.0038	-0.93
Gorgor	-0.0022	-0.4
Umu Batula	-0.0015	-0.167
Cise Qodax	-0.0013	-0.1
Soonikia (Digfer)	-0.0013	-0.1
Umu Caisha(Tarabuun)	-0.0011	-0.03

Lead was not detected in all sampling points. The concentration could have been below detection limit, which was 0.5 mg/l. The acceptable level of lead, according to WHO limit for drinking water is 0.01 mg/l.

#### 4.11.3 Zinc

Zinc standards in Table 4.47 were used to plot absorbance versus concentration depicted in Figure 4.17

**Table 4.47: Absorbance versus concentration of zinc standards**

Concentration (ppm)	Absorbance
0.5	0.6421
1	1.1533
1.5	1.6626
2.5	2.4977
3	2.8121

Figure 4.17 gave a linear equation,  $y = 0.870x + 0.273$ .

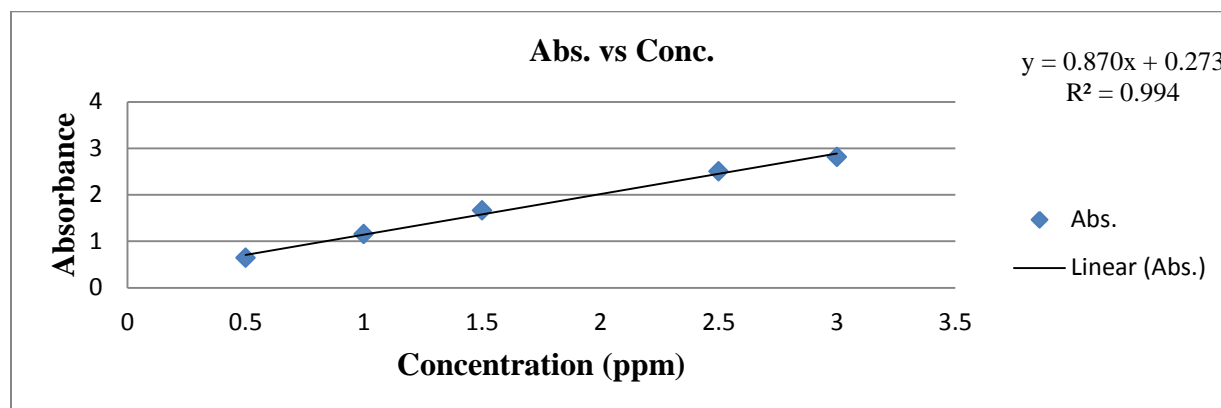


Figure 4.17: Calibration graph for zinc standards

The equation in figure 4.17 was used to calculate the concentration of zinc in the samples (Table 4.48).

**Table 4.48: Absorbance readings of the samples**

Borehole name	Absorbance (y)	x= Concentration (ppm) $x = \frac{y-0.273}{0.870}$
Rer M. Sheikh	0.0414	-0.266
Gorgor	0.0625	-0.242
Umu Batula	0.0125	-0.299
Cise Qodax	0.232	-0.047
Soonikia (Digfer)	0.1105	-0.186
Umu Caisha(Tarabuun)	0.0113	-0.3

Zinc was not detected in all the sampling points. The concentration could have been below detection limit, which was 0.1mg/l. The permissible level of zinc in drinking water, according to WHO limit is 3 mg/l.

## 4.12 Bacteriological Analysis

### 4.12.1 Confirmatory test

Some colonies were found to contain yellow creamy color. Table 4.49 indicated the color changes that were observed.

**Table 4.49: Results for E-coli confirmatory tests**

Borehole name	Colony colours	Organism(s) present
Rer M. Sheikh	No change in color	No. E.coli
Gorgor	No change in color	No. E.coli
Umu Batula	No change in color	No. E.coli
Cise Qodax	Yellow creamy colour with smooth surface and edge, and greenish metallic sheen on Eosine methylene blue Agar.	E.coli Present
Soonikia (Digfer)	No change in color	No. E.coli
Umu Caisha (Tarabuun)	No change in color	No. E.coli

Laboratory results showed zero concentration of Escherichia- Coli in water samples except Cise Qodax (4/100ml).This could have been caused by human and animal faeces contamination.

