

**IMPACT OF LAND USES ON WATER AVAILABILITY AND QUALITY IN
RURAL COMMUNITIES WITHIN THE HOHOE MUNICIPALITY**

BY

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DECLARATION

This is to certify that this thesis is the result of research work undertaken by Amedume Marcellinus towards the Degree of M.Phil. Nuclear and Environmental Protection in the Department of Nuclear Sciences and Applications, School of Nuclear and Allied Sciences (SNAS), University of Ghana, Legon, under the supervision of Prof. Joseph R. Fianko and Dr. Charles Klutse.

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DEDICATION

This Thesis is dedicated to the glory of God and my wonderful children Raphael
Etonam Amedume and Isaac Eynam Amedume.

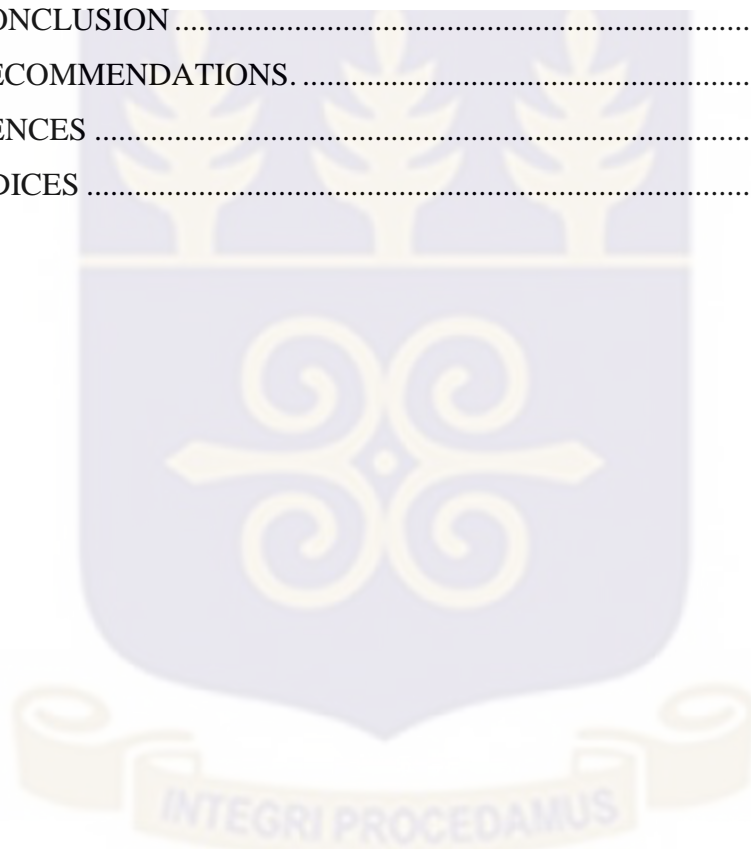


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LIST OF ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
Alk.....	Alkalinity
APHA.....	American Public Health Association
BGS.....	British Geological Survey
Col	Colour
DNHW	Department of National Health and Welfare
EC.....	Electrical Conductivity
EPA.....	Environmental Protection Agency
FAO	Food and Agriculture Organization
FC	Fecal Coliform
FWPCW.....	Federal Water Pollution Control Administration
HMHD	Hohoe Municipal Health Directorate
HU	Hazen Unit
ICPH.....	International Conference on Primary Health
IUCN	International Union for Conservation of Nature and Natural Resources
MOFA.....	Ministry of Food and Agriculture
NTU.....	Nephelometric Turbidity Unit
TC	Total Coliform
TDS.....	Total Dissolved Solids
Temp	Temperature
TSS.....	Total suspended solid
TSS.....	Total Suspended Solids
Turb.....	Turbidity

TVCTotal Viable Counts

UNEPUnited Nations Environment Program

USEPAUnited Nations Environment Agency

WHOWorld Health Organization

WQI.....Water Quality Index

WRCWater Resources Commission



ABSTRACT

The Hohoe Municipality in the Volta Region of Ghana has abundant water resources in the form of springs, rivers, streams and groundwater from high yielding aquifers. However, increasing population and economic activities within the municipality have significantly impacted on the availability and quality of these water resources. Rapid urbanization in the municipality includes Likpe, Lolobi, Wli, Fodome, Alavanyo, Santrokofi and Akpafu communities.

