

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

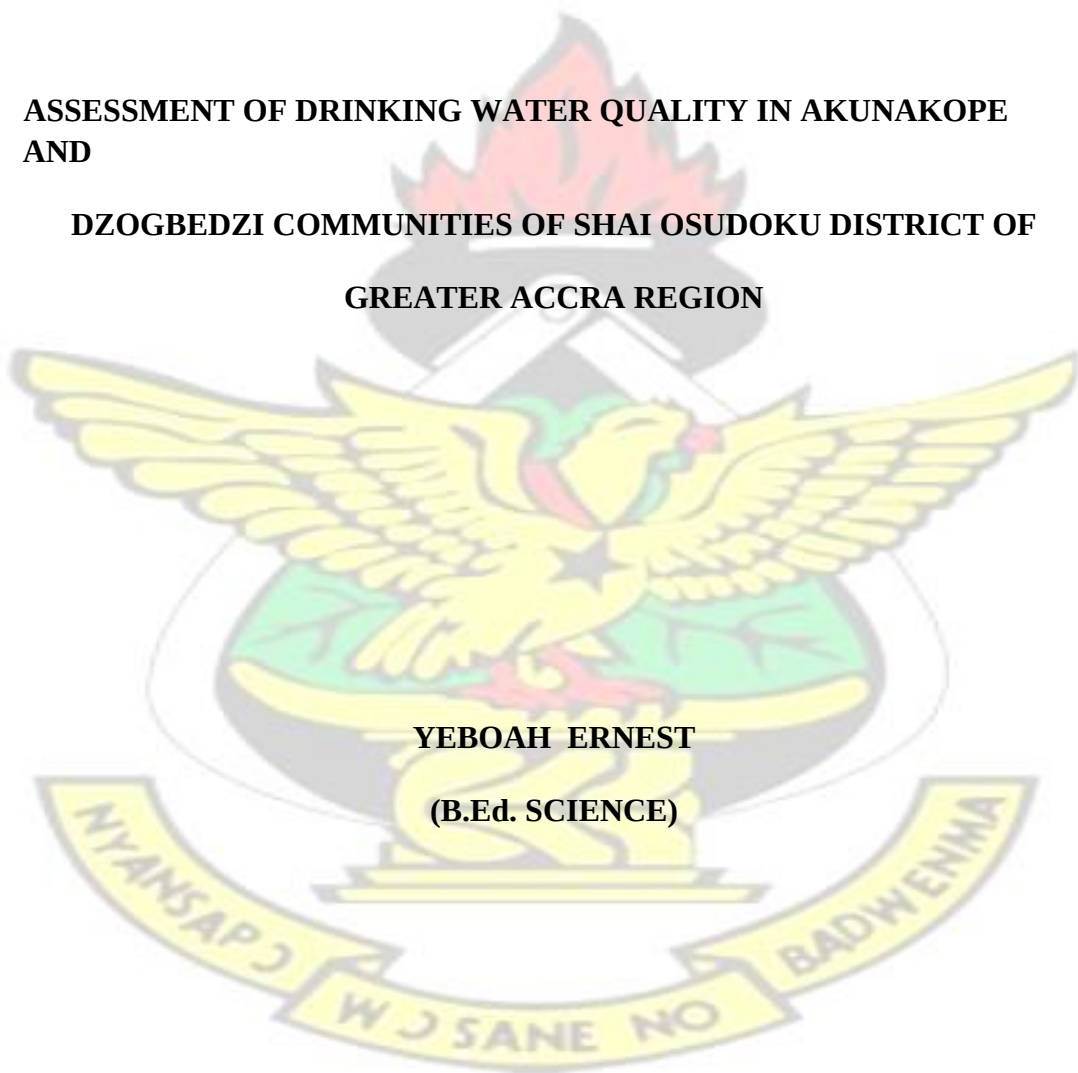
KNUST

**ASSESSMENT OF DRINKING WATER QUALITY IN AKUNAKOPE
AND**

**DZOGBEDZI COMMUNITIES OF SHAI OSUDOKU DISTRICT OF
GREATER ACCRA REGION**

YEBOAH ERNEST

(B.Ed. SCIENCE)



NOVEMBER, 2018

**ASSESSMENT OF DRINKING WATER QUALITY IN AKUNAKOPE AND
DZOGBEDZI COMMUNITIES OF SHAI OSUDOKU DISTRICT OF
GREATER ACCRA REGION**

KNUST

**BY
YEBOAH ERNEST
(B.Ed. SCIENCE)**

**A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND
APPLIED BIOLOGY, KWAME NKRUMAH UNIVERSITY OF SCIENCE
AND TECHNOLOGY, KUMASI, IN PARTIAL FULFILMENT OF
THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN
ENVIRONMENTAL SCIENCE**

SEPTEMBER, 2018

DECLARATION

I testify that this research work was carried out entirely by me in the Department of Theoretical and Applied Biology, KNUST. This thesis has never been presented, either in part or in whole, for the award of a degree in this University or any other institution. All cited works and assistance have been fully acknowledged.

YEBOAH ERNEST

(Student)

Signature

Date

MR. ALFRED K. APETORGBOR

(Supervisor)

Signature

Date

PROF. M. G. ADDO

(Head of Department)

Signature

Date

DEDICATION

This research is dedicated to my lovely wife, Joyce Acheampong and children, Curtis Asante Yeboah, Adwoa Twumwaa Yeboah and Kweku Asante Yeboah.

ACKNOWLEDGEMENTS

I render great appreciation to my supervisor, Mr. Alfred K. Apetorgbor of the Department of Theoretical and Applied Biology, KNUST for his constructive criticisms, guidance and encouragement during the preparation of this research report.

I am equally thankful to Mr. Emmanuel Ansah, Institute of Environmental and Sanitation Studies, University of Ghana, Legon and the entire people of Akunakope and Dzogbedzi communities for their enormous support.

I wish to also express my profound appreciation to Messrs. Richard Akpanglo-Nartey, Maxwell Agyapong and Daniel Martey all of Mount Mary College of Education, Somanya, for their material support and encouragement.

ABSTRACT

Lack of potable drinking water and basic sanitation system is a severe concern in Ghana, and as a result households without access to potable water are forced to use less reliable and less hygienic water sources contributing to most water related diseases. Investigations were conducted to assess the drinking water quality of boreholes and surface water in the Akunakope and Dzogbedzi communities of the Shai Osudoku District of the Greater Accra Region, Ghana. The geographical locations of the boreholes and the surface water were determined using global positioning satellite (GPS). Water quality analyses of some physic - chemical and bacteriological parameters were carried out on the water samples. The social survey revealed that 83% of the respondents perceived their water sources for drinking as poor and attributed

farming along the banks of the water body, indiscriminate dumping of waste in and around the water body and bathing/washing in the water body as the major contributing causes. Turbidity, colour, EC, TDS, TSS, total alkalinity, total hardness, bicarbonates, nitrates, chlorides, sulphate, fluoride, calcium, sodium, potassium, magnesium and total iron values for the surface water samples were significantly higher as compared to those in the boreholes. However, with the exception of EC, temperature, chloride and turbidity whose levels in both surface water and borehole far exceeded the WHO guideline values for drinking water, all other physico-chemical parameters were within the WHO recommended limits. No total coliform or faecal coliform counts were detected from the borehole water samples during the entire study period. The surface water, however recorded total coliform counts which ranged from 630 ± 20.8 – 1115 ± 73.5 cfu/100ml and faecal coliform (120 ± 54.2 - 292.5 ± 10.5 cfu/100ml) which far exceeded the WHO recommended limit. This study therefore accentuates the need to treat the water sources before drinking or using for domestic purpose because of the high microbial counts.

TABLE OF CONTENTS

DECLARATION	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES	xii
LIST OF FIGURES	xiii

LIST OF PLATES	xiv
CHAPTER ONE	
1 INTRODUCTION	1
1.1 Background	1
1.2 Statement of Problem	2
1.3 Justification	3
1.4 Objectives	4
1.4.1 Main objective	4
1.4.2 Specific objectives	4
CHAPTER TWO	
6 LITERATURE REVIEW	6
2.1 Introduction	6
CHAPTER THREE	35
MATERIALS AND METHODS	35
3.1 Study Area.....	35

3.2 Research Methodology	37
3.3 Sampling sites	40
3.4 Social and Sanitation Survey	41
3.5 Collection and processing of water samples	42
3.6 Water quality assessment	42
3.7 Determination of physico – chemical parameters	43
3.7.1 Temperature, pH, and Conductivity	43
3.7.2 Turbidity	43
3.7.3 Colour	43
3.7.4 Total Dissolved Solids (TDS)	43
3.7.5 Fluoride	44
3.7.6 Total Suspended Solids	44
3.7.7 Hardness (CaCO_3)	45
3.8 Nutrients	45
3.8.1 Nitrate - Nitrogen (NO_3^- -N)	45

3.8.2 Nitrite -Nitrogen (NO_2^- -N)	46
3.8.3 Phosphate (PO_4^{3-} – P)	46
3.8.4 Sulphate (SO_4^{2-})	46
3.9 Metals	47
3.9.1 Pre-Treatment of Samples	47
3.9.2 Atomic Absorption Spectroscopy	48
3.10 Total Iron	48
3.11 Bacteriological analyses	49
3.11.1 Total and faecal coliforms	49
CHAPTER FOUR	51
RESULTS	51
4.1 Social and Sanitation Survey	51
4.1.1 Background of respondents	51
4.1.2 Sources of water for drinking and domestic purpose	53

4.1.3 People's perception on the quality of water they consume	55
4.2 Physico-chemical parameters	62
4.2.1 Temperature	62
4.2.2 Turbidity ..	63
4.2.3 Colour	64
4.2.4 Electrical Conductivity	64
4.2.5 Total Dissolved Solids (TDS)	65
4.2.6 Total Suspended Solids	66
4.2.7 pH	67
4.2.8 Total Alkalinity	67
4.2.9 Total Hardness and Bicarbonates	68
4.2.10 Nitrate ...	68
4.2.11 Nitrite	69

4.2.12	Phosphate	6
	9	
4.2.13	Chloride	69
4.2.14	Fluoride	70
4.2.15	Sulphate	70
4.2.15	Calcium, Sodium, Potassium and Magnesium	71
4.2.16	Total Iron	72
4.20	Correlation between physico-chemical parameters	73
4.3	Bacteriological parameters	73
4.3.1	Total Coliform (TC)	73
4.3. 2	Faecal coliform	74
CHAPTER FIVE		75
DISCUSSIONS		75
5.1	Social and Sanitation Survey on Perception of Inhabitants on Water Quality	75
5.2	Physico-chemical Parameters	76

5.2.1 Temperature, Turbidity and Colour	76
5.2.2 Total Dissolved Solids, Electrical Conductivity and Total Suspended Solids	77
5.2. 3. pH, Total Alkalinity, Total Hardness and Bicarbonate	78
5.2.4 Nitrate, Phosphate and Nitrite	79
5.2.5 Chloride, Fluoride and Sulphate	80
5.2.6 Calcium, Sodium, Potassium and Magnesium	81
5.2.7 Total Iron and Manganese	82
5.3 Bacteriological parameters	82
CHAPTER SIX	84
CONCLUSION AND RECOMMENDATIONS	84
6.1 CONCLUSION	84
6.2 RECOMMENDATIONS	85
LIST OF REFERENCES	87
APPENDICES	94
APPENDIX A :Questionnaire for residents of Akunakope and Dzogbedzi	94
APPENDIX B : Drinking water standard of WHO, USEPA, EU and Ghana.	99

Appendix C: Raw data for physico-chemical and bacteriological parameters	100
APPENDIX C1: Total coliform at the sampling site	100
APPENDIX C2: Faecal coliform at the sampling site	100
APPENDIX C 3: Temperature at the sampling site	100
APPENDIX C4: Turbidity at the sampling site	101
APPENDIX C5: Colour of water at the sampling site	101
APPENDIX C6: Electrical conductivity at the sampling site	101
APPENDIX C7 : Total dissolved solids at the sampling site	102
APPENDIX C8: Total suspended solids at the sampling site	102
APPENDIX C9: pH at the sampling site	102
APPENDIX C10: Total Alkalinity at the sampling site	102
APPENDIX C11: Total Hardness and Bicarbonates at the sampling site	103
APPENDIX C12: Nitrate at the sampling site	103
APPENDIX C13: Nitrite at the sampling site	103

APPENDIX C14: Phosphate(mg/l) at the sampling site	104
APPENDIX C15: Chloride (mg/l) at the sampling site	104
APPENDIX C16: Fluoride (mg/l) at the sampling site	104
APPENDIX C17: Sulphate(mg/l) at the sampling site	104
APPENDIX C18: Calcium(mg/l) at the sampling sites	105
APPENDIX C19: Sodium (mg/l) at the sampling site	105
APPENDIX C20: Magnesium(mg/l) at the sampling sites	105
APPENDIX C21: Potassium (mg/l) at the sampling sites	106
APPENDIX C22: Total iron (mg/l) at the sampling site	106
APPENDIX C23: Manganese (mg/l) at the sampling site	106
Appendix D : Differences in physico-chemical parameters between borehole and surface water samples.	107
Appendix D Cont'd: Differences in physico-chemical parameters between borehole and surface water sample.	107
Appendix E : Differences in heavy metal between borehole and surface water sample.	108
Appendix F : ANOVA showing differences in bacteriological parameters between borehole and surface water sample samples.....	108

KNUST

LIST OF TABLES

TABLE 3.1 Sampling sites and their GPS locations.	41
TABLE 4.1 Demographic characteristics of respondents in the study area	52
TABLE 4.2: Distance of respondent's house to water source	54
TABLE 4.3: Respondents views on use of water	55
TABLE 4.4. Respondents views on factors that contribute to the changes in water colour	57
TABLE 4.5: Respondents views on authorities to be responsible for water protection	58
TABLE 4.6: Respondents views on measures to put in place to protect water sources	59
TABLE 4.7: Suggested waste disposal methods by respondents in the study area	59
TABLE 4.8 Views of respondents on diseases that can be attributed to pollution of water bodies	60
TABLE 4.9: Respondents suggestions to address water pollution	62

LIST OF FIGURES

FIG 3.1 Map of study area showing sampling locations	36
FIGURE 4.1 Respondents length of stay in the study area	53

FIGURE 4.2 Source of drinking water for people in the study area.	53
FIGURE 4.3 Seasons when residents rely on irrigation canal most.	55
FIGURE 4.4 Perception of quality of water from various sources by respondent	56
FIGURE 4.5: Respondents views on colour of water used	56
FIGURE 4.6 Mean temperature values of water samples at sampling sites	63
FIGURE 4.7: Mean turbidity values of water samples at sampling sites	63
FIGURE 4.10: Mean TDS values of water samples at sampling sites	66
FIGURE 4.11: Mean TSS values of water samples at sampling sites	66
FIGURE 4.12: Mean pH values of water samples at sampling sites	67
FIGURE 4.13: Mean total alkalinity values of water samples at sampling sites	68
FIGURE 4.15: Mean nitrate levels of water samples at sampling sites.....	69
FIGURE 4.16: Mean chloride levels in water samples at sampling sites	70
FIGURE 4.17: Mean sulphate levels in water samples at sampling sites	71
FIGURE 4.18: Mean total coliform counts in water samples at sampling sites	74
FIGURE 4.19 Mean faecal coliform counts in water samples at sampling sites	74

LIST OF PLATES

PLATE 1. A BOREHOLE AT AKUNAKOPE	38
PLATE 2: A LAKE AT AKUNAKOPE	38
PLATE 3:A CANAL AT AKUNAKOPE	38
PLATE 4: A BOREHOLE AT DZOGBEDZI.....	39
PLATE 5: A LAKE AT DZOGBEDZI	39
PLATE 6: A CANAL AT DZOGBEDZI	40

KNUST



CHAPTER ONE

INTRODUCTION

1.1 Background

Water is very necessary both for sustainable human development and for the healthy functioning of the planet's ecosystem (Adjomah, 2010). Its availability is an essential component in socio-economic development and poverty reduction. To safeguard this, the World community in the report of World Health Organization (WHO, 2005) committed itself to halve by 2015 the population of people without sustainable access to safe drinking water and basic sanitation.

In Ghana water is a major component of development and is linked to all eight of the MDGs (GoG, 2007). Unfortunately as is the case in most parts of sub-Saharan Africa, water demands far outstrip supply. Several problems have been encountered in Ghana concerning the use of water and this may include; scarceness, unavailability, contamination, crisis in homes, farming as well as production (Adjomah, 2010). The lack of potable drinking water and basic sanitation system is a severe concern in Ghana, contributing to 70% of diseases in the nation. Thus households without access to potable water are forced to use less reliable and less hygienic water sources (African Economic Outlook, 2007).

The main sources of water for households in Ghana are piped supply from treated water sources, untreated piped water from groundwater sources such as boreholes, and wells, surface water like springs, lakes, rivers and streams. Water from these sources, apart from treated piped water, may be microbiologically unsafe for drinking purposes. Microbial hazards are said to present an overall greater threat than chemical hazards and in developing countries it accounts for 5.7% of the global burden of diseases

(Larmie and Paintsil, 1996). The lack of microbiologically safe drinking water and adequate sanitation measures lead to a number of diseases such as salmonellosis, cholera and dysentery.

In the rural communities where 57% of Ghana's population lives, the sources of water for drinking are mostly groundwater in the form of boreholes and wells, springs, lakes, rivers and streams (Ghana Statistical Service, 2005). These sources according to World Health Organizations (2004) are mostly contaminated with disease vectors, pathogens and unacceptable levels of dissolved chemical and suspended solids, and using such water for domestic purposes leads to wide spread of acute and chronic illnesses and major cause of death in most developing countries.

1.2 Statement of Problem

Most of Ghana's water resources in recent times have come under threat of pollution from industrial and domestic wastes. Studies show that the quality of groundwater is generally good; however, samples of water taken from some boreholes recorded up to 41.5 mg/l and 10.0 mg/l concentrations of iron and manganese respectively (CWSA, 2007). Because of this about 40% of drilled wells with high manganese or iron levels have been abandoned by user communities while 60% use the water for purposes like laundry and washing of domestic items (CWSA, 2007).

The development of some water resources, dams and irrigation canals, has also led to some health problems especially for people living in and around those projects. These health problems include outbreak of diarrhoea, filariasis, malaria, bilharziasis and onchocerciasis. People living in communities around the lower Volta, precisely in the

Volta, Eastern and Greater Accra Regions, are at risk to water related diseases associated with the development of the Akuse Dam (Adjomah, 2010).

According to the National Community Water and Sanitation Programme (NCWSP), the Shai Osudoku District has achieved about 66% water coverage with 34% of the population lacking access to potable water supply. This situation has compelled most of the people to rely on alternative sources of water (DWDA, 2006). The inhabitants of Asutuare and its environs especially those in Akunakope and Dzogbedzi communities who depend on the raw water from the Volta Lake for rice production, rely on unprotected and unsafe water sources such as irrigation canals, streams, lakes (Lukpe and Kasu), and wells for domestic purposes. Boreholes, wells, lakes, streams and rivers may contain pathogens and unacceptable levels of dissolved and suspended solids (WHO, 2011). This study sought to assess the quality of the various sources of water available for these two communities.

1.3 Justification

Drinking unsafe water leads to the deaths of an estimated 1.5 million children under the age of five each year. Lack of access to safe water, sanitation and hygiene affects the health, security and livelihood and the quality of life of children, impacting women and girls the most (WHO, 2010; UNICEF, 2010). Most water resources in Ghana currently have come under the threat of pollution from industrial, solid, liquid and chemical wastes causing damage to human health and the environment. Hence, researching into drinking water quality may reduce the serious health and environmental risks on people who rely on river, lake, borehole and irrigation water for domestic purposes such as drinking and cooking.

The Ghana Water Company Limited and the Community Water and Sanitation Agency supply potable water to Shai Osudoku District. It is estimated that 34% of the inhabitants in the 231 settlements have no access to potable water. A total 18 towns have access to pipe borne water while the inhabitants in the remaining towns depend on unprotected and unsafe wells, and other sources of water, making them vulnerable to water borne diseases. These other sources are, sometimes, not hygienically good for domestic use (SODA, 2012).

The findings of this research will provide additional guidelines regarding the need to continuously monitor the quality of water within the district. The findings of the study would help the District Assembly to know the state of drinking water sources in the communities and take appropriate measures.

1.4 Objectives

1.4.1 Main objective

The general objective of the research was to measure the quality of drinking water sources used by farmers in Akunakope and Dzogbedzi communities in the Shai Osudoku District of the Greater Accra Region.

1.4.2 Specific objectives

The specific objectives were:

- To assess the perception of the inhabitants on the quality of water available for drinking.
- To assess the physico-chemical quality of the drinking water (Temperature,

Turbidity, Colour, Total Dissolved Solid, Total Suspended Solids, pH, Alkalinity, Total Hardness, Bicarbonate, Chloride, Fluoride, Calcium, Total Iron and Manganese) in the Akunakope and Dzogbedzi communities.

- To determine the microbial quality of water from boreholes, irrigation canal and lake used for drinking in the Akunakope and Dzogbedzi communities.



CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Franceys and Gerlach (2008) assert that water is an economic good as well as a basic need critical for health and social welfare. Drinking water or potable water is defined as having acceptable quantity in terms of its physical, chemical, biological and acceptability parameters so that it can be safely used for drinking and cooking (WHO, 2008).

2.2 Global Stressors on the Quality of Drinking Water Supply and Sanitation in the Developing World.

Water is a basic human need and access to minimum quantities of safe water (50 litres per person per day) should be everyone's right. Lack of access to safe drinking water and proper sanitation is directly related to poverty and poor health. WHO data shows that average water consumption in 33 countries in Africa stands at 35 litres per person per day, a figure seen to be far below the minimum average requirement of 50 litres per person per day (WHO, 2008). Safe drinking water and sanitation is the biggest problem for all developing countries which is being further accelerated due to several physical and social catalysts (Nyambod and Nazmul, 2010).

