

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,**

**KUMASI, GHANA**

**KNUST**

**ASSESSMENT OF GROUND WATER QUALITY IN TUBA AND KOKROBITE  
TOWNSHIPS IN THE GA SOUTH MUNICIPAL ASSEMBLY (GSMA) IN THE  
GREATER ACCRA REGION**

**BY**

**ISAAC DADZIE**

**(Bsc.Chemistry)**

A Thesis Submitted to the Department of Theoretical and Applied Biology, Faculty of  
Biosciences, College of Science

in partial fulfillment of the requirements for the degree of

**MASTER OF SCIENCE (ENVIRONMENTAL SCIENCE)**

**JULY, 2018**

## DECLARATION

It is hereby declared that this thesis is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any degree of the University, except where due acknowledgement has been made in the text.

Isaac Dadzie ..... Date

(PG 4499415)

Signature

Date

Certified by:

Mr. J. L. Terlabie .....

Supervisor

Signature

Date

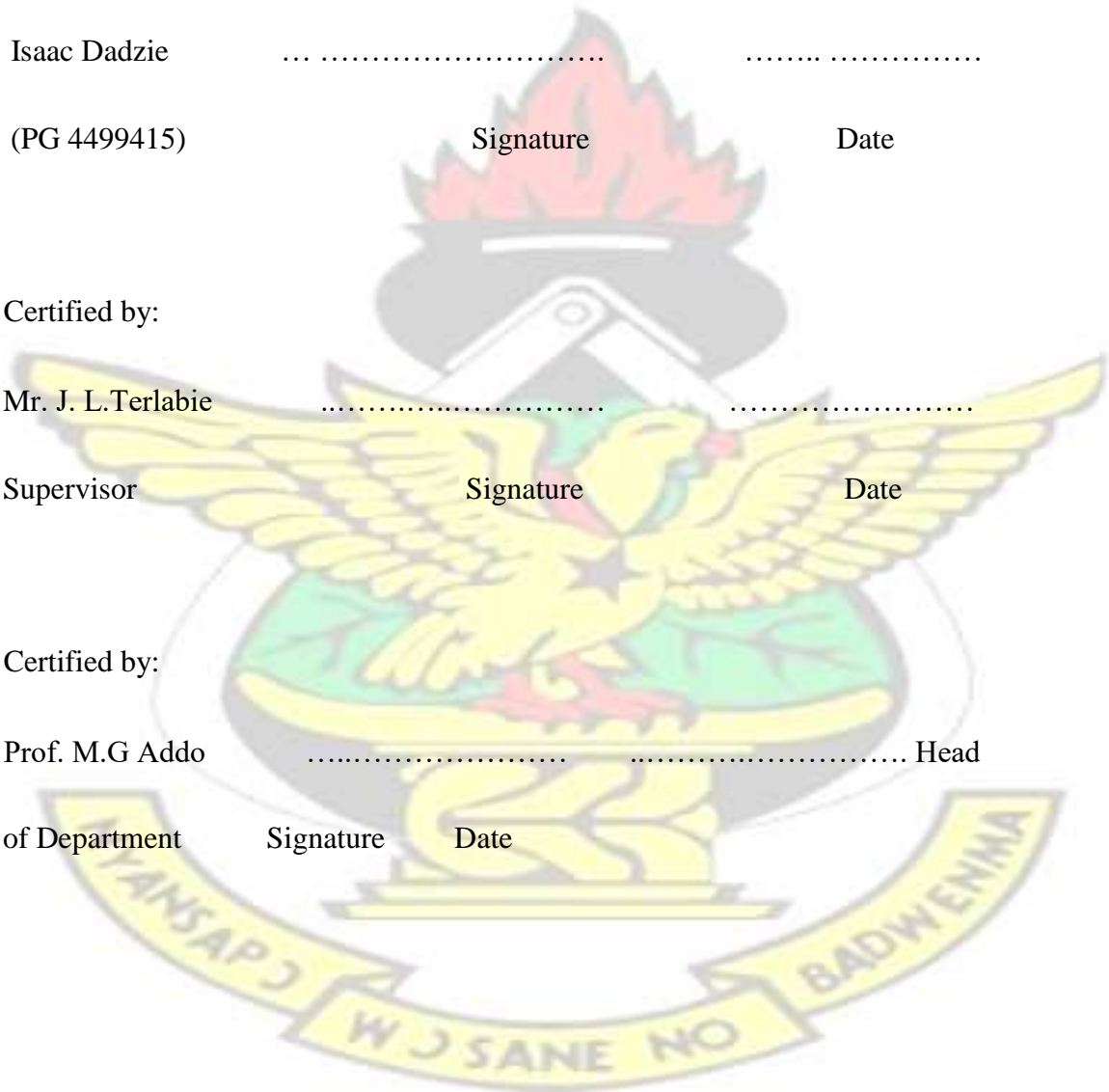
Certified by:

Prof. M.G Addo ..... Head

of Department

Signature

Date



KNUST



## DEDICATION

I dedicate this work to my dear wife, Mrs Mavis Abena Semwuaah Dadzie, my children, Ewura Adadzewa Dadzie and Korby Sam Dadzie, and parents, Mr. J. K. Dadzie and Madam Comfort Ama Sam Bentsil.

# KNUST



## ABSTRACT

Investigations were conducted to assess the quality of borehole water in residential households at Tuba and Kokrobite communities in Ga south municipality, Ghana. Groundwater samples were collected from 30 boreholes, 15 each from Tuba and Kokrobite and for both wet and dry seasons. The geographical locations of the boreholes were determined using global positioning system (GPS). Physico-chemical and bacteriological analysis were carried out on water samples collected from boreholes using processes outlined in the standard methods for the examination of water and wastewater, and the examination of water for pollution control (WHO). The results showed that temperature, pH, turbidity, total suspended solids, dissolved oxygen, calcium, magnesium, sulphate, fluoride, alkalinity, potassium, iron, colour, nitrates were within the recommended WHO standard for drinking water. However, some parameters including conductivity, phosphates, sodium and chloride exceeded the recommended limits. The bacteriological analysis indicated high levels of microbiological pollution indicator organisms; total coliform and faecal coliform with counts exceeding the recommended limit of 0 cfu/100ml for drinking water. The high faecal coliform and total coliform in most sampled water is an indication of possible influence by septic sewage from the septic tank and pit latrines close to the water source. The results showed that the respondents use the borehole water for various domestic purposes such as cooking (65%), bathing (90%), washing (75%), drinking (25%) and flushing (72%). It was observed that 85% of the respondents do not use the water for drinking purposes because it was saline. The study observed septic tanks and pit latrines as major significant contaminant sources of pollution around the water sources. The study therefore recommends that owners of the wells and boreholes should treat the ground water before use.

## LIST OF ABBREVIATIONS

- AAS - Atomic Absorption Spectrophotometer
- APHA - American Public Health Association
- CWSA- Community Water and Sanitation Authority
- DO – Dissolved Oxygen
- EDTA- Ethylenediamine tetra acetic acid
- EPA- Environmental Protection agency
- FAO- Food and Agriculture Organization
- GWCL - Ghana water Company Limited
- IDA- Irrigation Development Authority
- KB- Kokrobite
- NTU - Nephelometric Turbidity Unit
- NGO's- Non Governmental Organization
- TDS - Total Dissolved Solids
- TSS – Total Suspended Solids
- TB- Tuba
- USEPA - United State Environmental Protection Agency
- UNEP- United Nations Environmental Programme
- UNICEF- United Nations Children Fund

GPS - Global Positioning System

GSMA- Ga South Municipal Assembly

PURC- Public Utility Regulatory Commission

PWD- Public Works Department

WSRP- Water Sector Rehabilitation Project

WHO - World Health Organization

WRC - Water Resources Commission

VRA- Volta River Authority

## **ACKNOWLEDGEMENTS**

I wish to express my sincere and profound gratitude to the Almighty God for his divine protection and guidance throughout my life and during the entire study.

My greatest appreciation also goes to my supervisor –Mr. John Larweh Terlabie, Department of Theoretical and Applied Biology, Faculty of Biological science, College of Science for his constructive criticism, guidance, corrections and significant contributions made during the entire execution of the thesis.

I wish also to express my heartfelt gratitude to Mr. Emmanuel Ansah of the Ecological Laboratory (ECOLAB), University of Ghana, Legon and Mr. Fred Kogblenu of Ghana Standards Authority

(GSA) Chemistry Laboratory, Mr. Daniel Armah and Mr. Nii Sai Torto, all of GSA Metal Analysis Laboratory and Microbiological Laboratory respectively for their immense contributions during field data collection and the laboratory analysis.

I also wish to thank the entire staff of the Ga South Municipal Assembly for their corporation and assistance during the entire study period.

Finally, my thanks goes to my siblings, Deborah Dadzie, Eric Yaw Dadzie, Janet Dadzie and Gloria Dadzie, and all my friends and families for their prayers, encouragement and inspiration, God bless you all.

### **TABLE OF CONTENT**

<b>CONTENT</b>	<b>PAGES</b>
DECLARATION.....	2
DEDICATION.....	ii
ABSTRACT .....	iii
LIST OF ABBREVIATIONS .....	iv
ACKNOWLEDGEMENTS.....	v
TABLE OF CONTENT.....	vi
LIST OF FIGURES .....	ix
LIST OF TABLES.....	x
<b>CHAPTER ONE</b> .....	<b>1</b>
<b>INTRODUCTION</b> .....	<b>1</b>
1.1 Background.....	1
1.2 Problem Statement.....	3
1.3 Objective of Study .....	5
1.3.1 General Objective.....	5
1.3.2 Specific Objectives.....	5

1.4 Significance of Study /Justification .....	5
<b>CHAPTER TWO .....</b>	<b>6</b>
<b>LITERATURE REVIEW .....</b>	<b>6</b>
2.1 Ghana Water Profile .....	6
2.2 Development of water supply and management in Ghana .....	7
2.3 Usefulness of Groundwater.....	9
2.4 Groundwater Contamination and Health Effects .....	11
2.5 Conceptual Framework.....	13
2.6 Review of Research studies conducted on groundwater quality .....	13
<b>CHAPTER THREE.....</b>	<b>15</b>
<b>MATERIALS AND METHODS.....</b>	<b>15</b>
3.1 Description of Study Area .....	15
3.2 Study Design.....	16
3.4 Sampling Design for Socio-economic Survey .....	17
3.5 Administration of Questionnaire.....	17
3.6 Sampling Procedures .....	18
3.7 Sample Analysis.....	19
3.7.1 Nitrogen -Nitrate ( $\text{NO}_3^-$ ) Analysis.....	20
3.7.2 Phosphate -Phosphorus ( $\text{PO}_4^{3-}$ ) .....	20
3.7.3 Sulphate ( $\text{SO}_4^{2-}$ ) Analysis.....	20
3.7.4 Chloride Analysis .....	21
3.7.5 Total Alkalinity .....	21
3.7.6 Sodium, potassium, calcium and magnesium ions .....	22
3.7.7 Colour.....	22
3.7.8 Fluoride.....	23
3.7.9 Total hardness ( $\text{CaCO}_3$ ).....	23
3.7.10 Total iron .....	24
3.7.11 Bacteriological Analysis.....	24
3.8 Data Analysis .....	25
<b>CHAPTER FOUR .....</b>	<b>25</b>

<b>RESULTS .....</b>	<b>25</b>
4.1 Physico-chemical Parameters .....	25
4.1.1 Temperature.....	25
4.1.2 pH .....	26
4.1.3 Conductivity .....	27
4.1.4 Total Dissolved solids .....	28
4.1.5 Turbidity .....	29
4.1.6 Total Suspended Solids .....	30
4.1.7 Sulphate ( $\text{SO}_4^{2-}$ ).....	31
4.1.8 Nitrate nitrogen.....	32
4.1.9 Phosphate.....	33
4.1.10 Dissolved oxygen (DO).....	34
4.1.11 Total Hardness .....	35
4.1.12 Magnesium .....	35
4.1.13 Calcium.....	36
4.1.14 Sodium.....	37
4.1.15 Fluoride.....	38
4.1.16 Chloride .....	39
4.1.17 Total Alkalinity .....	40
4.1.18 Potassium.....	41
4.1.19 Iron .....	42
4.1.20 Colour .....	43
4.2 Bacteriological parameters.....	44
4.2.1 Total coliform counts .....	44
4.2.2 Faecal coliform.....	45
4.4 Correlation between the physico-chemical parameters of water samples .....	46
4.6 Social Survey .....	48
4.6.1 Background of respondent.....	48
<b>CHAPTER FIVE .....</b>	<b>52</b>
<b>DISCUSSION.....</b>	<b>52</b>

5.1. Temperature and pH.....	52
5.2. Conductivity, TDS, TSS, Turbidity .....	52
5.3. Dissolved Oxygen .....	54
5.4. Ions and Nutrients .....	54
5.4.1 Chloride, Sulphate and Phosphate- Phosphorus .....	54
5.5. Bacteriological parameters.....	59
<b>CHAPTER SIX.....</b>	<b>60</b>
<b>CONCLUSION AND RECOMMENDATIONS.....</b>	<b>60</b>
6.1 Conclusion .....	60
6.2 Recommendations.....	60
<b>REFERENCES .....</b>	<b>62</b>
<b>APPENDICES.....</b>	<b>66</b>
<b>APPENDIX 2: QUESTIONNAIRE .....</b>	<b>69</b>
<b>LIST OF FIGURES</b>	
Fig 2.1: Health impacts of physical, chemical and biological contamination. ....	13
Fig 3.1 Map of study area showing sampling point. ....	16
Fig 4.1: Mean temperature of water samples at Tuba and Kokrobite. ....	26
Fig 4.2: Mean pH of water samples at Tuba and Kokrobite. ....	27
Fig 4.3: Mean conductivity of water samples at Tuba and Kokrobite. ....	28
Fig 4.4: Mean total dissolved solids of water samples at Tuba and Kokrobite. ....	29
Fig 4.5: Mean turbidity of water samples at Tuba and Kokrobite. ....	30
Fig 4.6: Mean total suspended solids of water samples at Tuba and Kokrobite. ....	31
Fig 4.7: Mean sulphate of water samples at Tuba and Kokrobite. ....	32
Fig 4.8: Mean nitrate nitrogen of water samples at Tuba and Kokrobite. ....	33
Fig 4.9: Mean phosphate of water samples at Tuba and Kokrobite. ....	34
Fig 4.10: Mean dissolved oxygen of water samples at Tuba and Kokrobite. ....	34

Fig 4.11: Mean total hardness of water samples at Tuba and Kokrobite. ....	35
Fig 4.12: Mean magnesium of water samples at Tuba and Kokrobite .....	36
Fig 4.13: Mean calcium of water samples at Tuba and Kokrobite .....	37
Fig 4.14: Mean sodium of water samples at Tuba and Kokrobite .....	38
Fig 4.15: Mean fluoride of water samples at Tuba and Kokrobite .....	39
Fig 4.16: Mean chloride of water samples at Tuba and Kokrobite .....	40
Fig 4.17: Mean total alkalinity of water samples at Tuba and Kokrobite .....	41
Fig 4.18: Mean potassium of water samples at Tuba and Kokrobite.....	42
Fig 4.19: Mean Iron of water samples at Tuba and Kokrobite .....	43
Fig 4.20: Mean colour of water samples at Tuba and Kokrobite.....	44
Fig 4.21: Mean total coliform counts of water samples at Tuba and Kokrobite .....	45
Fig 4.21: Mean faecal coliform counts of water samples at Tuba and Kokrobite .....	46
Fig 4.23 Occupation of respondents .....	50
Fig 4.24. Use of water in the study area. ....	51

**LIST OF TABLES**

Table 2.1: Global Estimated percentage of drinking water supply obtained from groundwater ..	10
Table 4.1: Correlation matrix between parameters of water samples. ....	47
Table 4.2: Identified localized contamination sources around water sources in study area. ....	48
Table 4.3. Age of respondent in the study area. ....	49

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background

Safe and adequate water is an essential commodity for human survival (Adelana *et al.*, 2011). Clean water is required for domestic activities on a daily basis. Water is also needed for a variety of commercial activities and for agricultural activities. Water therefore drives the major sectors of the economy, including the provision of essential services like healthcare and manufacture of food products (Anornu *et al.*, 2009).

Despite the vital role water plays in supporting human life, fueling industries and developing agriculture, people in developing countries face challenges in accessing clean and safe drinking water. Urban sprawl has contributed immensely to the demand for safe and clean drinking water and as such pipe borne water is not supplied to many households (Kortatsi *et al.*, 2009). Many people therefore rely on groundwater sources for their daily activities (Dalvie *et al.*, 2003). It is estimated that nearly 80% of Africa's population use groundwater as its main source of drinking water (Adelana *et al.*, 2011). However, those who have access to improved groundwater sources, especially wells and boreholes, find it difficult to protect them from contamination.

Many households are not adequately educated on the safe ways of maintaining groundwater in their communities, particularly wells and boreholes. Similarly, households also find it difficult to access hydrologists to assess the quality of their ground water periodically to determine any differences in the water condition which may be caused by changes in anthropogenic activities.

All these shortcomings contribute to the vulnerability of ground water in local communities, which has adverse health impact on the consumers of the water.

The relationship between sanitation and water supply means that to maintain quality ground water in the communities, quality and adequate sanitation condition must be provided. An estimated 2.4 billion people are without access to improved sanitation facilities in the world (Gebrehiwot *et al.*, 2011). Out of this number, approximately 946 million defecate in the open (WHO/UNICEF Joint Monitoring Programme, 2015). The health impact of poor water quality is overwhelming. For instance, exposure to unsafe drinking water, inadequate sanitation and poor hygiene is a leading cause of cholera and a variety of infectious and tropical diseases in the African Region. Similarly, lack of access to safe water and proper sanitation limits education and food production. Furthermore, it harms health and leads to a cycle of poverty (The Water Project, 2016). An adequate protection against sanitary hazards can be enhanced through public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection (Gebrehiwot *et al.*, 2011).

The rate of urbanization in the Ga South municipality is high and this has resulted in the inability of the Ghana water company to provide enough pipeborne water to meet the increasing demands, therefore causing acute shortages (GSMA, 2012). In response to the acute shortage, many households resort to privately constructed boreholes located within their residential homes to access water for domestic use. Unfortunately, these water sources are not adequately subjected to comprehensive physico-chemical and bacteriological analysis to determine its suitability before used for human consumption. There are also several anthropogenic contamination hazards around

the water sources such as septic tanks, pit latrines and other unhygienic practices that may potentially pollute ground water sources (Kura *et al.*, 2013).

Though there have been a lot of studies on groundwater quality and management in Ghana, few of the studies have been carried in the sprawling urban areas along the coast of Ghana. This study sought to investigate the quality of groundwater in the study area to better understand its potential quality for human consumption to promote public health.

## **1.2 Problem Statement**

Water is a basic necessity for life. However access to clean, safe and adequate water is a challenge to governments, international agencies, communities and individuals (Razzolini *et al.*, 2011). Most people therefore rely on other sources of water to meet their domestic, commercial and other needs. Because improved pipe water are not easily accessible to many communities in Ghana, they rely on other sources of water which includes surface and groundwater (Samlafo *et al.*, 2015). Majority of the people living in Accra, however, use groundwater: wells and boreholes. The alarming rate of contaminated water sources worldwide is worrying and must be tackled with all seriousness.