(Figure 4.18)

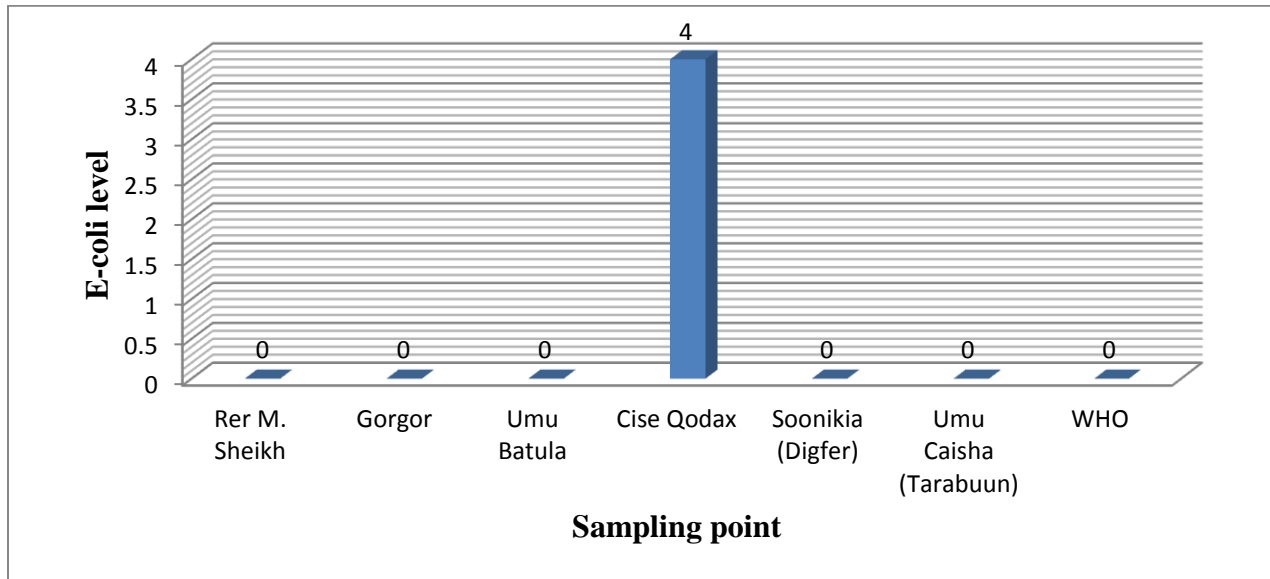


Figure 4.18: The level of E-coli in water samples at the sampling points

E-coli comes from human and animal wastes. In the area where there is the borehole with E-coli level, it was possible that during raining season, pollution of boreholes could have occurred.

#### 4.13 Statistical analysis

Statistical analysis was conducted using SPSS and the results were summarized as follows:

Sixteen (16) respondents out of thirty (53.3%) were female while fourteen (14) respondents (46.7%). were male. All the respondents pointed out that the borehole water were the main sources of water used both during the dry or rainy season in Hodan District. The findings also indicated that majority of the people 80% did not boil water before drinking while 20% of the people boiled water before drinking. Most respondents mentioned that the common disease in the

area was diarrhoea and the most common victims in the households were children. A few of the respondents pointed out that the people of Mogadishu suffered mostly from malaria followed by typhoid then cholera. About 40% of the of respondents in all the sampling points pointed out that the common disease in the area were diarrhoea, malaria (20%), typhoid (16.7%), cholera (10%) and the other diseases (13.3%). The total households dependent on the boreholes were about five thousand three hundred sixty five (5365).

## CHAPTER FIVE

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

Electrical conductivity, hardness, total dissolved solids, chloride and ammonium values were all higher than WHO limit. Fluoride, sodium and alkalinity were lower than the WHO limit while lead, cadmium and zinc were not detected. All the borehole samples had no E-coli except Cise Qodax. The pH values were lower than WHO limit except Cise Qodax borehole (8.9). Nitrate was lower than WHO standard except for samples from Rer M. Sheikh (146.6 mg/l) and Umu Batula boreholes (60.92 mg/l).

Borehole water in all places can be used for domestic purpose except Cise Qodax borehole which was contaminated by E-coli, so water from this borehole should be treated before use for drinking purposes.



## **5.2 Recommendations**

This study, therefore, recommends the following:

1. Reduce chloride ion in all boreholes by reverse-Osmosis or any other appropriate method.
2. Reduce pH of Cise Qodax borehole water.
3. Reduce hardness in all boreholes by appropriate method.
4. Reduce ammonium in all boreholes.
5. Lower detection limit to less than 0.5 mg/l so as to detect Cd, Zn and Pb.
6. The relevant authority to inspect any new borehole drilled in order to verify compliance with the WHO standards and regulations.
7. Treat Cise Qodax borehole to reduce E-coli to zero.
8. Sensitize the people on the importance of treating water for domestic purpose.

## REFERENCES

- Adebisi, N. O., Oluwafemi, O. S., Songca, S. P and Haruna, I. (2013). Flow system, physical properties and heavy metals concentration of groundwater: A case study of an area within a municipal landfill site. *International Journal of Water Resources and Environmental Engineering*.**5** (11): 630-638.
- Agency for Toxic Substances and Disease Registry (ATSDR) (2012). *Toxicological Profile for Cadmium*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
- Aharma, S.K., Vijendra, S. and Chandel, C.P.S. (2004). Borehole water pollution and evaluation of physico-chemical properties of borehole water. *Environment and Ecology*.**22**: 319-324.
- Akoteyson, I. S., Mbata, U. A and Olalude, G. A. (2011). Investigation of heavy metal contamination in groundwater around landfill site in a typical sub-urban settlement in Alimosho, Lagos-Nigeria. *Journal of Applied Sciences in Environmental Sanitation*. **6**(2): 155-163.
- ASTM annual Book of standards, part 31, (1976). "Water", Standard D1126-72, Method B, p: 312.
- Avery, A.A., (1999). Infantile methemoglobinemia: re-examining the role of drinking water nitrates. *Environmental Health Perspectives*.**107**(7):583–586.
- Behera, S., Ghanty, S., Ahmad, F., Santra, S. and Banerjee, S. (2012). UV-Visible Spectrophotometric Method Development and Validation of Assay of Paracetamol Tablet Formulation. *J Anal Bioanal Techniques*.**3**:151.