This study assesses the impact of land use changes on the availability and quality of the main sources of drinking water within the rural areas of the municipality. The impact of land use changes on water resources availability was assessed through Satellite images, administration of questionnaires, interviews and focus group discussions in collaboration with chiefs, opinion leaders, community members and other relevant stakeholders in the municipality.

Data for the classification of land use of the study area was derived from analysis of remotely sensed (Landsat 7, Enhanced Thematic Mapper) Satellite image for the year 2007 and (Landsat 8, Enhanced Thematic Mapper) Satellite image for the year 2017 spanning ten years covering the entire Hohoe Municipality from the Centre for Remote Sensing and Geographic Information Systems (CERSGIS), located at the Department of Geography and Resource Development of the University of Ghana for the analysis of land use changes and classification.

The data generated by the center showed a detailed land use maps which were classified into the following categories; built up, grassland, forest and bare land for analysis.

The result clearly showed an increase in urbanization within the Municipality over the last ten years. Built up has increased from 14.18 % to 21.80 %, grassland coverage has also extended from 26.45 % to 29.95 % while forest areas and bare lands have dwindled drastically from 12.11% to 4.42 % and 5.57 % to 2.14 % respectively .

Primary data for the study was derived from field survey carried out in October, November and December 2016. During the field survey sixty (60) questionnaires were administered in the six (6) sub zonal councils of the Hohoe Municipal Assembly namely Likpe, Lolobi , Agumatsa (Wli and Fodome), Alavanyo, Santrokofi and Akpafu communities. Out of the total of sixty respondents interviewed, 65 % were females and 35 % were males within the age range of 40 to 55 years and 56 to 70 years. Majority of respondents (85%) involved in the study asserted that there has been a strong impact of land use changes on water availability and quality within the study area.

Water samples were collected from thirty four (34) sampling sites within the various communities namely Alavanyo, Lolobi, Akpafu, Santrokofi, Likpe, Fodome and Wli. In all, twenty one (21) boreholes, three (3) hand dug wells and ten (10) surface water were analyzed to determine the physicochemical quality (pH, EC, temperature, alkalinity, turbidity, colour and TSS), the major ions (Flouride, Chloride, Nitrate, Sulphate, Phosphate, Sodium, Potassium, Calcium and Magnesium) and microbiological quality (fecal coliforms and total coliforms) of the water sources were analyzed.

Water samples collected were analyzed by both classical and automated instrumental standard methods for the analysis of water and wastewater (APHA, 2005). Water temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and pH were measured at each sampling site using portable (field-type) instruments (3210

SET 1 conductivity meter and ATC Neuftech - pH meter). The concentrations of ions (Flouride, Chloride, Phosphate, Sulphate, Calcium, Magnesium, Sodium and Potassium) were determined using ion chromatographic techniques (SHIMADZU HIC - 20A model ion chromatograph) and the analysis of microbiological quality was also determined using the membrane filtration method. These were done respectively in Hydrology Laboratory and the Microbiological Laboratory at Ghana Atomic Energy Commission.

A Microsoft Excel data analysis tool was used to determine the statistical summary of physicochemical and microbiological parameters. From the study, the physicochemical parameters of surface water and groundwater were within the WHO/ GSA standard of drinking water.

The water quality indices (WQI) classified 75 % of groundwater and 70 % of surface water samples as excellent for human use. However, the result of microbiological quality revealed that indicator organisms (total coliform and fecal coliform) were above the WHO/ GSA standards of 0.0 CFU/100ml in all surface water and ground water samples (boreholes and hand dug well) except four (4) boreholes representing 31.7 % that were totally free from fecal coliforms. The chemical characteristics of surface and groundwater show the same cationic dominance of $\text{Na}^+ > \text{K}^+ > \text{Ca}^{2+} > \text{Mg}^{2+}$ and anionic dominance $\text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{PO}_4^{3-}$.