Ghana is not excluded in this rate of water contamination. Though data on the amount of water sources contaminated is limited in Ghana, the country taken a giant stride to reduce the proportion of people without access to improved sources of water, from 44% in 1990 to 11% in 2015 (GWC, 2016). Specifically, out of 81% of the people who have access to improved water sources in urban areas for example, 61% of them rely on other water sources, which are mainly groundwater. This

means only 32% of the people in urban areas use pipe borne water (WHO/UNICEF Joint Monitoring Programme, 2015).

Though Tuba and Kokrobite are close to the Weija Dam, which serves as major source of water for commercial and industrial activities in most part of Accra, pipe water is scarce to the residents due to the frequent and sometimes lengthy periods of interruption. Many households, as a result, rely on other sources of water such as wells, borehole and rain water for their domestic activities, with 75% relying on boreholes (Samlafo *et al.*, 2015).

Groundwater could be contaminated by physical, chemical and biological pollutants from natural processes. However, majority of the pollutants are anthropogenic, especially poor sanitation, waste from septic tanks, poor farming practices, toxic waste release (Mensah *et al.*, 2015). This human behavior could contaminate groundwater, for instance nitrate, volatile organic compounds, and coliform bacteria, among others which may pose a high health risk to groundwater used for drinking (WHO, 1998). It is therefore advisable to test the quality of groundwater to determine its contamination at least once every year or immediately after a contamination, for instance, through flood. But many of the households which use groundwater for domestic purposes do not test the quality of their water before use. It is also to bridge the gap in literature concerning study in ground water quality in the coastal areas.

### **1.3 Objective of Study**

#### **1.3.1 General Objective**

The aim of this study is to assess groundwater quality in Tuba and Kokrobite townships in the Ga South Municipal Assembly in the Greater Accra Region.

#### **1.3.2 Specific Objectives**

The study specifically seeks to achieve the following objectives:

- i. To determine the concentrations of physico-chemical parameters of groundwater sources (chloride, conductivity, colour, calcium, magnesium, sodium, fluoride, turbidity, total suspended solids, total dissolved solids, nitrogen-nitrate, total hardness, sulphate, pH, phosphate, dissolved oxygen, temperature, potassium, iron and total alkalinity) in Tuba and Kokrobite townships.
- ii. To determine the levels of bacteriological parameters of groundwater sources (Faecal coliform and Total coliform) in Tuba and Kokrobite township
- iii. To conduct sanitary evaluation by identifying localized contamination sources around the groundwater.

#### **1.4 Significance of Study /Justification**

This study aims at providing evidence based data on the quality of ground water in the Tuba and Kokrobite Township. These data is specifically aimed at proving easily accessible data on the state of groundwater in the study area. The assessment of water resources vulnerability to human pollution has proved to be an effective means for the delineation of areas that are more susceptible to contamination from anthropogenic sources. The data will be useful to Government institutions

in developing a framework to supporting the households in the Tuba and Kokorobite areas in management of the quality of groundwater.

Donor organizations and Non-Governmental Organization (NGOs) will have evidence based data as a reference point to aid their work in improving water supply to the people in the areas under study. This should help in meeting the specific needs of the people regarding access to safe and adequate drinking water to save time and other resources which could be channeled to other productive areas. This study is focused on assessing the groundwater quality in Tuba and Kokorobite Township in the Ga- South, in the Greater Accra region. Tuba and Kokorobite were chosen for the study due to the fact that they are fast growing urban areas and also located along the coastal area. Water supply to the study area is interrupted, therefore, majority of the inhabitants depends on groundwater even though the area is close to the Waija Water Supply. Every study is prone to limitations: this study remains limited to boreholes used for domestic purposes alone, however, examining the other sources of water for irrigation purposes would have struck a better balance between an optimal and realistic levels of the water quality for both domestic and agricultural purposes. Finally, the study will add to the knowledge of the quality of groundwater, especially the coastal urban sprawls.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Ghana Water Profile**

Water resources abound greatly in Ghana having rainfall that runs from 2150mm within the extreme southwest to 800 millimeters within the southeast and about 1000m within the Northeast annually. The Volta (70 %), southwestern (22 %) and Coastal (8 %) are the three main river basin

systems covering the total area of the country. The Volta system in Ghana is shared with all the immediate neighbouring countries as well as Benin and Mali (Sarpong, 2008). “An amount of 38.7 billion m<sup>3</sup> of the total annual run-off of the basins (56.4 billion m<sup>3</sup>) originate from Ghana and the Volta River alone constitute 68 % (Addo *et al.*, 2011). From this, it can be ascertained that the economic life of the country is dominated by the water resources of Ghana which is same as the Volta River” (Sarpong, 2008).

The well endowment of Ghana in terms of ground and marine water resources are found in two rock formations; the sedimentary (43% of the total area with yields of 1.0-12.0 m<sup>3</sup>/hour at depths of 20-80 metres) and non-sedimentary (57 % of the total area of the country with yields of 1.5-2.0 m<sup>3</sup>/hour at depths of 20-100m). Disregarding few instances of localized pollution, the quality of groundwater resources in th country is gein general good (Ansa-Asare, 1996).

## **2.2 Development of water supply and management in Ghana**

The effort at water development and management by government within the post-independence and pre-modern era (1957– 1998) was centered on the creation of agencies with precise roles for water supply, irrigation and environmental management. As per the mandate and sector activities of seversl agencies, they managed regulated and controlled with little or no coordination and control from a central unit. In Ghana, no water sector existed to the extent of disregarding even a single ministry responsible for water management. In 1965, the water supply division under the Public Works Department (PWD) was converted into the Ghana Water and Sewage Corporation

(GWSC). This was as a result of a severe water shortage in 1959 followed by World Health Organizations (WHO) recommendation (Ministry of Works and Housing, 2002). The responsibility of the Ministry of Works and Housing oversees the duties of the Ghana Water Company, the Community Water and Sanitation Agency (CWSA), and the Hydrological Services Department. Other water bodies also existed in that the various relevant pieces of legislation vested powers in corresponding ministries, departments and agencies of State, for the varied and contemporary uses of water. Nevertheless, these performances did not alterate the regular rights; instead they sought to regulate water uses in areas that had previously not been addressed by customary law (Sarpong, 2008).

A lot of the undertakings by the ministries and different government agencies had been well financed by aid and lending agencies. These agencies have provided portable water to many populations in water stressed communities. However, the absence of strong leadership to promote sustained development of water resources has been the issue of the dispersion of institutional tasks for the water sector (Kortatsi, 2009). Also weak integration of diverse facets of water resources development, stock determined by what donors are ready to support rather than what has been determined to be strategic directions of government are few consequence as well (Agyenim & Gupta, 2010).

These foremost impacts have led to much improvements and the reorganization of the water division and the proclamation of laws and policies in line with the orders of the aid agencies. The World Bank had an instrumental role in the plan of the new framework of the water division through the institutional and legal reorganizations. This has involved the unbundling of rural and urban water (Agyenim & Gupta, 2010).

### 2.3 Usefulness of Groundwater

Groundwater forms close to ninety five per cent of the freshwater on the planet (omitting that inaccessible in the polar ice caps), making it central to human life and economic growth (UNEP, 2003). Aquifers, natural underground reservoirs, are suitable sources of water and can have a massive storage capacity, more than even the largest man-made reservoirs. More than three times the total volume of either Lake Kariba or Lake Nasser, was withdrawn from the Ogalalla aquifer that covers portions of eight states in central USA equivalent to about 500 km<sup>3</sup> of groundwater from the past four epochs up to the early 1980s. These storage enables suitable use of water, which can be pumped out during dry periods (UNEP, 2003).

Natural protection from contamination can be achieved from many aquifers. This means untreated groundwater can be far cleaner and safer for use than its untreated surface water equivalent (Kortatsi *et al.*, 2005). Groundwater is also fairly easy and cheap to use as can be brought onstream progressively with low financial implications. Nevertheless, the proximity of boreholes to water use end is key. Groundwater is organizationally easy to develop; individuals can design and manage a convenient one in their ecosphere (UNEP, 2003).

Over half of the mega-cities of the world as at the year 2000, rely upon equitable use of local groundwater (Table 2.2). Urban dependence on groundwater is not in any relation to climate and latitude. Many hundreds of cities worldwide depend on groundwater per estimate (Baba & Tayfur, 2011).

**Table 2.1: Global Estimated percentage of drinking water supply obtained from groundwater**

<b>Groundwater in rural areas and small towns</b>		
<b>Region</b>	<b>Percentage</b>	<b>Population served (millions)</b>
Asia–Pacific	32	1000 – 2000
Europe	75	200 – 500
Central and South America	29	150
USA	51	135
Australia	15	3
Africa	NA	NA
World	-	1500 –2750

**Source: UNEP, 2003**

In smaller towns and rural communities, the use of groundwater for local supply is widespread. An instance can be seen in eastern China, and it is estimated that about one-third of Asia’s drinking water supply emanates from groundwater. More than ninety five per cent of the rural population in the USA rely on aquifers to supply their drinking water. The role of private domestic supply has not been assessed and cities obtain their supplies from a mixture of surface water and groundwater with amounts changing either with the time of year or with demand patterns. This has made reliable and unequivocal global figures problematic to obtain.

## 2.4 Groundwater Contamination and Health Effects

Health aspects of groundwater is crucial and proper understanding is paramount. This can help develop management schemes and unlocks prospective management engagements that can be employed to safeguard drinking water sources. There are many biological, chemical and physical contaminants of groundwater with much health impact.

Fluoride is a good nutrient to human health. Fluoride is beneficial to both the bone and dental growth in human beings (Pontius, 1991). However, excessive ingestion of fluoride of more than 4mg/L can result in teeth mottling (dental fluorosis) and some other associated complications such as dental fluorosis. For example, Maughan-Brown (2010) stated in a study of the presence of spotted enamel in South Africa in borehole water that was reported to have a fluoride levels between 8 mg/L -25 mg/L (WRC, 2001). Studies conducted in South Africa found the occurrence of dental fluorosis to be high and this was attributed to high levels of fluoride above 4.5mg/l in groundwater used for domestic purposes (WRC, 2001; Ncube & Schutte, 2005).

Nitrate, one of the most commonly contaminants is normally conservative in groundwater sources. Nitrite, ammonium, nitrous oxide, and organic nitrogen are also dissolved forms of nitrogen. The primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, so called 'blue-baby syndrome' which is found in babies. Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize haemoglobin (Hb) to methaemoglobin (metHb). This form of Hb can not transport oxygen around the human body. This metHb concentrations can reach 10% and reduce oxygen transport becoming clinically manifest; the

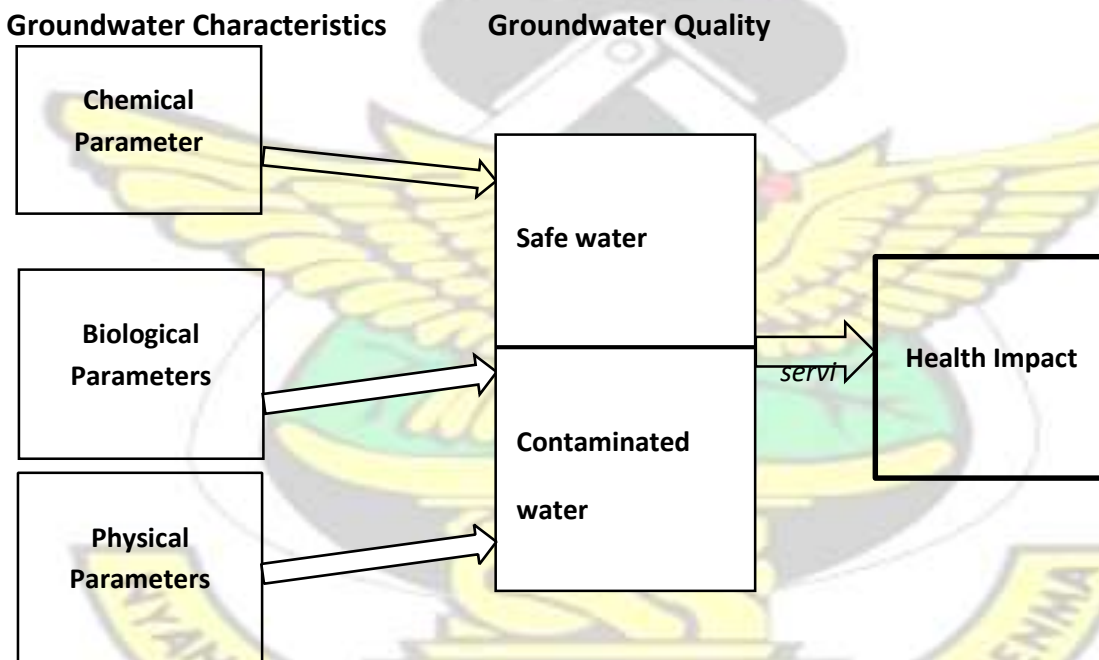
condition, called methaemoglobinaemia. This causes cyanosis and, at higher concentrations, asphyxia (Baird, 1999).

Adelana and Olasehinde (2013) noted that groundwater nitrate is a global problem that is assuming serious dimensions in Nigeria. Mapping and evaluation of analytical data for groundwater sources in southern, northern and central parts of Nigeria has shown that elevated concentrations of nitrate covers several kilometers, both in sparsely and closely human occupied areas. Survey results from researching of nitrate in 1,120 wells in 6 hydrostratigraphic zones in Nigeria reveals 84.5 % of the wells exceeded the drinking water standards of 10mg/l (Baird, 1999). Hantzsche and Finnemore (1992) investigated the quality of boreholes in three different communities in Enugu, Nigeria and reported mean nitrate concentrations of 96 to 139 mg/L. Concentrations in individual wells ranged from less than 30 mg/l to 650mg/L.

In general, transmissible diseases such as cholera, diarrhoea, dysentery, hepatitis A and typhoid are associated with contaminated water and poor sanitation (Robbertson, 1992). Absent, inadequate, or inappropriately managing water and sanitation facilities render the individuals insecure as far as health is concerned. In particular, both patients and staff using health care facilities are placed at additional risk of infection and disease when ever there is improper handling of water, sanitation and hygiene services. Globally, close to fifteen per cent of in-patients contract an infection with percentage much greater in low-income part of the world with low quality water (WHO, 2016).

## 2.5 Conceptual Framework

The literature shows that there is a strong theoretical foundation for an empirical exploration of the linkages between groundwater quality and public health (Baba & Tayfur, 2011; U.S. Geological Survey, 2016). This current study is therefore built on these theoretical framework provided by earlier scholars on geological and public health literature. The framework shows that chemical, biological, and physical parameters of groundwater determine the water quality and the health impact. It is therefore expected that determining the groundwater quality and improving its quality will improve health impact of ground water on human life. The conceptual grounding of the study is depicted below:



**Figure 2.1: Health impacts of physical, chemical and biological contamination.**

## 2.6 Review of Research studies conducted on groundwater quality

Tay and Kortatsi (2008) conducted a study on groundwater quality in the Densu Basin, Ghana. Physico-chemical water quality parameters were determined using standard methods. These were

done to assess the water types and their suitability for drinking and other local usage. Majority of the parameters determined were within the WHO permissible limits endorsed for drinking water. Nevertheless, few of the boreholes were slightly acidic. Tay (2007) researched into the physicochemical characteristics of the groundwater at Akatsi and Ketu districts. Water was sampled from the the Akatsi District (34 boreholes) and in the Ketu District (27 boreholes). Samples were analysed using standard methods. Majority of samples analysed were within permissible limits of the WHO and GWCL guidelines for drinking water. Survey recorded an acid content of 5.75–7.39 pH (Akatsi) and 5.14–7.15 pH (Ketu) in the two districts. Conductivity of 170-6440  $\mu\text{S}/\text{cm}$  (Akatsi) and 420-5180  $\text{mS}/\text{cm}$  (Ketu) were also recorded. The sulphate, chloride ion and nitrate values (ranging from 25-40  $\text{mg}/\text{L}$ ) recorded were somewhat in elevated quantities.

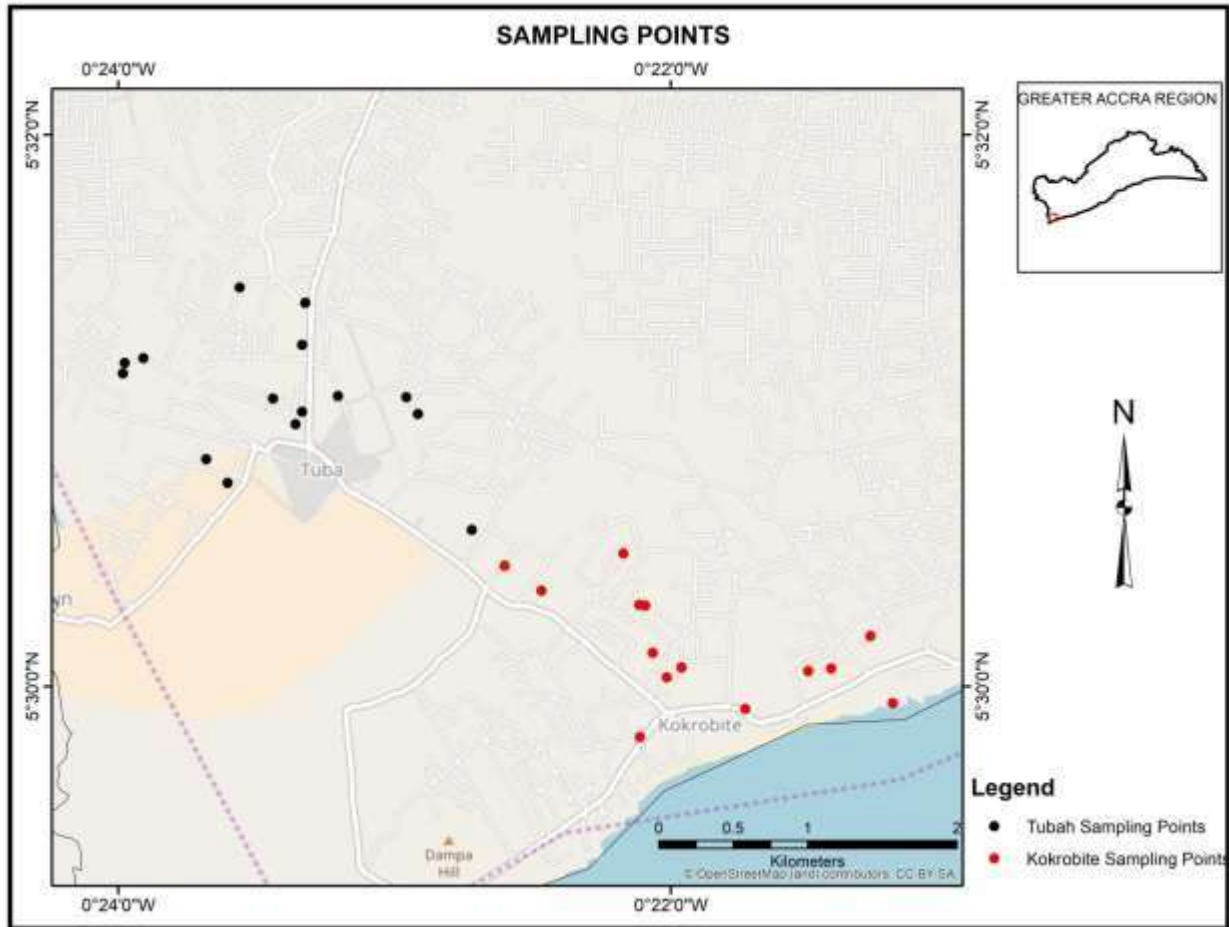
Bacteriological quality of borehole water was examined by Onwuka et al.(2004) in Enugu state, Nigeria as a prove of sewage contamination. Their study brought to light improved protocols of handling domestic wastes like the use of central sewer system. Also, Agbede and Akpen (2008) studied the bacteriological and physico-chemical qualities of ground water in Makurdi metropolis floodplains and reported showed that all the samples (10 boreholes) were contaminated with faecal bacteria with faecal coliform counts ranging from 5 to 25 cfu/100. Total coliform counts also ranged from 45 to 120 cfu/100ml.