Developing countries often have less capacity to improve water quality and depend on lower-quality water for a variety of uses; including drinking water (Zimmerman *et al.*, 2008). Supplying potable water has become a formidable problem in the rapidly expanding population in the developing world. Most rural and poor urban communities in developing countries do not have household pipe connections which supply potable

water directly on sustained basis. Consequently, many fetch water from rivers, streams, ponds, dugout wells and other sources for household use and for drinking (Amedzeame, 2004).

In most communities of the world, the aquatic environments are damaged by a variety of substances such as heavy metals, chemicals, high nutrient concentrations, large quantities of organic compounds and other pollutants. Chemicals may reach rivers as a result of point and non-point source discharge and these pollutants may be transported either by water or air from nearby or distant discharge points. The negative impacts of pollutants may be limited to a water body or to a specific organism. Also pollutants in water bodies often cause chronic and acute problems for the affected organisms, making detection far more difficult (Amedzeame, 2004).

2.3 Stressors on the Quality of Drinking Water Supply and Sanitation in Ghana.

The health status of a community and the wellbeing of its residents are dependent on the availability of and access to quality and affordable water and sanitation services. Estimates indicated that up to 40% of the Ghanaian population do not have direct access to potable and safe drinking water. Ghana Vision 2020, which aims at transforming Ghana into a middle income country with safe water supplies, high rates of industrial growth and an expanded and accelerated agricultural sector is based on the availability and efficient management of water resources, and would be expected to put further pressure on water use. Water brings three main issues in developing countries. These include public health, economic and socio-economic issues. It is estimated that about 4 million people die of water borne diseases, including 2 million children who die from diarrhoea (UNFPA, 2002).

Ghana has waste management difficulties that extend from the metropolitan, municipal, district, through to the local communities, and refuse dumps of all shapes and sizes are common sites in both urban and rural areas. Water pollution is another important potential outcome of inappropriately managed waste. The unregulated leachants from refuse near waterways increase the technical difficulty of providing potable water and subject city residents to urban flooding risk. Urban floods occur when drainage systems and other storm control devices overflow because of waterway blockages (Nyambod and Nazmul, 2010). Indiscriminate dumping and refuse overflow at CCCs can all be sources of drainage blockage. While it is true that seasonal rains can cause flooding in all parts of Accra, the poorer residences with their weaker drainage infrastructure are more likely to experience flood damage (Thompson, 2010).

2.4 Categories of Water Usage

The parameters for water quality are determined by the intended use. Work in the area of water quality tends to be focused on water that is treated for human consumption or in the environment

2.5 Human Consumption

Contaminants that may be in untreated water include microorganisms such as viruses and bacteria; inorganic contaminants such as salts and metals; pesticides and herbicides; organic chemical contaminants from industrial processes and petroleum use; and radioactive contaminants. Water quality depends on the local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, use of water bodies as a heat sink, and over use which may lower the level of the water.

The Environmental Protection Agency (EPA) limits the amounts of certain contaminants in tap water provided by public water systems. The Safe Drinking Water Act authorizes EPA to issue two types of standards: primary standards regulate substances that potentially affect human health, and secondary standards prescribe aesthetic qualities, those that affect taste, odour, or appearance. The Food and Drug Authority (FDA) regulations establish limits for contaminants in bottled water that must provide the same protection for public health. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of these contaminants does not necessarily indicate that the water poses a health risk (Baird, 2000).

2.6 Drinking Water Quality

The importance of drinking water quality has been enhanced in the last few years by increased awareness and attendant publicity afforded to the pollution of water courses, estuaries and coastal areas (Shaw, 1998). Globally, the UN declared an International Drinking water supply and Sanitation Decade between 1981 and 1991. Thus, Ghana was provided the impetus to identify and provide solutions to the problems of existing water supply and sanitation systems and also expand coverage so that more people would enjoy the benefits of good drinking water and adequate sanitation (Water Resource Institute, 1998). In the USA, the quality of drinking water is regulated by the safe Drinking Water Act of 1974, as amended in 1977 and 1986; it gives the EPA authority to set national standards to protect drinking water. These standards represent maximum contaminant levels (MCL) allowable and consist of numerical criteria for specified contaminants (Buchholz, 1993).

Water supplies, especially in developing countries, have been focused on quantity at the expense of quality and there are calls for marked improvement in quality and better management of chemicals and microorganism content (Barrow, 2005). In assessing the quality of drinking water, most consumers usually rely completely upon their senses. Water constituents may affect the appearance, smell or taste of water, thus, the consumer evaluates the quality and acceptability essentially on these criteria. However, we can no longer rely entirely upon our senses in the matter of quality judgment. The absence of any adverse sensory effects therefore does not guarantee the safety of drinking water.

In the submission on the drinking water quality control in small community supplies, WHO explains that although in the rural areas of developing countries, it is expected that a great majority of water quality problems are related to bacteriological contamination, a significant number of very serious problems may occur as a result of chemical contamination of water sources from agricultural practices and malpractices. The traditional emphasis on chemical indicators of water quality must be supplemented by more comprehensive indicators based on the total properties of water body including: chemical, physical, biological and ecological parameters. It must also be recognized that fresh water quality is impacted directly by natural and human activities outside the water sphere such as land use practices, erosion and deforestation. Some are also tied to acid deposition or natural contamination. Such problems often require monitoring and protection at the local level, while some have significant trans-boundary components which are addressed at National and International levels (International Conference on Water and the Environment Report, 1992).

2.7 Drinking water quality parameters

Physico - chemical and biological quality of raw water is important not only in the assessment of the degree of pollution but also in the choice of the best source and the treatment needed (WHO, 1984). Agricultural activity along a river or water body is a potential source of total solids. The parameters that were considered as part of this study are discussed below.

2.8 Microbial quality of drinking water

Although microorganisms had been observed in the 17th century, the recognition of water as a source of pathogenic organisms was made in the late 1800's when Von Fritsch described *Klebsiella pneumoniae* and *K. rhinoscleromatis* as microorganisms characteristically found in human faeces (Ashbolt *et al.* 2001). By 1914, the US Public Health Service (U.S.P.H.S.) had adopted the coliforms group as an indicator of faecal contamination of drinking water (Bitton, 2005). An ideal microbial indicator of faecal pollution is easily detected, always present in faecal waste and is more durable in the environment than most enteric pathogens; it should comprise a large percentage of the organisms in faecal waste, exceed the numbers of most enteric pathogens and be roughly proportional to the degree of pollution; and lastly because indicator organisms should be absent unless faecal contamination is present, they should ideally not be present in drinking-water that is microbiologically safe for consumption (Pedley *et al.*, 2006).

According to Ashbolt *et al.* (2001), microbial indicators are used because, it is less difficult, less expensive, and less time consuming to monitor indicators than to monitor

individual pathogens. Furthermore, the simple and inexpensive techniques used encourage a higher number of samples to be tested thereby, giving a better overall picture of the water quality and therefore better protection of public health. The most common indicators are total coliforms (TC), faecal coliforms (FC), *Escherichia coli* (*E. coli*), faecal streptococci and enterococci (Myers *et al.* 2007). Although the presence of indicator bacteria does not prove that pathogenic bacteria are present in the environment, the presence is indicative that contamination by faecal material has occurred and high concentration of microbial indicators that exceed standards pose an increased risk of exposure to harmful bacteria and the associated adverse effect (Gregory and Frick, 2000).

2.9 Total Coliform

Total coliform belongs to the family Enterobacteriaceae and includes the aerobic and facultative anaerobic, gram-negative, non-spore-forming, rod-shaped bacteria that ferment lactose with gas production in 24 to 48 hour at 35°C (APHA, 1998). They have the ability to produce the lactose fermenting enzyme, β -galactosidase, which most soil and water bacteria cannot produce (Schlegel, 1995). These criteria are not strictly taxonomic, although coliform belong to the family of Enterobacteriaceae and usually include *Escherichia coli* as well as members of the genera *Escherichia*, *Klebsiella*, *Enterobacter*, *Serratia*, *Hafnia*, are important in the microbiological analyses of water quality (WHO, 2006). These coliforms are normally discharged in relatively high numbers (2×10^9 coliforms/day/capita) in human and animal faeces (Bitton, 2005). However, some members of this group can be found in both faeces and the environment

(nutrient-rich waters, soil, decaying plant material) as well as in drinking-water containing relatively high concentrations of nutrients, as well as species that are rarely, if ever, found in faeces and may multiply in relatively good-quality drinking-water.

2.10 Faecal Coliform (Thermotolerant Bacteria)

Faecal coliforms are a subset of total coliform. They have the same definition as total coliform except that they grow at 44–45°C. They comprise the genus *Escherichia*, *Klebsiella*, *Enterobacter*, and *Citrobacter* (Department of National Health and Welfare, 2006). The reason for testing for faecal coliforms is that they are more restricted in their source to the gastrointestinal tract of warm-blooded animals and their presence in water could indicate faecal contamination from warm-blooded animals. Among the faecal coliforms, *E.coli* deserves further discussion. This bacterium does not only satisfy all of the criteria of the TC and FC in most cases but has additional characteristics that make it a useful microbiological indicator of water quality. It is the most common coliform among the intestinal flora of warm-blooded animals that has been demonstrated to be a more specific indicator for the presence of pathogens (Bitton, 2005)

2.11 Sources of microbial contamination of drinking water

Bacteria naturally occurring in water are largely responsible for the self-purification processes which biodegrade organic matter. Health risks arise when bacteria in faeces are discharged into water bodies. Domestic sewage effluents containing large numbers of certain bacterial species, which arise from the human intestine, influence the

legitimate use of water (Chapman, 1996). Bitton (2005) found that enteric pathogens enter the environment in the faeces of infected hosts and can enter water directly through defecating into water, contamination with sewage effluent or from solid waste and surface water. The presence of coliforms in a distribution results from inadequately treated water, subsequent regrowth and intrusion of the organisms into the water posttreatment. Additionally, pipe leaks with negative pressure event, pipe breaks, inadequate cleaning and disinfection after repairs, and cross-connections, etc. could result in coliforms being detected in water (Gregory and Frick, 2000).

Pedley *et al.* (2006) noted that source of microbial contamination could be classified into two groups according to their origin. A point source has identifiable source, such as a leaking septic tank, which may result in a well-defined plume. Contrary to this, a non-point source is difficult to control because it is larger in scale and produces relatively diffuse pollution originating from either widespread application of contaminated material or many smaller sources. Septic system located too close to a drinking well can contaminate the supply. Furthermore, runoff from feedlots, pastures, dog runs, and other land areas containing animal waste are potential sources of faecal contamination of wells. Bacteria from these sources can enter wells that are open at the land surface, lack water-tight casing or caps, that are shallow or do not have a grout seal in the annular space (the space between the wall of a drilled well and the outside of the well casing). The situation where there is no windlass at the well and users have to bring in their buckets (which may not be cleaned) in order to fetch water is a plausible means by which the water source may become contaminated.

According to WHO (2003), collected water that is initially of acceptable microbiological quality may become contaminated with pathogens of faecal origin during transport and storage and handling practices. Factors that may contribute to this problem include unsanitary and inadequate protected water collection and storage containers, the use of unsanitary methods of dispense water from household storage vessels (including faecally contaminated hands and dippers), lack of protection against contamination introduced by vectors; and inadequate cleaning of vessels to prevent biofilm formation and accumulation of sediments and pathogens. Where water sources are protected, a bucket handled by someone with a contaminated hand and lowered into a water source might contaminate the water and could cause a broader outbreak in the community.

2.12 Physico - chemical Parameters of Drinking Water

pH of Water

Scientists measure acidity or alkalinity of water by testing the pH level. The pH, therefore, is a measure of how acidic or alkaline (basic) the water is on a scale of 0 to 14. In pure or distilled water the concentration of positive hydrogen ion is in equilibrium with the concentration of negative hydroxide ions and the pH measures exactly 7. pH measurement below 7 indicates that the solution is acidic containing more H^+ ions than OH^- ions. Measurement above 7 indicates that the reverse situation exists making the water alkaline. It is important to note that for every one unit change on the pH scale, there is approximately a tenfold in how acidic or alkaline the sample is. The usual pH range for fresh water system is 6 to 9. Water ways around this pH is an indicator of existence of biological life as most of them thrive in a quite narrow and critical pH range.

According to the WHO (1984) drinking water should have pH range of 6.5 to 8.5. pH is related in several different ways to almost every other water quality parameter, as aqueous chemical equilibria invariably involve hydrogen ions, H^+ (WHO, 1984). Water sample with low pH is attributed to discharge of acidic water into these sources by anthropogenic activities. In fact 98% of all world ground water are dominated by Ca^{2+} and HCO_3^- due to lime stone weathering in the catchments and underground water beds. pH is important in water quality assessment as it influences many biological and chemical processes with the water body (Chapman, 1992).

Electrical Conductivity

Conductivity is a measure of how well water can conduct an electrical current and is strongly dependant on the number of ions available to participate in the conducting process. These ions, which come from the breakdown of compounds, conduct electricity because they are negatively or positively charged when dissolved in water. Therefore, conductivity is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution.

Electrical conductivity is widely used to indicate the total ionized constituents of water. It is widely related to the sum of cations or anions as determined chemically and is closely correlated, in general, with the total salt concentration (Chanda, 2010).

Human activities also influence conductivity. Acid mine drainage can add iron, sulphate, copper, cadmium and other ions if minerals containing them are exposed to air and water. Sewage and farm runoff can raise conductivity due to the presence of nitrate and phosphate. Runoff from roads can also carry salt and other materials that contribute ions to water. WHO (2006) recommended water conductivity of $700\mu S/cm$.

Total Solids

The term total solids refers to matter suspended or dissolved in water or waste water, and is related to both specific conductance and turbidity. Total solids includes both total suspended solids (TSS), the portion of total solids retained by a filter and total dissolved solids (TDS), the portion that passes through a filter (APHA, 1998).

TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further, and can harm aquatic life in many other ways. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with storm water. In the water, the pollutants may be released from the sediment or travel farther downstream (Federal Interagency Stream Restoration Working Group, 1998). High TSS can cause problems for industrial use, because the solids may clog or scour pipes and machinery.

TDS is a measure of the amount of material dissolved in water. This material can include carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because

the density of the water determines the flow of water into and out of an organism's cells. However, if TDS concentrations are too high or too low, the growth of many aquatic lives can be limited, and death may occur. TDS is used to estimate the quality of drinking water, because it represents the amount of ions in the water. Water with high TDS often has a bad taste and/or high water hardness, and could result in a laxative effect.

According to WHO (1984), there has not been any deleterious physiological reactions occurring in persons consuming drinking water that have TDS values in excess of 1000mg/l. Chanda (2010), reported a critical TDS value of 2450mg/l above which some long term health problems might be anticipated due to excessive concentrations of dissolved particles in drinking water.

Turbidity

Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in a straight lines through the sample. Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water (American Public Health Association, 1998). Organic particulates may harbour microorganisms. Thus, turbid conditions may increase the possibility for waterborne diseases. Nonetheless, inorganic constituents have no notable health effects. If turbidity is largely due to organic particles, dissolved oxygen depletion may occur in the water body. The excess nutrients may results in algal growth. Although it does not adversely affect human health, turbidity is an important parameter in that it can protect microorganisms from disinfection effects, can stimulate bacteria growth and indicates

problems with treatment processes (WHO, 2006). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2006). Eni and Efiong (2011) also recorded turbidity range of 0.4 to 23.5 NTU in ground water in Ketu District.

Total Alkalinity

Alkalinity or A_T is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH.

In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Other common natural components that can contribute to alkalinity include borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulphate.

Alkalinity not only helps regulate the pH of a water body, but also the metal content. Bicarbonate and carbonate ions in water can remove toxic metals (such as lead, arsenic, and cadmium) by precipitating the metals out of solution. Alkalinity in water comes from a high concentration of carbon-based mineral molecules suspended in the solution. Water with high alkalinity is said to be “hard.” The most prevalent mineral compound causing alkalinity is calcium carbonate, which can come from rocks such as limestone or can be leached from dolomite and calcite in the soil.

Fresh drinking water should have an alkalinity level of 20 to 200 milligrams of calcium carbonate per litre of water. Concentrations less than 100ppm are desirable for domestic

water supplies. The recommended range for drinking water is 30 to 400 ppm. A minimum level of alkalinity is desirable because it is considered a “buffer” that prevents large variations in pH.

Alkalinity is not detrimental to humans. Moderately alkaline water (less than 350mg/l), in combination with hardness, forms a layer of calcium or magnesium carbonate that tends to inhibit corrosion of metal piping. Many public water utilities employ this practice to reduce pipe corrosion and to increase the useful life of the water distribution system. High alkalinity (above 500mg/l) is usually associated with high pH values, hardness and high dissolved solids and has adverse effects on plumbing systems, especially on hot water systems (water heaters', boilers, heat exchangers, etc.) where excessive scale reduces the transfer of heat to water, thereby resulting in greater power consumption and increased costs. Water with low alkalinity (less than 75mg/l), especially some surface waters and rainfall, is subject to changes in pH due to dissolved gasses that may be corrosive to metallic fittings.

Chloride

Chlorides in groundwater and surface water can be naturally occurring in deep aquifers or caused by pollution from sea water, brine, or industrial or domestic wastes. Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium (CaCl_2) (Department of National Health and Welfare, Canada, 1992). Chloride in water may be considerably increased by treatment processes in which chlorine or chloride is used.

Chloride concentration in excess of about 250mg/litre can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can,

however, become accustomed to concentrations in excess of 250mg/litre. Chloride increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts (Chanda, 2010), thus increasing level of metal in drinking-water. In lead pipes, a protective oxide layer is built up, but chloride enhances galvanic corrosion. It can also increase the rate of pitting corrosion of metal pipes. Ansa Asare *et al.*, (2006) also observed concentration range of 2.0 to 64.5mg/l in surface waters of South – Western and coastal rivers basins of Ghana. Eni and Efiong (2011) observed that, ground water in Ketu and Akatsi Districts had chloride concentration ranging from 42.1mg/l to 1260mg/l.

Fluoride

Fluorine is a common element that does not occur in the element state in nature because of its high reactivity. Traces of fluorides are present in many waters; higher concentrations are often associated with underground sources. In seawater, a total fluoride concentration of 1.3mg/litre has been reported. In areas rich in fluoridecontaining minerals, well water may contain up to 10mg of fluoride per litre. Fluoride may also enter a river as a result of industrial discharges (Eni and Efiong, 2011). In groundwater, fluoride concentrations vary with the type of rock the water flows through but do not usually exceed 10mg/l (USEPA, 2001).

Many epidemiological studies of possible adverse effects of the long term ingestion of fluoride via drinking water have been carried out. These studies clearly establish that fluoride, primarily, produces effects on skeletal tissues (bones and teeth). Low concentration provides protection against dental caries, especially in children. The pre and post eruptive protective effects of fluoride involving the incorporation of fluoride

into the matrix of the tooth during its formation, the development of shallower tooth grooves, which are consequently less prone to decay, and surface contact with enamel increase with concentration up to about 2mg of fluoride per litre of drinking water; the minimum concentration of fluoride in drinking water required to produce it is approximately 0.5 mg/l (Chapman, 1992).

However, fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental fluorosis (prevalence: 12-33%) at drinking water concentrations between 0.9 and 1.2mg/l. This has been confirmed in numerous subsequent studies, including a recent large-scale survey carried out in China (Chen *et al.*, 1988) which showed that with drinking water containing 1 mg of fluoride per litre, dental fluorosis was detectable in 46% of the population examined. Elevated fluoride intakes can also have more serious effects on skeletal tissues. Skeletal fluorosis (with adverse changes in bone structure) may be observed when drinking water contains 3-6mg/l of fluoride per litre. Crippling skeletal fluorosis usually develops only where drinking water contains over 10 mg of fluoride per litre (WHO, 2006).

WHO set maximum contaminant concentration at 1.5mg/l in 1984 and reaffirmed it in 1993. Concentrations above this value carry an increasing risk of dental fluorosis, and much higher concentrations leads to skeletal fluorosis.

Total Hardness/Carbonate and Bicarbonate

Water hardness is a traditional measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to produce lather, and it also leads to scaling of hot water pipes, boilers and other household appliances. Water hardness is caused by dissolved polyvalent metallic ions. In fresh waters, the principal

hardness causing ions are calcium and magnesium; strontium, iron, barium and manganese ions also contribute.

The degree of hardness of drinking water may be classified in terms of its calcium carbonate concentration as follows: soft, 0 to <60mg/l; medium hard, 60 to <120mg/l; hard, 120 to < 180mg/l; and very hard, 180mg/l and above. Hardness caused by cations, it is often discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness. Carbonate hardness refers to the amount of carbonates and bicarbonates that can be removed or precipitated from solution by boiling. This type of hardness is responsible for the deposition of scale in hot water pipes and tea kettles. Non-carbonate hardness is caused by the association of the hardness causing cations with sulphates, chlorides and nitrates. It is also referred to as “permanent hardness” because it cannot be removed by boiling.

The principal natural sources of hardness in water are sedimentary rocks and seepage and runoff from soils. In general, hard waters originate in areas with thick topsoil and limestone formations. Groundwater is generally harder than surface water. Groundwater rich in carbonic acid and dissolved oxygen usually has a high solvating power; in contacting soil or rocks containing appreciable amounts of minerals, such as calcite, gypsum and dolomite, hardness levels up to several thousand milligrams per litre can result. The two main industrial sources of hardness are the inorganic chemical and mining industries. The cations that are the major contributors to hardness – calcium and magnesium – are not of direct public health concern. Soft water can lead to corrosion of pipes and, consequently, certain heavy metals such as copper, zinc lead and cadmium may be present in the distributed water. The degree to which this occurs is also a function of pH, alkalinity and dissolved oxygen concentration. In some communities, corrosion is so severe that the water must be treated (Chapman, 1992).

In areas with hard water, household pipes can become clogged with scale; hard waters also cause incrustations on kitchen utensils and increase soap consumption. Hard water is thus both a nuisance and an economic burden to the consumer. Public acceptance of hardness varies among communities; it is often related to the hardness to which the consumer has become accustomed, and in many communities hardness greater than 200mg/l is tolerated. It has been suggested that a hardness level of 80 to 100mg/l as CaCO_3 provides an acceptable balance between corrosion and incrustation (Chapman, 1992). However, waters with hardness in excess of 500mg/l are unacceptable for most domestic purposes.