In conclusion, there is the need to regulate land use activities through enforcement of environmental laws by the Municipal Assembly and agricultural extension officers should organize community based workshops to educate the people on the benefit of best farming practices on their water sources

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The Hohoe Municipality in the Volta Region of Ghana has abundant water resources in the form of springs, rivers, streams and groundwater from high yielding aquifers. However, increasing population and economic activities within the municipality have significantly impacted on the availability and quality of surface water sources. The challenges that accompany population increase in an area directly affect the surroundings including water bodies. The fast growing population of Hohoe Municipality is directly related to increased economic activities in the area which influence changes in land uses. Rapid urbanization in the municipality includes Likpe, Lolobi, Wli, Fodome, Alavanyo, Santrokofi and Akpafu communities. Land use changes such as settlements, agriculture, lumbering, waste disposal and sand winning within the municipality are also on the increase which could lead to water shortage and cause serious degradation of surface water and groundwater.

In many countries around the world including Ghana, the availability of water does not guarantee its safety for its intended use because of pollution from both natural and anthropogenic activities. Many people around the world mostly in developing countries do not have safe water to drink and for other domestic purposes (WHO/UNICEF, 2005). Many children die each year from diarrhoea and pneumonia diseases which are linked to limited access to safe water, improper sanitation and unhygienic conditions, (Gleick, 1996). The annual report of the Hohoe Municipal Health Directorate (HMHD) shows increasing cases of intestinal infections which are water related (HMHD, 2015). In situations where diarrhoeal diseases are not deadly, they may contribute to malnutrition as a result of long term effects of diarrhoea in

children, consequently affecting children development. Thus knowledge of the quality of water is an important indicator of the health status and the quality of the life in an area.

In many rural communities in Ghana, there is high dependence on surface and ground water (streams, rivers, dug outs, ponds and lakes) for their daily water needs (Ayibotele, 1969). According to Akoto and Adiyah (2007), some drinking water sources in Ghana have been polluted which is impacting negatively on the health and socio-economic status of people in the affected areas. The pollution of these water sources usually through natural or human activities leads to water related diseases like diarrhoea, bilharzia, dysentery, and cholera. It also gives bad taste to water, colour and odour and causes corrosiveness, staining and hardness of water.

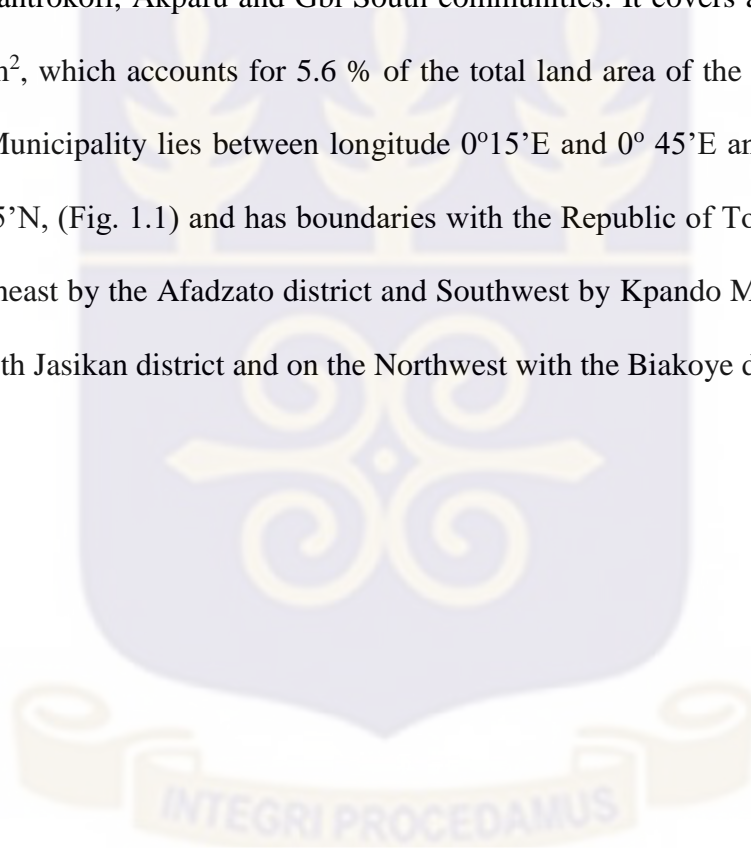
Studies have shown that urbanization affects “patterns of ecologic structure and function” altering the physical landscape, increasing imperviousness, and changing channel morphology (Walsh and Chace, 2006) and is one of the main challenges facing the Metropolitan, Municipal and District Assemblies in Ghana. It is estimated that 70% of watersheds in Ghana have its water quality affected negatively by urbanization (Danquah et al. 2011). Land use changes may lead to urban runoff which can also affect water chemistry and destroy aquatic life.