## CHAPTER THREE

### MATERIALS AND METHODS

#### 3.1 Description of Study Area

“Kokrobite lies on latitude 5° 30' N and longitude 0° 22' W and Tuba lies on latitude 5° 32' N and longitude 0° 21' W. Kokrobite and Tuba are connecting communities situated on a stretch along the Atlantic Ocean. Usually, the two communities are seen in the coastal plain enclosed by runs of isolated hills and the Gulf of Guinea to the north and south respectively. Kokrobite and Tuba can be located within the Dry Coastal Equatorial Climate (Finlayson *et al.*, 2000) (Fig 3.1). The area experiences a bi-modal rainfall pattern with an annual mean value of 790 mm. Temperatures of 25.1 °C in August and 28.4 °C in February have been experienced annually with the month of March being the warmest. The climatic conditions within these areas explains the coastal savannah vegetation and the grassland. Coconut palm (*Cocos nucifera*) and mangrove species (*Rhizophora racemosa*) are common around the two towns. Kokrobite and Tuba are considered among the fastest urbanizing communities in the Ga South Municipal Assembly in the Greater Accra region with populations of 4,183 (GSS, 2000). Nucleated and dispersed settlements are profound in Kokrobite and Tuba. The indigenes in Kokrobite have occupied the coastline which is built-up. Statistics have shown that about 80% of the population are into fishing. Farming is carried out on subsistence level. Local indigenes and migrants working in bars, restaurants, hotels and resorts and the likes have increase in recent times with regards to to the growth in coastal tourism (GSMA, 2012)”.



**Fig 3.1** Map of study area showing sampling point.

### 3.2 Study Design

The study used a survey design where households that used underground water were identified during a reconnaissance visit to the two communities namely, Tuba and Kokrobite. This was done using snowball sampling technique. Based on the snowball sampling technique, 39 boreholes in households of the two communities were identified for the study and 30 boreholes, 15 each from Tuba and Kokrobite, were selected and used for the study using systematic sampling method. Site evaluation was undertaken at each selected sampling to identify any possible risk that is more likely to contaminate the ground water resources under study.

The geographical locations of the boreholes were determined using the Global Positioning System (GPS, GARMIN etrex 20). Samples were picked every four weeks, within a duration of four months. That is, December to January represents the dry season and May to June represents the wet season. The data were taking in three triplicate for laboratory analysis. In all 180 water samples were analyzed for the two communities during the entire study period.

### **3.4 Sampling Design for Socio-economic Survey**

The data collection techniques used for the socio-economic survey involved a combination of purposive and incidental sampling technique. These techniques were used based on the objectives of the study and the questions were structured using open ended format. The purposive sampling techniques was used based on availability of water facility at homestead. In the incidental sampling technique, the samples were picked by accident where there was no prior decision. In this technique, any person found to be present at homestead and willing to answer the questions were included.

### **3.5 Administration of Questionnaire**

A total number of 50 respondents were interviewed, 25 each from Tuba and Kokrobite by a structured questionnaire using convenient sampling. The interviews were conducted in the sampling residential houses where the water is being investigated. Information that were asked include sources of water for domestic purposes, mindfulness of possible water contaminants from likely sources and the knowledge of any common water correlated infections that affects the community.

### 3.6 Sampling Procedures

The water samples were collected with 1.5 litre polypropylene containers, in two different containers kept in an ice box and transferred to the Ghana Standards Authority Laboratory in Accra. Containers were washed with acetone to get rid of any organic substances such as grease and fat residues. This was followed by washing the bottle with detergents and finally rinsed with de-ionized water. The sampling containers were then soaked in 1.0 M nitric acid solution for not less than 24 hours. The containers were finally rinsed three times with distilled water before taking them to the site for data collection.

At the sampling site, the sampling bottles were rinsed thoroughly with borehole water from which the sample was to be collected and the rinsed water was discarded away from the area being sampled. The borehole water was turned on and allowed to flow for about one minute and the water was fetched out into a clean plastic bucket for in-situ measurements. The chemical parameters of water are sensitive to environmental changes.

Physico-chemical parameters determined were; chloride, conductivity, colour, calcium, magnesium, sodium, fluoride, turbidity, total suspended solids, total dissolved solids, nitrognitrate, total hardness, sulphate, pH, phosphate, dissolved oxygen, temperature, potassium, iron and total alkalinity. Bacteriological parameters analysed were faecal coliform (FC) and total coliform (TC). The bottles were filled with the water and a number was given to each container. The number represented the address of the sampling site, and the date of sampling was also indicated. Samples that were not analyzed immediately at the sampling site were preserved

in an ice chest at a controlled temperature and finally transported to the Ghana Standards Authority's laboratory and stored in a refrigerator below 4°C.

### 3.7 Sample Analysis

All the water samples were analysed using appropriate, certified and acceptable procedures given by International Organization of Standardization for the analysis of water (APHA, 2005). Conductivity, dissolved oxygen, total dissolved solids, temperature, pH and turbidity are the physico-chemical parameters which were determined and recorded in-situ using HACH model multi-probe meter (Horiber series, U50 series).

The sodium and potassium ions were analyzed using Flame emission photometric methods by atomic absorption spectrophotometer whilst chloride was analyzed using titrimetric methods. Fluoride was determined by using SPADNS method (APHA, 2005). Total alkalinity was determined titrimetrically (APHA, 1998). Calcium and magnesium hardness were estimated using titrimetric methods with ethylenediamine tetra acetic acid (EDTA). Nitrogen-nitrate, phosphate, sulphate and total suspended solids were determined using HACH direct reading spectrophotometer and iron also by spectrophotometric method. The total coliform (TC) and faecal coliform (FC) were analyzed using membrane filtration technique (HACH, 1996, WHO, 1997) placed in a paqualab incubator. The growth media used was coliform selective media for total coliform and faecal coliform. They were placed in the incubator for 48 hours at 35 °C and for 24 hours at 44 °C for TC and FC respectively.

### 3.7.1 Nitrogen -Nitrate ( $\text{NO}_3^-$ ) Analysis

The presence of nitrate was detected spectrophotometrically. The nitrate content in each sample was determined by means of nitrate powdered pillows in a direct reading HACH spectrophotometer (Model DR. 6000). To the sample cell of the spectrophotometer, 10 ml of the sample was measured. To the sample, one piece of NitraVer 5 nitrate reagent powder pillows was added. The mixture was then mixed thoroughly by shaking for one minute, followed by additional 5 minutes, which was allowed for the solution to react. An orange colour signify the existence of nitrate. A blank was placed into the cell holder to calibrate it. The nitrate- nitrogen concentration was determined by placing prepared sample into the cell holder at 500 nm in mg/L (HACH, 6000).

### 3.7.2 Phosphate -Phosphorus ( $\text{PO}_4^{3-}$ )

“To the sample cell, 10 ml of prepared water was added together with phosVer 3 phosphate reagent powder pillow and swirled vigorously to mix. Additional 2 minutes reaction period was permitted. Appearance of blue color of the mixture confers the existence of phosphate. Finally to the cell holder, a blank was added to calibrate it and the prepared sample was then added. The reaction time and the level of phosphate-phosphorus was determined at 890nm (HACH, Model DR 6000)”

### 3.7.3 Sulphate ( $\text{SO}_4^{2-}$ ) Analysis

“The level of sulphate in the sample was determined using turbidimetry and spectrophotometric method in a direct reading HACH spectrophotometer (Model DR. 6000). An amount of 10 ml of the sample was measured into a sample cell. One piece of sulfa Ver 4 reagent powder pillows was added to the sample and swirled to dissolve. Another 5-minute reaction period was allowed.

Similarly, a blank sample was prepared and placed in the cell holder to calibrate it. To the cell holder the prepared sample was added after the reaction period and the concentration of the sulphate was measured at 450 nm. There will be the formation of insoluble barium sulphate which is turbid due to the reaction of sulphate ions in the sample and Barium in the sulfa Ver 4 reagent. The intensity of the turbidity formed was proportional to the sulphate concentration in the sample (HACH, 1996)".

### 3.7.4 Chloride Analysis

"The chloride level in the water sample was determined using Titrimetric method. Fifty millilitres of the water sample was pipetted into a conical flask and 3 drops of 0.1M potassium chromate ( $K_2Cr_2O_4$ ) indicator was added and titrated with 0.1M silver nitrate ( $AgNO_3$ ) to end point. The colour changes from yellow to light orange. The standard molarity of the silver nitrate used was 0.0141M (British Pharmacopoeia, 1993)". The chloride was computed mathematically as follows;

$$\text{Chloride Concentration mg/l} = \frac{A \times M \times 35.5 \times 1000}{\text{Vol. of Sample}}$$

Where;

A = Vol. of  $AgNO_3$  used for the titration

M = Concentration of the silver nitrate in mol/L.

35.5 is the molar mass of chlorine and 1000 is constant.

### 3.7.5 Total Alkalinity

" The determination of total alkalinity was done using titrimetric method. A 50 ml water sample was pipetted and drained into a 250 ml flask and two drops of methyl orange indicator was then

added. Hydrochloric acid (0.02M) was put into a burette and titrated against the prepared water solution until the solution changes from yellow to pink. The reading on the burette was recorded and Alkalinity was calculated as follows:

$$\text{Alkalinity as CaCO}_3 \text{ /mg/L} = \frac{A \times 1000}{\text{Vol. of Sample}}$$

where; A= Vol. of standard HCl acid (AWWA, 1998).

1000 is constant.

### **3.7.6 Sodium, potassium, calcium and magnesium ions**

Sodium, potassium, calcium and magnesium ions were analyzed by the atomic absorption spectrophotometry (AAS) method.

A 100 ml water samples was taken and placed in volumetric flask. Nitric acid (10 ml) was added. It was then filtered into a 100 ml volumetric flask. The sample was aspirated and the values read out from digital display. Sample whose concentrations were higher than that of the standard were diluted and results multiplied by the dilution factor. Trace amount of K were determined at wavelength of 768  $\mu\text{m}$  and Na was determined at a wavelength of 589  $\mu\text{m}$ . The intensity of light at these wavelengths is approximately proportional to the concentration of K and Na respectively in the sample. The levels of calcium and magnesium were also determined at their respective wavelengths.

### **3.7.7 Colour**

“The Platinum-Cobalt Standard method was employed. The stored programme number set to 120 on the spectrophotometer and the 455 nm wavelength used. Exactly 25 ml of the sample was added

to the sample cell. The blank was also added to the cell holder and standardized. The prepared sample was added to the cell holder and the result was displayed in platinum-cobalt units “(HACH Company, 2001).”

KNUST

### 3.7.8 Fluoride

“The level of fluoride in the water sample was analyzed using the SPADNS method. Twnty five millilitres of the sample was measured into a dry 25 ml sample cell (the prepared sample). Another sample cell was filled with 25 ml deionized water (the blank). Five millilitres of SPADNS reagent was added to each cell and swirled to mix and one minute reaction period was allowed. The blank sample was placed into the cell holder of the spectrophotometer to calibrate it to a zero reading. The prepared sample was then placed into the cell holder, after the reaction period, to determine the fluoride concentration at 580 nm”.

### 3.7.9 Total hardness (CaCO<sub>3</sub>)

The total hardness is done by titrimetric method as follows: A 50 ml water sample was pipetted into a 500ml conical flask. An ammonia buffer solution (1 ml) was added, followed by a few drops of Eriochrome black T. The solution turned to wine colour. A 0.02 M EDTA solution was then placed in a burette and titrated against the sample solution until it changed colour from wine to clear blue.

$$\text{Total Hardness(mg/L)} = \frac{\text{Titre} \times 1000}{\text{Vol. of Sample used.}}$$

### 3.7.10 Total iron

The total iron determination was performed using the HACH UV spectrophotometer as follows:

To the sample cell which has previously been cleaned, 10 ml of the water sample was added and two drops of 1.0 M ethylene diamine tetra acetic acid (EDTA) Solution was added and swirled to mix. The sample cell was cleaned and inserted into the cell holder and then zeroed to show a display of 0.0 mg/L Fe. The sample cell was removed from the cell holder and the content of one “Ferrover Iron reagent powder pillow” was added to the sample cell. Again, the whole content was swirled to mix and a 3-minutes reaction time was allowed. The cleaned sample cell was inserted into the sample holder and the result read in mg/L Fe.

### 3.7.11 Bacteriological Analysis

“One water sample for bacteriological analysis was taken at each site. Glass bottles with metal cap were used to collect the water sample. The bottles were sterilized before used and the mouth was covered with aluminum foil to avoid contamination during sampling. After collection, the samples were stored in an ice to avoid the multiplication of the bacteria. The total and faecal coliforms were determined using membrane filtration (MF) technique (HACH, 1996, WHO, 1998). Membrane filter with 0.45  $\mu\text{m}$  pore size was sterilized in an incubator and used to filter 100 ml of water mixed with 10 ml of the sampled water. The results obtained from the colony counting were then multiplied by 10 to obtain the actual count per 100 ml. The membrane filter was lifted from the system with a sterilized forceps after filtration and carefully placed on the sterile media in Petri dish. *Escherichia coli*/ coliform selective media were used as the growth medium for the culture of the faecal and total coliforms.

Using the pour plate method, 2 ml of sterilized *E. coli*/ coliform selective media was poured on an absorptive pad placed in a Petri dish. The Petri dish were covered and incubated for 24 hrs at 37 °C and 44 °C for total coliform and faecal coliforms, respectively. Plates were read and colonies counted after 24 hrs using a colony counting chamber (Gallenkamp, UK) and recorded in coliform forming units per 100 ml (CFU/100ml)".

### **3.8 Data Analysis**

The data collected were entered into Microsoft spreadsheet version 2010. Statistical Package for Social Sciences (SPSS) software version 22 was used to compute the means, minimum and maximum ranges for the various parameters used for both the social survey and the water quality. Student t-test was used to test for the significant difference in water quality between the wet and dry seasons and statistical significance was accepted at  $p \leq 0.05$ . A correlation analysis (Pearson's correlation) was used to determine the association between the physico-chemical and microbiological counts of the boreholes water samples.

## **CHAPTER FOUR**

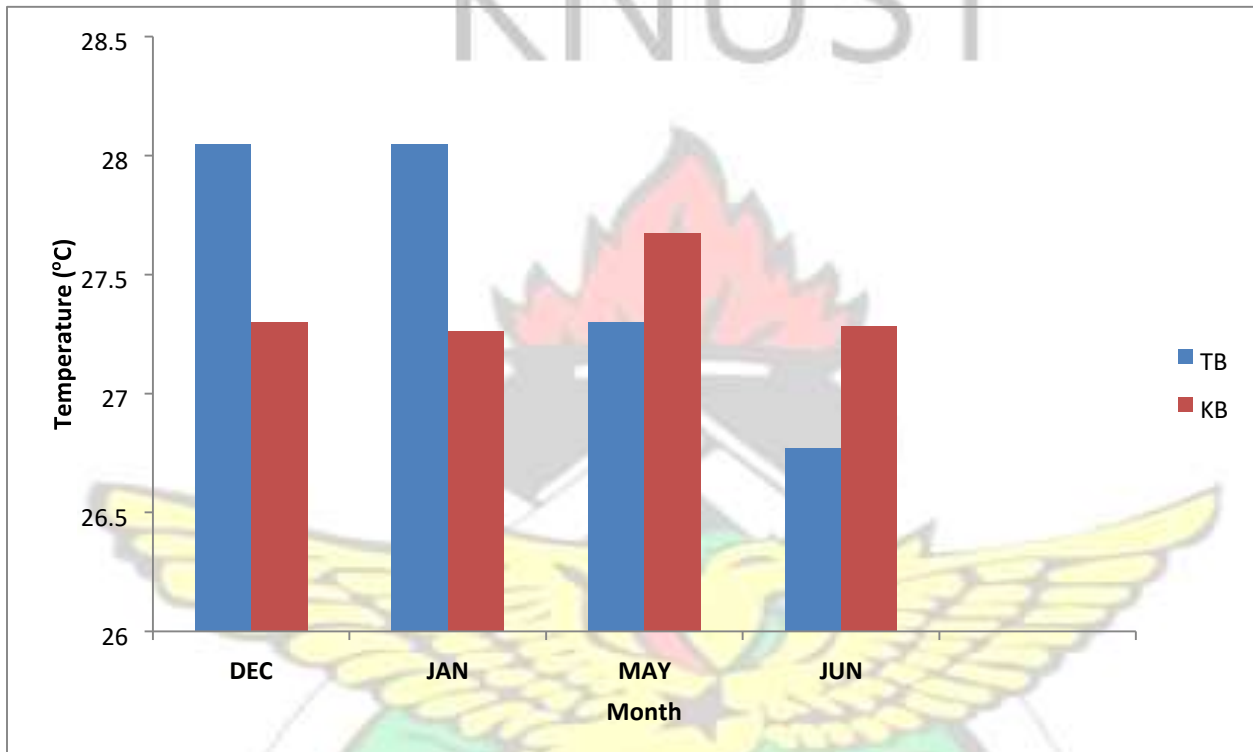
### **RESULTS**

#### **4.1 Physico-chemical Parameters**

##### **4.1.1 Temperature**

The mean temperature of water samples ranged from 26.8 °C to 28.1 °C at Tuba community. That of Kokrobite community ranged from 27.3 °C to 27.7°C. The lowest temperature was recorded in June at Tuba whilst the highest temperature was recorded in December and January at Tuba (Fig 4.1). The students t-test at 95% confidence interval showed that temperature was not statistically

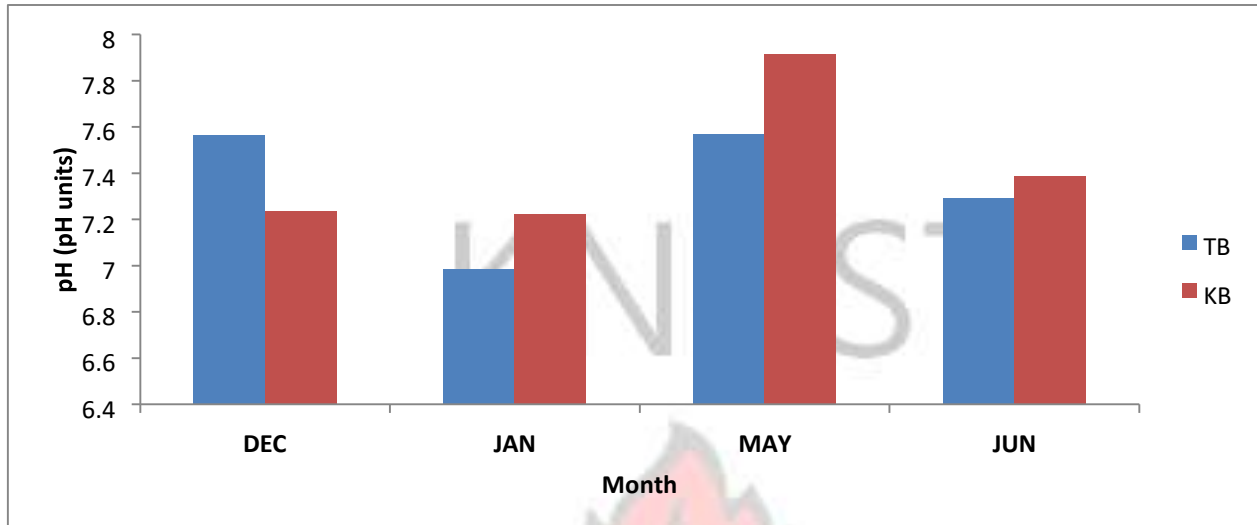
significant between the wet and dry season ( $p = 0.345$ ). However, the dry season (December and January) showed higher variations in temperature compared to wet seasons (May and June) in both communities. The temperature difference between the two communities was not statistically significant ( $p=0.325$ ).