Nitrate

Nitrate (NO_3^{2-}) is highly soluble in water and is stable over a wide range of environmental conditions. It is easily transported in streams and groundwater. Nitrates feed plankton, aquatic plants, and algae, which are then eaten by fish. Nitrite (NO_2) is relatively short-lived in water because it is quickly converted to nitrate by bacteria.

Excessive concentrations of nitrate and/or nitrite can be harmful to humans and wildlife. Nitrate is of most concern for humans. Nitrate is broken down in our intestines to become nitrite. Nitrite reacts with haemoglobin in human blood to produce methaemoglobin, which limits the ability of red blood cells to carry oxygen. This condition is called methaemoglobinemia or "blue baby" syndrome (because the nose and tips of ears can appear blue from lack of oxygen). It is especially serious for infants, because they lack the enzyme necessary to correct this condition. Wells contaminated by sewage or agricultural runoff are a major concern in some areas, because of the possibility of water high in nitrite/nitrates and the subsequent increased risk of blue

baby disease. High nitrate and nitrite levels can also cause methemoglobinemia in livestock and other animals.

High concentrations of nitrate and/or nitrite can produce "brown blood disease" in fish. Nitrite enters the bloodstream through the gills and turns the blood a chocolate-brown colour. Brown blood cannot carry sufficient amounts of oxygen, and affected fish can suffocate despite adequate oxygen concentration in the water.

If excessive amounts of phosphorus and nitrates are added to the water, algae and aquatic plants can be produced in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This process is called eutrophication. Dissolved oxygen concentrations can drop too low for aquatic organisms to breathe, leading to their death.

Phosphate

Phosphates enter the water ways through both non-point sources and point sources. The non-point sources of phosphates include: natural decomposition of rocks and minerals, storm water runoff, agricultural runoff, erosion and sedimentation and direct input by animals/wildlife; whereas: point sources may include: wastewater treatment plants and permitted industrial discharges. In general, the non-point source pollution typically is significantly higher than the point sources of pollution. Phosphorus is used extensively in fertilizer and other chemicals, so it can be found in higher concentrations in areas of human activity. Many seemingly harmless activities added together can cause phosphorus overloads. Therefore, the key to sound management is to limit the input from both point and non-point sources of phosphate. High concentration of phosphate in water bodies is an indication of pollution and largely responsible for eutrophication (Harman *et al.*, 2006).

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate. WHO (2006), set maximum contaminant level at 0.3mg/l. Ansa-Asare *et al.*, (2006) recorded concentration ranging from <0.001 to 0.92mg/l in surface water in South Western Ghana.

Sulphate

Sulphates are combination of sulphur and oxygen and are part of naturally occurring minerals in some soil and rock. The mineral dissolves over time and is released into groundwater, as water moves through the soil and rock that contain sulphate minerals. Sulphates are discharged into the aquatic environment in wastes from industries that use sulphates and sulphuric acid, such as mining and smelting operations, pulp and paper mills, textile mills and tanneries (Chapman, 1992).

Atmospheric sulphur dioxide (SO₂) formed by the combustion of fossil fuels and by the metallurgical roasting process, may also contribute to the sulphate content of surface waters. It has frequently been observed that the levels of sulphate in surface water correlate with the levels of sulphur dioxide in emissions from anthropogenic sources (Chapman, 1992).

Sulphur trioxide (SO₃), produced by the photolytic or catalytic oxidation of sulphur dioxide, combines with water vapour to form dilute sulphuric acid, which falls as “acid” rain or snow. These “acid” rains or snows flow in to water bodies and increase the sulphate contents. Sulphates have a detoxifying effect on the liver and stimulate the function of the gall bladder.

WHO (2006) set the Maximum contaminant level of sulphate in drinking water at 200mg/l. Dehydration has been reported as a common side effect following the

ingestion of large amounts of magnesium or sodium sulphate. Sulphates can interfere with disinfection efficiency by scavenging residual chlorine in the distribution system. The presence of sulphate salts in drinking water could increase corrosion of mild steel in the delivery system. Sulphate-reducing bacteria may be involved in the tuberculation of metal pipes. The hydrogen sulphide produced by these bacteria may lower the aesthetic quality of the water by imparting an unpleasant taste and odour and may increase corrosion in both metal and concrete pipes (WHO, 2006).

Sodium ion

Sodium is a soft, silvery white, highly reactive metal that is never found in nature in the uncombined state. Sodium, an alkali metal element, has a strong tendency to exist in the ionic form. In biological systems and even in solids such as sodium chloride, sodium remains distinctly separate as the sodium ion.

The sodium ion is ubiquitous in water. Saline intrusion, mineral deposits, seawater spray, sewage effluents, and salt used in road de-icing can all contribute significant quantities of sodium to water. In addition, water treatment chemicals, such as sodium fluoride, sodium bicarbonate, and sodium hypochlorite, can together result in sodium levels as high as 30mg/litre. Domestic water softeners can give levels of over 300mg/l, but much lower ones are usually found (WHO, 2006).

Sodium is the most abundant cations in the extracellular fluid. It is largely associated with chloride and bicarbonate in regulation of acid-base equilibrium. Maintenance of the osmotic pressure of body fluid, and thus prevention of excess fluid loss, is another important function of sodium. Sodium also acts in preserving the normal irritability of muscle and permeability of cells (WHO, 2006).

In general, sodium salts are not acutely toxic because of the efficiency with which mature kidneys excrete sodium. However, acute effects and death have been reported following accidental overdoses of sodium chloride. Acute effects may include nausea, vomiting, convulsions, muscular twitching and rigidity, and cerebral and pulmonary oedema (Department of National Health and Welfare, Canada, 2006). Excessive salt intake seriously aggravates chronic, congestive heart failure, and ill effects due to high levels of sodium in drinking water have been documented (Chapman, 1992). The effects on infants are different from those in adults because of the immaturity of infant kidneys. Infants with severe gastrointestinal infections can suffer from fluid loss, leading to dehydration and raised sodium levels in the plasma (hypernatraemia); permanent neurological damage is common under such conditions.

An excessive level of sodium is easily detected by taste. In solutions at room temperature, taste thresholds for sodium present in salts such as sodium chloride and sodium sulphate are approximately 130 to 140 mg/l. generally, the taste is offensive at a concentration of >200 mg/l sodium (whether chloride or sulphate)(WHO, 2006).

Potassium ion

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. It occurs widely in the environment, including all natural waters. It can also occur in drinking water as a consequence of the use of potassium permanganate as an oxidant in water treatment. In some countries, potassium chloride is being used in ion exchange for household water softening in place of, or mixed with, sodium chloride, so potassium ions would exchange with calcium and magnesium ions (WHO, 2006).

Although concentrations of potassium normally found in drinking water are generally low and do not pose health concerns, the high solubility of potassium chloride and its use in treatment devices such as water softeners can lead to significantly increased exposure.

Potassium and sodium maintain the normal osmotic pressure in cells. Potassium is a cofactor for many enzymes and required for the secretion of insulin, creatinine phosphorylation, carbohydrate metabolism and protein synthesis. Excessive loss of salts, such as through severe diarrhoea or intense and prolonged sweating, can result in a loss of potassium, which can result in hypocalcaemia if the loss is sufficient. This can cause a range of effects, including cardiac arrhythmia, muscle weakness, nausea and vomiting, and low muscle tone in the gut. Longer-term hypocalcaemia is believed to cause a predisposition to hypertension (WHO, 2006). Adverse health effects due to potassium consumption from drinking water are unlikely to occur in healthy individuals. Potassium intoxication by ingestion is rarer, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting (Chapman, 1992). Case-studies of toxicity resulting from high doses of salt substitutes have described chest tightness, nausea and vomiting, diarrhoea, hypercalcaemia, shortness of breath and heart failure (WHO, 2006). WHO set maximum contaminant level at 30mg/l.

Iron ions(Fe^{2+} and Fe^{3+})

Iron is the second most abundant metal in the earth's crust, and it accounts for about 5% of the metal. Iron is most commonly found in nature in the form of its oxides

(Harman *et al.*, 2006). The median iron concentration in rivers has been reported to be 0.7 mg/litre. In anaerobic groundwater where iron is in the form of iron(II), concentrations will usually be 0.5-10mg/l, but concentrations up to 50mg/l can sometimes be found (WHO, 2006). Concentration of iron in drinking water are normally less than 0.3mg/l but may be higher in countries where various iron salts are used as coagulating agents in water treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution.

Aeration of iron containing layers in the soil can affect the quality of both groundwater and surface water if the groundwater table is lowered. Dissolution of iron can occur as a result of oxidation and decrease in pH. In drinking water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide, which settles out as a rust coloured silt. Staining of laundry and plumbing may occur at concentrations above 0.3mg/litre. 0.3mg/l is however; set to be maximum contaminant level. Iron also promotes undesirable bacterial growth (“iron bacteria”) within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping (Department of National Health and Welfare Canada, 2006). Iron in water can cause yellow, red or brown stains on laundry, dishes, and plumbing fixtures such as sink. In addition, iron can clog wells, pumps, sprinklers, and other devices such as dishwasher which can lead to costly repairs. Iron gives a metallic taste to water, and can affect foods and beverages – turning tea, coffee, and potatoes black. Iron is an essential element in human nutrition. Iron gives the haemoglobin of blood its red colour that enable it to carry oxygen round the body (Chanda, 1992).

Calcium ion (Ca^{2+})

Calcium occurs in water naturally. One of the main reasons for the abundance of calcium in water is its natural occurrence in the earth crust. Calcium is also a constituent of coralreef which generally contain 1-2ppm calcium, but in limestone areas, rivers may contain calcium concentrations as high as 100 ppm. Calcium is essential to human health (WHO, 2006). In a watery solution calcium is mainly present as Ca^{2+} (aq), but it may also occur as CaOH^+ (aq) or $\text{Ca}(\text{OH})_2$ (aq), as CaSO_4 in seawater. Calcium is an important determinant of water hardness, and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste.

Hard water may assist in strengthening bones and teeth because of its high calcium concentration. Calcium carbonate has a positive effect on lead pipes, because it forms a protective lead (II) carbonate coating. This prevents lead from dissolving in drinking water, and thereby prevents it from entering the human body. Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Most of these disorders have treatments but no cures.

Calcium is unique among nutrients, in that the body's reserve is also functional: increasing bone mass is linearly related to reduction in fracture risk. The WHO Guideline for maximum contaminant level of calcium in drinking water is 200mg/l. When one takes up large amounts of calcium this may negatively influence human health (WHO, 2006).

Magnesium ion (Mg^{2+})

Rivers contain approximately 4 ppm of magnesium, marine algae 6000-20,000 ppm, and oysters 1200 ppm. Magnesium and other alkali earth metals are responsible for water hardness. Water containing large amounts of alkali earth ions is called hard water, and water containing low amounts of these ions is called soft water. (<http://lenntect/elements-and-water/magnesium-and-water.hmt>).

Large number of minerals contains magnesium, for example dolomite – calcium magnesium carbonate, $\text{CaMg}(\text{CO}_3)_2$ and magnesite, magnesium carbonate, (MgCO_3) . Magnesium is washed from rocks and subsequently ends up in water. It also ends in the environment from fertilizer application and from cattle feed. Magnesium sulphate is applied in beer breweries, and magnesium hydroxide is applied as a flocculent in wastewater treatment plants. It is unusual to introduce legal limits for magnesium in drinking water, because there is no scientific evidence of magnesium toxicity. However, due to the role magnesium plays in water hardness, WHO drinking water guideline has maximum contaminant level to be 150mg/l (WHO, 2006).

Scientists have observed that people in areas with higher levels of magnesium in their drinking water exhibit rates of sudden cardiac death that are three to four times lower than those of people living in municipalities with the lowest magnesium levels in drinking water (Chapman, 1992). This has drawn the attention of national and international public health officials. For example, a recent world health organization (WHO) report on the quality of drinking water cited 80 studies that have examined the relationship between cardiovascular death and water “hardness” (measured principally by magnesium and calcium content). The WHO concluded that the magnesium content of water is indeed a cardiovascular risk reducing factor and that supplementing drinking water with magnesium should be a priority, much as fluoride became one.

Manganese

The element manganese is present in over 100 common salts and mineral complexes that are widely distributed in rocks, in soils and on the floors of lakes and oceans. Manganese is most often present as the dioxide, carbonate or silicate. It may exist in oxidation states ranging from 3 to +7; the manganous (Mn^{2+}) and manganic (Mn^{4+}) oxidation states are the most important for aquatic systems (WHO, 2006). Manganese occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. In surface waters, Manganese occurs in both dissolved and suspended forms, depending on such factor as pH, anions present and oxidation – reduction potential (Chapman, 1992). Anaerobic groundwater often contains elevated levels of dissolved manganese. The divalent form (Mn^{2+}) predominates in most water at pH 4-7, but more highly oxidized forms may occur at higher pH values or result from microbial oxidation (WHO, 2006). However, human activities are also responsible for much of the manganese contamination in water in some areas.

Manganese is an essential element for many living organisms, including humans. For example, some enzymes require manganese (e.g. manganese superoxide dismutase), and some are activated by the element (e.g. kinases, decarboxylases). Adverse health effects can be caused by inadequate intake or overexposure. Manganese deficiency in humans appears to be rare, because manganese is present in many common foods, at concentrations exceeding 0.1mg/l. The manganese ion imparts an undesirable taste to beverages and stains plumbing fixtures and laundry (WHO, 2006). When manganese (II) compounds in solution undergo oxidation, manganese is precipitated, resulting in encrustation problems. At concentrations as low as 0.02 mg/l, manganese can form

coating on water pipes that may later slough off as a black precipitate (Zimmerman et al., 2008). A number of countries have set standards for manganese of 0.05 mg/l, above which problems with discolouration may occur.

The WHO recommended limits of manganese in drinking water is set at 0.1mg/l. Concentrations below 0.05 mg/litre are usually acceptable to consumers, although this may vary with local circumstances (WHO, 2006).



CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

Akunakope and Dzogbedzi communities (Fig 3.1) are located in the Shai - Osudoku District in the south-eastern part of Ghana in the Greater Accra Region with Dodowa as the district capital. This district was carved out from the Dangme West District in June, 2012 by LI 2137. The district occupies about 968.361 square km land area, representing 29.84% land space of the Greater Accra Region and shares boundaries with the Akwapim - North District on the west, Kpone Katamanso District on the south - west, Ningo Prampram District on the east. The Central Tongu District occupies the north – eastern boundary. It shares 7km stretch boundary with the River Volta.

The population of the District in 2013 was projected to be about 55,741. This comprises 27,146 males (representing 48.7%) and 28,595 females (representing 51.3%). The District is predominantly rural, with about 76.4% of the population living in rural areas. Akunakope and Dzogbedzi are two of the rural communities with an estimated population of 428 and 314 respectively (SODA, 2012).

The communities are in the northern part of Shai Osudoku District around Asutsuare and Osuwem areas which constitute an aspect of the dominant sectors of the Accra plains. The topography of this area is usually gentle and undulating , a ground plain with height not above 70m. The general pattern of drainage in the area is dendritic with several of the water courses getting their bases out of the Akwapim range that as well helps as a watershed and then move in a north-west to south-west way into ponds on the coast (SODA, 2012).

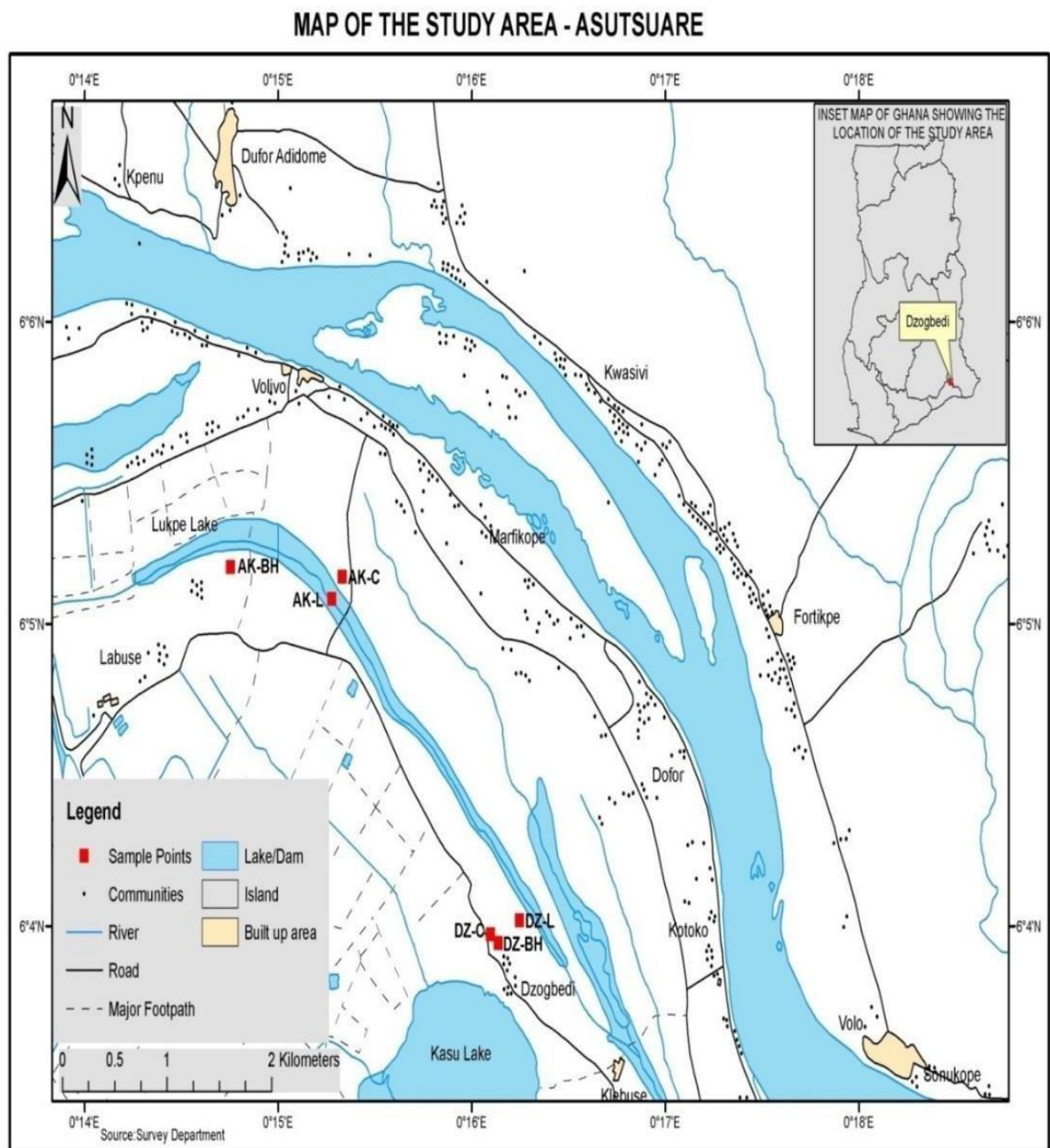


Fig 3.1 Map of the study area showing sampling locations

Temperatures are noticeably great for several portions of the year with the maximum throughout the major dry period (November – March) and minimum throughout the

short dry period (July – August). The main undergrowth kind established in this place is of the short grass savannah scattered with shrubs and short trees, a typical of the Sub-Saharan kind.

3.2 Research Methodology

A reconnaissance survey was embarked on to the selected communities in order to identify the sources of water for drinking and other domestic purpose. At Akunakope, the sources of drinking water identified were boreholes, lake and irrigation canal (Plates 1, 2 and 3) and at Dzogbedzi, the drinking water sources were also boreholes, lake and irrigation canal (Plates 4, 5 and 6).



Plate 1. A borehole at Akunakope



Plate 2: Lukpe lake at Akunakope



Plate 3: A canal at Akunakope



Plate 4: A borehole at Dzogbedzi



Plate 5: Kasu lake at Dzogbedzi



Plate 6: A canal at Dzogbedzi

3.3 Sampling sites

Water samples were collected from surface water and boreholes at various locations in Akunakope and Dzogbedzi communities within a period of three months from February to April, 2011. Table 3.1 shows the sampling site codes, water sources and the geographical positions.

Table 3.1 Sampling Sites and their GPS locations.

Water source	Coordinates	Sampling site code
---------------------	--------------------	---------------------------

Borehole	N06°05.173'W000°15.268'	Akunakope
Irrigation canal	N06°05.083'W000°15.278'	AK – BH
Lake Lukpe	N06°05.045'W000°15.194'	AK – C
		AK – L
		Dzogbedzi
Lake Kasu	N06°05.157'W000°15.333'	DZ – L
Borehole	N06°04.200'W000°16.247'	DZ – BH
Irrigation canal	N06°03.944'W000°16.137'	DZ – C

3.4 Social and Sanitation Survey

The social survey looked at the various anthropogenic activities in and around the sources of drinking water and perception of the inhabitants on the quality of water they consume. In all, a total of 80 questionnaires (Appendix A) were administered to residents of Akunakope and Dzogbedzi communities using purposive sampling technique. The following questions were also considered during the sanitation survey:

- Do people farm around the lake and the river?
- Do they dump their sewage and other solid wastes around the water bodies?
- Do livestock drink from these water bodies?
- Is the lake or river located far away from place of convenience and what type of place of convenience is being used at the villages?

3.5 Collection and processing of water samples

Standard methods of sample collection and processing as described by Cheesbrought (1984) were used to collect water from boreholes, irrigation canals, and lakes. All water samples were collected using sterilized 500ml autoclavable Duran bottles. These bottles were capped and sterilized by autoclaving at 21°C for 20 minutes prior to use. All collected water samples were kept cold in an ice-chest and sent to the Volta Basin Research laboratory, University of Ghana and the Public Health laboratory of the Volta River Authority, Akosombo, for physico-chemical and bacteriological analyses, respectively.

3.6 Water quality assessment

The parameters assessed were:

Physico-chemical: pH, temperature, conductivity, turbidity, colour, TSS, TDS, Alkalinity, chloride, fluoride, calcium hardness, Total hardness and magnesium hardness.