- Bouwer, E.J. and Crowe, P.B. (1988). Biological processes in drinking water treatment. *J. Am. Water Works Assoc.* **80**(9): 82-93.
- Chatwal, G.R. and Anand, S. (2002). Instrumental Methods of Chemical Analysis. (5<sup>th</sup>ed), Himalaya Publishing House, New Delhi. p. 32-40.
- Davidson, A.G. (2002). Ultraviolet-visible absorption spectrophotometry. In Beckett, A.H, Stenlake, J.B., (4<sup>th</sup>ed), *Practical Pharmaceutical chemistry*. CBS Publishers and distributors, New Delhi, p: 275-278.
- Dombek, P. E., Johnson, L.K., Zimmerley, S.T and Sadowsky, M.J. (2000). Use of repetitive DNA sequences and the PCR to differentiate Escherichia coli isolates from human and animal sources. *Applied and Environmental Microbiology*. **(66)**: 2572-2577.
- Ezenwaji, E. E. and Otti, V. I. (2013). Water Related Diseases as a Challenge to the implementation of Reproductive Health of Pregnant Women in Anambra State, Nigeria. *International Journal of Engineering and Technology*. **3**: 2049-3444.
- Fawell, J.K. (2003). Fluoride in Drinking Water, Background document for development of WHO guidelines for Drinking water Quality.
- Gu, S.L., Rongli, J. and Shouren, C. (1990). The physical and chemical characteristics of particles in indoor air where high fluoride coal burning takes place. *Biomedical and Environmental Sciences*. **3**(4): 384-390.
- Gosselin, D.C., Headrick, J., Harvey, F.E., Tresmblay, R. and McFarland, K. (1999). Fluoride in Nebraska's groundwater. *Groundwater monitoring and remediation*. **19** (2): 87-95
- Heilman, J.R., Kiritsy, M.C., Levy, S.M and Wefel, J.S. (1999). Assessing fluoride levels of carbonated soft drinks. *J. Am. Dent. Assoc.* **130**: 1593-1599.

- Holden, J.M., Bhagwat, S.A., and Patterson, K.Y. (2002). Development of a Multi Nutrient Data Quality Evaluation System. *J. Food Comp. Anal.* **15**(4): 339-348.
- Jackson, R.D., Brizendine, E.J., Kelly, S.A., Hinesley, R., Stookey, G.K., and Dunipace, A.J. (2002). The fluoride content of foods and beverages from negligibly and optimally fluoridated communities. *Community Dent.Oral Epidemiol.***30**: 382-39.
- Kaushal, S.S., Groffman, P.M., Likens, G.E., Belt, K.T., Stack, W.P., Kelly, V.R., Band, L.E., and Fisher, G.T.( 2005). Increased salinization of fresh water in the northeastern United States:*Proceedings of the National Academy of Sciences.***102**: 13517–13520.
- Kaur, H. (2008). Analytical Chemistry. Meerut, IND: Pragati Prakashan. Retrieved from <http://www.ebrary.com>, February, 2015.
- Marque. S., Jacqmin-Gadda, H., Dartigues, J.F., and Commenges, D. (2003).Cardiovascular mortality and calcium and magnesium in drinking water. An ecological study in elderly people. *.Eur. J.Epideminol.* **18** (4):305-309
- Ministry of Energy and Water Resource (MEWR). (2012).Water Source Data Collection of Banadir Region, Mogadishu, Somalia. P. 2-3
- Murray, J.J. [Ed.] (1986). *Appropriate Use of Fluorides for Human Health*: World Health Organization, Geneva.
- Naslund, J. and Snell, I. (2005). GIA-mapping of Fluoride Contaminated Ground water in Nakuruand Baringo District, Kenya. Unpublished MSc program in Engineering, Lulea University of Technology, Sweden. p. 23-24.
- Nduka, J. K. and Orisakwe, O. E. (2007). Heavy Metal Levels and Physico – Chemical Quality of Potable Water Supply in Warri, Nigeria.*Annali di Chimica.***97**: 867-874.
- Peden,M.E. and Skowron,L.M. (1978).Ionic Stability of precipitation Samples. *Atmospheric Environment.***12**: 2343-2349.