**Fig 4.1: Mean temperature of water samples at Tuba and Kokrobite.**

#### 4.1.2 pH

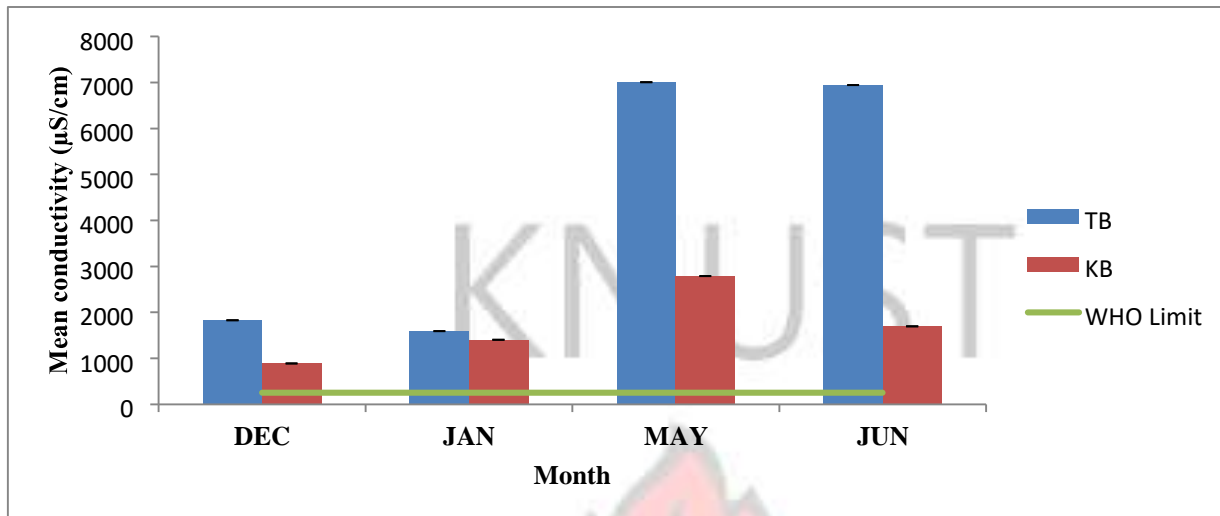
The pH of water samples in the Tuba ranged between 7.0 - 7.6 whereas that of Kokrobite sites was 7.2 to 7.9 pH units (Fig 4.2). There was statistically insignificant differences in pH of water samples obtained between the wet and dry season ( $p = 0.283$ ). Though statistically insignificant, the wet season (May and June) had higher variations compared to dry season (December and January) in both communities. The pH of the water samples was also not statistically significant between the two communities ( $p = 0.57$ ).



**Fig 4.2: Mean pH of water samples at Tuba and Kokrobite.**

#### 4.1.3 Conductivity

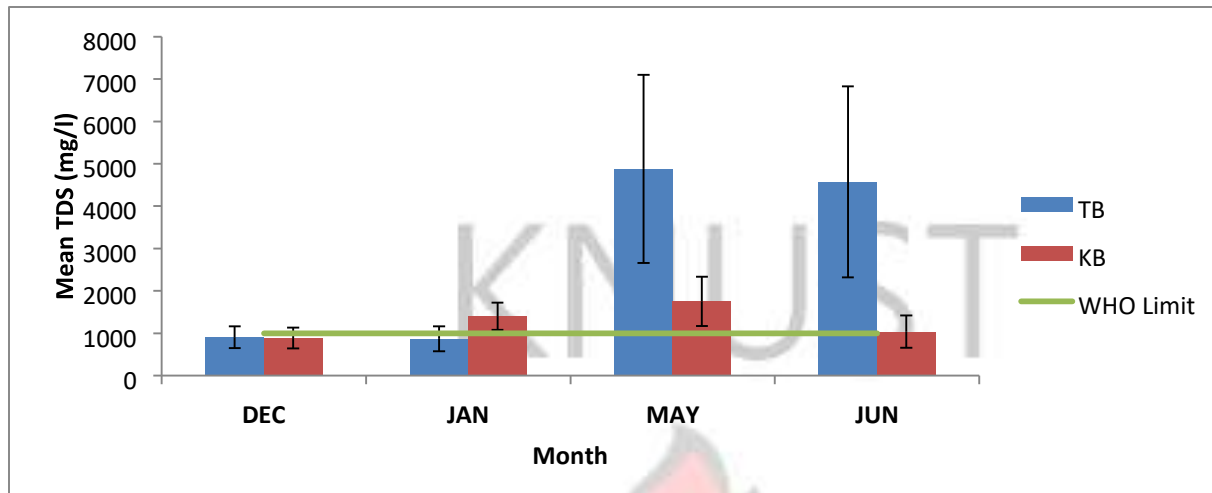
The mean electrical conductivity of water was 7007.0  $\mu\text{S}/\text{cm}$  at Tuba and 887.5  $\mu\text{S}/\text{cm}$  at Kokrobite. The conductivity of the water samples for the dry season (December and January) differed from that of the wet season (May and June) ( $p = 0.028$ ). Values from Tuba were higher compared to those of Kokrobite during the entire study period. There was a statistically significant differences in conductivity between the two communities ( $p = 0.043$ ). The conductivity values obtained for the wet and dry seasons were above the WHO recommended limit of 250mg/l for drinking water sources.



**Fig 4.3: Mean conductivity of water samples at Tuba and Kokrobite.**

#### 4.1.4 Total Dissolved solids

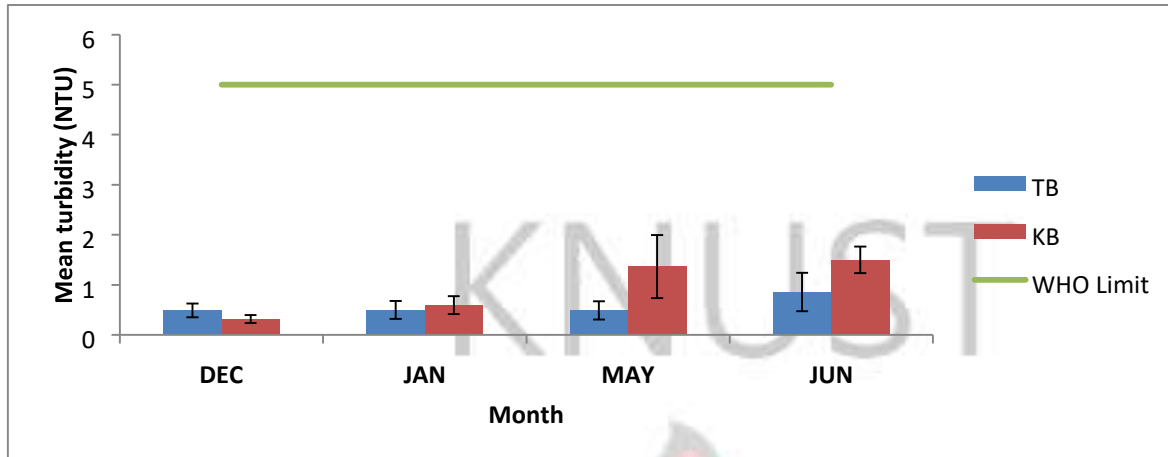
The mean total dissolved solids of water sampled from Tuba sampling site ranged from a lowest value of 870.7 mg/l to a highest value of 4882.5 mg/l. The Kokrobite sampling sites had TDS values varying from 887.5 mg/l to 1752.4 mg/l (Fig 4.4). There was a statistically significant differences in total dissolved solids between the wet and dry seasons ( $p = 0.025$ ). The difference in total dissolved solids of water samples between the two community was statistically significant at 95% confidence level ( $p = 0.015$ ). The results indicated that the total dissolved solids for the wet and dry seasons of the two communities exceeded the WHO recommended limit of 1000mg/l for water meant for drinking purposes.



**Fig 4.4: Mean total dissolved solids of water samples at Tuba and Kokrobite.**

#### 4.1.5 Turbidity

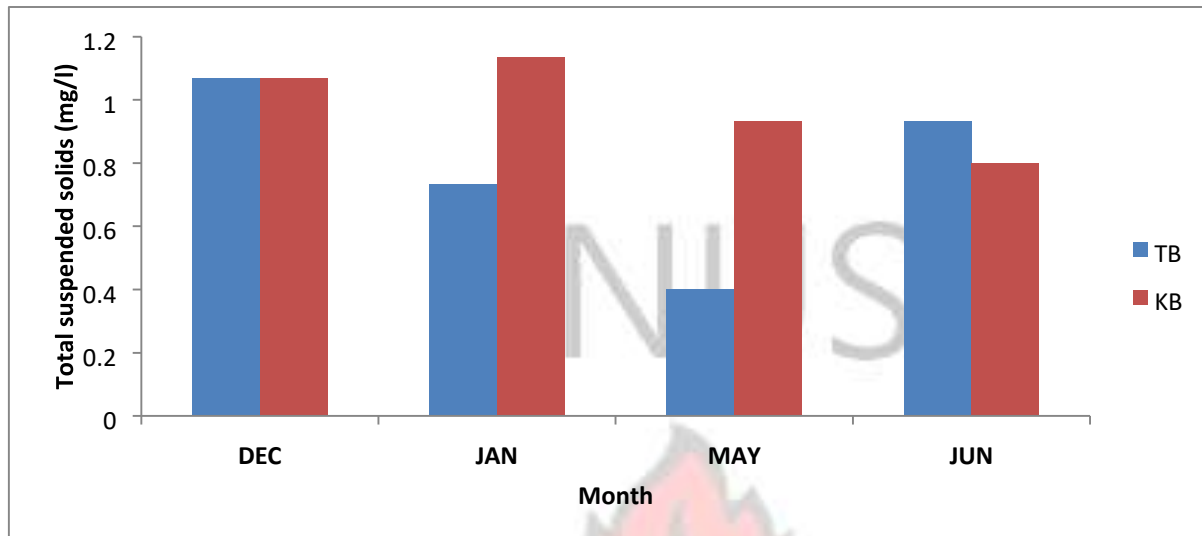
Generally, turbidity values of water samples ranged from 0.49 NTU to 0.90 NTU at Tuba. Mean values at Kokrobite varied from 0.32 - 1.40 NTU (Fig 4.5). The highest value was recorded at Kokrobite during the wet season (1.4 NTU) and the lowest recorded at same community (0.32 NTU) during the dry season. Statistical analysis showed that Turbidity of the wet season differed significantly from that of the dry season ( $p = 0.002$ ). However, between the two communities, turbidity was not statistically significant ( $p = 0.345$ ). The results showed that turbidity for both wet and dry seasons of the two communities were below the recommended limit of 5 NTU for water meant for drinking purposes.



**Fig 4.5: Mean turbidity of water samples at Tuba and Kokrobite.**

#### 4.1.6 Total Suspended Solids

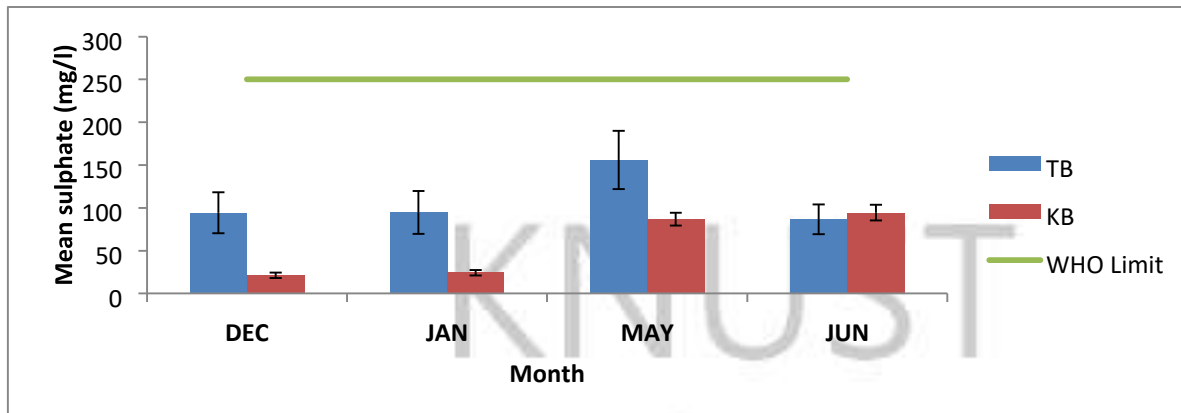
Total suspended solids of water samples ranged from minimum of 0.4 mg/l (Tuba) in the wet season to 1.1 mg/l at Kokrobite in the dry season (Fig 4.6). The student's t-test revealed statistically insignificant differences in TSS for the wet and dry seasons ( $p = 0.348$ ). However, values for the wet seasons (May and June) were higher compared to that of the dry seasons (December and January) in both communities. The values obtained from Tuba did not differ significantly between the two communities ( $p = 0.217$ ). The results showed that TSS for the wet and dry seasons of the two communities were below the recommended limit for water meant for drinking purposes.



**Fig 4.6: Mean total suspended solids of water samples at Tuba and Kokrobite.**

#### **4.1.7 Sulphate (SO<sub>4</sub><sup>2-</sup>)**

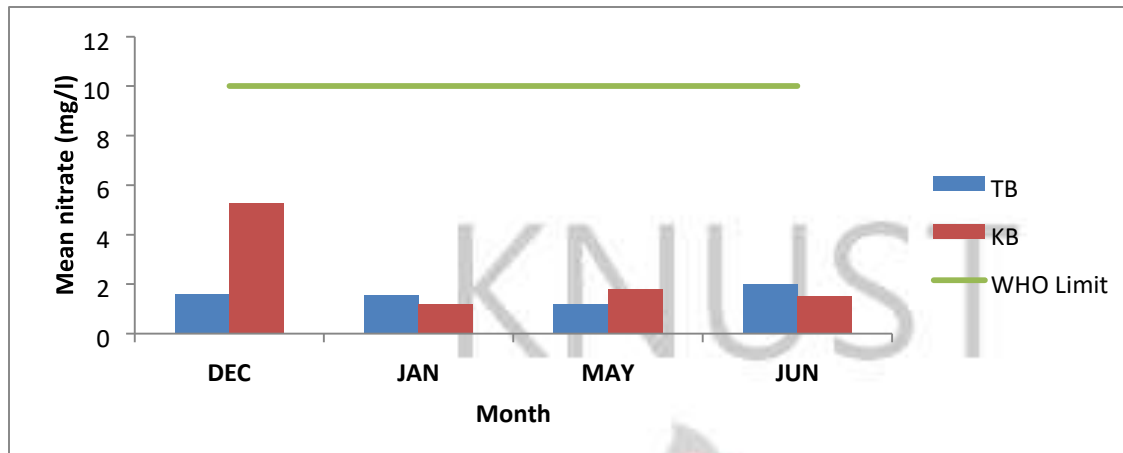
Mean sulphate of water samples recorded a minimum value of 86.8 mg/l to maximum of 156.1mg/l at Tuba. That of Krokrobite also varied from 21.3 mg/l to 94.5 mg/l (Fig 4.7). There was a statistically significant difference in sulphate concentrations between the wet (May and June) and dry seasons (December and January) ( $p = 0.018$ ) of the two communities. Statistical analysis to compare the differences in sulphate revealed a statistically significant difference in sulphate concentrations between the two communities ( $p = 0.032$ ). The sulphate values obtained for both seasons in the two communities were all below the WHO recommended limit of 250 mg/l for drinking water sources.



**Fig 4.7: Mean sulphate of water samples at Tuba and Kokrobite.**

#### 4.1.8 Nitrate nitrogen

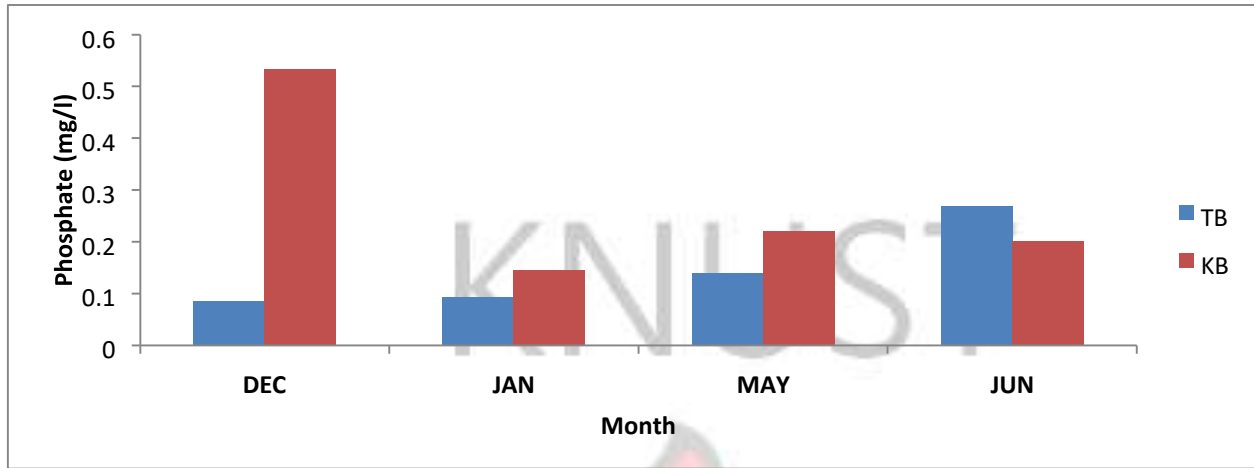
Nitrate levels in water samples were observed to be very low during both seasons. The highest mean value was recorded at Kokrobite in the dry season with mean value of 5.30 mg/l and the lowest value recorded at Tuba in the wet season with mean value of 1.17mg/l (Fig 4.8). There was a statistically significant differences in nitrate nitrogen levels of water samples between the wet (May and June) and dry seasons (December and January) ( $p = 0.021$ ). There was also statistically significant differences in nitrates concentration between the two communities ( $p = 0.014$ ). The nitrogen nitrate values obtained in water samples for both seasons in the communities fell below the WHO recommended limit of 10 mg/l for drinking water sources.