Nutrients: sulphate, phosphate, nitrate, nitrite and bicarbonate.

Trace elements or metals: Total iron, manganese, sodium, potassium, calcium and Magnesium

Bacteriological: faecal and total coliforms.

3.7 Determination of physico – chemical parameters

3.7.1 Temperature, pH, and Conductivity

The water temperature, pH, conductivity were measured in situ with a Horiba water meter (model U-10, HACH). This composite meter permits reading to be taken fast and thereby eliminates errors due to changes with time. All four parameters were recorded concurrently.

3.7.2 Turbidity

Turbidity of the water was measured with the use of Turbidity meter (Model 2100P, HACH). Twenty- five milliliters of test materials were estimated and put in the cell container. Every estimate was led by a standardization.

3.7.3 Colour

The Platinum Cobalt Standard technique was employed. The stored program unit 120 was keyed in on the spectrophotometer and the 455nm wavelength employed. Precisely 25ml of the sample was decanted in a tester cell. The control was put into the cell container and made uniform. The ready tester was put into the cell container and the outcome was showed in platinum-cobalt scale (APHA, 1995).

3.7.4 Total Dissolved Solids (TDS)

TDS was determined using the Gravimetric method (APHA, 1995) in which the sample was vigorously shaken and a measured volume of 20ml of each of the samples transferred into a 100ml calibrated cylinder via funnel. The sample was filtered via a glass fibre and a vacuum used for approximately 3 minutes to guarantee that enough water has taken out. The tester was cleaned with distilled water as well as suction

continued for a minimum of 3 minutes. The total filtrate was transferred to a measured evaporating dish and evaporated to dryness on a water bath. The evaporated sample was dehydrated for a minimum of one hour at 180°C. The dehydrated sample was cooled in a desiccator and weight measured.

3.7.5 Fluoride

The fluoride levels of the water to be tested was assessed employing the SPADNS Technique. 25ml of the sample was weighed in a dry 25ml sample chamber. Additional tester cell was filled with 25ml distilled water. 5ml of SPADNS chemical was pipetted into every cell and shaken gently to mix, one minute reaction time was allowed. After the reaction time, the blank tester was put in the cell container of the spectrophotometer to calibrate it to zero measure. The prepared tester was hence put into the cell container to estimate the fluoride levels at 580nm.

3.7.6 Total Suspended Solids

About 500ml of sample was blended for exactly two minutes. The blended sample was decanted into a 1L beaker, stirred and 25ml aliquot immediately decanted into a sample container. The prepared tester was shaken gently to eliminate every bubble and homogeneously suspended every deposit and the reading recorded with a spectrophotometer set at 810 nm which had *previously* been calibrated using 25ml of demineralized water (blank) to zero reading.

3.7.7 Hardness (CaCO_3)

Calcium concentration was determined by titration with standard (0.800M) ethylenediaminetetraacetic acid disodium salt (EDTA) in a high alkaline solution in the presence of an indicator, calVer 2 calcium. An appropriate sample volume and titration cartridge corresponding to the expected calcium concentration was selected. A delivery tube was inserted into the titration cartridge. The delivery tube knob was turned to eject a few drops of the titrant. The counter was zeroed and the tip wiped. A graduated cylinder was used to measure 100ml of the sample and transferred into a clean 250ml Erlenmeyer flask. Exactly two drops of potassium hydroxide was added to the sample and one content of calcium 2 Indicator Powder Pillows added and swirled to mix. The delivery tube tip was placed into the solution and the flask swirled while titrating with EDTA from pink to blue colour (APHA, 1995).

3.8 Nutrients

3.8.1 Nitrate - Nitrogen ($\text{NO}_3\text{-N}$)

The nitrate amount in every tester was estimated employing Nitrate Powder Pillows in a straight recording Hach spectrophotometer (Model DR. 2000). 25ml of the tester was weighed in a tester container. One Nitrover 5 Nitrate Chemical Powder Pillow was combined to the tester and energetically stirred for one minute. The mixture was allowed to react for 5 minutes after which additional container was filled with 25ml of the sample alone (blank). After the 5- minutes reaction time, the blank tester was put in the spectrophotometer for graduation. The prepared tester was afterwards put in the cell container to measure the nitrate levels at 500nm. The recordings were displaced and documented (APHA, 1995).

3.8.2 Nitrite -Nitrogen (NO_2^- -N)

Fifty millilitre of sample or an aliquot diluted to 50ml was placed in a Nessler tube, set aside until preparations of standards were completed. Approximately 2ml of buffer colour reagent was added to each standard sample, mixed for colour to develop for at least 15 minutes. The pH of solutions at this stage was between 1.5 and 2.0. The absorbance in the spectrophotometer was measured at 540 nm against the blank and concentration of nitrite nitrogen plotted against absorbance. The concentration of nitrite nitrogen was directly read from the calibration curve. If less than 50 ml of sample was taken, calculation of the concentration was as follows: NO_2^- -N in mg/l = (mg/l from standard curve x 50)

sample

The outcome was presented in mg/l to two decimal places.

3.8.3 Phosphate (PO_4^{3-} – P)

The sample container was filled with 25ml of sample. One PhosVer 3 Phosphate Powder pillow was combined to the cell content, shaken gently and instantaneously to blend. A two minutes reaction time was allowed. Additional sample container (the blank) was filled with 25ml of sample and put in the cell container to standardise it. After the reaction time the prepared sample was put in the cell container and the concentration of phosphorus was measured at 890 nm.

3.8.4. Sulphate (SO_4^{2-})

The sulphate concentrations in the water was measured by employing the turbidimetric technique. The sulphate ion was solidified in an acid medium that had barium chloride to generate a barium sulphate crystal with uniform size. The absorbance of the BaSO_4

suspension was measured by a photometer at 420nm and the sulphate concentration was determined by comparison of the reading with a standard curve.

100ml sample or suitable portion was measured and diluted to 100ml into a 250 ml Erlenmeyer flask. Exactly 5ml conditioning reagent was added and mixed by stirring. A spoonful of barium chloride crystals was added while still stirring and timed for 60 seconds at a constant speed. After stirring, the absorbance was measured at 420 nm on the spectrophotometer within 5 minutes. The result was read directly from the calibration curve, and expressed in mg/l, to 2 significant figures (APHA, 1998)

3.9 Metals

The study considered the following metals for analyses: Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe) and Manganese (Mn).

3.9.1 Pre-Treatment of Samples

Five milliliter of water samples were measured and 6ml of 69% nitric acid, 3ml of 37% HCl and 6.25ml of 30% H₂O₂ were added. The samples were digested using industrial microwave oven (model: ETHOS 900 Lab Station) for 21 minutes at high temperature and pressure. The digested solution was transferred into test tubes for the analyses using atomic absorption spectroscopy. Sodium and potassium concentrations were measured separately using flame photometer (model: Sherwood 420) which runs on LPG.

3.9.2 Atomic Absorption Spectroscopy

The measurement of major and trace metals concentrations were done by aspiration of the acidified, filtered samples directly into the atomic spectrophotometer (model: Varian 240FS). Individual hollow cathode lamps were used to hold samples for the

various metals. The concentration of the metal was equal to the concentration as measured by the spectrophotometer multiplied by the dilution factor where applicable. A graph of standards was plotted and readings for concentrations of samples also measured using excel software. Before the measurements were done, the atomic analytical equipment was calibrated using standard solutions of known concentrations of the various major ions and trace metals. The instrumental parameters of the various elements were dependent on the manufacturer specifications. The appropriate matrix modifiers and ionisation buffers were added to both the samples and standards where applicable to suppress interference from other elements, ionisation and at times to increase the sensitivity of the spectrophotometer. Air-acetylene gas flame was used.

3.10 Total Iron

The Iron amount within every sample was estimated using Powder Pillows in a direct recording Hach spectrophotometer (Model DR. 2000). 10 ml of the sample was weighed in the sample container. One Ferro Ver Iron chemical Pillow was added to the sample cell (prepared sample) and swirled to mix. The mixture was allowed to react for 3 minutes, once done additional cell was filled with 10ml of only the sample (blank). After 3 minutes reaction time, the control sample was put in the spectrophotometer for graduation. The prepared sample was then put into the cell holder to determine the Iron level at 510 nm.

3.11 Bacteriological analyses

The samples were analysed for faecal as well total coliforms. The pour-plate technique was used to analyse the samples for faecal and total coliforms. The Violet Red Bile Glucose Agar (VRBGA) and Mac Conkey-Agar media were prepared for total coliform and faecal coliform determination, respectively.

Method of Sterilisation

The equipment for the bacteriological analyses including sampling glass bottles, petri dishes, funnel, etc. were sterilised in industrial microwave (model: THOS 900 Lab Station microwave) at 121.0°C for 15 minutes before they were used. The working area was cleaned with 70% ethanol (methylated spirit) to prevent contamination from the working area; further contamination from the atmosphere was prevented by working in a heated environment.

3.11.1 Total and faecal coliforms

The enumeration of faecal and total coliforms was done using the Membrane Filtration (MF) Method. Serial dilutions were prepared in order to reduce the concentration of the water sample. A growth pad was dispensed into a sterile petri dish and saturated with Membrane Lauryl Sulphate Broth (MLSB). A pair of sterilized forceps was used to pick the filter membrane (0.45µm pore size) onto the bronze membrane support of the filtration unit. The water sample was poured into the filter funnel up to the 100ml graduation and the hand vacuum pump was applied to pass the water through the membrane. For faecal coliform, the filter was placed on the top of the MLSB saturated pad in a sealed Petri dish, inverted, and submerged in a water bath and incubated at 44°C for 18 hours. Colonies which appeared red with a metallic green sheen were counted and expressed in CFU/100ml. For total coliform, the filter was placed on the top of the MLSB saturated pad in the petri dish and incubated at 37°C for 18 hours.

Visible colonies which appear yellow were counted and expressed in CFU/100m.

KNUST



CHAPTER FOUR

RESULTS

4.1 Social and Sanitation Survey

4.1.1 Background of respondents

This part entails the analysis of the questionnaires given to participants in the selected communities within the study area. The researcher in an attempt to collect data relevant to the study sampled 80 respondents from two communities, namely Akunakope and Dzogbedzi. However, only 54 of the questionnaires were filled and returned. As a result, the analysis, the findings and the conclusions of the social survey were based on the 54 responses representing 67.5% response rate. A total of 18 (33%) of the respondents were males whilst 36(67%) were females (Table 4.1).

With regard to the age distribution of the respondents, 7.4 % were less than 20 years old, 16.7% were from 20 to 29 years old, 22.2% were from 30 to 39 years old, 14.8% were between 40 and 49 years old whilst 38.9% were 50 years and above (Table 4.1).

The results showed that 29.6% of the respondents had Primary education, 22.2% had Senior Secondary or Middle School education; 1.9% had Secondary or Technical education, 5.6% had non-formal education whilst 40.7% had no formal education at the time the interview was conducted. On the religious affiliation of the respondents, 90.7% were Christians; 5.6% were muslims and 3.7% were traditionalists (Table 4.1).

Table 4.1 Demographic characteristics of respondents in the study area

Variable	Frequency counts (n)	Percentage (%)
N=54		
Gender		
Male	18	33.3
Female	36	66.7
Age(Yrs)		
< 20	4	7.4
20 – 29	9	16.7
30 – 39	12	22.2
40 – 49	8	14.8
>50	21	38.9
Level of education		
None	22	40.7
Non-formal	3	5.6
Primary	16	29.6
Secondary/Technical	1	1.9
SSS/Middle School	12	22.2
Religion		
Christianity	49	90.7
Islam	3	5.6
Traditional	2	3.7

The respondents were asked to indicate the number of years they stayed in the present location: 14.8% had stayed in their present location for a period less than 2 years, 1.9% had stayed for a period from 2 to 5 years, 9.3 % each had stayed between a period of 6

to 10 years, and 11 to 15 years, respectively. However, 64.8 % representing majority of the respondents had stayed in their present location for 16 years and above(Fig. 4.1).

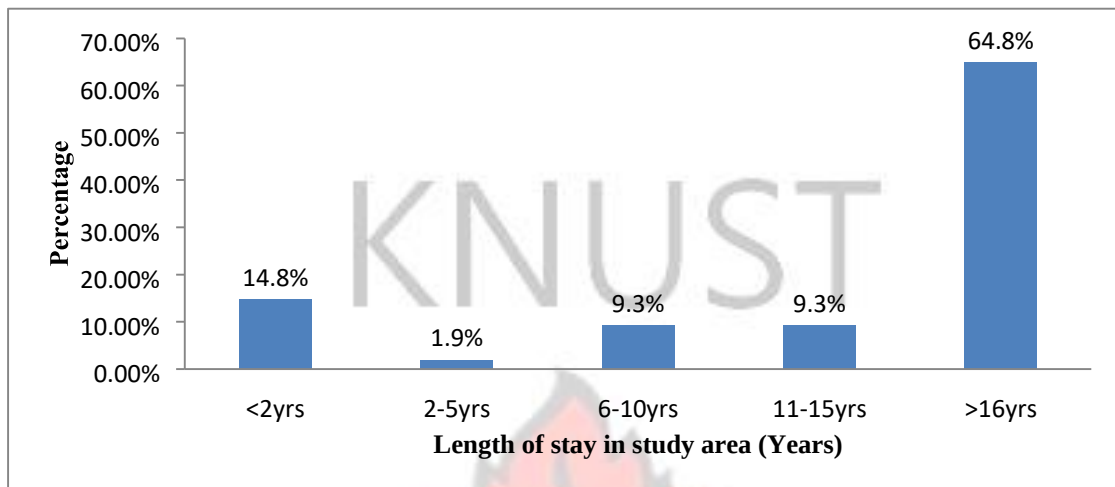


Fig. 4.1: Respondents' length of stay in the study area

4.1.2 Sources of water for drinking and domestic purpose

Concerning respondents' sources of water for drinking and other domestic purposes, 35% had their drinking water from boreholes, 34% said they had theirs from irrigation canal and 31% had their water from lakes(Fig. 4.2).

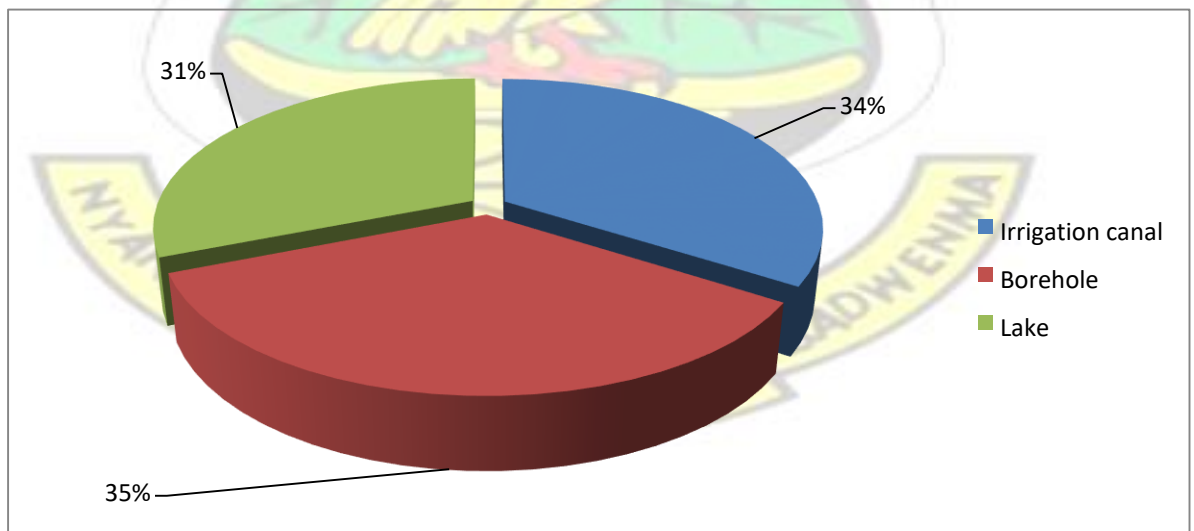


Fig. 4.2: Source of drinking water for people in the study area.

When the respondents were asked to estimate the distance from their house to the source of water for domestic purposes, 7.4 % of them estimated the distance to be less than 20 metres for both the boreholes and surface water; 5.6% estimated the distance from their house to the source of water to be between 20 and 59 metres; 66.7% estimated the distance to be between 60 and 99 meters; 16.6% estimated the distance to be between 100 and 129 metres whilst 3.7% estimated the distance to be 300 metres (Table 4.2).

Table 4.2: Distance of respondent's house to water source

Distance(m)	Frequency	Percentage (%)
Less than 20	4	7.4
20 – 59	3	5.6
60 – 99	36	66.7
100 – 129	9	16.6
300 and above	2	3.7

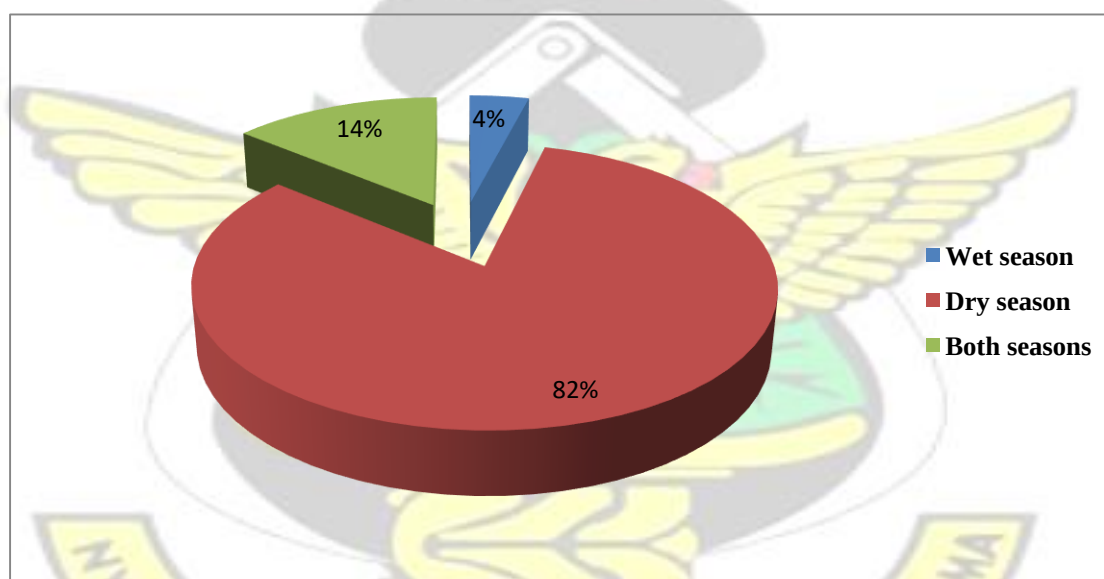
The respondents were asked if they fetch water from irrigation canal for domestic use. In response, 94% of the respondents representing majority of them answered in the affirmative whilst 5.6% of the respondents indicated they do not fetch water from irrigation canal.

When the respondents, who indicated they use water from irrigation canal for domestic purposes were asked to mention what they use the water for, 48.1% said they use the water from the canal for washing, 5.6% said they use it for bathing, 33.3% said they use it for cooking while 7.4 % said they use it for drinking (Table 4.3).

Table 4.3: Respondents' views on use of water

Use of water	Frequency	Percentage (%)
Washing	26	48.1
Bathing	3	5.6
Cooking	18	33.3
Drinking	4	7.4

Fig. 4.3 shows the season when residents rely most on water from the irrigation canal. Four percent of the respondents mentioned they rely mostly on water from irrigation canal during the wet season; 82% representing majority of the respondents rely on water from irrigation canal during the dry season whilst 14% indicated they rely on water from irrigation canal during both seasons.

**Fig. 4.3: Seasons when residents rely on irrigation canal most.**

4.1.3 People's perception on the quality of water they consume

Figure 4.4 shows the perception the respondents have about the quality of water from the various sources. Two percent of the respondents perceived source of their water as

very good, 15% perceived their water source as good whilst 83% representing majority perceived their water source as bad.

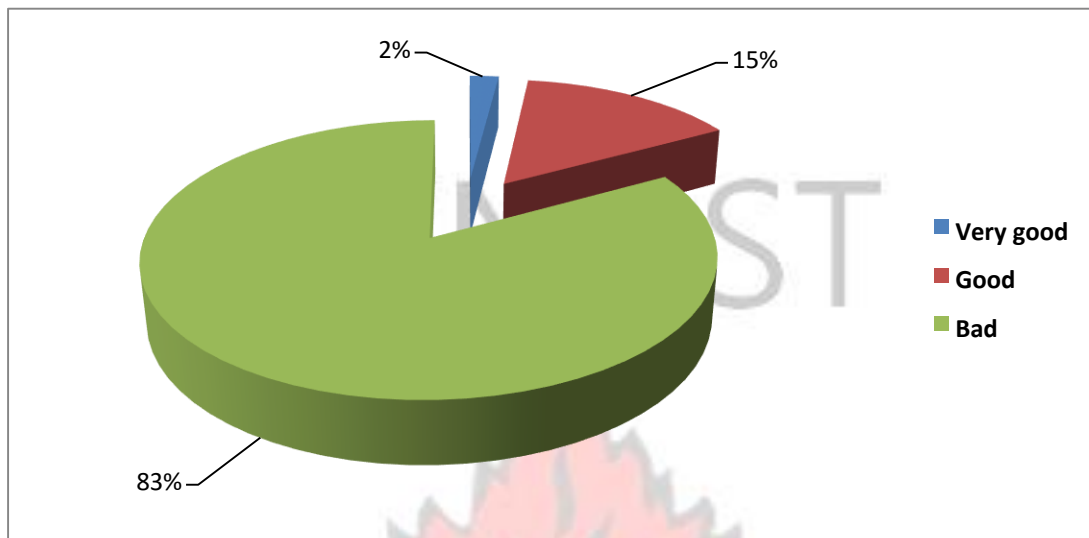


Fig. 4.4: Perception of quality of water from various sources by respondent

When the respondents were asked to indicate the colour of the water they use, 1.9 % indicated the water was colourless, 38.9 % indicated it was slightly brown, whilst 59.3% representing the majority indicated it was dirty brown (Fig 4.5).