- Reeves, T.G., (1994). Water Fluoridation. *A Manual for Water Plant Operators*. United States Department of Health and Human Services, Centres for Disease Control and Prevention, pp 99.
- Schilling, K.E. (2002). Occurrence and distribution of ammonium in Iowa groundwater. *Water Environ. Res.* **74** (2): 177-186.
- Standard Methods for Examination of water and wastewater. (1975), 14<sup>th</sup> Edition, p460-616. Method 309-604B.
- Teckle-Haimanot, R. (2006, December). Fluoride and Fluorosis in Ethiopia. Workshop on Excess fluoride Problem in the Ethiopian Rift Valley. Nazret, Ethiopia.
- Thomas, H. and Schiettecatte, L.S.(2008). Enhanced Ocean Carbon Storage from Anaerobic Alkalinity Generation in Coastal Sediments. *Biogeosciences Discussions.* **5**: 3575-3591
- USNRC.(1993). Health Effects of Ingested Fluoride. *National Research Council, National Academy Press*, Washington D.C.
- USEPA. (1979). Methods for Chemical Analysis of Water and Wastes, USEPA Publication No.EPA-600/4-79-020, United States Environmental Protection Agency.
- World Health Organization (WHO). (2004). Guidelines for Drinking-water Quality; Third Edition. WHO, Geneva.
- WHO. (2011). Cadmium in Drinking-water Background document for development of WHO Guidelines for Drinking-water Quality WHO/SDE/WSH/03.04/80/Rev/1.

## APPENDICES

### APPENDIX AI: Values for Rer Mohamed Sheikh compared to WHO

**Table 5.1: Values for Rer Mohamed Sheikh compared to WHO**

Parameter	Result	
	RESULT OBTAINED	Guide value (maximum allowable) (WHO)
pH	8.2 ± 0.06	6.5-8.5
Alkalinity	157.3 mg/l	600 mg/l
Hardness	435.12 mg/l	200 mg/l
Electrical conductivity	3.28 mS /cm ± 0.005	0.25 mS /cm
Total dissolved solids	3177mg/l ± 1.9	1000 mg/l
Fluoride	0.596 mg/l	1.5 mg/l
Chloride	725.62 mg/l	250 mg/l
Ammonium	0.64 mg/l	0.2 mg/l
Nitrate NO <sub>3</sub> <sup>-</sup>	146.6 mg/l	50 mg/l
Sodium	149.7 mg/l	200 mg/l
Cadmium	ND	0.003 mg/l
Lead	ND	0.01mg/l
Zinc	ND	3 mg/l
E.coli	Nil/100 ml	Nil/100 ml

ND = Not detected

**APPENDIX AII: Value for Gorgor borehole compared to WHO**

**Table 5.2: Value for Gorgor borehole compared to WHO**

Parameter	Result	
	RESULT OBTAINED	Guide value (maximum allowable)
pH	8.1± 0.05	6.5-8.5
Alkalinity	138.32 mg/l	600 mg/l
Hardness	501.76 mg/l	200 mg/l
Electrical conductivity	3.040 mS /cm ± 0.005	0.25 mS /cm
Total dissolved solids	3428 mg/l ± 4.5	1000 mg/l
Fluoride	0.289 mg/l	1.5 mg/l
Chloride	888.85 mg/l	250 mg/l
Ammonium	0.7 mg/l	0.2 mg/l
Nitrate NO <sub>3</sub> <sup>-</sup>	14.05 mg/l	50 mg/l
Sodium	108.6 mg/l	200 mg/l
Cadmium	ND	0.003 mg/l
Lead	ND	0.01mg/l
Zinc	ND	3mg/l
E.coli	Nil/100 ml	Nil/100 ml

ND = Not detected

**APPENDIX AIII: Value for Umu Batula borehole compared to WHO**

**Table 5.3: Value for Umu Batula borehole compared to WHO**

Parameter	Result	
	RESULT OBTAINED	Guide value (maximum allowable)
pH	8.4 ± 0.05	6.5-8.5
Alkalinity	153.74 mg/l	600 mg/l
Hardness	377.3 mg/l	200 mg/l
Electrical conductivity	2.33 mS /cm ± 0.005	0.25 mS /cm
Total dissolved solids	2315 mg/l ± 5.8	1000 mg/l
Fluoride	0.299 mg/l	1.5 mg/l
Chloride	584.97 mg/l	250 mg/l
Ammonium	0.53 mg/l	0.2 mg/l
Nitrate NO <sub>3</sub> <sup>-</sup>	60.92mg/l	50 mg/l
Sodium	104.4 mg/l	200 mg/l
Cadmium	ND	0.003 mg/l
Lead	ND	0.01mg/l
Zinc	ND	3 mg/l
E.coli	Nil/100 ml	Nil/100 ml