**Fig 4.8: Mean nitrate nitrogen of water samples at Tuba and Kokrobite.**

#### 4.1.9 Phosphate

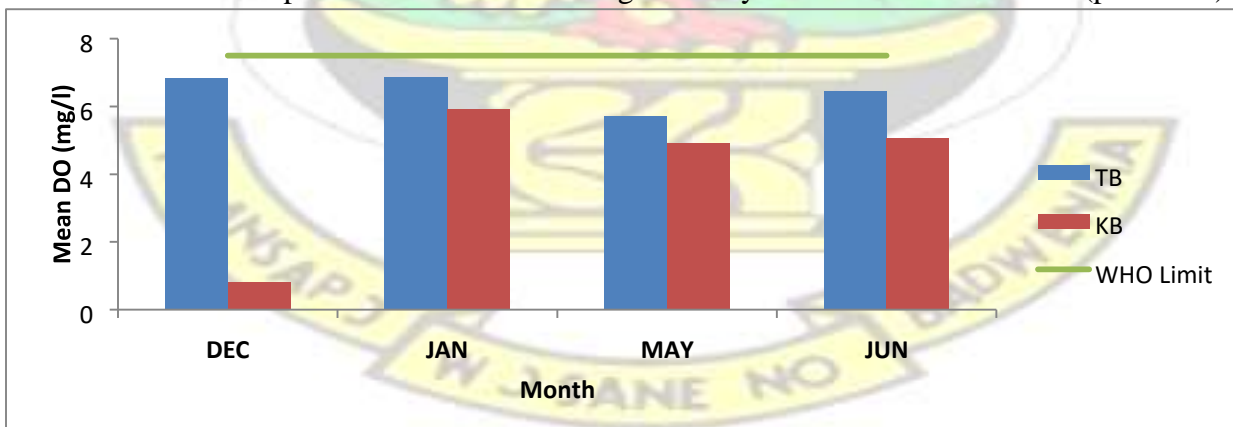
The highest concentration of phosphate was recorded at Kokrobite (0.53mg/l) in the dry season and the lowest at Tuba in the same dry season (0.08mg/l) (Fig 4.9). Student t-test showed that there was a statistically significant differences in phosphate levels of water samples between the wet and dry season ( $p = 0.014$ ). The phosphate levels of the two communities however did not show any statistically significant differences ( $p = 0.234$ ). Though the WHO does not have recommended levels for phosphate in drinking water, for public health purposes, a value between 0.0010.005mg/l have been proposed. The values obtained in this study fell above the recommended limit.



**Fig 4.9: Mean phosphate of water samples at Tuba and Kokrobite.**

#### 4.1.10 Dissolved oxygen (DO)

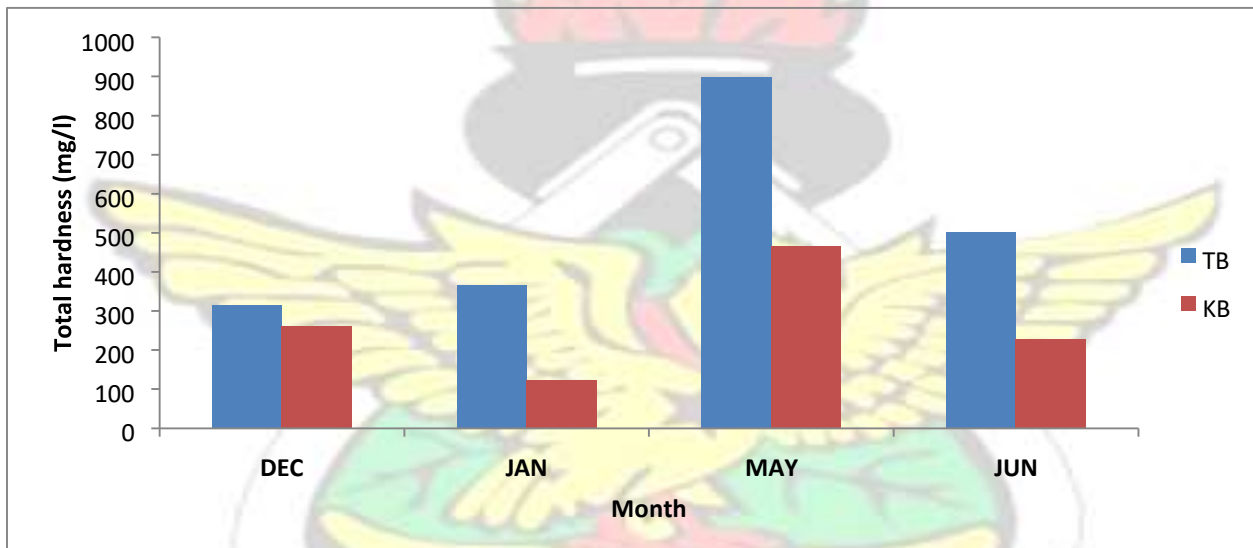
The dissolved oxygen was generally lower than the required standard for the World Health Organization for at least 7.5 mg/l for the purpose of public health significance. The lowest levels were recorded at Kokrobite during the dry season with mean value of 0.8mg/l. The highest value was recorded at Tuba in the dry season with mean value of 6.9 mg/l (Fig 4.10). There was statistically significant differences in DO of water samples between the two seasons ( $P = 0.039$ ). The DO of water samples from Tuba differed significantly from those of Kokrobite ( $p = 0.020$ ).



**Fig 4.10: Mean dissolved oxygen of water samples at Tuba and Kokrobite.**

#### 4.1.11 Total Hardness

Mean total hardness of water samples varied from a minimum of 315.6 mg/l at Tuba during the dry season to maximum of 899.2 mg/l at the same community in the wet season (Fig 4.11). The Total hardness of the water sample was higher for Tuba during the dry and wet season compared to Kokrobite ( $P = 0.034$ ). The total hardness of Tuba community differed significantly from that of Kokrobite ( $p = 0.028$ ). The total hardness in most samples at Tuba and Kokrobite in the wet season exceeded the recommended limit of 400mg/l whilst in the dry season they were below the recommended limit.

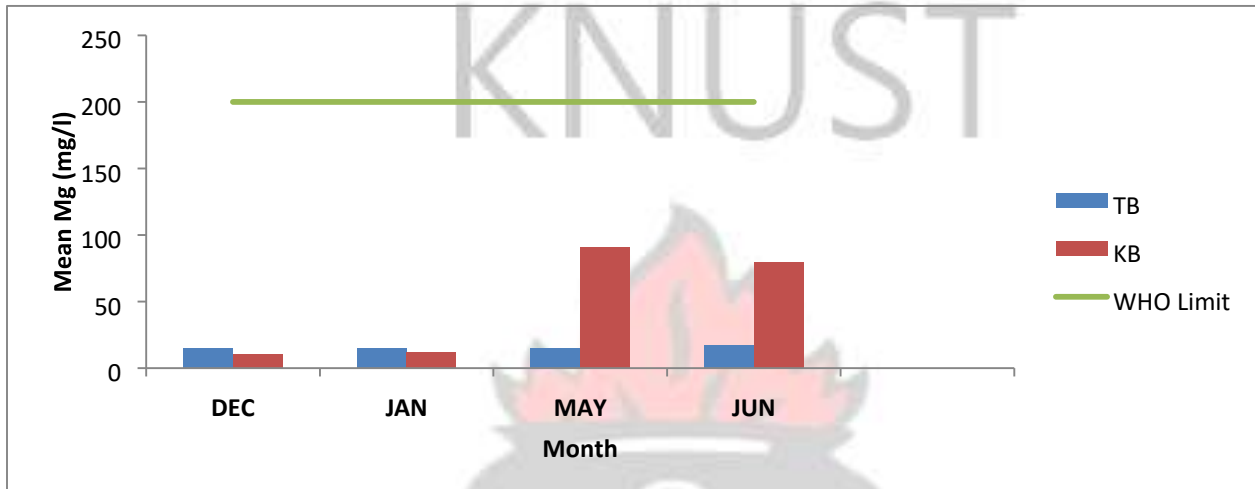


**Fig 4.11: Mean total hardness of water samples at Tuba and Kokrobite.**

#### 4.1.12 Magnesium

The highest magnesium concentrations of water samples was recorded at Kokrobite in the wet season with mean values of 90.4 mg/l. The lowest value however was recorded at same kokrobite community with mean value of 10 mg/l in the dry season. (Fig 4.12). The magnesium concentrations in the wet season differed significantly from that of dry season ( $p = 0.045$ ). There

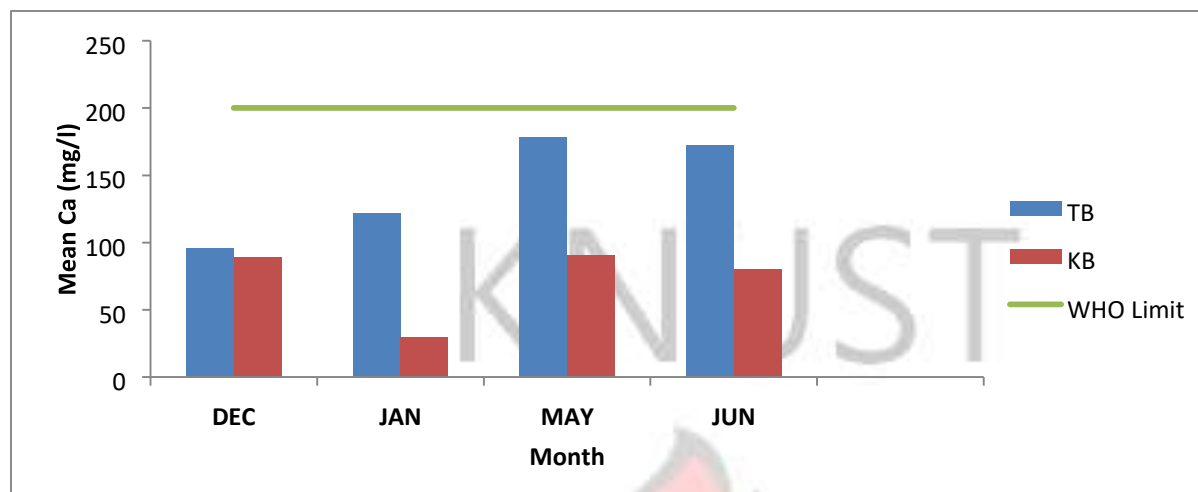
was differences in magnesium concentrations in water samples between the two communities ( $p = 0.035$ ). The magnesium concentrations obtained in water samples for the two seasons were less than the WHO recommended limit of 200 mg/l for potable drinking water sources.



**Fig 4.12: Mean magnesium of water samples at Tuba and Kokrobite**

#### 4.1.13 Calcium

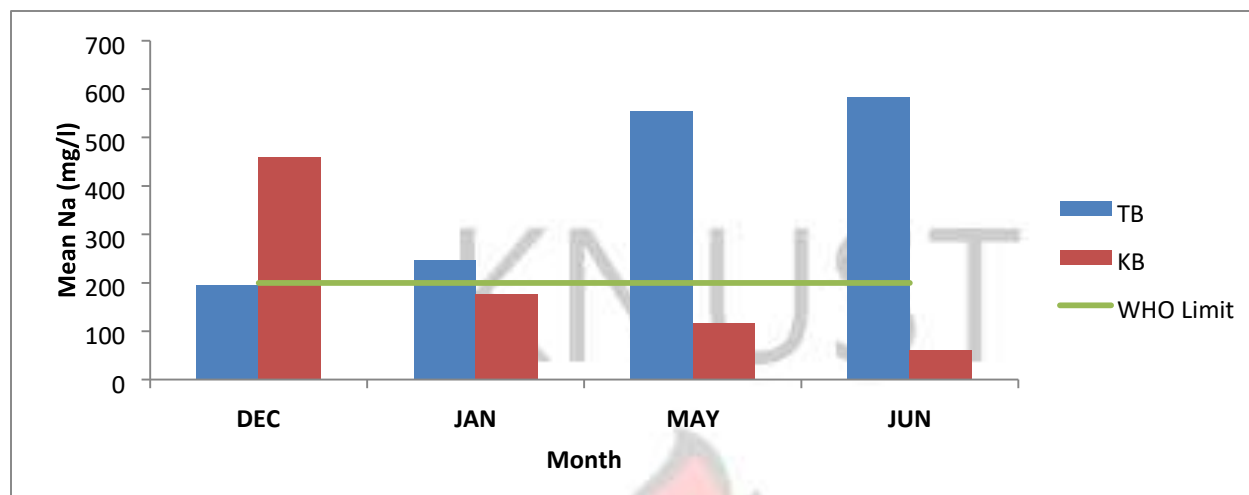
Mean calcium concentrations of water samples ranged from minimum of 29.4mg/l at Kokrobite in the dry season to a maximum of 178.2 mg/l at Tuba in the wet season (Fig 4.13). There was statistically significant differences in calcium concentrations between the wet seasons (May and June) and dry seasons (December and January) ( $p = 0.045$ ). The calcium concentrations in water samples at Tuba community differed from that of Kokrobite community ( $p = 0.025$ ). The calcium values obtained in water samples for the dry and wet season in the two communities were below the WHO recommended limit of 200 mg/l for drinking water sources.



**Fig 4.13: Mean calcium of water samples at Tuba and Kokrobite**

#### 4.1.14 Sodium

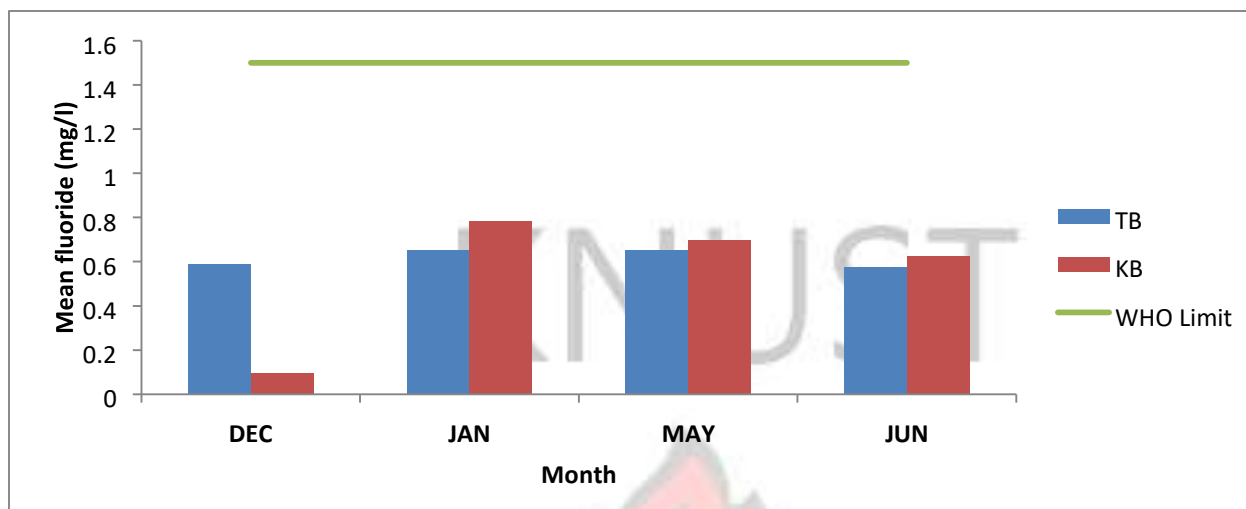
The highest sodium concentrations was recorded at Tuba sampling sites with mean value of 582.7 mg/l and the lowest was recorded at Kokrobite in the wet season with mean value of 60.8 mg/l (Fig 4.14). There was a statistically significant differences in sodium concentrations of the water samples between the wet and dry season ( $p = 0.035$ ). There was statistically significant differences in sodium levels in water samples obtained from the two communities ( $p = 0.032$ ). The samples taken from Kokrobite in December in the dry season recorded a mean sodium value above the WHO recommended limit of 200mg/l. However values obtained in the wet season exceeded the recommended limit at Tuba.



**Fig 4.14: Mean sodium of water samples at Tuba and Kokrobite**

#### 4.1.15 Fluoride

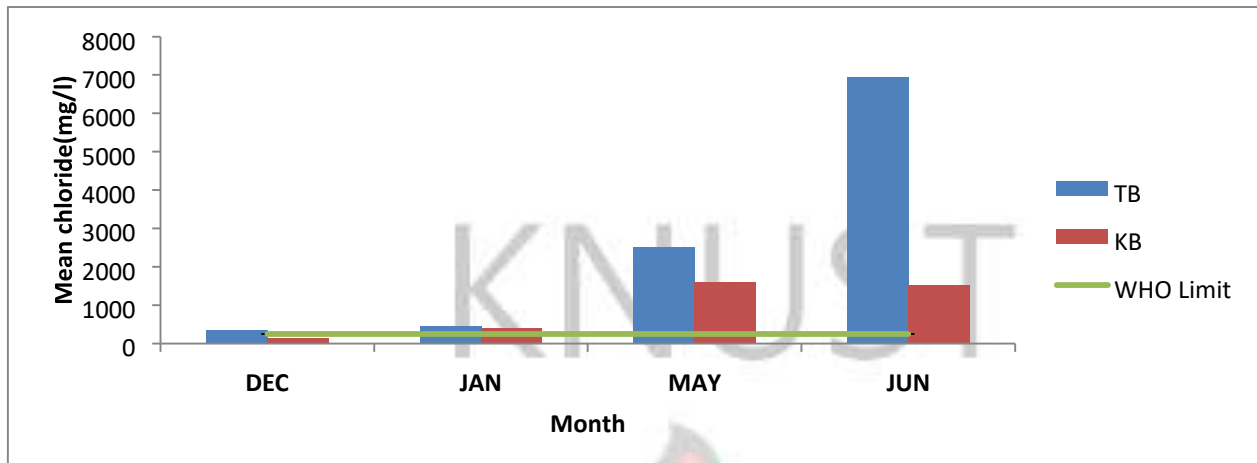
The highest mean level of fluoride was recorded at Kokrobite (0.78 mg/l) in the dry season and the lowest recorded at same community with mean value of 0.09 mg/l. There was a statistically significant differences in fluoride levels of the water samples between the dry and wet season seasons ( $P = 0.029$ ). Comparative analysis of fluoride levels of water samples of the two communities was statistically insignificant at 95% confidence level ( $p = 0.023$ ). The fluoride concentrations obtained in water samples for the two seasons fell below the WHO recommended limit of 1.5 mg/l for potable drinking water sources.