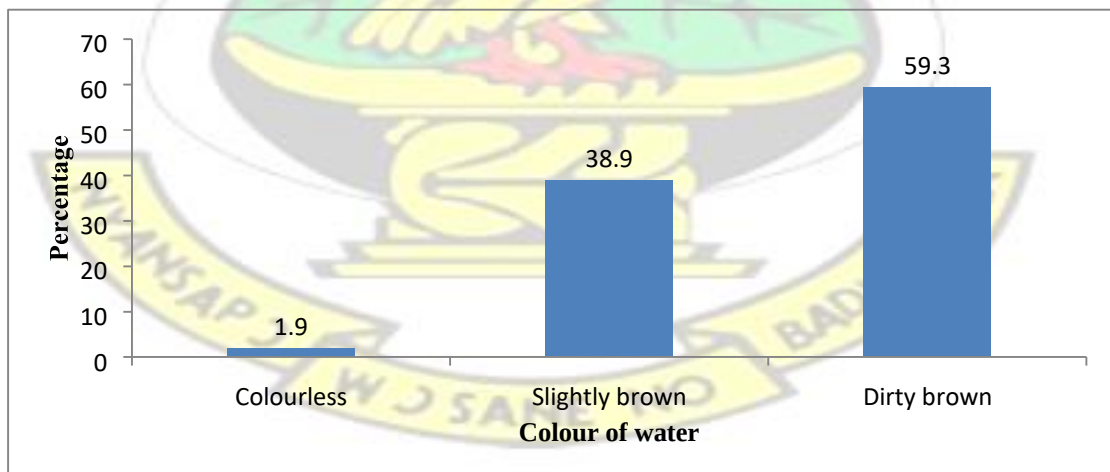


Fig. 4.5: Respondents views on colour of water used

Table 4.4 enumerates the factors that account for the colour of the water used by the respondents. 48.1% of them mentioned that farming along the banks of the water body contributes to the colour of the water they use; 22.2% mentioned dumping of waste in and around the water body, 20.4% mentioned release of chemicals from weedicides and pesticides into the water body, whilst 9.3% mentioned that people bathing in the water bodies contribute to the change in colour of the water from the various sources (Table 4.4).

Table 4.4. Respondents views on factors that contribute to the changes in water colour

Factors contributing to change in water colour	Frequency	Percentage (%)
Farming along the banks of the water body	26	48.1
Dumping of waste in and around the water body	12	22.2
Release of weedicide and pesticides into the water body	11	20.4
People bathing in the water body	5	9.3

When the respondents were asked if water from the various sources should be protected, they all agreed that water from these sources should be protected. When asked further to mention the institution or the authority which should be responsible for protecting the water sources, 64.8% of them mentioned the District Assembly, 29.6% mentioned Community Water and Sanitation Agency (CWSA), 1.9% mentioned the traditional authorities while 3.7% were undecided (Table 4.5).

Table 4.5: Respondents' views on Authorities to be responsible for water protection

Authority	Frequency	Percentage (%)
District Assembly	35	64.8
CWSA	16	29.6
Traditional Authorities	1.0	1.9
Undecided	2.0	3.7

With regard to the places of refuse disposal, 24% of them dispose of refuse around the canal, whilst 76% dispose of refuse in the surroundings. When asked to indicate if defecation and dumping of refuse into lakes, rivers, irrigation canal could pollute the water bodies, 98% answered in the affirmative whilst 2% said no.

Table 4.6 presents the measures suggested by respondents to be put in place to ensure people do not pollute water bodies. From the results, 72.2% mentioned the construction of more toilets and refuse dump sites, 9.3% mentioned regular education on the environment while 13% mentioned inspection by environmental health inspectors.

Table 4.6: Respondents' views on measures to put in place to protect water sources

Measures to protect water sources	Frequency	Percentage (%)
Construction of more toilets and refuse dump sites	39	72.2
Regular environmental education	5	9.3

Inspection by environmental health inspectors	7	13.0
Undecided	3	5.6

When respondents were asked to indicate the method of disposal of domestic waste, 29.6% mentioned into nearby water bodies, 14.8% mentioned pouring into gutters, 53.7% mentioned disposing it outside the home surroundings (Table 4.7).

Table 4.7: Suggested waste disposal methods by respondents in the study area

Waste disposal method	Frequency	Percentage
Into nearby water body	16	29.6
Pouring into gutters	8	14.8
Outside surroundings	29	53.7
Undecided	1	1.9

When respondents were asked if they farm close to a river or canal, majority of them said they farm close to a river or a canal. However, 20% of them said they do not farm close to a river or canal. When the student researcher mentioned that fertilizer application in farms around water sources could negatively affect the quality of water in the river, lake or canal, 52% of the respondents indicated they strongly agree with the assertion, 30% said they agree, 11% disagree with the assertion whilst 4% strongly disagree with the assertion. However 2% of the respondents were undecided on the assertion.

In response to whether or not pollution of water bodies could bring about health problems, 41 respondents representing 76% of the respondents indicated yes and 19 % said no. However, 6% were undecided.

Table 4.8 shows the list of diseases that could be attributed to pollution of water bodies. Multiple response analysis was applied since a respondent could experience more than one disease that may be attributed to pollution of water bodies. The results show 25.6% of them indicating they had experienced bilharziasis as result of water pollution, 10.9% of the respondents indicated they experienced skin diseases, 7.3% indicated they experienced malaria, 23.6% indicated they experienced river blindness, 14.5 % had diarrhoea, 12.7% had cholera and 4.5% had experienced vomiting.

Table 4.8 Views of respondents on diseases that can be attributed to pollution of water bodies

Disease	Frequency counts	Percentage (%)
Bilharziasis	28	25.6
Skin disease	12	10.9
Malaria	8.0	7.3
River blindness	26	23.6
Diarrhoea	16	14.5
Cholera	14	12.7
Vomiting	5.0	4.5

As to how to solve the problem of water pollution, 20.4% of the respondents recommended educating the people in the area on water pollution and its effects, 28.2% recommended a ban on open defecation and dumping of refuse into water bodies, 18.3% of them suggested the construction of toilets, refuse dump sites and pipe borne water, 24.6% of the respondents suggested sanitary inspectors visiting the area frequently, whilst 8.5% recommended the removal of water weeds from the water bodies(Table 4.9).

Table 4.9: Respondents suggestions to address water pollution

Variable	Frequency counts	Percentage
Education on water pollution and its effects	29	20.4
Ban on open defecation and dumping of refuse into water bodies	40	28.2
Construction of toilet and refuse dump sites and pipe borne water	26	18.3
Sanitary inspectors visiting the area frequently	35	24.6
Removal of water weeds	12	8.5

4.2 Physico-chemical parameters

4.2.1 Temperature

Average temperature values for the borehole water ranged from a minimum of 29.3 °C at sampling site AKBH to a maximum of 30.5 °C at sampling site DZBH whilst that for the surface water samples ranged from a minimum of 28.5°C at site AKL (lake) to a maximum of 29.4°C at site AKC (Irrigation canal) (Figure 4.6). Analysis of Variance(ANOVA) at 95% confidence level showed that the temperature of the water samples did not differ significantly among the three water sources (boreholes, canal and lake) ($p=0.35$)(Appendix D).

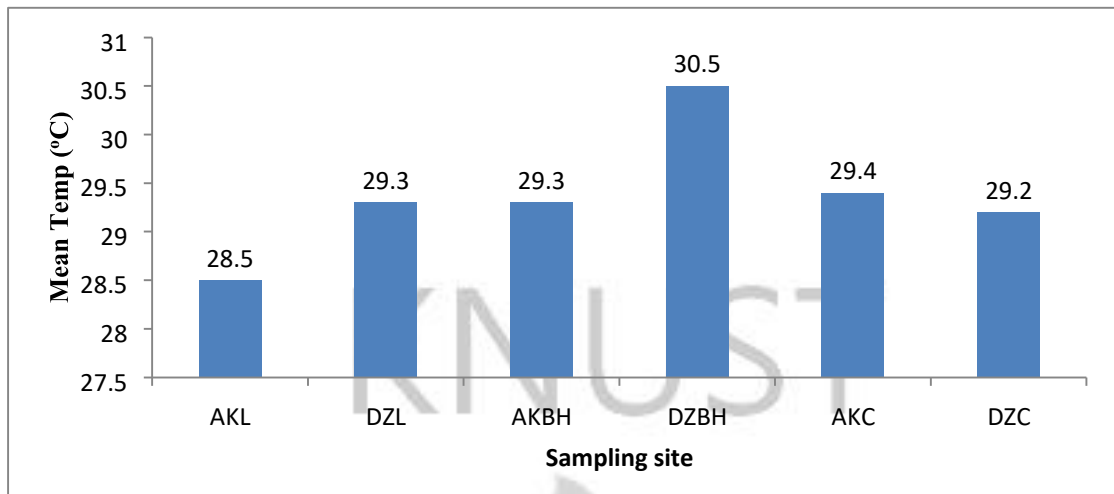


Fig.4.6 Mean Temperature values of water samples at sampling sites

4.2.2 Turbidity

The mean turbidity of the borehole water samples varied from a minimum of 1.3NTU at site DZBH to a maximum of 1.7 NTU at site AKBH whilst that of the surface water samples ranged from 11.0 NTU at site DZL (lake) to 41.6 NTU at site AKL (lake)(Fig 4.7) (Appendix C4). Analysis of Variance (ANOVA) at 95% confidence level revealed statistically significant differences in turbidity among the water sources($p = 0.004$) (Appendix D).

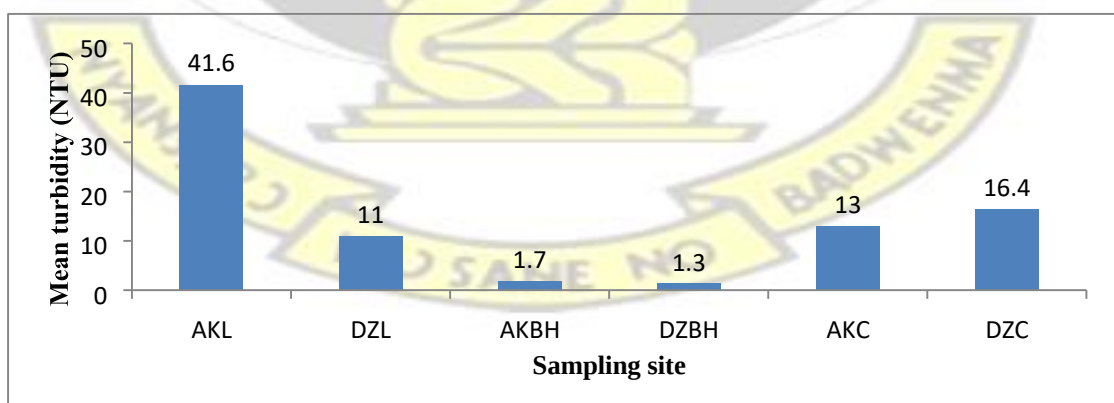


Fig. 4.7: Mean turbidity values of water samples at sampling sites

4.2.3 Colour

The mean values for the colour of the water samples from the boreholes ranged from 1.3 PtCo at site DZBH to a maximum of 3.0 PtCo at site AKBH whilst that of surface water samples ranged from 36.5 PtCo at site AKC (canal) to 127.5 PtCo at site AKL (Lake)(Fig 4.8). Analysis of variance (ANOVA) at 95% confidence level revealed that the colour of the water samples from boreholes and those from the surface water samples (lake and irrigation canal) was statistically significant ($p=0.018$)(Appendix D).

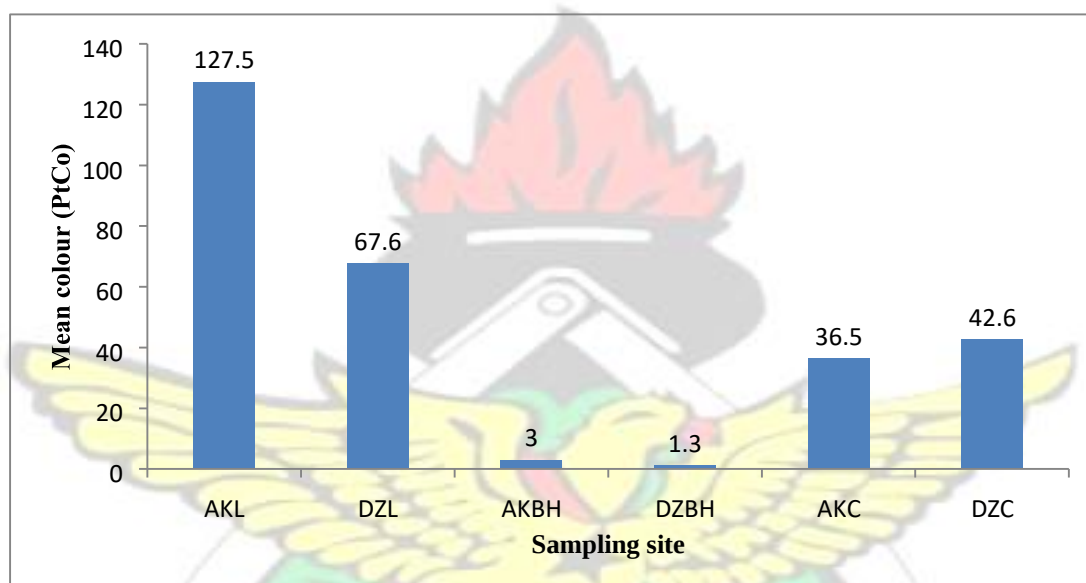


Fig. 4.8: Mean colour values of water samples at sampling sites

4.2.4 Electrical Conductivity

The mean conductivity of watersamples from the boreholes and those from the surface water are presented in Fig. 4.9. The values for the boreholewater samples recorded a minimum conductivity values of 801.0 $\mu\text{S}/\text{cm}$ at site AKBH to a maximum of 1047.6 $\mu\text{S}/\text{cm}$ at site DZBH. The values for the surface water samples varied from 77.9 $\mu\text{S}/\text{cm}$ at site AKC (canal) to 250.5 $\mu\text{S}/\text{cm}$ at site DZC (canal)(Fig.4.9).The conductivity of the water from boreholes, canal and lake was statistically significant at 95% confidence level ($p=0.001$)(Appendix D).

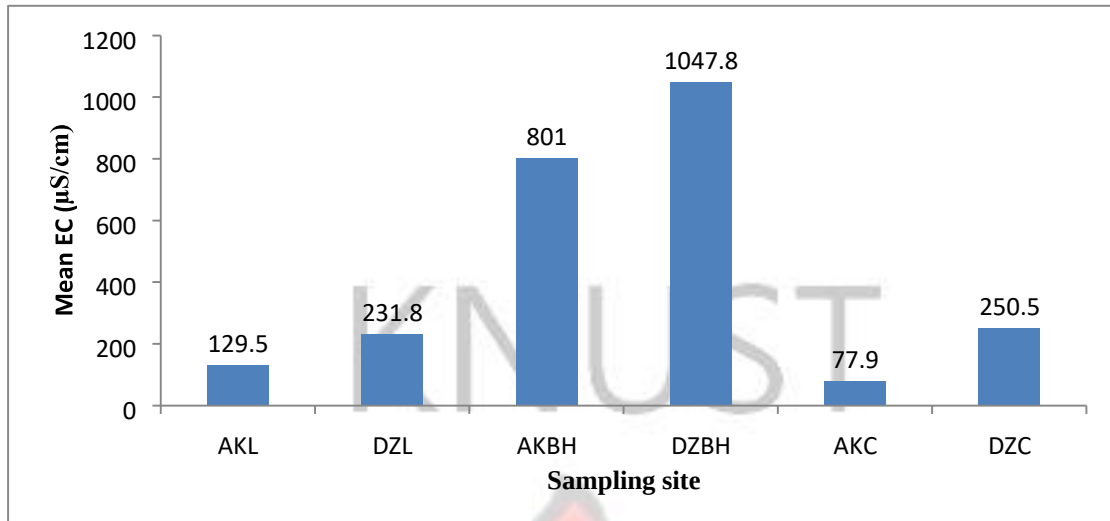


Fig. 4.9: Mean conductivity values of water samples at sampling sites

4.2.5 Total Dissolved Solids (TDS)

Figure 4.10 illustrates the mean TDS concentrations of water samples from boreholes and surface water for the sampling sites in the two communities studied. The mean values for the borehole water samples ranged from a minimum of 400.5mg/l at sampling site AKBH to a maximum of 523.9 mg/l at DZBH whilst that of the surface water varied from 36.2 mg/l at sampling site AKL (canal) to 115.9 mg/l at site DZC (canal) (Fig. 4.10). Analysis of Variance (ANOVA) at 95% confidence level showed that the TDS of the water samples differed significantly among the three water sources (boreholes, irrigation canal and lake)($p=0.015$) (Appendix D).

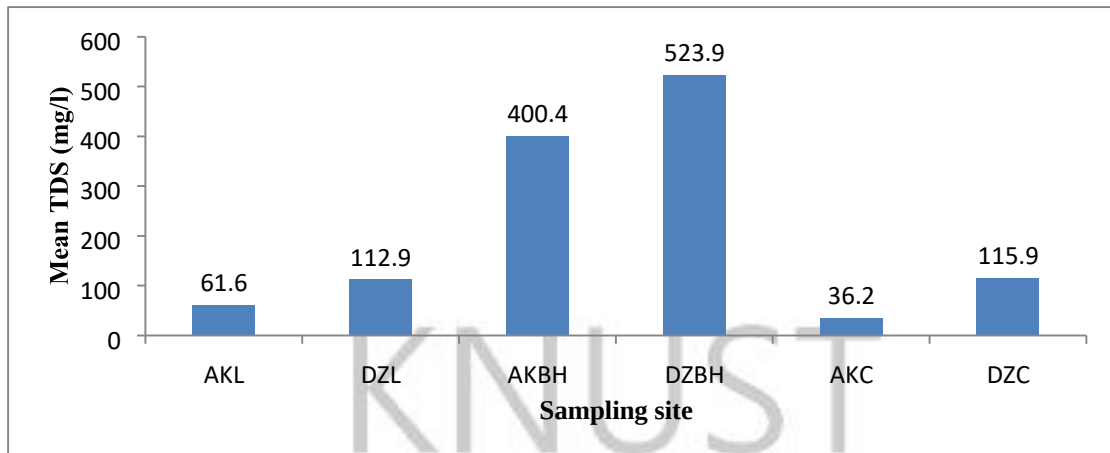


Fig. 4.10: Mean TDS values of water samples at sampling sites

4.2.6 Total Suspended Solids

Mean TSS concentrations recorded for the borehole water samples varied from 1.8 mg/l at site AKBH to 3.5 mg/l at site DZBH whilst that of the surface water sample also ranged from a minimum 5.5mg/l at site AKC (canal) to a maximum of 39.0 mg/l at site AKL (Lake) (Fig. 4.11). The TSS concentrations of the water samples from boreholes and those from the surface water samples (canal and lake) differed significantly ($p=0.002$) (Appendix D).

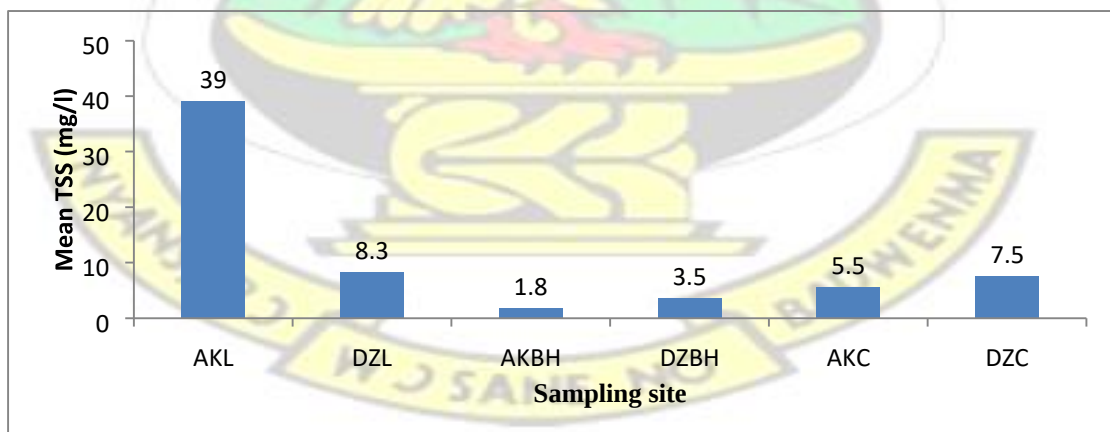


Fig. 4.11: Mean TSS values of water samples at sampling sites

4.2.7 pH

The mean pH values of water from the boreholes ranged from a minimum of 7.7 at site DZBH to a maximum of 7.8 at site AKBH. The mean values for surface water ranged from 6.7 at site AKL (lake) to 7.3 at site DZC (canal) (Fig. 4.12). Statistical analysis using Analysis of Variance (ANOVA) at 95% confidence level revealed that pH of water from boreholes and those from the surface water (lake and irrigation canal) was not statistically significant ($p=0.10$) (Appendix D).