The increase in anthropogenic activities over the years in the rural communities of the Hohoe Municipality has reached a point where they influence water resources in the area. Research has shown that agricultural land use which is common in the study area has influence on some water quality parameters like phosphorous and nitrogen (Ahearn et al., 2005; Li et al., 2008). To effectively control these impacts of landscape transformations on water resources, the levels, types and principal sources of

pollution must be identified to understand the link between human activities and water related problems for sustainable management.

1.2 THE HOHOE MUNICIPALITY

Hohoe Municipal Assembly is one of the 25 administrative districts of the Volta region of Ghana. It was established by the Legislative Instrument (L.I. 2072) of 2012 and is made up of six sub municipal areas namely; Alavanyo, Lolobi, Agumatsa, Likpe, Santrokofi, Akpafu and Gbi South communities. It covers a total land area of 1,172 km², which accounts for 5.6 % of the total land area of the Volta region. The Hohoe Municipality lies between longitude 0°15'E and 0° 45'E and latitude 6° 45'N and 7° 15'N, (Fig. 1.1) and has boundaries with the Republic of Togo on the East, on the Southeast by the Afadzato district and Southwest by Kpando Municipality; on the North with Jasikan district and on the Northwest with the Biakoye districts.



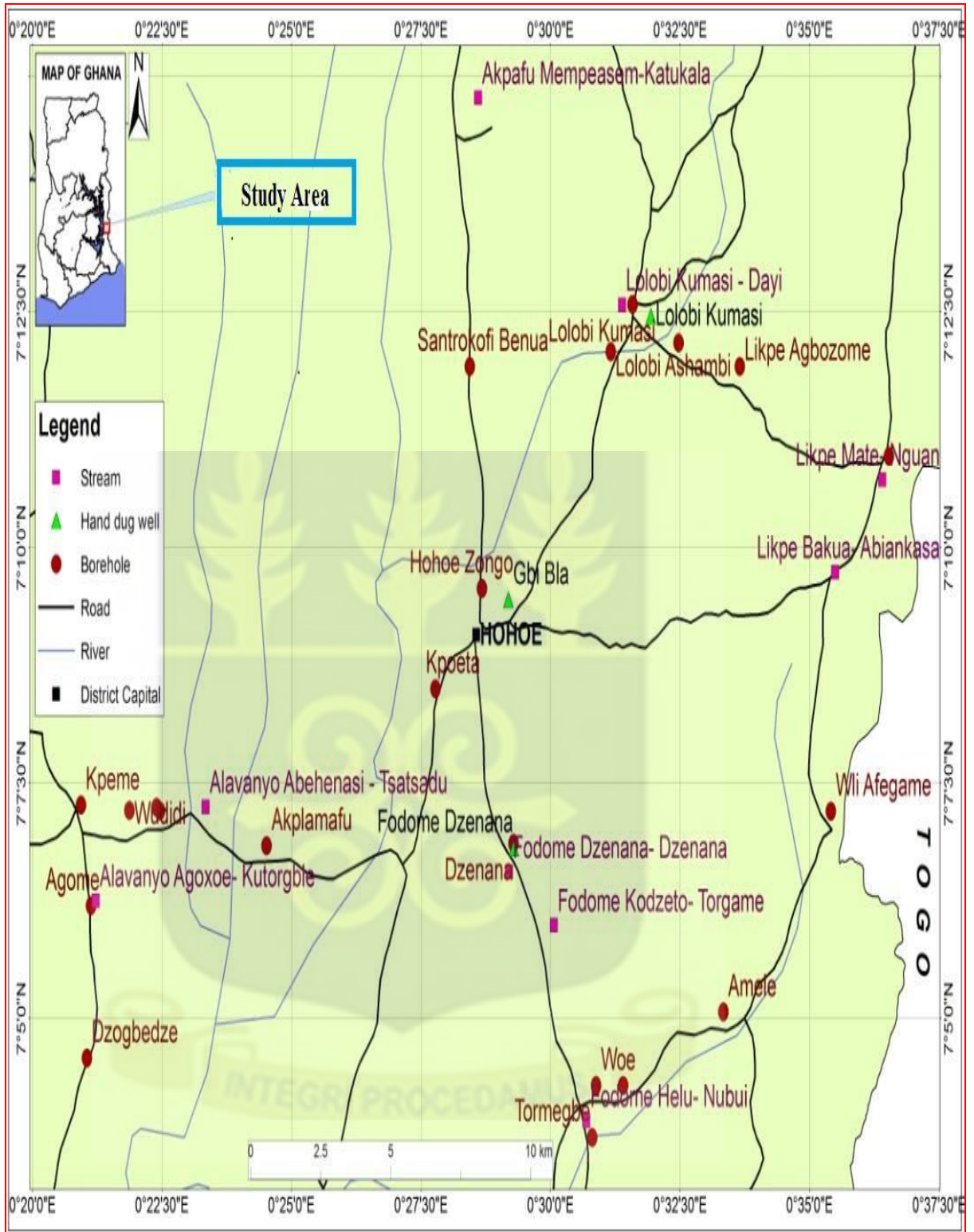


Figure 1.1: Map of the study area

1.2.1 Vegetation, Climate and Drainage

The municipality lies within the forest – savanna transitional ecological zone of Ghana. The vegetation is made up of Forest, Savannah woodlands and tall grasses with the forest zone in the Northern, Eastern and middle parts while the Savannah zone in the South- Western parts of the Municipality. The area covers about 72% of the River Dayi Basin with tropical climate. The rainfall pattern is bimodal with two different seasons. The major raining season begins in April through to July and the minor season begins in September through to November. At times the bimodal pattern changes and gives continue rainfall from April through to November (WRC, 2011). The total annual rainfall of the municipality ranges between 1100 mm and 1500 mm with an average of 1300 mm and averagely the major and minor raining seasons constitute about 43 % and 40 % respectively of the total rainfall yearly. The temperatures range from 26 °C during the raining seasons to about 32 °C in the dry seasons (MOFA, 2015)