**Fig 4.15: Mean fluoride of water samples at Tuba and Kokrobite**

#### 4.1.16 Chloride

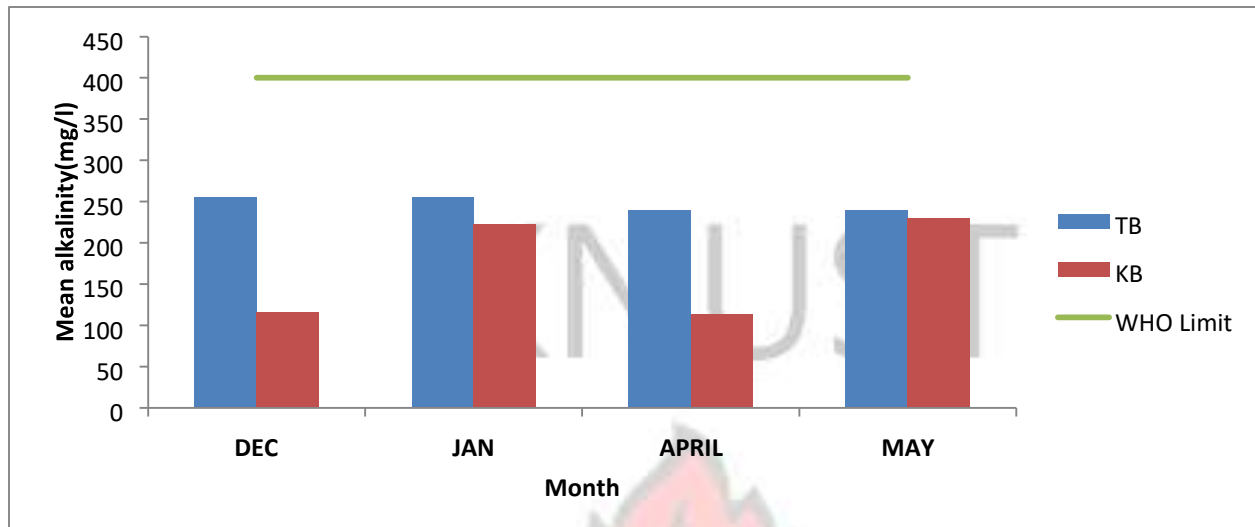
The highest mean chloride concentrations of water samples was recorded at Tuba with mean value of 6943 mg/l whilst the lowest value was recorded at Kokrobite in the dry season with mean value of 127 mg/l (Fig 4.16). Statistical Analysis showed that there was a significant differences in chloride concentrations between the two seasons ( $p = 0.001$ ). The chloride concentrations in water samples obtained from the two communities was statistically significant ( $p = 0.001$ ). With the exception of Kokrobite sampling site in December that recorded mean concentrations which were less than the WHO recommended limit of 250mg/l for portable drinking water source, all other sites recorded above the limit for the two seasons.



**Fig 4.16: Mean chloride of water samples at Tuba and Kokrobite**

#### 4.1.17 Total Alkalinity

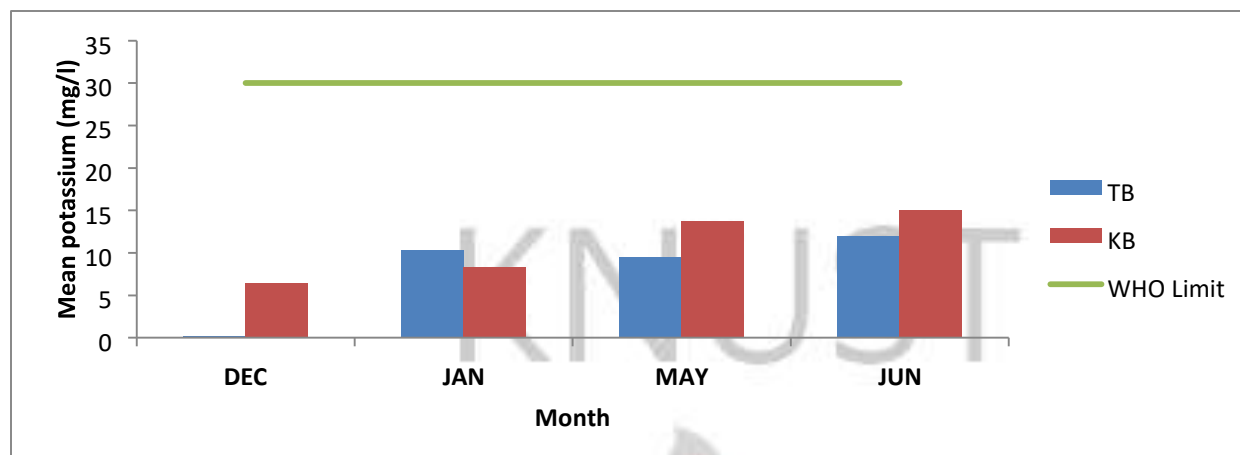
Generally, the total alkalinity of water samples from both Tuba and Kokrobite sampling site were lower than the recommended limit of 400 mg/l according to the World Health Organization for portable drinking water sources. The highest value of 254.9 mg/l was recorded at Tuba sampling site in the dry season (Fig 4.17). There was a significant differences in alkalinity between the two seasons ( $p = 0.001$ ). The differences in alkalinity of water samples obtained from the two communities was, however, insignificant at 95% confidence level ( $p = 0.238$ ).



**Fig 4.17: Mean total alkalinity of water samples at Tuba and Kokrobite**

#### **4.1.18 Potassium**

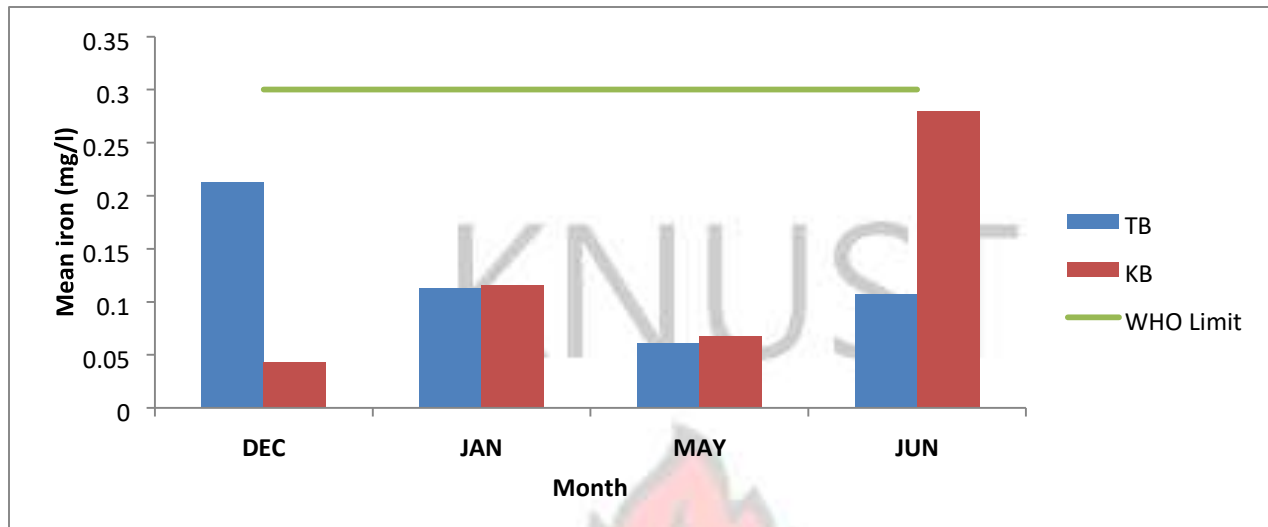
The highest mean potassium concentrations of water samples was recorded at Kokrobite in the wet season with mean value of 15.1mg/l and the lowest was recorded at Tuba in the dry season with mean value of 0.2 mg/l (Fig 4.18). The potassium concentrations in the wet seasons were higher compared to that of the dry seasons in both communities ( $p = 0.043$ ). However, there was no differences in potassium concentrations between the two communities ( $p = 0.472$ ). The potassium concentrations obtained in water samples for the dry and wet seasons in the two communities were below WHO recommended limit of 30 mg/l for potable drinking water sources.



**Fig 4.18: Mean potassium of water samples at Tuba and Kokrobite**

#### 4.1.19 Iron

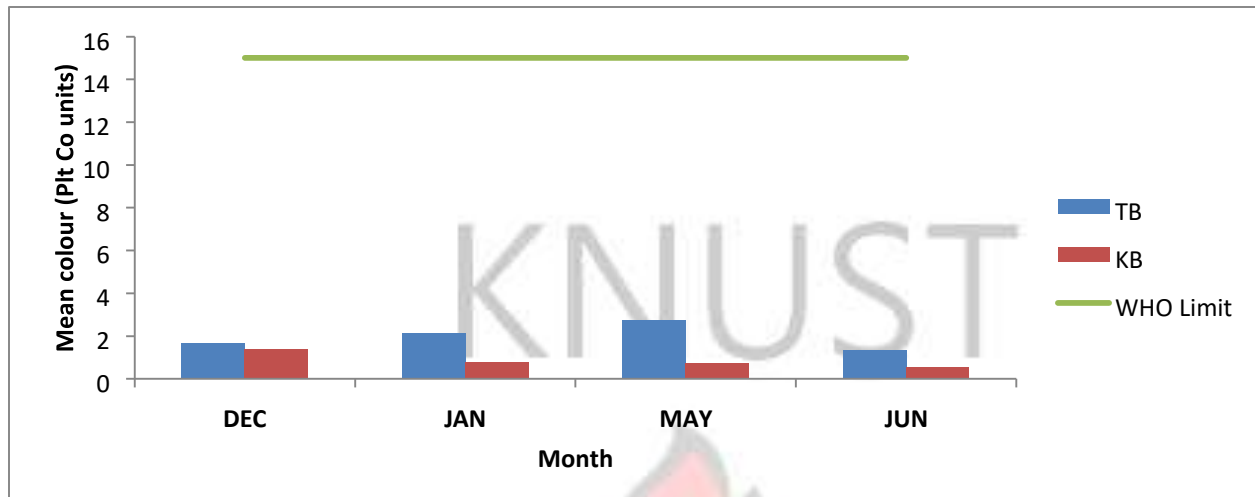
Mean iron levels of water samples varied from minimum of 0.04 mg/l at Kokrobite in the dry season to maximum of 0.28mg/l at same community in the wet season (Fig 4.19). There was a statistically significant differences in iron concentrations between the wet and dry season ( $p = 0.032$ ). There was statistically significant differences in iron levels in water samples from the two communities ( $p = 0.046$ ). The iron concentrations obtained in water samples for the two seasons were below the WHO recommended limit of 0.3 mg/l for potable drinking water sources.



**Fig 4.19: Mean Iron of water samples at Tuba and Kokrobite**

#### 4.1.20 Colour

The colour of water from Kokrobite sampling sites was comparatively higher than that of Tuba sampling sites with mean value of 2.7 Plco (platinum cobalt units) at Tuba in the wet season and the lowest was recorded at Kokrobite in the wet season with mean value of 0.5mg/l (Fig 4.20). The colour of water samples from the wet season did not differ from that of vthe dry season ( $p = 0.568$ ). The differences in the color of the water samples between the two communities was also statistically insignificant ( $p = 0.238$ ). The colour of the water samples for the two seasons were below the WHO recommended limit of 15 Plco for potable drinking water sources.

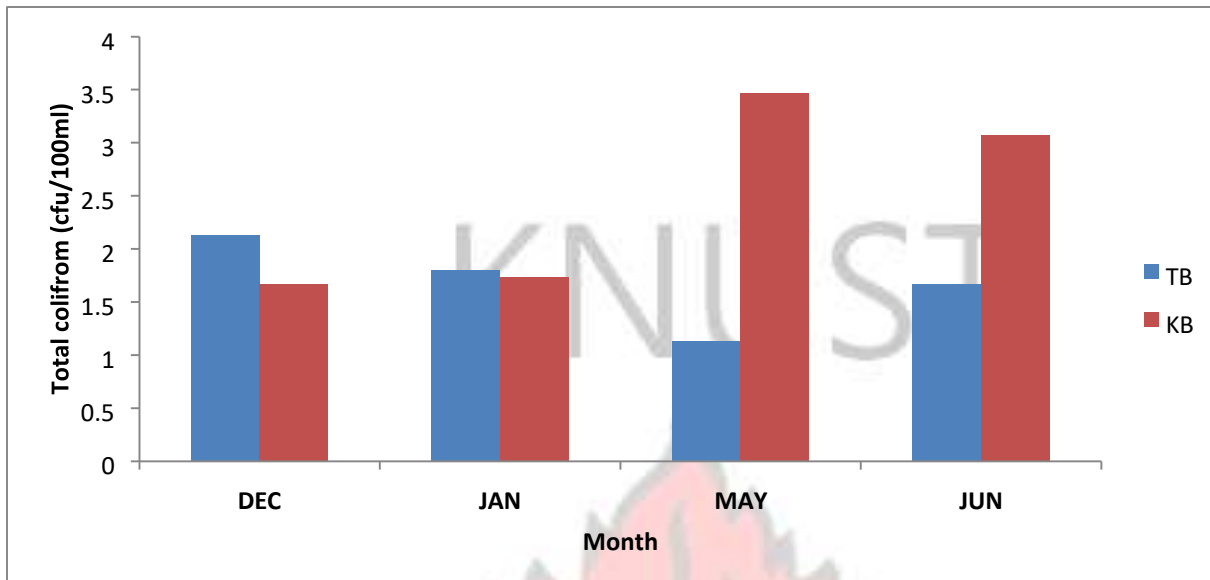


**Fig 4.20: Mean colour of water samples at Tuba and Kokrobite**

## 4.2 Bacteriological parameters

### 4.2.1 Total coliform counts

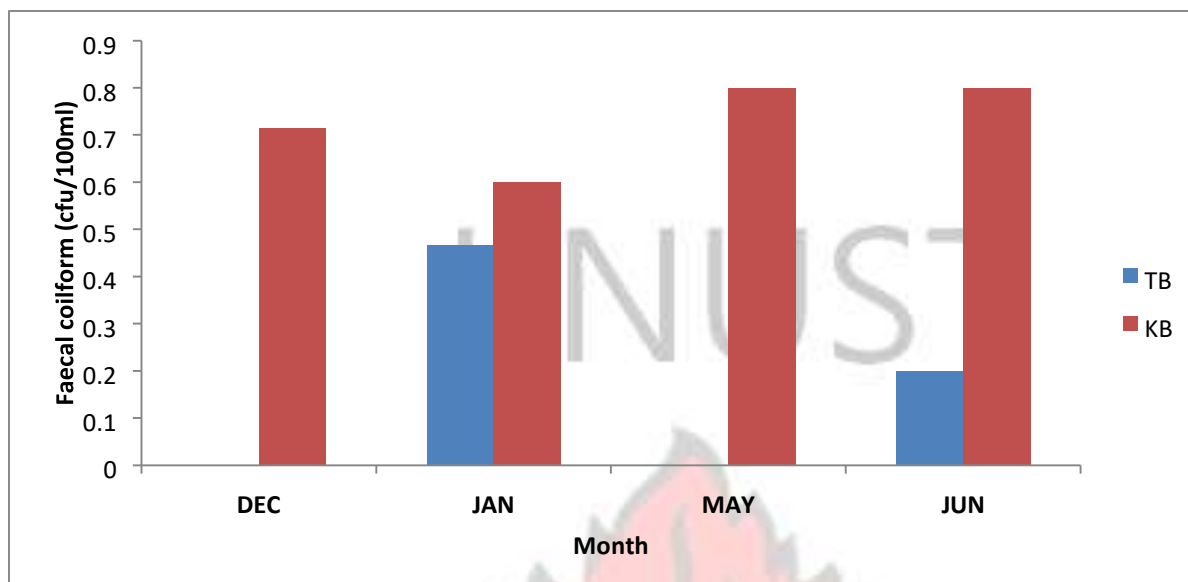
For the purposes of drinking water, total coliform should not be detected and should be zero cfu/100ml. Mean total coliform was observed to be higher in the wet season compared to dry season and varied from 1.1 cfu/100ml to maximum of 2.1 cfu/100ml at Tuba whilst that of Kokrobite ranged from 1.7 cfu/100ml mg/l to a maximum of 3.5 cfu/100ml (Fig 4.21). The total coliform counts in the wet season differed significantly from that of the dry season ( $p = 0.048$ ). The difference in coliform counts between the two communities was also statistically significant ( $p = 0.043$ ).



**Fig 4.21: Mean total coliform counts of water samples at Tuba and Kokrobite**

#### 4.2.2 Faecal coliform

The mean faecal coliform counts ranged from non detection at Tuba at both the dry and wet season to maximum of 0.8 cfu/100ml at Kokrobite in the wet season (Fig 4.22). There was statistically significant differences in faecal coliform counts between the wet and dry season ( $p= 0.032$ ). The faecal coliform counts of the Tuba community also differed significantly from that of the Kokrobite community ( $p=0.048$ ). Most samples in the wet and dry season in the two communities exceeded the zero limit set by WHO..



**Fig 4.21: Mean faecal coliform counts of water samples at Tuba and Kokrobite**

#### 4.4 Correlation between the physico-chemical parameters of water samples

A number of significant positive correlations were found between the following physico-chemical parameters; Na and conductivity ( $r = 0.685$ ), Ca and total hardness ( $r = 0.845$ ), Mg and total hardness ( $r = 0.728$ ), Na and  $\text{SO}_4^{2-}$  ( $r = 0.765$ ), Ca and  $\text{SO}_4^{2-}$  ( $r = 0.745$ ), Na and  $\text{Cl}^-$  ( $r = 0.945$ ) (Table 4.1).

**Table 4.1: Correlation matrix between parameters of water samples.**

VAR	EC	Hardness	Ca	Na	SO <sub>4</sub> <sup>2-</sup>	Mg	Cl <sup>-</sup>
EC	1			0.685*			
Hardness		1	0.845**			0.728*	
Ca			1		0.745*		
Na				1	0.765**		0.945**
SO <sub>4</sub> <sup>2-</sup>					1		
Mg						1	
Cl <sup>-</sup>							1

\*. Correlation is significant at the 0.05 level (2-tailed). \*\*. Correlation is significant at the 0.01 level (2-tailed). EC: Electrical conductivity. Values not recorded for some parameters did not show significant correlation and were not shown on the table.

#### 4.5 Sanitary evaluation of localized contamination sources around groundwater.

From the study, three main localized contaminants sources were identified, the results showed that in the Tuba community, 5 and 1 households had their water source distance less than 10m away from septic tanks and pit latrines respectively. However, 6 households had their water source 1030m away from septic tank whilst 3 and 2 households had theirs away from pit latrines and refuse dump respectively (Table 4.2). With regards to Kokrobite community, 6 and 1 households had their water source distance less than 10m away from septic tanks and pit latrines respectively and one household had their water source less than 10m away from a refuse dump. However, 3

households each had their water source 10-30m away from septic tank and pit latrines whilst 1 households had their water source away from refuse dump (Table 4.2).