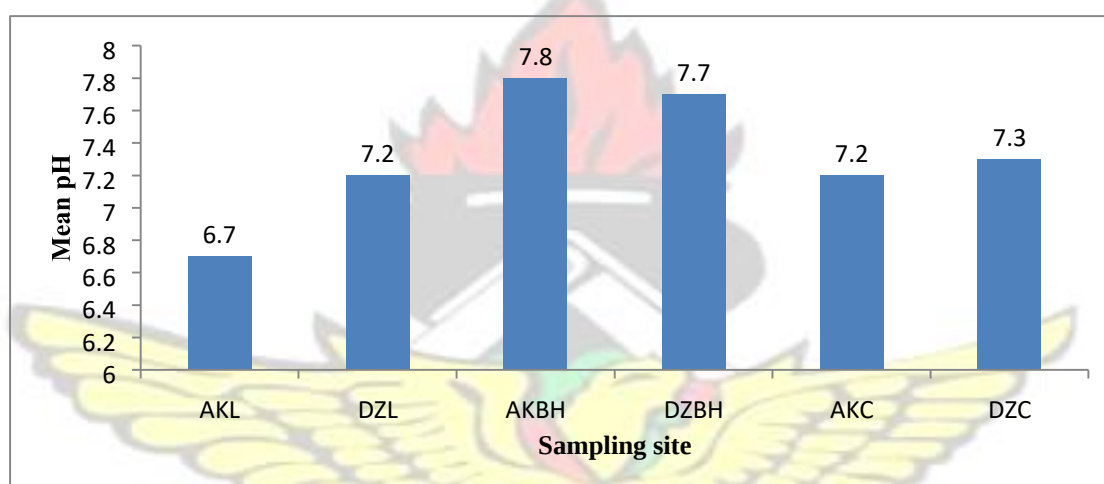


Fig. 4.12: Mean pH values of water samples at sampling sites

4.2.8 Total Alkalinity

The mean total alkalinity of the borehole water samples ranged from 104mg/l at DZBH to 219mg/l at AKBH whilst that of surface water ranged from 27.3mg/l at site DZC (canal) to 50.5 mg/l at AKL (lake) (Fig 4.13). There exist a significance in entire alkalinity among the three water sources (borehole, canal and lake) at 95% confidence level. Borehole and canal ($p=0.024$), borehole and Lake ($p= 0.013$) and canal and lake ($p= 0.028$) (Appendix D).

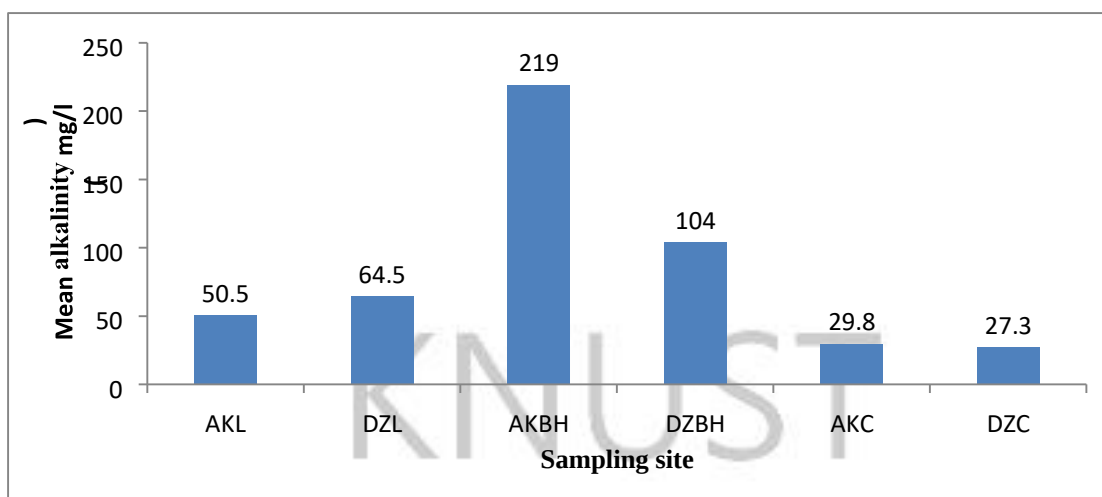


Fig. 4.13: Mean total alkalinity values of water samples at sampling sites

4.2.9 Total Hardness and Bicarbonates

Mean values for total hardness and bicarbonates of borehole water samples ranged from 29 mg/l at site DZBH to 191 mg/l at site AKBH. That of the surface water samples ranged from 33 mg/l at site DZC (canal) to 341 mg/l at site DZL (lake) (Appendix C18). The total hardness and bicarbonates of the water samples from boreholes, irrigation canal and lake were statistically significant at 95% confidence level ($p=0.032$)(Appendix D).

4.2.10 Nitrate

The mean nitrate concentrations of the boreholewater samples varied from a minimum of 0.32 mg/l at site AKBH to a maximum of 0.63 mg/l at site DZBH whilst those of the surface water varied from 0.05mg/l at site AKL (lake) to 0.45mg/l at site AKC (canal)(Fig. 4.15). Analysis of Variance (ANOVA) at 95% confidence level showed that the nitrate concentrations of the water differed significantly among the three water sources (boreholes, irrigation canal and lake) ($p=0.001$) (Appendix D).

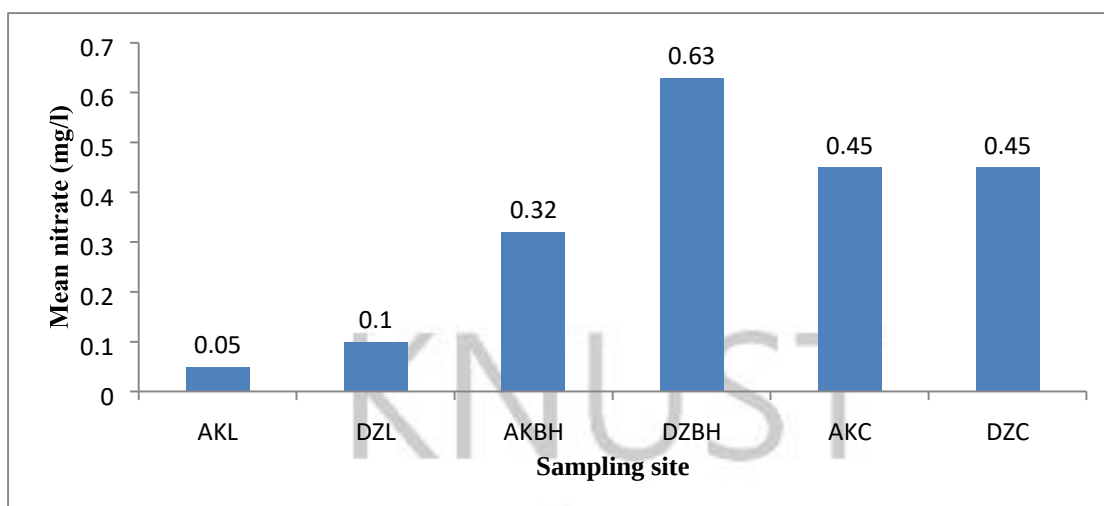


Fig. 4.15: Mean nitrate levels of water samples at sampling sites

4.2.11 Nitrite

Mean nitrite concentrations of the boreholes varied from 0.002 mg/l at site DZBH to 0.004 mg/l at site AKBH with surface water reaching 0.007 mg/l at site AKL (lake) to 0.015 mg/l at site AKC (canal) (Appendix C13). There were no significant observations in nitrite levels among the water samples ($p=0.425$) (Appendix D).

4.2.12 Phosphate

Mean phosphate concentrations of the borehole water samples ranged from 0.20 mg/l at AKBH to 0.26 mg/l at DZBH whilst that of the surface water varied from 0.21 mg/l at AKC to 0.27 mg/l at DZC (Appendix C14). There were no statistically significant differences between water samples from the boreholes and those from surface water (lake/canal) at 95% confidence level ($p=0.328$) (Appendix D).

4.2.13 Chloride

Mean chloride concentrations for borehole water samples ranged from 8.7 mg/l at site AKBH to a maximum of 229.8 mg/l at DZBH whilst values for surface water ranged from 2.00 mg/l at site AKC (canal) to 16.7 mg/l at site DZL (lake) (Fig. 4.16). There

was a statistically significant differences in chloride concentrations among the water samples (boreholes, canal and lake) at 95% confidence level(Appendix D). Borehole and canal (($p=0.001$), borehole and lake ($p= 0.012$), canal and lake ($p= 0.015$).

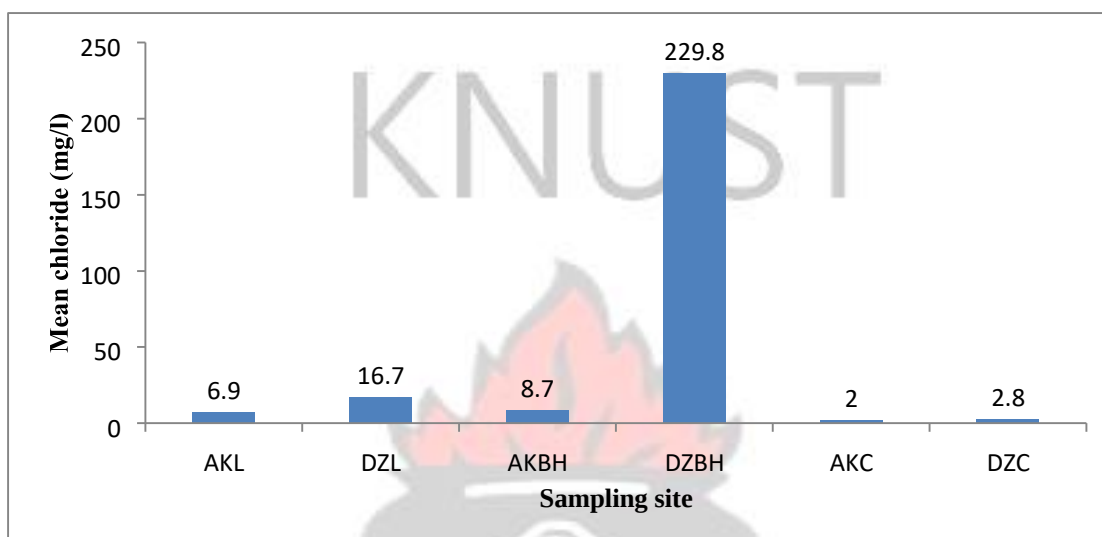


Fig. 4.16: Mean chloride levels in water samples at sampling sites

4.2.14 Fluoride

Meanfluoride concentrations in water samples from boreholes varied from 0.585 mg/l at site AKBH to 0.958 mg/l at site DZBH. Mean values for surface water samples also ranged from 0.007mg/l at site DZC (canal) to 0.983 mg/l at AKC (canal)(Appendix C16). There was no statistically significant differences in fluoride concentrations among the borehole, canal and lake water samples at 95% confidence level ($p> 0.05$)(Appendix D).

4.2.15 Sulphate

Mean sulphate concentrations for borehole water samples ranged between 18.57mg/l at site DZBH and 72.16mg/l at sampling site AKBH whilst that of the surface water varied from 5.61mg/l at site AKC (canal) to 12.25mg/l at site DZL (lake) (Fig 4.17).

Analysis of Variance (ANOVA) at 95% confidence level showed that the sulphate concentrations of the water samples was statistically significant. Borehole and canal ($p = 0.004$), borehole and lake ($p= 0.003$), canal and lake ($p= 0.232$)(Appendix D).

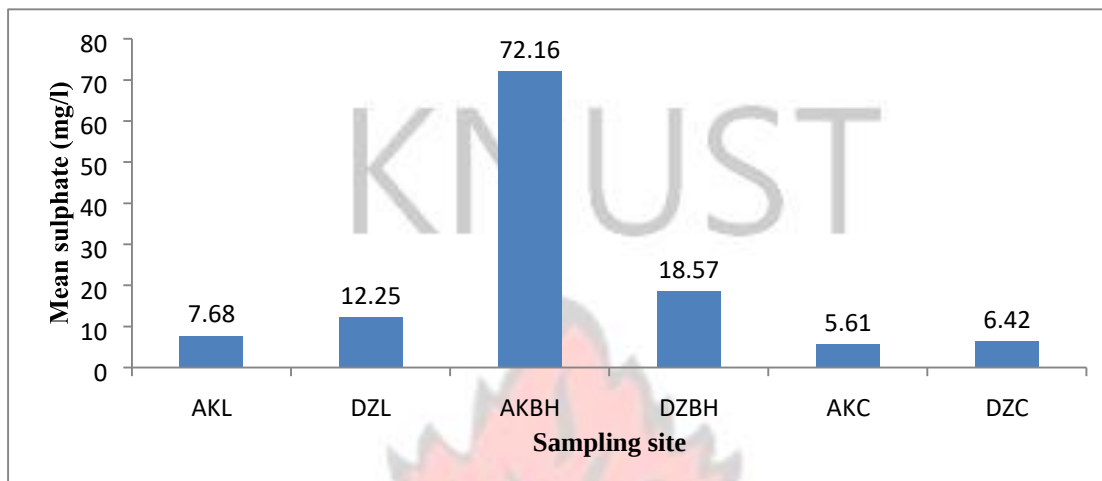


Fig. 4.17: Mean sulphate levels in water samples at sampling sites

4.2.15 Calcium, Sodium, Potassium and Magnesium

Mean calcium concentrations for boreholes water samples recorded over the period ranged from 27.23 mg/l at site AKBH to 58.65 mg/l at DZBH whilst those for surface water samples also varied from 7.4 mg/l at site AKC (canal) to 11.6 mg/l at site DZL (lake) (Appendix C18). Statistical analysis showed that there were significant variations in calcium concentrations among water samples from borehole, canal and lake ($p=0.001$) (Appendix D).

Mean sodium concentrations of borehole water samples also ranged from a minimum of 128.3 mg/l at site AKBH to a maximum of 133.3 mg/l at DZBH. Values for surface water varied from a minimum of 4.9 mg/l at DZC (canal) to a maximum of 25.6 mg/l at site DZL (lake) (Appendix C19). The sodium concentrations differed significantly among the water samples ($p=0.02$) (Appendix D).

The mean potassium values for borehole water samples varied from 4.1 mg/l at site AKBH to 5.9 mg/l at site DZBH whilst that of surface water samples varied from 1.8 mg/l at AKL (lake) to 3.8 mg/l at DZL (lake)(Appendix C 21). There were statistically significant differences in potassium concentrations among the borehole water samples and those of the surface water samples (canal and lake)($p=0.04$) (Appendix D).

Mean magnesium values for borehole water samples ranged from 9.65 mg/l at site DZBH to 25.8 mg/l at site AKBH. The concentrations for surface water samples ranged from 2.4 mg/l at site DZL (lake) to 12.4 mg/l at AKL (lake)(Appendix C20). Analysis of Variance (ANOVA) at 95% confidence level showed that the magnesium concentrations of the water samples was statistically significant ($p=0.001$) (Appendix D).

4.2.16 Total Iron

The mean total iron values for borehole water samples ranged from 128.3 mg/l at site AKBH to 133.2 mg/l at site AKBH whilst that of the surface water samples ranged from 4.85 mg/l at site DZC (canal) to 25.6 mg/l at site DZL (lake). There was statistically significant difference in total iron concentrations among the borehole water samples and the surface water samples (canal and lake)($p=0.012$)(Appendix E).

The mean manganese concentrations for borehole water samples varied from 0.24 mg/l at site AKBH to 0.33 mg/l at site DZBH. The mean concentrations for surface water samples also varied from 0.54 mg/l at site AKC (canal) to 0.64 mg/l at DZL (lake) (Appendix C 23). There was statistically significant difference in manganese

concentrations among the borehole water samples and the surface water samples (canal and lake) ($p=0.004$) (Appendix E).

4.20 Correlation between physico-chemical parameters

To investigate the association, the direction and strength of the physico-chemical features of the water samples, Pearson's product moment correlation coefficient was used. The following correlations were observed among the following physico-chemical variables: Iron correlated positively with Manganese, $r = 0.740$. Manganese correlated negatively with conductivity with a correlation coefficient $r = -0.76$. Sodium correlated positively with potassium with correlation coefficient of $r=0.913$. TDS and conductivity were strongly correlated with a correlation coefficient of $r = 0.99$. A significantly positive correlation ($r = 0.65$) amid calcium and magnesium was observed.

4.3 Bacteriological parameters

4.3.1 Total Coliform (TC)

The mean total coliform count was 0 cfu/100ml for borehole water samples both at sites AKBH and DZBH throughout the entire sampling period. The surface water samples however recorded values ranging from a minimum of 630 cfu/100ml at site AKC (canal) to a maximum of 1115 cfu/100ml at site AKL (lake) (Fig. 4.18). There were statistically significant differences in total coliform counts among the borehole water samples and the surface water samples (canal and lake) ($p=0.01$) (Appendix F).

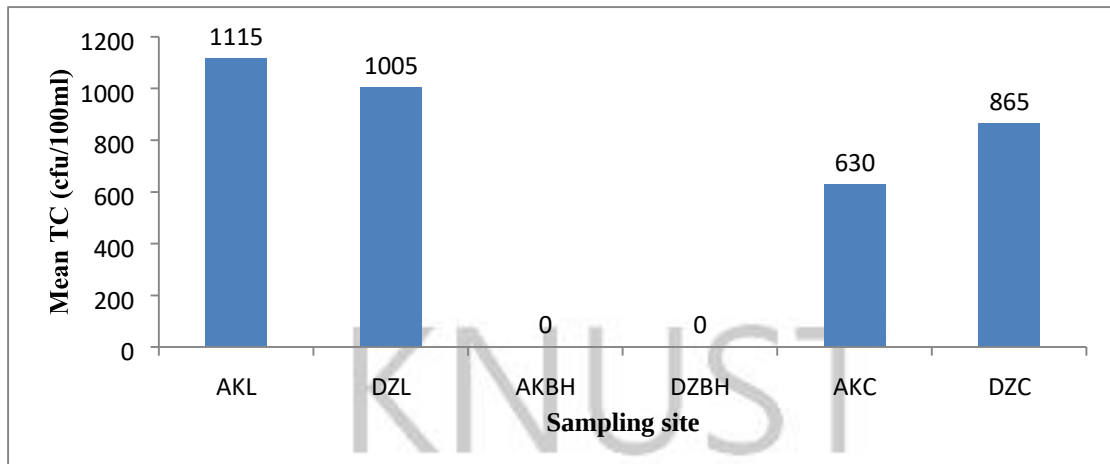


Fig. 4.18: Mean Total coliform counts in water samples at sampling sites

4.3. 2 Faecal coliform

Mean faecal coliform count was zero cfu/100ml both at sites AKBH and DZBH for the borehole samples whilst those of the surface water samples ranged from a minimum of 120 cfu/100ml at site DZC (canal) to a maximum of 292 cfu/100ml at site AKL (lake) (Fig 4.19). Significance was observed for faecal coliform among the borehole water samples and the surface water samples (canal and lake) ($p = 0.04$)(Appendix F).

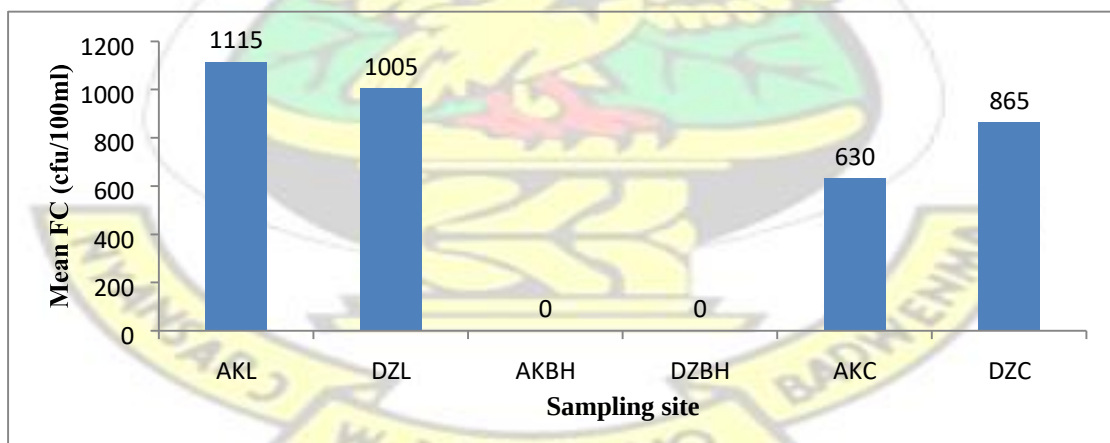


Fig. 4.19: Mean Faecal coliform counts in water samples at sampling sites

CHAPTER FIVE

DISCUSSIONS

5.1 Social and Sanitation Survey on Perception of Inhabitants on Water Quality

The research on people's perception on drinking water quality is usually done to assist in the generation of water quality standards and monitoring of drinking water quality (Jayyousi, 2001; WHO, 2011).

Although public opinion on drinkable water excellence is critical for the management of water resource and generation of water quality criteria, it is most times questionable because it does not always reflect the actual water quality standards (Jayyousi, 2001). Association between perceptions of public drinking water quality and actual drinking water quality was investigated in a community-based exploratory study in Newfoundland, Canada. Nutrients, metals, and physical parameters were determined. The findings show that colour, manganese, total dissolved materials, iron, turbidity were the main identified limits in the public water observed to be above the recommended limit set by the WHO. However, in the social survey of public perception about the quality of water, majority of the respondents (>56%) were very content with the quality of the drinking water (Ochoo *et al.*, 2017).

In this study, apart from colour, turbidity and electrical conductivity that recorded high levels at most of the sampling points, the remaining parameters were within the WHO limits for drinking and domestic use of water. However, in the social survey 83% of the respondents perceive their water sources for drinking as poor and attributed farming along the banks of the water body, indiscriminate dumping of waste in and around the water body and bathing/washing in the water body as major contributing factors. It was also observed from this study that, people have to travel several distance to access water for drinking purposes and other domestic usage. About 66.7% estimated the distance to their water sources to be between 60 to 99 meters from their households.

According to Eni and Efiong (2011), provision of accessible, affordable and acceptable safe drinking water to each and every individual of the world is essential irrespective of geographical location, gender, ethnicity and socio-economic status.

5.2 Physico-chemical Parameters

5.2.1 Temperature, Turbidity and Colour

The water temperatures of the boreholes were slightly higher than those of the irrigation canal and lake which are surface waters. This could be attributed to influences such as the heating of the metal pipes during sampling. The mean water temperature ranged from a minimum of 28.6°C at AKL (lake) to a maximum of 30.1°C at DZBH (borehole). The temperature of water samples from the irrigation canal, lake and boreholes were all slightly above the natural background level of 22°C – 27°C set by WHO as drinking water in the tropics (WHO, 1998). Temperature is a parameter of significant importance for aquatic ecosystem as it influences the water organisms as well as other physicochemical properties of water (Nkansah, *et al.*, 2010).