The Northern and Eastern areas like Akpafu, Lolobi and Likpe are the forest zones which generally record high rainfalls within the municipality. Some notable trees in the forest areas include Wawa, Obeche, Odum and Mahogany and these areas are good for tree crops like cocoa, oil palm and citrus cultivations. Apart from the Alavanyo area which is also a forest area, the south- western areas bordering the Kpando Municipal area relatively drier with extensive savanna vegetation which is generally suitable for cultivation of vegetables and livestock production.

River Dayi takes its source from the Akpafu ranges and drains through the municipality covering the low-lying portion of the Akwapim - Togo ranges and enters the Volta-lake in the Kpando municipal area. River Dayi has tributaries such as Koloe, Agumatsa, Tsatsadu and Aflabo which serves as sources of water for

neighbouring communities and for vegetable farming mostly during the dry seasons. Some of the low-lying areas like Akpafu Odomi, Akpafu Mempeasem, Santrokofi and Godenu are swampy and are used for rice cultivation (MOFA, 2015)

1.2.2 Geology and Soil Type

The geology of the Municipality is mainly composed of the Buem and Togo Structural Units which form about 50 % and 48 % respectively of the River Dayi Basin. The geology of the area consists of thick series of shale, sandstone, and volcanic rocks, with different highlands and adjacent lowlands. According to the Water Resources Commission report in 2011 on the River Dayi Basin, the quantity and recharge rate of groundwater in the municipality is high and can be tapped for irrigation and domestic water supply. The major types of soils of the study site are ochrosols and oxysols with greater accumulation of organic matter in the surface horizon. The soil types also exhibits a greater depth, weathering and acidity as compared to its savanna portions. There are four (4) soil groups in the municipality with the forest ochrosols and their interior savanna types - groundwater laterite – ochrosols integrades being the major components. The other components are forest ochrosols-oxysol integrades interlacing the forest hiltosols strips along the Eastern border with the Republic of Togo. The advantage of the soil groups is that both savanna and forest crops grow well in the municipality (Hohoe Municipal Development Directorate, 2014).