**Table 4.2: Identified localized contamination sources around water sources in study area.**

Contaminant Source	Number of boreholes and distances to sanitary contaminants			
	Tuba community		Kokrobite community	
	<10m	10-30m	<10m	10-30m
Septic tank	5	4	6	3
Pit latrines	1	3	1	3
Refuse dump	None	2	1	1
<b>Total</b>	<b>15</b>		<b>15</b>	

## 4.6 Social Survey

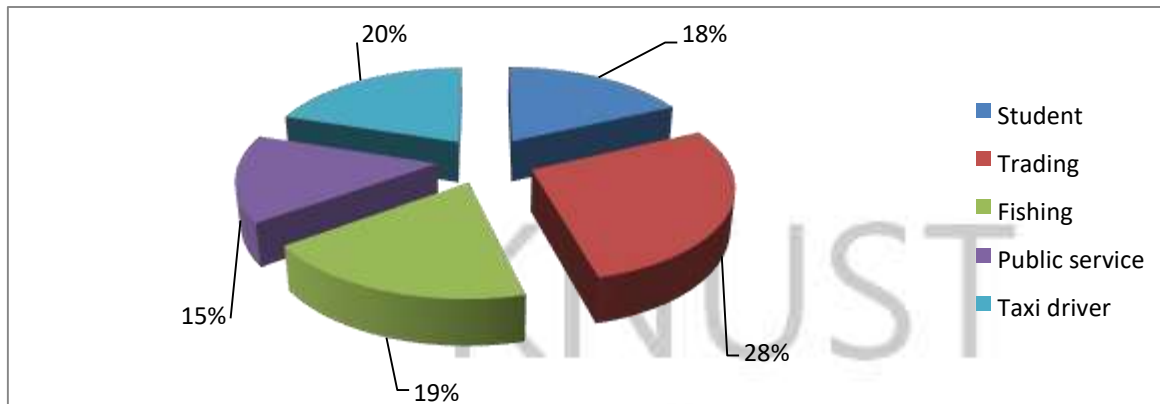
### 4.6.1 Background of respondent

A total number of 50 respondents, 25 each from the two communities were interviewed of which 65% were males whilst 35% were females. Table 4.2 below indicates the ages of the respondents. Fifteen (15%) of the respondent interviewed were below 20 years, 42 %, 20 % and 10% were between the ages of 20-29, 30-39 and 40-49, respectively whilst only 13 % were 50 years and above.

**Table 4.3. Age of respondent in the study area.**

Age Group (Years)	percentage (%)
below 20yrs	15.0
20-29yrs	42.0
30-39yrs	20.0
40-49yrs	10.0
50 and above	13.0
Total	100.0

In terms of occupation showed, 18% of them were students whilst 28% were engaged in various trading activities, 19% were into fishing, 20% were taxi drivers and 15% were public servants (Fig 4.21).



**Fig 4.23 Occupation of respondents**

The educational levels of the respondents showed that sought (48%) had had SSS/6<sup>th</sup> form education, whilst 32% had primary education, 14% had tertiary education and 6% had no formal education. With regards to marital status, 45% were married, single (32 %) with 10% and 3% divorced and widowed respectively.

Concerning the type of water facility used in the study area and the nature of the water, the results showed that the type of water facility used by households were mainly boreholes and majority representing 85% of the respondents asserted that the nature of the water was saline and this accounted for why few individuals use the water as drinking water sources by treating it.

With regards to the various uses of the borehole water, the results showed that the respondents use the water for various domestic purposes such as cooking (65%), bathing (90%), washing (75%) and drinking (25%) and flushing (72%)(Fig.4.24). The respondents, however, noted that, most do not use the water for purposes of drinking because it is saline as 85% and 15% admitted that it was saline and turbid respectively.

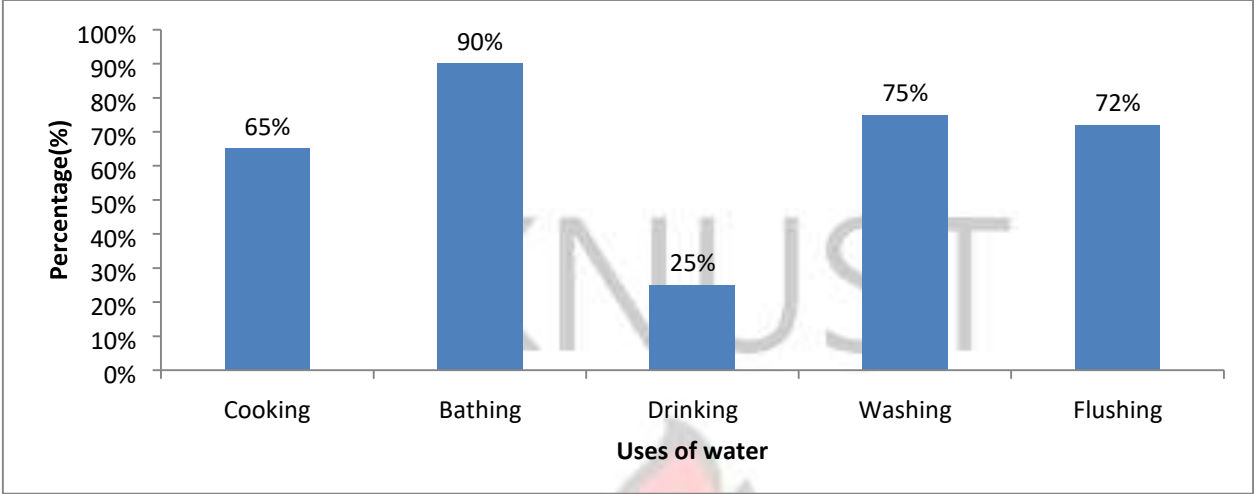
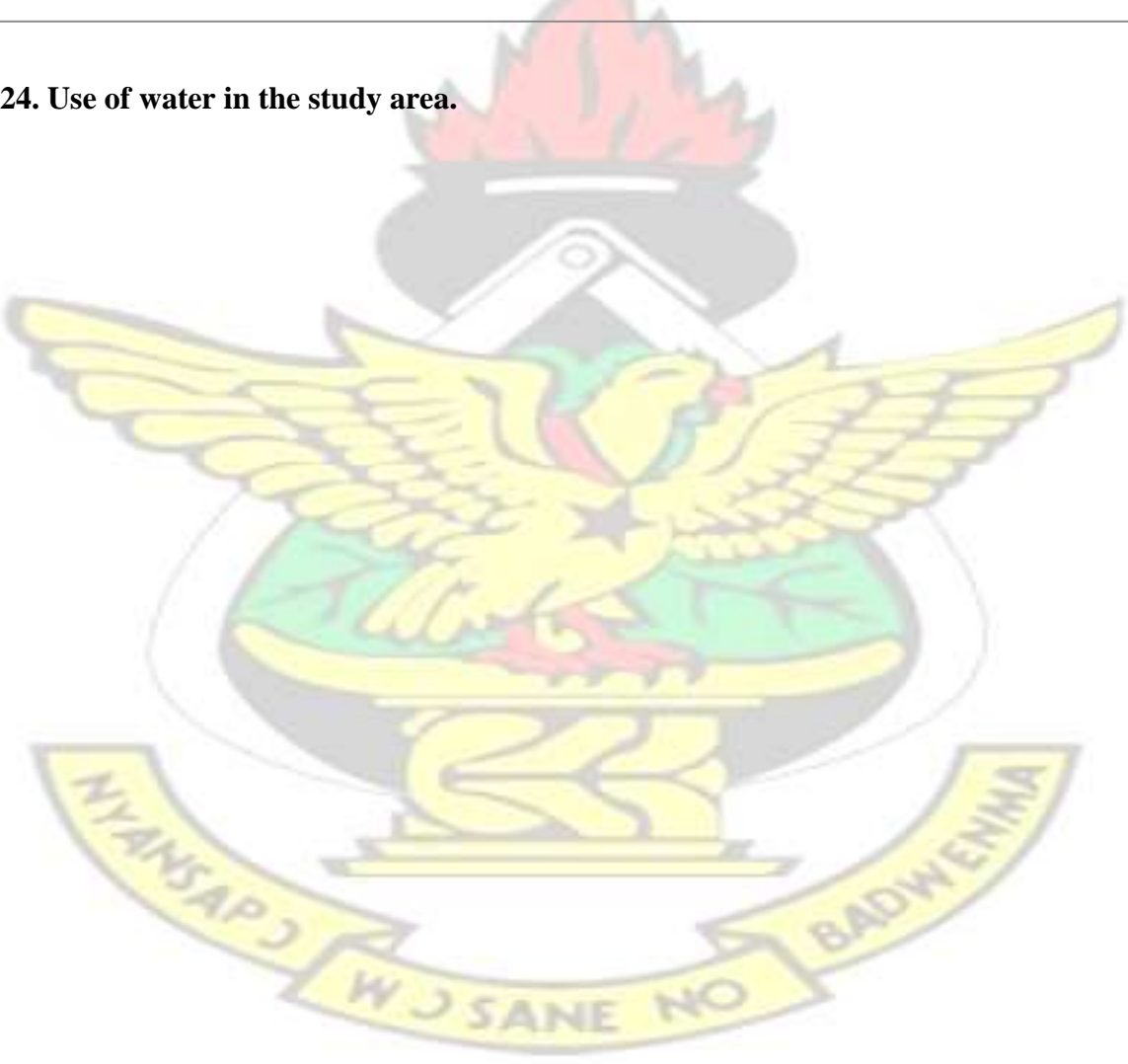


Fig 4.24. Use of water in the study area.



## CHAPTER FIVE

### DISCUSSION

#### 5.1. Temperature and pH

The water temperature did not show any significant differences in both the dry and wet seasons. The natural background limit for temperature for the World Health Organization for the purpose of public health significance is between 22 °C to 29 °C (WHO, 2010). The temperature values obtained from the water sampled from both communities in the dry and wet season were within the natural background limit. Temperature is a critical parameter of significance for aquatic ecosystem as it influences water organisms as well as the physico-chemical properties of water (Nkansah, 2010). The low temperature recorded could be due to time of sampling since the samples were taken very early in the morning. The pH of all the water samples in both dry and wet seasons were within the WHO range for potable water of 6.5-8.5. The results obtained indicated neutral to alkaline conditions and this may be attributed to the presence of higher levels of carbonate and bicarbonates ions which have very high buffering capacity and can resist acidity. These ions may have accounted for the high pH levels recorded.

#### 5.2. Conductivity, TDS, TSS, Turbidity

The conductivity of all the water samples for both the dry and wet seasons exceeded the WHO regulatory limit of 250  $\mu\text{S}/\text{cm}$ . The wet season, however, showed higher conductivity values in relation to the dry season. The high figures recorded indicated that during the wet season, the water table comes up and can easily be polluted by dissolved substances from run off. The dissolved ions were too high for human consumption and the high values obtained may also be attributed to

high levels of ionic exchange or sea water intrusions since the two communities are closer to the sea (Karikari *et al.*, 2007).

Total dissolved solids measures the total organic and inorganic matter dissolved in water samples (Efe *et al.*, 2005). The World Health organization has reported that any water with total dissolved solids above 1000 mg/l is not suitable for human consumptions (WHO, 2010). The TDS values obtained at Tuba and Kokrobite in the wet season and January in the dry season exceeded the recommended limit of 1000 mg/l. The high concentrations of TDS in the wet season could be attributed to a rise in water table which may cause dissolution of ions into the water mostly from run off containing salts, and the natural geochemistry of the area (Roy & Malenica , 2013). The TSS of the sampled water ranged from 0.4 mg/l to 1.1mg/l indicating an excellent measure of the quality of the water for human consumption. Water must have a TSS value not exceeding 500 mg/l for it to be considered safe (WHO, 2010). The figures recorded for TSS during the entire study period was far less than the recommended limit. The results obtained for TSS is consistent with that recorded by the work of Amoako *et al.*, (2011) who reported TSS in ground water to be between 1mg/l and 5 mg/l in a study conducted in Ga East District, Accra. As the water passes through the soils before finally reaching the aquifer, most of the suspended matter are effectively removed and this may have accounted for the low values obtained.

The WHO recommends the turbidity of drinking water to be not above 5NTU. Though the turbidity of the water samples in the wet season was comparatively higher than those in the dry season, they fell within the WHO permissible limit indicating an excellent measure for human consumption.

### 5.3. Dissolved Oxygen

“The World Health Organization does not have a specific guideline for dissolved oxygen in drinking water, however, provisional health based guideline value of at least 7.5mg/l have been given for the purpose of public health protection (WHO, 2010).” The dissolved oxygen was generally low in the dry seasons within the two communities. The results obtained for dissolved oxygen in this study is consistent with similar values reported for borehole water in “Western Niger Delta, Nigeria where the dissolved oxygen ranged from 3-7 mg/l” (Efe *et al*, 2005). The generally lower value of DO in the water samples may be due to high levels of oxidizable substances and also the decomposition of organic matter. One factor that significantly influences dissolved oxygen in water is salinity and the high salinity levels of the water may have contributed to the low dissolved oxygen values since the sampling area are closer to the sea. Dissolved oxygen decreases exponentially as salt levels increases (Robertson, 1992). The low DO levels may encourage anaerobic respiration activities and could lead to bad odour in the water rendering it unwholesome for human consumption.

### 5.4. Ions and Nutrients

#### 5.4.1 Chloride, Sulphate and Phosphate- Phosphorus

The WHO permissible limit for chloride in drinking water is 250 mg/l (WHO, 2010). The chloride concentrations in water samples for both the dry and wet season at Tuba and Kokrobite sampling site exceeded the recommended limit of 250 mg/l with the exception of samples that were taken in November that recorded 127 mg/l. Higher levels of chloride in water may be harmful, dependent on the available cation (ie, sodium, calcium, magnesium and potassium). The greatest effect is the salty taste it induces in water when it combines with sodium ions forming sodium

chloride in excess of 200 mg/l (WHO, 2004). The results obtained in this study agrees with a similar studies on groundwater from boreholes in the “Eastern region of Ghana where a mean chloride levels between 87.97 mg/l to 5142.1 mg/l were reported (Addo *et al.*,2012).” Chloride was also found to have a significant strong positive correlation with sodium, this is of significant health concern as higher levels of this may combine with sodium to form sodium chloride salts which induce a salty taste in the water. The results obtained confirms the findings of social survey where 75% of residents mentioned that they do not drink the water due to its high salinity level, and of those that drink it they have special filters to remove the salts. Chlorides in surface and groundwater may come from anthropogenic sources such as the use of mineral fertilizers, run off containing salts, industrial leachate, intensive irrigation, septic tank effluent, and sea water intrusion in areas close to the sea.

Sulphate is also non-toxic anion that is of significant health concern when not adequately monitored in water meant for drinking purposes. The World Health Organization recommends that water samples should not have sulphate levels higher than 250 mg/l. Higher levels of sulphate in water may cause gastrointestinal problems, dehydration, catharsis, and digestive problems (WHO, 2005). Higher levels of sulphate in water normally causes a laxative effect and also feels a bitter taste. The sulphate levels in the water for both dry and wet season were within the recommended limit of 250 mg/l. Phosphate is a limiting nutrient for algal growth and a major cause of eutrophication in surface waters. The availability of phosphate in water is an indication of human activities (anthropogenic pollution) since it is conservative in ground water resources. The phosphate level in the water sample ranged from 0.08 to 0.53 mg/l. “The WHO does not have specific guidelines for phosphates drinking water. However, Addo *et al.* (2011) reported that

phosphate concentration in most natural waters ranged from 0.005 to 0.020 mg/l. Karikari *et al.* (2007) also reported that in pristine waters phosphate concentration may be as low as 0.001mg/l.” The results obtained exceeded the recommended limit for pristine water. The levels of phosphates obtained might have arisen from the anthropogenic activities such as pit latrines and septic tanks. Phosphorus in a form of orthophosphate may be present in septic tanks and pit latrine systems due to phosphorus rich human excrement or phosphate detergents and cleaning products (Pieterse *et al.*, 2003).

The highest value of 0.78 mg/l for fluoride was recorded. The acceptable limit for fluoride concentration is 1.5 mg/l (WHO, 2010). Fluoride has an important health mitigation influence against dental caries if its value is approximately 1.0 mg/l. However, continuous or increase intake of higher concentrations in excess of 4 mg/l is likely to cause dental fluorosis and in threatening cases even skeletal fluorosis (Nkansah *et al.*, 2010). The levels recorded in this study depicts satisfactory cases in which the water samples may boost healthy teeth if the consumers drink from the well water. However, excessive fluoride consumption, will usually climaxed to teeth mottling (dental fluorosis) and some associated teeth issues.

Nitrate is a contaminant that needs to be examined in water as higher levels may cause health problems. The WHO has adopted 10 mg/l as the highest limit contaminant mark for nitratennitrogen in water. Average values of nitrate varied between 1.2 to 5.3 mg/l. Baird (1999) reported that, high levels of nitrate in water in excess of 10 mg/l are directly in relation to

Methemoglobinemia or “blue baby syndrome”. This being an acute condition which usually is associated with bottle-fed infants who are three months of age. Nitrates has also been known to

cause ailment like diarrhea and have also been suggested as a known carcinogen when it combines with amines to form nitrosamines. The nitrate concentrations obtained in this study are not alarming and fell within the recommended limit. The results obtained for nitrate is consistent with a similar findings reported by Arnade (1999) who also recorded a range between 4 to 34 mg/l in borehole water sampled in a residential household in Ibadan, Nigeria.

Alkalinity of water is its capacity and ability to resist changes in acidity. Total alkalinity for portable drinking water according to WHO (2004) is 400 mg/l. The concentrations in the water sample from the two communities were within the WHO permissible limit. Alkaline levels of 500 mg/l is accepted by the USEPA and Ghana Water Company (GWC). Alkalinity is very important because it is used in the control of pH. The major ionic species that contribute to alkalinity in water are usually carbonates, bicarbonates and hydroxides. The low levels of alkalinity recorded could be attributed to the geology of the study area since the area is characterized by sedimentary rocks comprising limestone and sandstone which is very rich in carbonates and bicarbonates ions which are capable of resisting acidity by consuming hydrogen ions in the water (Amoako *et al.*, 2011).

Salinity is a measure of the total soluble or dissolved salt in water. It is normally a measure of the total dissolved solids or the electrical conductivity of the water. WHO recommends that water that is considered to be safe for human consumption should not have salinity levels exceeding 200 mg/l as it will induce a salty taste in the water (WHO, 2004). All the water samples analyzed for the entire study period exceeded the WHO permissible limit. This confirms result obtained from the social survey where 85% of the respondents confirmed that the water was saline and as such according to the survey used the water for bathing, cooking, washing and flushing and not drinking

because of too much salt. The high salinity in the water samples may be attributed to the high levels of conductivity and total dissolved solids recorded possibly from the sea water intrusion since sea water have high salt content.

Sodium is a highly soluble chemical element that is naturally found in groundwater sources because most rocks and soils contain sodium compounds from which sodium is easily dissolved. The World Health Organization (WHO) recommends that sodium should not exceed 200 mg/l (WHO, 2010). All the water samples for both Tuba and Kokrobite fell within the WHO permissible limit of 200 mg/l. The correlation matrix revealed a very strong positive correlation between sodium and chloride ions. This is of significant health concern since the sodium and chloride could combine to form sodium chloride salt which may induce a salty taste in the water when the sodium ions exceed 200 mg/l (WHO, 2010).

Calcium and magnesium are the major ions that contribute to water hardness and are of significant concern in water quality assessment. The World Health Organization recommends that calcium and magnesium ions in water should not exceed 200 mg/l due to its ability to cause water hardness (WHO, 2010). All the water samples for both Tuba and Kokrobite were within the WHO permissible limit of 200 mg/l. A number of significant positive correlations were found between calcium and total hardness, magnesium and total hardness, calcium and sulphate.

Mean iron concentrations of water samples ranged from 0.06 mg/l to maximum of 0.21 mg/l at Tuba whilst that of Krokrobite ranged from 0.04 mg/l to a maximum of 0.28 mg/l. The iron levels recorded in the study were less than WHO permissible level of 0.3 mg/l.