ND = Not detected



**APPENDIX AIV: Value for Cise Qodax borehole compared to WHO**

**Table 5.4: Value for Cise Qodax borehole compared to WHO**

Parameter	Result	
	RESULT OBTAINED	Guide value (maximum allowable)
pH	8.9 ± 0.05	6.5-8.5
Alkalinity	158.9 mg/l	600 mg/l
Hardness	229.32 mg/l	200 mg/l
Electrical conductivity	1.47 mS /cm ± 0.005	0.25 mS /cm
Total dissolved solids	1339 mg/l ± 8.3	1000 mg/l
Fluoride	0.42 mg/l	1.5 mg/l
Chloride	281.09 mg/l	250 mg/l
Ammonium	0.45 mg/l	0.2 mg/l
Nitrate NO <sub>3</sub> <sup>-</sup>	4.27mg/l	50 mg/l
Sodium	77 mg/l	200 mg/l
Cadmium	ND	0.003 mg/l
Lead	ND	0.01mg/l
Zinc	ND	3 mg/l
E.coli	4/100ml	Nil/100ml

ND = Not detected

**APPENDIX AV: Value for Soonikia (Digfer) borehole compared to WHO**

**Table 5.5: Value for Soonikia (Digfer) borehole compared to WHO**

Parameter	Result	
	RESULT OBTAINED	Guide value (maximum allowable)
pH	8.5 ± 0.05	6.5-8.5
Alkalinity	119.3 mg/l	600mg/l
Hardness	268.52 mg/l	200 mg/l
Electrical conductivity	1.428 mS /cm ± 0.005	0.25 mS /cm
Total dissolved solids	2542 mg/l ± 4.7	1000 mg/l
Fluoride	0.349 mg/l	1.5 mg/l
Chloride	315.28 mg/l	250 mg/l
Ammonium	0.53 mg/l	0.2mg/l
Nitrate NO <sub>3</sub> <sup>-</sup>	6.79 mg/l	50 mg/l
Sodium	52.4 mg/l	200 mg/l
Cadmium	ND	0.003 mg/l
Lead	ND	0.01mg/l
Zinc	ND	3mg/l
E.coli	Nil/100 ml	Nil/100 ml

ND = Not detected

**APPENDIX AVI: Value for Umu Caisha (Tarabuun) borehole compared to WHO**

**Table 5.6: Value for Umu Caisha (Tarabuun) borehole compared to WHO**

Parameter	Result	
	RESULT OBTAINED	Guide value (maximum allowable)
pH	8.4 ± 0.05	6.5-8.5
Alkalinity	140.22 mg/l	600 mg/l
Hardness	251.86 mg/l	200 mg/l
Electrical conductivity	1.521 mS /cm ± 0.005	0.25 mS /cm
Total dissolved solids	1494 mg/l ± 3.1	1000 mg/l
Fluoride	0.284 mg/l	1.5 mg/l
Chloride	338.07 mg/l	250 mg/l
Ammonium	0.5 mg/l	0.2 mg/l
Nitrate NO <sub>3</sub> <sup>-</sup>	21.7mg/l	50 mg/l
Sodium	58.2 mg/l	200 mg/l
Cadmium	ND	0.003 mg/l
Lead	ND	0.01mg/l
Zinc	ND	3 mg/l
E.coli	Nil/100 ml	Nil/100 ml

ND = Not detected

## APPENDIX BI: Alkalinity calculation of Gorgor borehole

Average volume of hydrochloric acid used = 14.575 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488\text{M} \times 14.575 \text{ ml}}{1000 \text{ ml}} = 1.383 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample}$

Therefore molarity of  $\text{OH}^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001383 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}}$   
= 0.05532 M

For bicarbonate content of Gorgor borehole

Volume of acid used = 12.5 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488\text{M} \times 12.5 \text{ ml}}{1000 \text{ ml}} = 1.186 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample.}$

Excess mole of NaOH that reacted with HCl =  $1.186 \times 10^{-3} \text{ mole}$

Moles of NaOH added to the water sample =  $\frac{0.097\text{M} \times 25 \text{ ml}}{1000 \text{ ml}} = 2.425 \times 10^{-3} \text{ mole.}$

A mole of NaOH that reacted with  $\text{HCO}_3^-$  was calculated thus;

= (Original mole of NaOH – Excess moles of NaOH) =

=  $(2.425 \times 10^{-3} \text{ mole} - 1.186 \times 10^{-3} \text{ mole}) = 1.239 \times 10^{-3} \text{ mole} = \text{moles of HCO}_3^- \text{ in 25 ml of sample.}$

Moles of  $\text{HCO}_3^-$  that reacted with NaOH =  $1.239 \times 10^{-3} \text{ mole}$

Molarity of  $\text{HCO}_3^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001239 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.04956 \text{ M}$

Total alkalinity =  $[\text{HCO}_3^-] + 2[\text{CO}_3^{2-}]$  (5.1)

From equation (5.1) carbonate ion concentration was calculated:

$$0.05532 \text{ M} = 0.04956 \text{ M} + 2x [\text{CO}_3^{-2}] \quad (5.2)$$

$$[\text{CO}_3^{-2}] = \frac{0.05532 \text{ M} - 0.04956 \text{ M}}{2} = 0.00288 \text{ M of } \text{CO}_3^{-2}$$

Therefore concentration of carbonate ion in 25 ml of sample = 0.00288 M.