1.2.3 Population and Socioeconomic Activities

According to the GSS (2014) report, the population of the Hohoe Municipality in the 2010 Population and Housing Census (PHC) was 167,016 constituting about 79,967 males and 87,049 females. It has been estimated that the population of the municipality will increase to 88,250 males and 91,391 females in the next five years.

About 52.6 % of the population is living in urban centers and 47.4 % are in rural areas of the Municipality. About 71.0% of the people are employed in the informal sector like petty trading, hair dressing, carpentry, masonry, and electrical works.

About 65% of the population is engaged in agricultural activities which are rain – fed and dependent on the traditional use of hoes and cutlasses. The notable crops grown are rice, maize, cassava, plantain, cocoyam, bananas, coffee, cocoa and vegetables like okro, pepper, tomatoes and garden eggs. Human activities over years have greatly modified the landscape through intensified agriculture and urbanization leading to encroachment of farm lands, sprawling of new settlements, the operations of factories which depend on forest products, sand winning and waste disposal.

1.3 PROBLEM STATEMENT

The Hohoe Municipality is experiencing rapid and increasing population and economic activities. These increasing population growth and socio- economic activities are leading to different land uses which are negatively affecting water resources. Extensive land use changes such as settlements, agriculture, lumbering, waste disposal and sand winning have been on the increase in recent years within the Municipality and this could lead to limited access to safe water. The Hohoe Municipality is also noted for food crop production notably cereals and tubers with extensive use of agrochemicals (fertilizers and pesticides). The rapid urbanization has significantly impacted on the availability and quality of these water resources in the rural communities of the Municipality (MOFA, 2015).

The Municipality is densely populated (123/km²) above national average (69/ km²), and rural urban ratio of 80:20, indication of large number of people in the rural

communities within the Municipality (Hohoe Municipal Agricultural Development Directorate, 2014). The increasing population and rapid socio-economic growth within the Hohoe Municipality lead to landscape modifications which are having dire consequences on the availability and quality of the various water resources, resulting in water pollution and water scarcity. River Dayi and groundwater sources supply water to support the fast developmental activities.

There are many concerns of access to safe water within the rural areas because many of the communities use untreated surface water and groundwater. Many of the rural communities within the municipality have challenges with water supply especially in the dry season when most of surface water dry up or decrease in volume. The people travel long distances in search of water or even stay without potable water for days. Lack of potable water is one of the main factors of public health concern. Several studies in Ghana have been on water quality of major rivers and groundwater in the cities and have explored the relationship between land use and water quality in a few streams (Asante et al, 2008; Ansa-Asare and Asante 2000; Asante and Ansa – Asare, 2001). Urbanization is on the ascendency in the rural communities with its increase in land use changes but knowledge of the effect of the changing land transformation on the health of water sources in the area continues to be a challenge due to lack of monitoring. The hydrologic system is also influenced by land use changes which have potential to affect the availability of water resources.

1.4 OBJECTIVE OF THE STUDY

The main objective of the study is to assess the impact of land uses on water availability and quality in rural communities within the Hohoe Municipality.

1.4.1 Specific Objectives

- Assess the land use changes over a decade in the rural communities of the Hohoe Municipality
- Assess the physico – chemical characteristics of streams, river, hand- dug wells and boreholes used as sources of drinking water in the rural communities.
- Assess the levels of bacteriological contamination of the hand dug wells, streams, boreholes as well as other water sources of drinking water from the locality.

1.5. JUSTIFICATION AND SIGNIFICANCE

Rural communities within Hohoe Municipality used to be the hub of streams and rivers that supplied potable water to the urban areas but currently most of them cannot even be traced. The quantity and quality of those left are of concern to public health. Increased and rapid urban growth has led to the degradation of the ecosystem. The impact of anthropogenic modifications resulting from urbanization and lack of education on water availability and quality is of important concern to policy makers. Many people within the rural areas of Hohoe Municipality use groundwater and surface waters as their main sources of drinking water without any form of treatment. An intensive experimental analysis of the effect of land use changes on water resources in a rapidly growing Hohoe Municipality will identify the changes in land use that result in water quality degradation.