Generally, with the exception of two boreholes (AKBH and DZBH) that recorded a mean turbidity levels below WHO recommended limits, that of the lake and irrigation canals exceeded the natural background level of 5 NTU set by WHO for drinking water (WHO, 1998). The low values of turbidity recorded for the boreholes samples are typical of groundwater since suspended material is filtered by rock during groundwater flow. The high values of turbidity in surface water on the other hand, could be due to high siltation of the surface water. Turbidity is caused by the presence of suspended matter such as clay, silts, and finely divided organic and inorganic matter, plankton and other microscopic organisms and this may have accounted for the high values recorded from the lake and irrigation canal water sources. According to Spellman and Drinan

(2000), the turbid nature of surface water results from erosion of small colloidal material from soil, micro-organisms and vegetable material (Lester and Birkett, 1992).

The colour of the lake and irrigation canal water samples exceeded the WHO acceptable level of 15 PtCo but that of the borehole water samples at site DZBH and AKBH were within the acceptable limit.

5.2.2 Total Dissolved Solids, Electrical Conductivity and Total Suspended Solids

Conductivity can be defined as the ability of aqueous solution to conduct an electrical current. Conductivity provides indication of mineralization. The conductivity values recorded during the study period far exceeded the WHO regulatory limit of 250 $\mu\text{S}/\text{cm}$. The mean conductivity of water in the boreholes was very high and exceeded the natural background level. Site DZBH also exceeded the WHO limits of 250 $\mu\text{S}/\text{cm}$. The high conductivity in the boreholes (AKBH and DZBH) could be attributed to dissolved ions. This was evident with relatively high amount of sodium, potassium, magnesium and calcium ions in the samples. The correlation matrix revealed a strong positive relationship between conductivity and the dissolved ions. Conductivity of most fresh waters ranges from 10-1000 $\mu\text{S}/\text{cm}$ and is related to the dissolved solids and major ions (Chapman, 1992; Lester and Birkett, 1992).

Total dissolved solids is a common indicator of polluted water. The maximum acceptable limit for TDS in drinking water is 1000 mg/l (WHO, 2006). The TDS concentrations recorded for all the sites were below the WHO recommended limit. Total dissolved solids and conductivity were strongly correlated with a correlation coefficient of $r=0.99$. Total suspended solid relatively measure the visual observation of water

sample. The WHO value guideline shows that, water must have a TSS value not exceeding 500 mg/l for it to be considered safe for human consumption (WHO, 2006). The Total suspended solids for all water samples recorded for boreholes and canal and were within the WHO acceptable limit.

5.2. 3. pH, Total Alkalinity, Total Hardness and Bicarbonate

The pH of a liquid expresses the concentration of hydrogen ions. pH is important in water quality assessment as it influences many biological and chemical processes within a water body (Chapman, 1992). The pH, which is neutral to slightly alkaline, recorded at the various sites fell within the WHO acceptable limits for potable water of 6.5-8.5. In unpolluted water, pH is principally controlled by the balance between the carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds such as humic and fulvic acids (Chapman, 1992).

Hardness is a measure of calcium and magnesium in the form of their carbonates and sulphate. Total hardness for all the water samples were less than the WHO guideline value of 500 mg/l. The low values imply that the water can be used for laundering and bathing. This results corroborates the findings obtained in the social survey where some of the users of the surface water interviewed, asserted that they do not have problems with the use of the water during washing since it lathers easily with soap. This claim is confirmed by the relatively low total hardness which falls within the soft category of classification (0-60 mg/l) as set by WHO (2006). Conversely, the users of the boreholes complained of using too much soap on washing and bathing. Their claim was

corroborated by the relatively high total hardness in the boreholes.

From the above discussion, alkalinity which depends significantly on the concentration of carbonates, bicarbonates and hydroxide ions is not expected to have very high values

in the case of the surface water. However values recorded for the boreholes were relatively high and this was expected due to corresponding high concentrations of carbonate, bicarbonates and hydroxides.

5.2.4 Nitrate, Phosphate and Nitrite

Nitrate and Nitrite concentration was generally low in all the sampling sites. The mean concentrations were within the WHO guideline value for drinking water of 10mg/l and 1.0 mg/l respectively. The low level of nitrate and nitrite concentrations suggests that the water sources were not contaminated by human or livestock waste, excessive fertilization or seepage from dump sites.

Phosphorous was measured as a constituent of soluble reactive phosphate (SRP) (also sometimes called phosphate (PO_4) or orthophosphate (ortho-P). Phosphorous occurs in natural waters and in waste waters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates) and organically bound phosphates. They occur in solution, in particles or detritus, or in the bodies of aquatic organisms. Phosphorous is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water. Orthophosphates applied to agricultural or residential cultivated land as fertilizers are carried into surface waters with storm runoff. They are major constituents of many commercial cleaning preparations (APHA, 1995). The mean phosphate concentrations recorded over the study period for boreholes and surface water fell within the WHO permissible limits.

5.2.5 Chloride, Fluoride and Sulphate

The chloride concentrations were within the WHO recommended permissible limits of 0 to 250 mg/l. However, site DZBH (borehole) recorded the highest mean value of 229.7 mg/l. Chloride concentrations of more than 250 mg/l can give rise to detectable taste in water when it combines with sodium in excess of 200 mg/l (WHO, 2004). The DNHW, Canada (2006) stated that chlorides in shallow and ground-water might come out of both usual and human base-like run-off holding salts, the utilization of inorganic fertilizers, septic tank effluent, manufacturing leachate, concentrated irrigation as well as marine water invasion in places near the ocean.

The mean fluoride concentrations in all the samples were within the WHO guideline value of 1.5 mg/l. Fluoride occurs naturally in most groundwater wells and can help prevent dental cavities. Between 1 and 1.5 mg/l is desirable. As fluoride levels increase above this amount, there is an increase in the tendency to cause tooth mottling. Fluoride levels less than 2 mg/l are not considered a problem for livestock (Chapman, 1992).

Sulphate is as well a non-toxic anion which is of significant health concern. The WHO proposes that levels of sulphate greater than 250 mg/l must be documented to medical specialists as a result of challenges with purification, dryness, stomach as well as gastric challenges (WHO, 2005). Extra sulphate in water beyond 500 mg/l is considered to result in a purgative influence as well as encourage an unpleasant palate to the water basis. The average sulphate levels were normally minimal as well as dropped inside allowable bounds of household utilization of water.

5.2.6 Calcium, Sodium, Potassium and Magnesium

The calcium level in both boreholes and surface water were all within the WHO acceptable limit of 200mg/l. The presence of calcium in water supplies results from passage through or over deposits of limestone, dolomite, gypsum and gypsiferous shale. Appreciable calcium salts precipitate on heating to form harmful scale in boilers and pipes. Calcium contributes to the total hardness of water (APHA, 1995). According to EPA (2002), calcium has little effect on the physiological functions of the ecosystem thus no criteria are needed. For domestic use however, the recommended range falls between 0-32 mg/l. Above 32.0 mg/l, lathering of soap is impaired and the value at DZBH (borehole) was above this range. There was a positive relationship between calcium and magnesium with a correlation coefficient of $r = 0.65$.

The mean sodium level in the study area varied from 4.86 mg/l to 133.25 mg/l, which fell within the WHO acceptable limits for drinking and potable water of 200mg/l. Sodium is a significant factor in assessing water for irrigation and plant watering. High sodium levels affect soil structure and a plant's ability to take up water.

The mean concentrations of potassium in the water samples area ranged from a minimum of 2.08 mg/l to a maximum of 4.63 mg/l. The potassium ion level fell within the WHO acceptable limits for drinking and portable water of 30 mg/l. Sodium correlated positively with Potassium with correlation coefficient of $r = 0.913$.

Magnesium exist at the eight position amid the minerals according to level of profusion and is a shared component of raw water. As a significant donor to the rigidity of water, magnesium salts breakdown after heating, making scale in boilers (APHA, 1995). Magnesium rises mainly out of the breakdown of rocks having ferromagnesian elements

as well as out of certain carbonate rocks (Chapman, 1992). Accordingly, DZC (canal) recorded the minimum mean value for Magnesium of 2.4 mg/l whilst AKBH (borehole) recorded the maximum mean value of 14.8 mg/l. Both values fell within the WHO acceptable limits of 200 mg/l.

5.2.7 Total Iron and Manganese

The mean values for total iron of both surface water samples and boreholes exceeded the WHO recommended guideline value of 0.3 mg/l. The mean values for manganese of water samples obtained from irrigation canal, borehole and lake water sources also exceeded the WHO recommended limit of 0.1mg/l. The high levels of iron and manganese recorded in this study could be attributed to the natural availability of iron and manganese in the soil. Generally, trace amounts of metals are always present in waters as a result of weathering of rocks (Mc Bride 1994; Chapman, 1992). Iron is essential to the human body and its intake through drinking water is normally an insignificant portion of the body requirement (Freeze & Cherry, 1979). Iron correlated positively with Manganese, $r=0.740$. Manganese correlated negatively with conductivity with a correlation coefficient $r = 0.76$.

5.3 Bacteriological parameters

The bacterial counts showed considerable variations during the period of investigation. The high coliform counts recorded in the surface water could be attributed possibly to pollution at the sampling sites resulting from intense human activity such as runoff of street waste and drainage water which contains residue from open defecation as well as livestock excreta. The high level of faecal coliform counts could also be linked to the type of toilet facilities, usually pit latrine that are common in the area and may result in

washout during rains. Due to limited toilet facilities in most of these communities, most of the inhabitants defecate in the open.

From the social survey, a common practice identified in these communities is the indiscriminate disposal of refuse. With the exception of the two boreholes (AKBH and DZBH), the presence of such high coliform bacteria suggests the presence of harmful bacteria. The zero cfu/100ml counts of the two boreholes indicate that the water was not polluted from any contamination source. The physical barriers of the boreholes, such as the concrete sanitary seal and usage of proper connecting pipes stops onland runoffs with anthropological, livestock as well as household gagagge from contaminating the water sources.

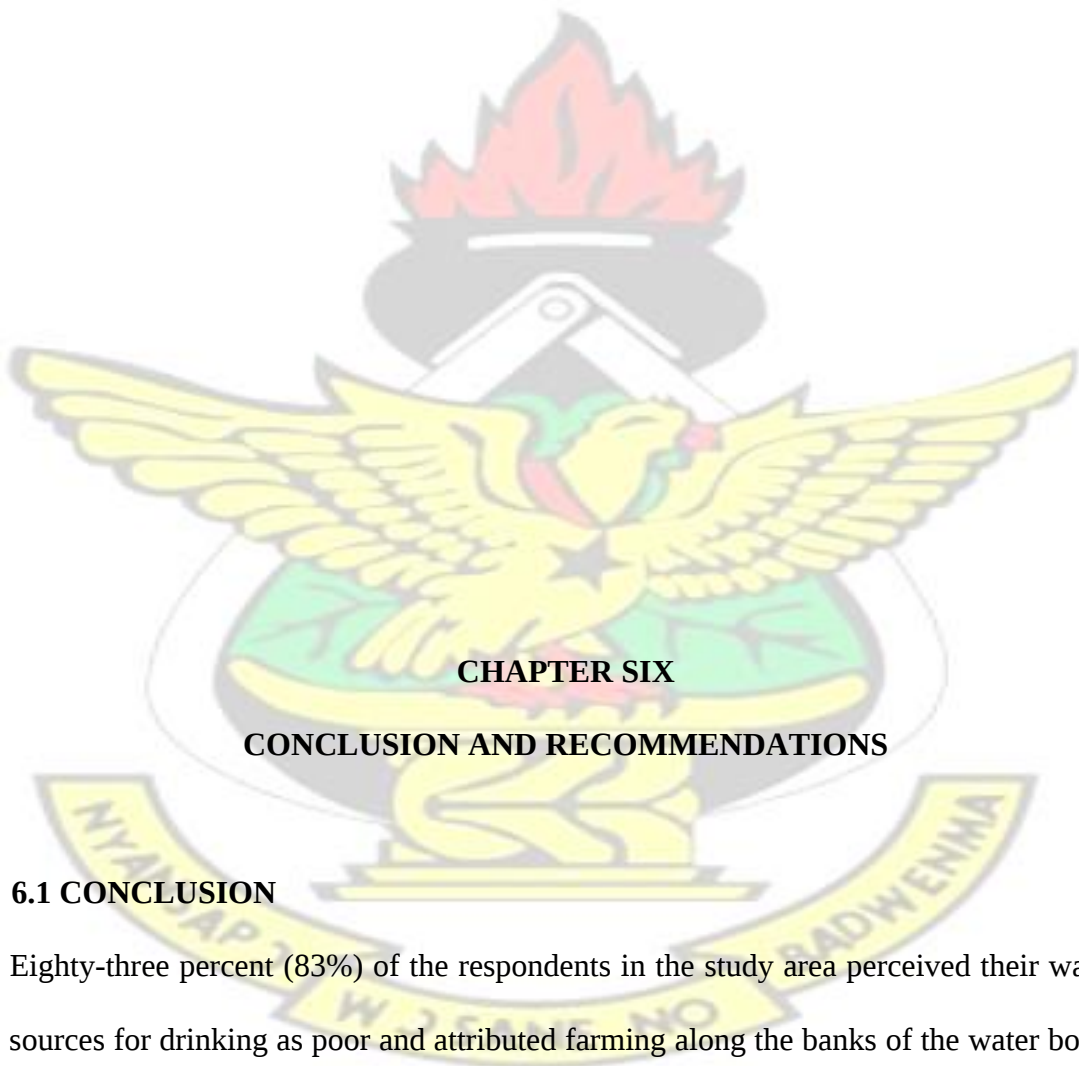
WHO (2006) stated that groundwater is not much susceptible to pollution because of blockade impact and that when the protecting wall is broken, immediate pollution might happen. Total coliform correlated negatively with conductivity, Total dissolved, sodium, potassium and magnesium. Faecal coliform correlated positively with the turbidity and total suspended solids. Coliform bacteria are the most widely used indicators of water quality. According to WHO guidelines for drinking water, no coliform organisms should be detected in 100ml sample of all waters intended for drinking. The presence of high levels of coliform in the lake and canal water samples in the study area indicates a risk of infection by drinking the contaminated water.

According to Oduro-Koranteng (2003), majority of water-borne diseases arise as a result of contamination of water used for drinking by human and animal faeces.

World Health Organization recommends a zero cfu/100ml faecal coliform level for drinking water, while acceptable levels for river water depend on the specific use of the

river. For example, the total and faecal coliform levels recommended for unrestricted irrigation of crops likely to be eaten raw is $1000/100^{-1}$ (Hammer, 1975). In this study the canal water was mostly used in irrigating vegetables which could pose potential health concerns.

KNUST



CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Eighty-three percent (83%) of the respondents in the study area perceived their water sources for drinking as poor and attributed farming along the banks of the water body, indiscriminate dumping of waste in and around the water body and bathing/washing in the water body as major contributing factors.

Turbidity, colour, EC, TDS, TSS, total alkalinity, total hardness, bicarbonates, nitrates, chlorides, sulphate, fluoride, calcium, sodium, potassium, magnesium and total iron in

the surface water samples were significantly higher as compared to those in the boreholes. The EC, temperature, chloride and turbidity in both surface water and borehole far exceeded the WHO guideline for drinking water. High concentrations of the overall coliform as well as fecal coliform numbers were encountered in the surface water samples. This consequently proposes that the water was contaminated with feces, perhaps out of the indiscriminate dumping of refuse and defecation along the water body. High positive and negative correlations were observed among the following physicochemical variables: Fe and Mn, $r=0.740$; Mn and EC, $r = -0.76$; Na and K, $r = 0.913$. TDS and EC, $r = 0.99$. Ca and Mg, $r = 0.65$.

6.2 RECOMMENDATIONS

Upon the findings of this research, the following recommendations are being formed:

1. The District Assembly must train the societies on the necessity to save their water bodies hygienic through effective education.
2. The water especially from the lake and irrigation canal should be treated by boiling before using it for domestic purposes because of its high microbiological counts.
3. The District Assembly should provide places of convenience such as community toilet facilities in the district to prevent people from indiscriminate defecation along the river banks

KNUST



LIST OF REFERENCES

- Adjomah, X. J. (2010).** *Overcoming the Challenges of Water Resource Management and Utilisation Ghana.*
www.ghanaweb.com/GhanaHomePage/featurearticle.php? Accessed April 25, 2011.
- African Economic Outlook (2007).** *Ghana Country Note.*
Online. www.oecd.org/dataoecd/26/51/38562673.pdf. Accessed on July 25, 2011.
- Amedzeame, D. E. (2004).** *Analysis of effluent from Cocoa Processing Company Limited*, pp 1 – 3. Unpublished thesis, Department of Chemistry, Faculty of Science, University of Ghana, Legon.
- Ansa-Asare, O. and Darko, H. F. (2006).** Surface Water Quality Monitoring and Assessment of South-West and Coastal River Basin of Ghana. Water Research Institute, Council for Scientific and Industrial Research, Ghana, Annual Report 2006.
- APHA (1995).** American Public Health Association. *Standard Methods for the Examination of Water and Waste Water*. 19th Edition APHA Washington, DC pp 2 – 57.
- APHA (1998).** *Standard Methods for the Examination of Water and Waste Water*. 19th Edition APHA Washington, DC pp 57 – 64.
- Ashbolt, N. J., Grabow, W. O. K. and Snozzi, M. (2001)** Indicators of microbial water quality In: *WHO (2001) Water Quality: Guidelines, Standards and Health*. Edited by Fewtrell, L. and Bartram, J. by IWA London, UK. Pp. 291, 295-295.
- Baird, C. (2000)** . *Environmental Chemistry*, 2nd Edition. W. H. Freeman and Company, 41 Madison Avenue, New York pp 381 – 414.

- Barrow, G.W.S. (2005).** *Robert Bruce and the community of the Realm of Scotland*, 4th edition, Edinburgh: Edinburgh University Press.
- Bitton, G. (2005).** Microbial indicator of faecal contamination: Application to microbial source tracking, Report submitted to the Florida Storm water Association, 719 East Park Avenue, Tallahassee, 32301. Pp.4-6.
- Buchholz, A. R. (1993).** Principles of Environmental Management 2nd Edition. The greening of business, pp 179 – 187.
- Chapman, D. (1996).** Water Quality Assessments: A Guide to Use of Biota Sediments and Water in Environmental Monitoring, 2nd ed. E&FM Spon.
- Chanda, D.K. (2010).** Seasonal study of physico-chemical parameters of groundwater in industrial area, Jaipur. *Hydrology Journal*, 7(5), 431-439.
- Chen, C. J and Zhang, W. (1988).** A nationwide Survey on Drinking Water Quality and Water Borne Diseases in China. Beijing Institute of Environmental Health and Monitoring, Chinese Academy of Preventive Medicine, pg. 95-99.
- CWSA (2007).** The Community Water and Sanitation Agency: Corporate Brochure. pp 1-33.
- DWDA (2006).** District Medium Term Plan for Dangme West District Assembly (2006 – 2009): District Profile and Investment Potential, Dangme West District Assembly.
- Department of National Health and Welfare, Canada. (2006).** Guideline for Canadian drinking water quality. Supporting Documentation. DNHW: Ottawa, Canada.
- Eni, D. I. And Efiong, J. (2011).** Seasonal variations in hydrochemical parameters of groundwater in Calabar south, Cross River State, Nigeria. *British Journal of Arts and social science*, 85-97.

EPA Ghana (2002). Water Quality Standards.National Workshop on Water Quality Standards. Accra, 30th September, 2002.

Federal Interagency Stream Restoration Working Group (1998). Stream Corridor Restoration: Principles, Processes, and Practices.

http://www.usda.gov/stream_restoration/newgra.html.

Franceys, R and Gerlach, E. (2008). Regulating Water and Sanitation for the Poor: Economic Regulation for Public and Private Partnerships, Earthscan, London (UK). pp 10 – 11.

Freeze , A. R. And Cherry J. A. (1979). Groundwater. Prentice-Hall Inc., Englewood Cliffs, New Jersey .

Ghana Districts (2008). A repository of all Districts in the Republic of Ghana.Retrieved from <http://www.ghanadistricts.com/region/?r=1859=603>.

Ghana Standard Board, (2008). “Ghana Standard 175 – 1: 2008. Water Quality: Specification for Drinking water”.

Ghana Statistical Service (2005). Population and Housing Census, Eastern Region.Analysis of the District Data and Implication for Planning.Ghana Statistical Service 2005.

GoG (2007). Ghana Natural Water Policy.Government of Ghana and Ministry of Water Resources, Works and Housing.Pp 5, 29 – 33.

Gregory, M. B. and Frick, E. A. (2000). Faecal-Coliform bacterial Concentrations in Streams of the Chattahoochee River National Recreation Area, Metropolitan Atlanta, Georgia, May-October 1994 and 1995, U.S Geological Survey water –resources investigations Report 00-4139. Pp. 1-8.

Hammer, M. J. (1975). Water and Wastewater Technology, John Wiley and Sons, Inc. NY.

Harman, J., Robertson, W. D., Cherry, J. A .and Zanini, L. (1996). Impacts on a sand aquifer from an old septic system: Nitrate and phosphorus. *Ground Water*.

34; 1105–1114.

Health Canada (2006). Guidelines for Canadian Drinking Water Quality: Guidelines Technical Document – Total Coliforms, Water Quality and Health Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa. Pp.9-10.

International Conference on water and the Environment (1992). The Dublin statement on water and Environment, the Action Agenda of the Dublin statement; 26 – 31 Jan, 1992; Dublin, Ireland pp2.

Jayyousi, T. (2001). Sources of ground water contamination, Agricultural and Biological Engineering Department, Purdue University, Indiana

Larmine, S. A. And Paintsil, D. A. (1996). A Survey of Hygienic Quality of Drinking Water Sold in Accra. CSIR – WRI. February, 1996.

Lester, J. N. and Birkett, J. W. (1992). Microbiology and Chemistry for Environmental Science. Wm. C. Publishers.

McBride, M. B. (1994). Environmental Chemistry of Soils. Oxford University Press, Oxford. U.K 406p.