Since it was assumed that the sample contained a mixture of carbonate and bicarbonate:

$$\text{ppm of compound} = \text{molarity} \times (\text{molecular weight}) \times (\text{Av. vol. of sample used}) \times (1000 \text{ mg/g})$$

$$\text{ppm CaCO}_3 = (0.00288 \text{ mole/1000 ml}) \times (100.0869 \text{ g/mole}) \times (25 \text{ ml}) \times (1000 \text{ mg/g}) = 7.21 \text{ mg/l}$$

$$\text{ppm KHCO}_3 = (0.04956 \text{ mole/1000ml}) \times (100 \text{ g/mole}) \times (25 \text{ ml}) \times (1000 \text{ mg/g}) = 123.9 \text{ mg/l}$$

$$\text{Therefore alkalinity} = [\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}] = 123.9 \text{ mg/l} + (2 \times 7.21 \text{ mg/l})$$

$$= 123.9 \text{ mg/l} + 14.42 \text{ mg/l} = 138.32 \text{ mg/l}$$

## APPENDIX BII: Alkalinity calculation of Umu Batula borehole

Average volume of hydrochloric acid used = 16.2 ml

$$\text{Moles of acid} = \frac{MV}{1000 \text{ ml}} = \frac{0.09488\text{M} \times 16.2 \text{ ml}}{1000 \text{ ml}} = 1.537 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample}$$

$$\text{Therefore molarity of OH}^- \text{ in 25 ml of sample} = \frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001537 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} =$$

0.06148 M

For bicarbonate content of Umu Batula borehole

Volume of acid used = 13.025 ml

$$\text{Moles of acid} = \frac{MV}{1000 \text{ ml}} = \frac{0.09488\text{M} \times 13.025 \text{ ml}}{1000 \text{ ml}} = 1.236 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample.}$$

Excess mole of NaOH that reacted with HCl =  $1.236 \times 10^{-3}$  mole

$$\text{Moles of NaOH added to the water sample} = \frac{0.097\text{M} \times 25 \text{ ml}}{1000 \text{ ml}} = 2.425 \times 10^{-3} \text{ mole.}$$

A mole of NaOH that reacted with  $\text{HCO}_3^-$  was calculated thus;

$$= (\text{Original mole of NaOH} - \text{Excess moles of NaOH}) =$$

$$= (2.425 \times 10^{-3} \text{ mole} - 1.236 \times 10^{-3} \text{ mole}) = 1.189 \times 10^{-3} \text{ mole} = \text{moles of HCO}_3^- \text{ in 25 ml of sample.}$$

Moles of  $\text{HCO}_3^-$  that reacted with NaOH =  $1.189 \times 10^{-3}$  mole

$$\text{Molarity of HCO}_3^- \text{ in 25 ml of sample} = \frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001189 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.04756 \text{ M}$$

$$\text{Total alkalinity} = [\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}] \tag{5.3}$$

From equation (5.1) carbonate ion concentration was calculated:

$$0.06148 \text{ M} = 0.04756 \text{ M} + 2x [\text{CO}_3^{-2}] \tag{5.4}$$

$$[\text{CO}_3^{-2}] = \frac{0.06148 \text{ M} - 0.04756 \text{ M}}{2} = 0.00696 \text{ M of CO}_3^{-2}$$

Therefore concentration of carbonate ion in 25 ml of sample = 0.00696 M.

Since it was assumed that the sample contained a mixture of carbonate and bicarbonate:

ppm of compound = molarity  $\times$  (molecular weight)  $\times$  (Av. vol. of sample used)  $\times$  (1000mg/1g)

$$\text{ppm CaCO}_3 = (0.00696 \text{ mole/1000 ml}) \times (100.0869 \text{ g/mole}) \times (25 \text{ ml}) \times (1000\text{mg}/1\text{g}) = 17.42 \text{ mg/l}$$

$$\text{ppm KHCO}_3 = (0.04756 \text{ mole/1000ml}) \times (100\text{g}/\text{mole}) \times (25 \text{ ml}) \times (1000 \text{ mg}/1\text{g}) = 118.9 \text{ mg/l}$$

$$\text{Therefore alkalinity} = [\text{HCO}_3^-] + 2[\text{CO}_3^{-2}] = 118.9 \text{ mg/l} + (2 \times 17.42 \text{ mg/l})$$

$$= 118.9 \text{ mg/l} + 34.84 \text{ mg/l} = 153.74 \text{ mg/l}$$

**APPENDIX BIII: Alkalinity calculation of Cise Qodax borehole**

Average volume of hydrochloric acid used = 16.75 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488M \times 16.275\text{ml}}{1000 \text{ ml}} = 1.589 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample}$

Therefore molarity of  $\text{OH}^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001589 \text{ mole} \times 1000\text{ml}}{25 \text{ ml}} = 0.06356 \text{ M}$