Water is life, and potable water is a necessity for the survival of human beings. This is because many water borne diseases such as diarrhoea, dysentery, cholera and typhoid

occur as a result of using contaminated water. Thus water chemistry is directly affected by changes in the land use pattern resulting from release of contaminants into natural water bodies. Contaminated water can pose a serious health effect to human life. Septic systems that are not properly sited, designed, constructed, or maintained can contaminate water with bacteria, viruses, nitrates, detergents, oils, and other chemical substances that may have adverse effects on human life.

The results obtained from this study will provide baseline data for future investigation to monitor the impact of land use changes on water resources within the Hohoe Municipality. The information can also be used to predict the likely impacts of any potential changes in land use on the water resource systems for policy makers towards sustainable water resource management.

1.6 RESEARCH DESIGN

The main objective of the study is to assess the impact of land uses on the water availability and quality in rural communities within the Hohoe Municipality. The research adopted the satellite image analysis, administration of questionnaires, interviews and focus group discussions to assess the land use changes over a decade in the rural communities of the Hohoe Municipality and collection of water samples from the main water abstraction points in the study area for analysis. This is to determine the physico – chemical characteristics and levels of microbiological contamination of surface water (streams and river) and ground water (hand- dug wells and boreholes) used as source of drinking water in the rural communities within the municipality.

1.7 LIMITATIONS

In spite of the researcher's effort to conduct a thorough study, there were certain limitations to this study originating from ground situations including: lack of baseline data, financial and time constraint. Even though some studies have been done on the relationship between land use and water quality in Ghana, there was few records on impact of land use changes on water availability and quality in the municipality.

1.8 DELIMITATION

The focus of this study is limited to the assessment of the impact of land uses on the water availability and quality in rural communities within the Hohoe Municipality. The findings, conclusions, and recommendations may be applicable to contemporary situations with similar administrative and social backgrounds.

1.9 ORGANIZATION OF THE STUDY

The first chapter gives an introduction to the study and this deals with vital subtopics such as background of the study, statement of the problem, purpose of the research, limitations and delimitations of the study. Chapter two deals with the review of relevant literature related to the study while the focus of chapter three is the methodology used in the research, (sampling technique, sampling, sample preparation, sample analysis and procedure for data analysis). The fourth chapter is results and discussions while chapter five is the summary, conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

A large proportion of the Ghanaian population depends on land-based resources for their livelihoods and issues of land degradation are of serious concern to the nation. The main types of land degradation in Ghana include soil erosion, nutrient depletion, vegetation degradation and water resources degradation (Ayivor and Gordon, 2012). Inappropriate land use practices that lead to the exposure of soil surfaces facilitate erosion process. Erosion has a negative effect on soil quality and its agronomic productivity as well as water quality.

Human activities lead to deforestation and land degradation which continue to impact on the catchments of surface waters as well as groundwater. In 1995, Ansa-Asare reported that water sources were being polluted by elevated erosion caused by deforestation, rapid urbanization, unapproved methods of abstracting water and eutrophication.

2.2 URBANIZATION IN GHANA

The challenges of urbanization in most cities around the world especially in developing countries like Ghana cannot be underestimated. This is because the rate of urbanization is high in the cities which extend to neighbouring rural setups. It has been estimated that urbanization in Africa and for that matter, Ghana has increased over the last twenty years by 3.5% annually which will still continue by the year 2050 (AfDB, 2012). The rate of urban population of cities in Ghana, like Ho, Kumasi, Hohoe, Cape Coast, Tamale and Accra is on the increase. For example the population

of Hohoe according to 2010 population census report was 167, 061 which has been estimated to jump to 179, 641 in three years' time (GSS, 2014). This rapid increase in urban areas puts pressure on land use resulting in the destruction of the ecosystem of neighbouring rural settlements. Studies have shown that urbanization in many cities in Ghana and its neighbouring countries like Cote d'voire, Togo, Benin and Nigeria has destroyed vast vegetation through encroachments which directly contribute to changes in water quality (McGregor, 2006). Land degradation coupled with problems of sanitations in many cities eventually end up degrading water resources.