Myers, D. N., Stoeckel, D. M., Bushon, R. N., Franczy, D. S., and Brady,

A. M. G. (2007), Faecal indicator bacteria: U.S. Geological Survey Techniques of Water-Resources Investigation, Book 9, Chap. A7, section 7.1(version2.0).Retrieved from theWorld Wide Web:
<http://water.usgs.gov/owq/FeldManual/Chapter7/index.html>

Nkansah, M. A., Boadi, M. O. and Badu, M. (2010). Assessment of the Quality of Water from Hand-Dug Wells in Ghana, Environmental Health Insights 4, 7–12.

Nyambod, M. E. and Nazmul, H. (2010) . *Integrated Water Resources Management and Poverty Eradication –Policy Analysis of Bangladesh and Cameroon.* *J. Water Resource and Protection*, 2; 191-198 doi:10.4236/jwarp.2010.23021 Published Online March 2010 (<http://www.scirp.org/journal/jwarp>).

- Ochoo, B., Valcour, J., and Sarkar, A. (2017).** Association between perceptions of public drinking water quality and actual drinking water quality: A communitybased exploratory study in Newfoundland (Canada). *Journal of Environmental Researc*, 25; 5 - 12.
- Oduro-Koranteng, L. E. A. (2003).** Gender and Natural Resource Management of the Weijsa Lake and its environs.
- Pedley, S., Yates, M., Schijven, J. F., West, J., Howard, G. and Barrett, M. (2006).** Pathogens: Health, relevance, transport and attenuation In: WHO, Protecting Groundwater for Health: Managing the Quality of Drinking-water Sources. Edited by Schmoll, O., Howard, G., Chilton, J. and Chorus. I. Published by IWA Publishing, London, UK. Pp.54-56.
- Poulous, E , S. I., Ogban, F. E., Horsfall, M. J. and Akporhonor, E. E. (2012).** Seasonal variations of physico-chemical characteristics in water resources quality in Western Niger Delta Region, Nigeria, *J. Appl. Sci. Environ.Mgt*. 9 (1); 191.
- Schlegel, H. G. (1995).** *General Microbiology*, 7thed. Cambridge University Press Cambridge, UK.pp.311-314.
- SODA (2012).** District Analytical Report, Shai Osudoku District Assembly. pp 5 -69 www.statsghana.gov.gh
- Shaw, M. E. (1998).** *Hydrology in Practice* 3rd edition, pp 177. The McGraw-Hill Companies, USA.
- Spellman, F. R. and Drinan, J. (2000).** *The Drinking Water Handbook*. Technomic Publishing Company. Inc. U.S.A. 260p.
- Thompson, I. A., (2010).** Domestic Waste Management Strategies in Accra, Ghana and Other Urban Cities in Tropical Developing Nations.
- UNICEF (2010).** Joint Monitoring Programme (JMP). “Progress on Sanitation and Drinking-Water.” (Progress in Access to Safe Drinking Water – Sanitation Needs Greater Effort), Cape Town.

United Nations Population Fund (UNFPA), *Annual Report*, (2002).www.unfpa.org

USEPA (United States Environmental Protection Agency), (2001). National primary drinking water regulations. EPA 816-F-09-004. Washington, D.C.

Water Aid (2008). *Urban Sector Assessment Report*, August, 2008. (www.usepa.gov/docs/owminet/water-efficiency/pubs/supply.htm).

Water Resource Institute (1998). Water resource management study, Volume 3.

WHO (1984). Guidelines for drinking water quality.Vol.2.Health Criteria and other supporting information.Ch 16.Geneva pp. 145 -150.

WHO (1998). Guidelines for drinking-water quality: surveillance and control of community supplies, 2nd ed. vol.3, World Health Organization, Geneva, Switzerland.pp.59-62, 94.

WHO (2003). Managing Water in the Home: Accelerated Health Gains from Improved Water Supply, World Health Organization, and Geneva. WHO/SDE/WSH/02.07. PP.6-7.

WHO (2004). Guideline for Drinking Water Quality www.who.int/watersanitationhealth/publications/facts2004/en/index.html.date retrieved 31-04-11

WHO (2005). WASH Promotion: Programme Guidance by Water Supply and Sanitation Collaborative Research Council and World Health Organisation, WHO Press, Geneva, Switzerland.

WHO (2006). Guidelines for drinking-water quality: incorporating first addendum, Vol. 1, Recommendations, 3rded. World Health Organization, Geneva, Switzerland.pp. 222-240,

WHO (2008). Guidelines for Drinking-Water Quality, 3rd ed., World Health Organization: Geneva, Switzerland, 2008; Volume 1, Recommendations.

WHO and UNICEF Joint Monitoring Programme (2010). Progress on Drinking Water and Sanitation: Special Focus on Sanitation, UNICEF, New York and WHO, Geneva.

WHO (2011) Guideline for Drinking-Water Quality. Geneva: World Health Organization, 2011.

Zimmerman, J. B., Mihelcic, J. R., and Smith, J. (2008). Global Stressors on Water Quality and Quantity. American Chemical society Journal on Environmental Science & Technology, 42(47) June 15, 2008.



APPENDICES

APPENDIX A :Questionnaire for residents of Akunakope and Dzogbedzi

This questionnaire is designed to solicit your views and contribution on the quality of drinking water sources available in your community. This study is being conducted

purely for academic purpose to elicit information on the impact of human activities on sources of water and quality of water people consume in the Akunakope and Dzogbedzi communities.

Please tick () in the bracket { } and write in the appropriate space provided.

Interview date Questionnaires No.

Time..... Location.....

SECTION A

Background information of respondents

1. Sex: male [] Female []
2. Age category
(e) Less than 20yrs [] (b) 20-29yrs [] (c) 30-39yrs [] (d) 40-49yrs []
]50yrs and above []
3. Level of education
(e) Primary [] (b) SSS/Middle School [] (c) Secondary/Tech []
(d) Tertiary [] (e) Non Formal Education [] (f) none []
4. Religion
(a) Christianity [] (b) Islam [] (c) Traditional [] (d) Others.....
5. For how long have you been staying in the area?
(a) Less than 2yrs [] (b) 2-5yrs [] (c) 6-10yrs []
(d) 16yrs [] and (e) above []

SECTION B

Source of water for drinking and domestic purpose 6.

What are source of water are in your community or where do you get your drinking water from (you can tick minimum of 3 options)

- (a) Irrigation by canal river / stream [] (b) borehole [] (c) Lake [] (d)
Sachet water[]

7. Which of these sources of water do you use very often?
 (a) Nearby river / stream [] (b) borehole [] (c) Lake [] (d) Sachet water []
8. Which of these sources of water is more reliable?
 (a) Nearby river / stream [] (b) borehole [] (c) Lake [] (d) Sachet water []
9. How far is your house from the source(s) of water?
 300Less than 20metres [] (b) 20-59metres [](c) 60-99metres [](d)
 1000129metres[]metres and above []
10. Do you fetch water from nearby irrigation canal for domestic use?
 Yes [] No []
11. If yes, what do you use the water for?
 (a) Washing [] (b) bathing [] (c) cooking[] (d) drinking []
12. Which of these seasons do you rely on the irrigation canal most? (a) Wet season [] (b) dry season []

SECTION C

People perception on the quality of water they consume.

13. What can you say about the quality of water from stream/river or irrigation canal?
 (a) Excellent [] (b) very good [] (c) good [] (d) poor []
14. What is the usual colour of the water you use / consume?
 (a) colourless [] (b) slightly brown [] (c) dirty brown [] (d) very dirty []
- 15 What do you think accounts for the colour of the water?

- (a) Farming along the banks of the water body [] (b) dumping of waste in and around the of the water [] (c) release of chemicals from machines into the water body [] (d) People bathing in the water body []

16 To what extent do you think your source(s) of water is polluted?

- (a) Highly polluted [] (b) moderately polluted [] (c) not polluted [] (d) in decided []

17. Do you think the source(s) of water should be protected to reduce pollution?

- Yes [] No []

18. If yes, who should do the protection?

- (a) District assembly [] (b) CWSA [] (c) Traditional authorities (chiefs) [] (d) in decided []

SECTION D

Impact of human activities on water bodies

19. Where do you dump your refuse?

- (a) Around the canal [] (b) around the lake [] (c) an area far from the canal [] (d) into the environment (bush) []

20. Do you think defecating and dumping of refuse into lakes, rivers, canal, and water can pollute the water bodies?

- Yes [] No []

21. What can be done to ensure that people do not pollute water bodies? (a)

- Construction of more toilet and refuse dump site [] (b) regular environmental education [] (c) inspection by environmental health inspectors [] (d) in decided []

22. Where do you dispose domestic waste water?

(a) Near-by water body [] (b) pour into sewer (gutter) [] (c) outside home
(environment) [] (d) in decided []

23. Do you have a farm close to a river or canal?

Yes [] No []

24. If yes, do you apply fertilizers on your farm?

Yes [] No []

25. Fertilizer application can negatively affect the quality of water in the
river/lake/canal.

(a) Strongly agree [] (b) agree [] (c) disagree [] (d) Strongly disagree
[]

26. Have you experienced any health problem which can contribute to pollution of
water bodies?

Yes [] No []

27. If yes, list some of this health problems (diseases)

- (a)
(b)
(c)
(d)

28. In the past three months, has member of your household had diarrhea related to
disease

Yes [] No []

29. If yes, what do you think is the cause of the diarrhea?

- (a)
.....
(b)
.....
(c)
.....

(d)

30. What solution do you recommend to solve pollution of water bodies in your area?

.....

31. What kind of toilet facility do you use?

(a) KVIP ☐ (b) pit latrine ☐ (c) in the environment(bush) ☐ (d) in decided
☐

APPENDIX B : Drinking water standard of WHO, USEPA, EU and Ghana.

Parameter	Units	WHO	USEPA	EU	GHANA
pH Range	-	6.5-8.5	6.5-8.5	6.5-9.5	6.5-8.5
Temperature	⁰ C	22-29	-	-	-
Conductivity	μS/cm	250	250	250	-
Total Dissolved Solids	mg/l	1000	500	-	1000
Total Suspended Solids	mg/l	NA	-	500	-
Turbidity	NTU	< 1-5	5	0-4	5
Sulphate	mg/l	250	250	250	250
Nitrate	mg/l	10	10	50	-
Salinity	mg/l	200	-	-	-

Dissolved Oxygen	mg/l	>7.5	-	8.5(24 ⁰ C)	-
Chloride	mg/l	250	250	250	-
Sodium	mg/l	200	200	-	200
Calcium	mg/l	200	-	-	-
Zinc	mg/l	5	5	5	5
Iron	mg/l	0.3	0.3	0.3	0.3
Copper	mg/l	1.0	1.0	1.0	1.0
Alkalinity	mg/l	400	-	-	500
TC(CFU/100ml)	0	0	0	0	0
FC(CFU/100ml)	0	0	0	0	0
Phosphate	mg/l	-	-	-	-

Source: Ghana Standards Board, (2008) and WHO (2011).

Appendix C: Raw data for physico-chemical and bacteriological parameters

APPENDIX C1: Total coliform at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	1020	1134	1191	1020	1191	1115
AKBH	0	0	0	0	0	0
AKC	680	490	720	490	720	630
DZL	775	1200	1045	775	1200	1005
DZBH	0	0	0	0	0	0
DZC	523	987	1085	523	1085	865

APPENDIX C2: Faecal coliform at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN

AKL	280	248	350	248	280	292.5
AKBH	0	0	0	0	0	0
AKC	65	55	30	30	65	50
DZL	130	85	190	85	190	135
DZBH	0	0	0	0	0	0
DZC	135	105	120	105	135	120

APPENDIX C 3: Temperature at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	28.4	28.7	28.3	28.3	28.7	28.5
AKBH	28.9	30.1	29.4	28.9	30.1	29.3
AKC	29.7	28.8	29.7	28.8	29.7	29.4
DZL	28.4	29.9	30.2	28.4	30.2	29.3
DZBH	31.2	28.6	31.4	28.6	31.4	30.5
DZC	29.6	28.7	28.9	28.7	29.6	29.2

APPENDIX C4: Turbidity at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	65.4	30.8	28.6	28.6	65.4	41.62
AKBH	1.80	1.70	1.71	1.70	1.80	1.71
AKC	18.20	9.50	11.30	9.50	18.20	13.0
DZL	10.50	11.20	11.30	10.50	11.50	11.0
DZBH	1.24	1.72	0.97	0.97	1.72	1.31
DZC	18.3	16.4	13.3	13.3	18.3	16.43

APPENDIX C5: Colour of water at the sampling site

MONTH

SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	143.2	118.9	120.4	118.9	143.2	127.5
AKBH	2.0	5.0	2.0	2.0	5.0	3.0
AKC	18.8	54.3	36.4	18.8	54.3	36.5
DZL	64.3	68.4	70.19	64.3	70.19	67.63
DZBH	1.25	1.42	1.08	1.08	1.42	1.25
DZC	45.5	42.8	39.6	39.6	45.5	42.63

APPENDIX C6: Electrical conductivity at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	120.4	140.5	127.6	120.4	140.5	129.5
AKBH	760	890	753	753	890	801
AKC	74.8	84.9	73.9	73.9	84.9	77.85
DZL	222	286	188	188	286	231.82
DZBH	135	87.2	92.0	87.2	135	104.75
DZC	273	284	194.4	194.4	284	250.47

APPENDIX C7 : Total dissolved solids at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	58.9	68.5	57.4	57.4	68.5	61.6
AKBH	560	480	162	162	560	400.5
AKC	35.5	42.7	30.4	30.4	42.7	36.2
DZL	120	108.7	110	108.7	120	112.9
DZBH	570	480	522	570	480	523.9
DZC	120	90	138	90	138	115.9

APPENDIX C8: Total suspended solids at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	38	28	51	28	38	39

AKBH	1.8	1.5	1.9	1.5	1.9	1.75
AKC	4.8	5.5	6.2	4.8	5.5	5.5
DZL	8.8	7.2	8.8	7.2	8.8	8.25
DZBH	4.2	2.5	3.8	2.5	4.2	3.5
DZC	10.8	6.5	5.2	5.2	10.8	7.5

APPENDIX C9: pH at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	6.5	6.8	6.6	6.5	6.8	6.7
AKBH	7.6	7.4	8.3	7.4	8.3	7.8
AKC	7.3	6.8	7.2	6.8	7.3	7.2
DZL	7.4	6.9	7.1	6.9	7.4	7.2
DZBH	7.7	7.5	8.2	7.5	8.2	7.7
DZC	7.9	6.4	7.4	6.4	7.9	7.3

APPENDIX C10: Total Alkalinity at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	68	45	39	39	68	50.5
AKBH	287	128	242	128	287	219
AKC	32	23	34	23	34	29.75
DZL	85	62	47	47	85	64.5
DZBH	120	95	97	95	120	104
DZC	28	32	22	22	32	27.25

APPENDIX C11: Total Hardness and Bicarbonates at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	180	113	82	82	180	125
AKBH	232	187	154	154	232	191
AKC	142	132	107	107	142	127
DZL	354	240	249	240	354	341
DZBH	25	28	34	25	34	29
DZC	24	37	38	24	38	33

APPENDIX C12: Nitrate at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	0.02	0.09	0.04	0.02	0.09	0.05
AKBH	0.45	0.38	0.13	0.13	0.45	0.32
AKC	0.75	0.42	0.18	0.18	0.75	0.45
DZL	0.09	0.15	0.06	0.09	0.15	0.1
DZBH	0.9	0.4	0.5	0.4	0.9	0.6
DZC	0.8	0.3	0.7	0.3	0.8	0.45

APPENDIX C13: Nitrite at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	0.0018	0.0015	0.0027	0.0015	0.0027	0.002
AKBH	0.0038	0.0042	0.004	0.0038	0.0042	0.004
AKC	0.001	0.0015	0.0005	0.001	0.0015	0.001
DZL	0.002	0.003	0.016	0.016	0.003	0.007
DZBH	0.0018	0.0012	0.0039	0.0012	0.0039	0.0023
DZC	0.0124	0.018	0.018	0.0124	0.018	0.0153

APPENDIX C14: Phosphate(mg/l) at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	0.19	0.23	0.24	0.19	0.24	0.22
AKBH	0.18	0.21	0.21	0.18	0.21	0.20
AKC	0.28	0.15	0.20	0.15	0.28	0.21
DZL	0.28	0.25	0.16	0.16	0.28	0.23
DZBH	0.25	0.34	0.19	0.19	0.34	0.26
DZC	0.18	0.32	0.31	0.18	0.32	0.27

APPENDIX C15: Chloride (mg/l) at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	4.8	9.2	6.6	4.8	9.2	6.87
AKBH	10.2	7.2	8.7	7.2	10.2	8.7

AKC	2.4	1.2	2.4	1.2	2.4	2.0
DZL	12.5	18.5	19.0	12.5	19.0	16.65
DZBH	250	180	260	250	260	229.75
DZC	1.8	2.9	3.6	1.8	3.6	2.75

APPENDIX C16: Fluoride (mg/l) at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	0.02	0.05	0.21	0.02	0.21	0.095
AKBH	0.92	0.45	0.38	0.38	0.92	0.585
AKC	1.20	1.50	0.20	0.20	1.50	0.983
DZL	0.92	0.28	0.72	0.28	0.92	0.641
DZBH	0.85	1.28	0.74	0.74	1.28	0.958
DZC	0.003	0.002	0.01	0.001	0.003	0.007

APPENDIX C17: Sulphate(mg/l) at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	9.8	7.5	5.8	5.8	9.8	7.68
AKBH	85	72	60	60	85	72.16
AKC	4.9	4.2	7.7	4.2	7.7	5.61
DZL	12.5	9.8	14.5	9.8	14.5	12.25
DZBH	22.8	15.4	17.5	15.4	22.8	18.57
DZC	5.4	6.2	7.7	5.4	7.7	6.42

APPENDIX C18: Calcium(mg/l) at the sampling sites

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	7.2	8.9	9.7	7.2	9.7	8.6
AKBH	28	24.5	29.2	24.5	29.2	27.23
AKC	8.2	7.3	6.7	6.7	8.2	7.4
DZL	12	11.8	11.0	11	12	11.6
DZBH	54.8	65.2	55.9	54.8	65.2	58.65
DZC	8.2	10.5	6.2	6.2	10.5	8.3

APPENDIX C19: Sodium (mg/l) at the sampling site

MONTH						
-------	--	--	--	--	--	--

SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	16.8	17.2	16.5	16.5	17.2	16.95
AKBH	145	119	120	119	145	128.25
AKC	8.2	7.3	7.4	7.3	8.2	7.63
DZL	22.5	24.2	30.2	22.5	30.2	25.63
DZBH	135	180	85	85	180	133.25
DZC	4.8	3.9	5.9	3.9	4.8	4.85

APPENDIX C20: Magnesium(mg/l) at the sampling sites

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	11.5	12.8	12.9	11.5	12.9	12.40
AKBH	52.6	28.9	23.7	23.7	52.6	25.80
AKC	7.20	5.45	6.45	5.45	7.20	6.35
DZL	2.80	2.90	1.50	1.50	2.90	2.40
DZBH	8.90	11.50	8.55	8.55	11.50	9.65
DZC	8.20	5.20	10.0	5.20	8.20	7.80

APPENDIX C21: Potassium (mg/l) at the sampling sites

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	4.28	2.50	3.54	2.50	4.28	3.44
AKBH	3.80	2.90	5.66	2.90	5.66	4.12
AKC	1.20	2.41	3.0	1.20	2.41	1.82
DZL	3.80	4.76	2.90	3.80	4.76	3.82
DZBH	4.80	5.40	7.60	4.80	7.60	5.93
DZC	4.10	2.40	3.6	2.40	4.10	3.38

APPENDIX C22: Total iron (mg/l) at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	16.8	17.2	16.5	16.5	17.2	16.95

AKBH	145	119	120	119	145	128.25
AKC	8.2	7.3	7.4	7.3	8.2	7.63
DZL	22.5	24.2	30.2	22.5	30.2	25.63
DZBH	135	180	85	85	180	133.25
DZC	4.8	3.9	5.9	3.9	4.8	4.85

APPENDIX C23: Manganese (mg/l) at the sampling site

MONTH						
SITE	FEB	MAR	APR	MIN	MAX	MEAN
AKL	0.82	0.65	0.39	0.39	0.82	0.62
AKBH	0.28	0.18	0.26	0.18	0.28	0.24
AKC	0.42	0.38	0.82	0.38	0.82	0.54
DZL	0.54	0.42	0.96	0.42	0.96	0.64
DZBH	0.28	0.39	0.32	0.28	0.39	0.33
DZC	0.49	0.86	0.45	0.45	0.86	0.6

Appendix D : Differences in physico-chemical parameters between borehole and surface water samples.

Variable	F-value	P-value
Temperature	1.24	0.35
pH	4.32	0.10*
Turbidity	3.41	0.004*
Colour	2.45	0.018*
Conductivity	3.65	0.001*
Total dissolved solids	3.45	0.015*
Total suspended solids	3.28	0.002*
Total alkalinity	3.42	0.024*
Total hardness	3.68	0.001*
Bicarbonates	3.25	0.032*

*significant at $P \leq 0.05$

Appendix D Cont'd: Differences in physico-chemical parameters between borehole and surface water sample.

Variable	F-value	P-value
Nitrate	7.48	0.001*
Nitrite	3.18	0.425
Phosphate	3.68	0.328
Chloride	5.25	0.001*
Sulphate	8.21	0.004*
Fluoride	6.60	0.246*
Calcium	5.76	0.001*
Sodium	4.25	0.02*
Potassium	5.45	0.04*
Magnesium	5.19	0.001*

***significant at $P \leq 0.05$**

Appendix E : Differences in heavy metal between borehole and surface water sample.

	F-value	p-value
Variable Total iron	6.14	0.012*
Manganese	5.6	0.04*

***significant at $P \leq 0.05$**

Appendix F : ANOVA showing differences in bacteriological parameters between borehole and surface water sample samples.

	Fvalue	p-value
Variable Faecal coliform	7.14	0.01*
Total coliform	6.56	

*significant at $P \leq 0.05$
0.02*

KNUST