For bicarbonate content of Cise Qodax borehole

Volume of acid used = 8.65 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488M \times 8.65\text{ml}}{1000 \text{ ml}} = 8.21 \times 10^{-4} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample.}$

Excess mole of NaOH that reacted with HCl =  $8.21 \times 10^{-4} \text{ mole}$

Moles of NaOH added to the water sample =  $\frac{0.097M \times 25 \text{ ml}}{1000 \text{ ml}} = 2.425 \times 10^{-3} \text{ mole.}$

A mole of NaOH that reacted with  $\text{HCO}_3^-$  was calculated thus;

= (Original mole of NaOH – Excess moles of NaOH) =

=  $(2.425 \times 10^{-3} \text{ mole} - 8.21 \times 10^{-4} \text{ mole}) = 1.604 \times 10^{-3} \text{ mole} = \text{moles of HCO}_3^- \text{ in 25 ml of sample.}$

Moles of  $\text{HCO}_3^-$  that reacted with NaOH =  $1.604 \times 10^{-3} \text{ mole}$

Molarity of  $\text{HCO}_3^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001604 \text{ mole} \times 1000\text{ml}}{25 \text{ ml}} = 0.06416 \text{ M}$

Total alkalinity =  $[\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}]$  (5.5)

From equation (5.1) carbonate ion concentration was calculated:

$0.06356 \text{ M} = 0.06416 \text{ M} + 2x [\text{CO}_3^{-2}]$  (5.6)



$$[\text{CO}_3^{-2}] = \frac{0.06356 \text{ M} - 0.06416 \text{ M}}{2} = -0.0003 \text{ M of CO}_3^{-2}$$

Therefore concentration of carbonate ion in 25 ml of sample = -0.0003 M.

Since it was assumed that the sample contained a mixture of carbonate and bicarbonate:

ppm of compound = molarity × (molecular weight) × (Av. vol. of sample used) × (1000mg/1g)

ppm  $\text{CaCO}_3$  = (-0.0003 mole/1000 ml) × (100.0869 g/mole) × (25 ml) × (1000mg/1g) = -0.75 mg/l

ppm  $\text{KHCO}_3$  = (0.06416 mole/1000ml) × (100g/mole) × (25 ml) × (1000 mg/1g) = 160.4 mg/l

Therefore alkalinity =  $[\text{HCO}_3^-] + 2[\text{CO}_3^{-2}] = 160.4 \text{ mg/l} + (2 \times -0.75 \text{ mg/l})$

$$= 160.4 \text{ mg/l} - 1.5 \text{ mg/l} = 158.9 \text{ mg/l}$$

**APPENDIX BIV: Alkalinity calculation of Soonikia (Digfer) borehole**

Average volume of hydrochloric acid used = 12.575 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488M \times 12.575 \text{ ml}}{1000 \text{ ml}} = 1.193 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample}$

Therefore molarity of  $\text{OH}^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001193 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.04772 \text{ M}$

For bicarbonate content of Soonikia (Digfer) borehole

Volume of acid used = 12.15 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488M \times 12.15 \text{ ml}}{1000 \text{ ml}} = 1.153 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample.}$

Excess mole of NaOH that reacted with HCl =  $1.153 \times 10^{-3} \text{ mole}$

Moles of NaOH added to the water sample =  $\frac{0.097M \times 25 \text{ ml}}{1000 \text{ ml}} = 2.425 \times 10^{-3} \text{ mole.}$

A mole of NaOH that reacted with  $\text{HCO}_3^-$  was calculated thus;

= (Original mole of NaOH – Excess moles of NaOH) =

=  $(2.425 \times 10^{-3} \text{ mole} - 1.153 \times 10^{-3} \text{ mole}) = 1.272 \times 10^{-3} \text{ mole} = \text{moles of HCO}_3^- \text{ in 25 ml of sample.}$

Moles of  $\text{HCO}_3^-$  that reacted with NaOH =  $1.272 \times 10^{-3} \text{ mole}$

Molarity of  $\text{HCO}_3^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001272 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.05088 \text{ M}$

Total alkalinity =  $[\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}]$  (5.7)

From equation (5.1) carbonate ion concentration was calculated:

$0.04772 \text{ M} = 0.05088 \text{ M} + 2x [\text{CO}_3^{-2}]$  (5.8)

$$[\text{CO}_3^{-2}] = \frac{0.04772 \text{ M} - 0.05088 \text{ M}}{2} = -0.00158 \text{ M of CO}_3^{-2}$$

Therefore concentration of carbonate ion in 25 ml of sample = -0.00158 M.