## 5.5. Bacteriological parameters

For water to be considered wholesome for human use, coliform bacterial such as total coliform and faecal coliform should be zero (WHO, 2010). Most water samples had their faecal coliform counts exceeding the recommended guideline coliform indicating faecal contamination. The high faecal coliform and total coliform counts recorded for the study could be attributed to unhygienic practices associated with the water points that might have introduced coliforms. The possible sources to attribute the high faecal coliform counts could also be due to the closeness of the water sources to septic tanks and pit latrines whose leachate may contaminate the ground water supply especially in the wet season when there is increase in water table. This high coliform counts therefore pose a significant health problem to the consumers of the water if the water is used without treatment.



## **CHAPTER SIX**

### **CONCLUSION AND RECOMMENDATIONS**

#### **6.1 Conclusion**

Physico-chemical and bacteriological characteristics of water were investigated to assess the quality of borehole water in Tuba and Kokrobite communities in the Ga south Municipality. Physico-chemical parameters such as temperature, pH, turbidity, total suspended solids, dissolved oxygen, calcium, magnesium, sulphate, fluoride, alkalinity, potassium, iron and colour, nitrates were below WHO recommended limit for drinking water. Nevertheless, some parameters including conductivity, phosphates, sodium and chloride were above recommended limit set by the WHO. The bacteriological analysis indicated high levels of total coliform and faecal coliform with counts exceeding the recommended limit of zero cfu/100ml. This therefore suggests that the water had been polluted with faecal matter possibly from the septic sewage and pit latrines. The study observed septic tanks and pit latrines as major significant contaminant sources of pollution around the water sources. It was revealed in the social survey that most respondents use the borehole water for various domestic purposes such as cooking, bathing, washing and flushing whilst few use it for drinking after treatment due to its salty nature. About 85% indicated that it was saline.

#### **6.2 Recommendations**

Based on the findings of the study, some effective measures were recommended. These suggestions would ensure efficient utilization and management of groundwater.

The district assembly should educate the communities about the benefits of keeping their environments clean particularly around the water sources.

- ❖ It is recommended that boreholes should be sited few meters away from septic tank and pit latrines other potential contaminants like refuse dump within the confines of their homes.
- ❖ Hand-dug wells and boreholes were polluted by faecal matter and therefore the well and borehole owners should resort to treatment processes like boiling before using the water for domestic purposes.



## REFERENCES

- Addo, M. A., Darko, E. O., Gordon, C., Nyarko, B. J. B., & Gbadago, J. K. (2011). Heavy metal concentrations in road deposited dust at Ketu-South District, Ghana. *International Journal of Science and Technology*, 2 (1), 28-39.
- Adelana, S., Fantong, W., Nedaw, D., & Duah, A. (2011). Groundwater and Health: Meeting Unmet Needs in Sub-Saharan Africa. In J.A.A. Jones (ed.), *Sustaining Groundwater Resources*, International Year of Planet Earth, New York:NY, Springer.
- Adelana, S. M. A., & Olasehinde, P. I. (2013). High nitrate in water supply in nigeria: implications for human health. *Journal of Nigerian Association of Hydrogeologists* , 14, 1-11.
- Agbede, I. O., & Akpen, G. D. (2008). Bacteriological and physico-chemical qualities of groundwater in Makurdi metropolis. *Global J. Env. Sci.*, 7(1 & 2), 29 – 34.
- Agyenim, J. B., & Gupta, J. (2010). The Evolution of Ghana's Water Law and Policy. *Review of European Community & International Environmental Law*, 9 (3), 339-350.
- Amoako, J., Karikari, A. Y., & Ansa-Asare, O. D. (2011). Physico-chemical quality of boreholes in Densu Basin of Ghana. *Appl Water Sci.*, 1, 41–48.
- Anornu, G. K., Kortatsi, B. K., & Saeed, Z.M. (2009). Evaluation of groundwater resources potential in the Ejisu-Juaben district of Ghana. *African Journal of Environmental Science and Technology* 3 (10), 332-340.
- Ansa-Asare, O. D. (1996). Environmental impact of the production of exportable pineapples-A case study of Densu Basin. *Ghana Journal of Chemistry*, 2(1), 1–7.
- APHA. (2005). *Standard Methods for the Examination of Water and Wastewater (20 ed)*. American Public Health Association, Washington D. C., U.S.A.
- APHA (American Public Health association), (1998). *Standard methods for the examination of water and wastewater, (20th Ed.)*, American Public Health Association, American Water and Wastewater Environment Federation.
- Arnade, L. J. (1999). Seasonal correlation of well contamination and septic tank distance. *Ground water*, 37, 920–923.
- AWWA (American Water Works Association), (1998). *Water Quality and Treatment: A handbook of Community water supplies (4<sup>th</sup> ed.)*. Mc Graw Hill, Inc.USA
- Baba, A., & Tayfur, G. (2011). Groundwater contamination and its effect on health in Turkey. *Environmental Monitoring and Assessment* 183(1-4), 77-94.

- Baird, C. (1999). *Environmental Chemistry* (2<sup>nd</sup> ed.). W.H. Freeman and Company, New York
- British Pharmacopoeia, (1993). *The British Pharmacopoeia*. HMSO Publication center, London, 604-605
- Dalvie, M. A., Cairncross, E., Solomon, A., & London, L. (2003). Contamination of rural surface and groundwater by endosulfan in farming areas of the Western Cape, South Africa. *Environmental Health: A Global Access Science Source* 2003, 2(1), 1-15.
- Efe, S. I., Ogban, F. E., Horsfall, M. J., & Akporhonor, E. E. (2005). Seasonal variations of physico-chemical characteristics in water resources quality in Western Niger Delta Region, Nigeria, *J. Appl. Sci. Environ. Mgt*, 9 (1) 19.
- Ga South Municipal Assembly (2012). Municipality information. [www.gasouth.ghanadistricts.gov.gh](http://www.gasouth.ghanadistricts.gov.gh). Accessed: November, 2016.
- Gebrehiwot, A.B., Tadesse, N. & Jigar, E. (2011). Application of water quality index to assess suitability of groundwater quality for drinking purposes in Hantebet watershed, Tigray, Northern Ethiopia. *Journal of Food and Agriculture Science*, 1(1), 22-30.
- Ghana Statistical Services. (2000). 2010 National Population and Housing Census. Ghana, Accra: Ghana Publishing Corporation.
- HACH (2001). *Water quality procedures: A handbook of Community water supplies* (4<sup>th</sup> ed.). McGraw Hill, Inc. USA.
- Hantzsche, N. N., & Finnemore, E. J. (1992). Predicting ground-water nitrate–nitrogen impacts. *Ground Water.*, 30 (4), 490–499.
- Karikari, A. Y., Bernasco, J. K., & Bosque-Hamilton, E. K. A. (2007). “An Assessment of Water Quality of Augaw river in South-Eastern Coastal Plain of Ghana”. Unpublished paper, CSIR-Water Research Institute, P.O. Box M32, Accra-Ghana.
- Kortatsi, B. K. (2009). Groundwater Quality in the Wassa West District of the Western Region of Ghana. *West African Journal of Applied Ecology*, 11(1) .
- Kortatsi, B. K., Young, E. & Mensah-Bonsu, A. (2005). Potential Impact of Large Scale Abstraction on the Quality of Shallow Groundwater for Irrigation in the Keta Strip, Ghana . *West African Journal of Applied Ecology*, 8 (1).
- Kura, N., Ramli, M., Sulaiman, W., Ibrahim, S., Aris, A., & Mustapha, A. (2013). Evaluation of Factors Influencing the Groundwater Chemistry in a Small Tropical Island of Malaysia. *International Journal of Environmental Research and Public Health*, 10, 1861-1881.

- Mensah, A., Kissi, E., Krah, K., & Mireku, O. (2015). The extent of groundwater use for domestic and irrigation activities in Thiririka sub-catchment, Gatundu South District, Kiambu County, Kenya. *African Journal of Environmental Science and Technology*, 9 (6), 5195-30.
- Maughan-Brwn, T.(2010). The extent of mottled enamel in groundwater use for domestic activities in South Africa *of Environmental Science and Technology*, 12 (4), 312-410.
- Ncube, E. J. & Schutte, C.F.(2005) . The occurrence of fluoride in South African groundwater: A water quality and health problem. *Water SA*, 31 (1), 35-40.
- Nkansah, M. A., Boadi, M. O. & Badu, M. (2010). “Assessment of the Quality of Water from Hand-Dug Wells in Ghana”, *Environmental Health Insights* 4, 7–12.
- Onwuka, O. S., Uma, K. O., & Ezeigbo, H. I. (2004). Potability of shallow groundwater in Enugu town, Southeastern Nigeria. *Global J. Env. Sci.*, 3(1&2), 33 – 39.
- Pieterse, M., Bleuten, W., & Jorgensen, S. (2003). Contribution of point sources and diffuse sources to nitrogen and phosphorus loads in lowland river tributaries. *Journal of Hydrology.*, (271): 213-225.
- Pontius, F. W.(1991). Fluoride regulation and water fluoridate. *J. Am. Water Works Association*, 83 (11), 20-22.
- Razzolini, M., Günther, W., Peternella, F., Martone-Rocha, S., Bastos, V., Santos, T., & Cardoso, M. (2011). Quality of water sources used as drinking water in a Brazilian periurban area. *Brazilian Journal of Microbiology*, 42, 560-566.
- Robertson, W. D., & Cherry, J. A. (1992). Hydrogeology of an unconfined sand aquifer and its effect on the behavior of nitrogen from a large-flux septic system. *Applied Hydrogeology* 1, 32–44.
- Roy, D. & Malenica, D. K. (2013). Seasonal study physico-chemical parameters of groundwater in industrial area, Jaipur. *Hydrology Journal*, 7(5), 431-439
- Samlafo, B. V., Bobobee, L. H. , Quarshie, E., Sarsah, L. A., & Kaka, E. A. (2015). Quality assessment of groundwater from Avenorfeme: Akatsi District, Ghana, *International Journal of Innovative Research and Development*, 4 (12), 126-139.
- Sarpong, G. A.(2008).*Customary Water Laws and Practices*. Food and Agricultural Organization Retrieved from <http://www.fao.org/Legal/advserv/FAOIUCNcs/Ghana.pdf>

- Schafer, A.I., Rossiter, H.M., Owusu, P.A., Richards, B.S., & Awuah, E. (2009). Physicochemical water quality in Ghana: prospects for water supply technology implementation. *Desalination*, 248 , 193–203.
- Tay, C. & Kortatsi, B. (2008). Groundwater Quality Studies: A Case Study of the Densu Basin, Ghana. *West African Journal of Applied Ecology*, 12.
- Tay, C. K. (2007). Chemical Characteristics of Groundwater in the Akatsi and Ketu Districts of the Volta Region, Ghana. *West African Journal of Applied Ecology*, 11(1).
- Tay, C., & Kortatsi, B., (2008). Groundwater Quality Studies: A Case Study of the Densu Basin, Ghana *West African Journal of Applied Ecology*, Vol. 12, 2008.
- The Water Project (2016). Facts about water: statistics of the water crisis. Why Water? ...By the numbers (Last Update: 8/31/2016). Retrieved from [https://thewaterproject.org/waterscarcity/water\\_stats](https://thewaterproject.org/waterscarcity/water_stats).
- U. S.Environmental Protection Agency (1993).Getting Up to Speed:Ground Water Contamination, adapted from US EPA Seminar Publication. Wellhead Protection:A Guide for Small Communities Chapter 3 EPA/625/R-93/002 <https://www.epa.gov/sites/production/files/2015-08/documents/mgwc-gwc1.pdf>
- U.S. Geological Survey (2016). Contaminants found in groundwater. Retrieved from <http://water.usgs.gov/edu/groundwater-contaminants.html>.
- UNESCO. (2001). Integrated drought management: Lessons for sub-Saharan Africa. Brochure with summary and recommendations of 1999 International Drought Conference, Pretoria, September.
- United Nations Environment Programme (2003). Groundwater and its susceptibility to degradation: A global assessment of the problem and options for management. Retrieved from [www.unep.org/dewa/Portals/67/pdf/Groundwater\\_INC\\_cover.pdf](http://www.unep.org/dewa/Portals/67/pdf/Groundwater_INC_cover.pdf)
- Water Resources Commission (2001). Annual Report, 2001. Water Resources Institute, Accra.
- WHO (1998). *Guidelines for drinking-water quality (2nd ed addendum to vol.2)*. Health Criteria and other supporting information. World Health Organization, Geneva, Switzerland .
- WHO and UNICEF Joint Monitoring Programme (2008).Progress on Drinking Water and Sanitation: Special Focus on Sanitation, UNICEF, New York and WHO, Geneva.

WHO (2004).Guidelines for Drinking water quality, Volume 1:Recommendations.WHO, Geneva, 2<sup>nd</sup> Edition, World Health Organization, Geneva, 88.

WHO (2005). Global Water Supply and Sanitation Assessment Report. Geneva, World Health Organization. 94 4156201.

WHO (1997). Guidelines for drinking water quality. Recommendations, Vol. 1, second ed. World Health Organization, Geneva, Switzerland.

WHO (2008). Guidelines for drinking-water quality, third edition, incorporating the first and second addenda volume 1, Recommendations. WHO, Geneva

WHO (2010). Guidelines for drinking-water quality, third edition, incorporating the first and second addenda volume 1, Recommendations. WHO, Geneva

WHO (2015). WHO/UNICEF Joint Monitoring Programme. Key Facts from JMP 2015 Report.

WHO (2016). WHO/UNICEF Joint Monitoring Programme. Key Facts from JMP 2016 Report.

WHO/UNICEF (2010). Global Water Supply and Sanitation Assessment Report. Geneva, World Health Organization. 94 4156201.



## APPENDICES

### APPENDIX 1: Mean data for physico-chemical and microbiological parameters

	Temp (°C)	pH	COND $\mu\text{S}/\text{cm}$	TDS (mg/l)	TURBIDITY (NTU)

MONTH	TB	KB	TB	KB	TB	KB	TB	KB	TB	KB
DEC	28.05	27.30	7.57	7.24	1826.80	887.46	908.33	887.47	0.48	0.32
JAN	28.05	27.26	6.98	7.22	1590.47	1404.33	870.73	1404.30	0.50	0.59
MAY	27.30	27.67	7.57	7.92	7007.00	2790.27	4882.50	1752.40	0.48	1.37
JUNE	26.77	27.28	7.29	7.39	6943.00	1695.20	4570.90	1038.90	0.85	1.50
<b>MAX</b>	28.05	27.67	7.57	7.92	7007.00	2790.27	4882.50	1752.40	0.85	1.50
<b>MIN</b>	26.77	27.26	6.98	7.22	1590.47	887.47	870.73	887.47	0.48	0.32

	NO <sub>3</sub> -N (mg/l)		PO <sub>4</sub> -P (mg/l)		SO <sub>4</sub> (mg/l)		DO (mg/l)		Mg (mg/l)	
MONTH	TB	KB	TB	KB	TB	KB	TB	KB	TB	KB
DEC	1.58	5.28	0.08	0.53	94.26	21.27	6.84	0.80	15.04	10.02
JAN	1.54	1.20	0.09	0.14	94.73	24.33	6.87	5.93	15.11	11.98
MAY	1.17	1.78	0.14	0.22	156.13	86.80	5.71	4.91	15.04	90.44
JUNE	2.01	1.53	0.27	0.20	86.80	94.46	6.44	5.06	17.42	79.84
<b>MAX</b>	2.01	5.28	0.27	0.53	156.13	94.47	6.87	5.93	17.42	90.44
<b>MIN</b>	1.17	1.21	0.08	0.14	86.80	21.27	5.71	0.80	15.04	10.02

	Ca (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	F (mg/l)

MONTH	TB	KB	TB	KB	TB	KB	TB	KB	TB	KB
DEC	95.36	88.74	194.70	458.70	0.21	6.42	0.21	0.04	0.58	0.09
JAN	121.53	29.41	248.20	176.70	10.29	8.29	0.11	0.11	0.65	0.78
MAY	178.25	90.44	554.10	116.90	9.51	13.73	0.06	0.06	0.65	0.69
JUNE	172.60	79.84	582.70	60.85	11.92	15.09	0.11	0.27	0.57	0.62
<b>MAX</b>	178.24	90.44	582.70	458.70	11.92	15.09	0.21	0.27	0.65	0.78
<b>MIN</b>	95.36	29.41	194.70	60.85	0.21	6.42	0.06	0.04	0.57	0.09

MONTH	Colour ( Pt.co)		TSS (mg/l)		TC (cfu/100ml)		FC (cfu/100ml)	
	TB	KB	TB	KB	TB	KB	TB	KB
DEC	1.67	1.37	1.07	1.06	2.13	1.66	0.00	0.71
JAN	2.13	0.80	0.73	1.13	1.80	1.73	0.47	0.60
MAY	2.73	0.73	0.40	0.93	1.13	3.47	0.00	0.80
JUNE	1.33	0.53	0.93	0.80	1.66	3.07	0.2	0.80
<b>MAX</b>	2.73	1.37	1.06	1.13	2.13	3.46	0.46	0.80
<b>MIN</b>	1.33	0.53	0.40	0.80	1.13	1.67	0.00	0.60

**APPENDIX 2: QUESTIONNAIRE**

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY MSc.**

**ENVIRONMENTAL SCIENCE**

**TOPIC: ASSESSMENT OF GROUND WATER QUALITY IN KOKROBITE AND TUBAH TOWNSHIP IN THE GA SOUTH MUNICIPAL ASSEMBLY (GSMA) IN THE GREATER ACCRA REGION.**

INTRODUCTION: The administration of this questionnaire is to solicit responses from households and community members in order to assess ground water quality in kokrobite and Tuba township in the Ga South Municipal Assembly (GSMA) in the Greater Accra Region. All the information is strictly for academic purposes and will be highly treated with the greatest level of confidentiality.

Date.....

Locality.....

Interviewer.....

**PART A: DEMOGRAPHIC INFORMATION OF RESPONDENTS**

1 .House number.....

2. Sex  male  female

3. Age  <20yrs  20-29 yrs  30-39yrs  40-49yrs  50-59 yrs  >60yrs

5. Marital status  single  married  divorced  widowed

6. Occupation  Farming  trading  public service  Fishing Others

7. Level of Education

None  primary/JSS  SSS/6<sup>th</sup> Form  Tertiary  Non-Formal

**PART B. KNOWLEDGE OF RESPONDENT.**

8. Do you have a water facility in your house  Yes  No

8a. .if yes what type of water facility  Borehole  Hand dug well  pipeborne

8b. if no where do you or people without water access water?

Borehole  Hand dug well  pipe borne streams

9. What is the nature of the water from the well or borehole?

Turbid     Saline     Clear     coloured     others/specify

10. What human activities do you observe around the water source?

Washing of automobiles     washing clothes     refuse dumping     others, specify.....

**PART C. ATTITUDE AND PERCEPTION OF RESPONDENTS**

11. What source of water do you prefer for household use?

Ground water     Rain water     Surface water     pipeborne

12. (b) Give reasons for your response in 11(a) above .....

13. What do you use the water for? Tick as many as applied to you.

Washing     Cooking     Drinking     Bathing     Flushing

**PART D. SANITATION RELATED CONDITIONS**

14. (a) DO you have any refuse dump, septic tank, pit latrines in your house or community?

Yes     No

25(b) if no where do you dump your refuse?

Backyard     burning     composting     others/specify

**Thank you.**