Since it was assumed that the sample contained a mixture of carbonate and bicarbonate:

ppm of compound = molarity × (molecular weight) × (Av. vol. of sample used) × (1000mg/1g)

ppm  $\text{CaCO}_3$  = (-0.00158 mole/1000 ml) × (100.0869 g/mole) × (25 ml) × (1000mg/1g) = -3.95 mg/l

ppm  $\text{KHCO}_3$  = (0.05088 mole/1000ml) × (100g/mole) × (25 ml) × (1000 mg/1g) = 127.2 mg/l

Therefore alkalinity =  $[\text{HCO}_3^-] + 2[\text{CO}_3^{-2}] = 127.2 \text{ mg/l} + (2 \times -3.95 \text{ mg/l})$

$$= 127.2 \text{ mg/l} - 7.9 \text{ mg/l} = 119.3 \text{ mg/l}$$

## APPENDIX BV: Alkalinity calculation of Umu Caisha (Tarabuun) borehole

Average volume of hydrochloric acid used = 14.775 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488\text{M} \times 14.775\text{ml}}{1000 \text{ ml}} = 1.402 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample}$

Therefore molarity of  $\text{OH}^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001402 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.05608 \text{ M}$

For bicarbonate content of Umu Caisha (Tarabuun) borehole

Volume of acid used = 12.35 ml

Moles of acid =  $\frac{MV}{1000 \text{ ml}} = \frac{0.09488\text{M} \times 12.35\text{ml}}{1000 \text{ ml}} = 1.172 \times 10^{-3} \text{ mole} = \text{moles of OH}^- \text{ in 25 ml of sample.}$

Excess mole of NaOH that reacted with HCl =  $1.172 \times 10^{-3} \text{ mole}$

Moles of NaOH added to the water sample =  $\frac{0.097\text{M} \times 25 \text{ ml}}{1000 \text{ ml}} = 2.425 \times 10^{-3} \text{ mole.}$

A mole of NaOH that reacted with  $\text{HCO}_3^-$  was calculated thus;

= (Original mole of NaOH – Excess moles of NaOH) =

=  $(2.425 \times 10^{-3} \text{ mole} - 1.172 \times 10^{-3} \text{ mole}) = 1.253 \times 10^{-3} \text{ mole} = \text{moles of HCO}_3^- \text{ in 25 ml of sample.}$

Moles of  $\text{HCO}_3^-$  that reacted with NaOH =  $1.253 \times 10^{-3} \text{ mole}$

Molarity of  $\text{HCO}_3^-$  in 25 ml of sample =  $\frac{\text{mole} \times 1000 \text{ ml}}{\text{volume of base used}} = \frac{0.001253 \text{ mole} \times 1000 \text{ ml}}{25 \text{ ml}} = 0.05012 \text{ M}$

Total alkalinity =  $[\text{HCO}_3^-] + 2x[\text{CO}_3^{-2}]$  (5.9)

From equation (5.1) carbonate ion concentration was calculated:

$0.05608 \text{ M} = 0.05012 \text{ M} + 2x [\text{CO}_3^{-2}]$  (5.10)

$$[\text{CO}_3^{-2}] = \frac{0.05608 \text{ M} - 0.05012 \text{ M}}{2} = 0.00298 \text{ M of CO}_3^{-2}$$

Therefore concentration of carbonate ion in 25 ml of sample = 0.00298 M.

Since it was assumed that the sample contained a mixture of carbonate and bicarbonate:

ppm of compound = molarity  $\times$  (molecular weight)  $\times$  (Av. vol. of sample used)  $\times$  (1000mg/1g)

$$\text{ppm CaCO}_3 = (0.00298 \text{ mole/1000 ml}) \times (100.0869 \text{ g/mole}) \times (25 \text{ ml}) \times (1000\text{mg}/1\text{g}) = 7.46 \text{ mg/l}$$

$$\text{ppm KHCO}_3 = (0.05012 \text{ mole/1000ml}) \times (100\text{g}/\text{mole}) \times (25 \text{ ml}) \times (1000 \text{ mg}/1\text{g}) = 125.3 \text{ mg/l}$$

$$\text{Therefore alkalinity} = [\text{HCO}_3^-] + 2[\text{CO}_3^{-2}] = 125.3 \text{ mg/l} + (2 \times 7.46 \text{ mg/l})$$

$$= 125.3 \text{ mg/l} + 14.92 \text{ mg/l} = 140.22 \text{ mg/l}$$

## **APPENDIX C: Interview Guide**

### **Interview guide for assessment of borehole water use**

- 1) How many people use this BOREHOLE?
- 2) Where do you get water for home use?
- 3) Where do you get water from during rainy season?
- 4) Where do you get water from during dry season?
- 5) How far is nearest water sources?
- 6) Where do you get water for drinking?
- 7) Where do you get water for domestic uses?
- 8) Where do you get water for livestock?
- 9) What do you use water from boreholes for?
- 10) Do you boil the water for drinking?
- 11) Who collects water for domestic use in this household?
- 12) How often do you clean the containers ?
- 13) Who cleans the containers used for domestic water collection and storage in this household?
- 14) What is used in the cleaning of domestic water containers used for collection and storage in this household?
- 15) What are the common diseases in the area?
- 16) Among the members of the household, who are the most affected?
- 17) What suggestion do you give to overcome these diseases?