2.3 IMPACT OF LAND USES ON WATER SOURCES IN GHANA

The importance of land use cannot be ignored when considering the impacts of human activities on water sources in Ghana. Land use is man's activities on the land in different ways such as agriculture, settlements, waste disposal, industry, mining, irrigation, sand winning, transportation and the likes. Each of this land uses increases due to urbanization. The effects of land uses on water resources are dependent on both natural and anthropogenic factors. However, water quality and availability is largely influenced by anthropogenic factors (Alvani et al. 2011).

Illegal mining in Ghana is a great threat to the operations of water treatment plants and access to safe drinking water. This leads to high cost of water treatment and also possible closure of water treatment plants in the catchment areas, making access to safe water a mirage. An overview of water bodies badly affected by illegal mining, irrigation and sand winning activities in some regions of Ghana as reported by Ghana Water Company Limited in January, 2017 are outlined in Table 2.1.

Table 2.1: Water bodies affected by land use changes in Ghana

Regions	Water sources	Impact of land uses
Greater Accra	Densu River feeds the Weija Dam which supplies water to Western Accra.	It is polluted as a result of farming activities and industrial waste disposal. The magnitude of pollution has increased the cost of treating water.
Eastern Region	Birim River supplies water to Kyebi treatment plant. River Volta supplies water to Koforidua and New Juaben treatment facilities.	High pollution levels due to 'galamsey' cause shutdown of water treatment plant. And fishing activities pollute River Volta.
Western Region	The main water bodies that have been polluted are River Pra, Daboase, and Ankobra.	Polluted by illegal mining activities which led to closure of treatment plants.
Upper West Region	Black Volta supplies water to the Wa Municipality	New treatment plant but currently polluted as a result of 'galamsey' operations.
Ashanti Region	Enu River in the Ashanti Region serves Konogo catchment area	Polluted due to 'galamsay' activities
Northern Region	Nawuni River	Sand winning is the main activity polluting water bodies. It changes the colour of the river leading to high cost of treatment.
Brong Ahafo Region	The Tano River.	Life in the Brong-Ahafo Region can now be described as very dangerous for inhabitants, because their major source of drinking water, the Tano River, is under serious attack by activities of illegal miners. The Tano River, which serves as the only source of water which is treated by Ghana Water Company and supplied to the Sunyani Municipality and its environs, Techiman Municipality and its environs, as well as Hwidiem, Acherensua and Goaso – all in the Brong-Ahafo region has its quality and existence endangered due to the invasion of Chinese and other illegal miners.
Central Region	Pra River is the main water resources that supplies water to Cape Coast	Have been polluted by 'galamsey' activities.

Source: citifmonline.com/Ghana

Modifications in land use expose water bodies to changing climatic conditions which affect the natural water supply and its quality to support living things. According to Solbe (1996) many environmental challenges result from increasing changes in land use and this significantly affects water resources as well. Smol (2002) has stated that the impact of anthropogenic influences is much greater than natural influences on water sources. The use of pesticides and fertilizers in farming activities along river banks also affect water bodies. Many important sources of potable water (surface and groundwater) supplies have been affected by influx of urban farm wastes (Smol, 2002).



Figure 2.1: Water source affected by land use change

During urbanization there is increased soil compaction and imperviousness which influences the ability of soil to hold water. Studies have shown that building of road infrastructure such as asphaltic roads or impervious surfaces can influence flooding (Falkenmark and Chapman, 1989).

2.4 LAND USE IMPACTS ON HYDROLOGIC SYSTEM

Land use can also influence the entire water cycle and may impact on surface water and groundwater differently. Deforestation may lead to surface runoff and flooding. According to Bosch and Hewlett (1982), depletion of forest cover lowers water availability. This shows that the availability of water depends on proper land management methods. Thick forests cover prevents loss of moisture and increases stream flow than the logged vegetation (Calder, 1998).

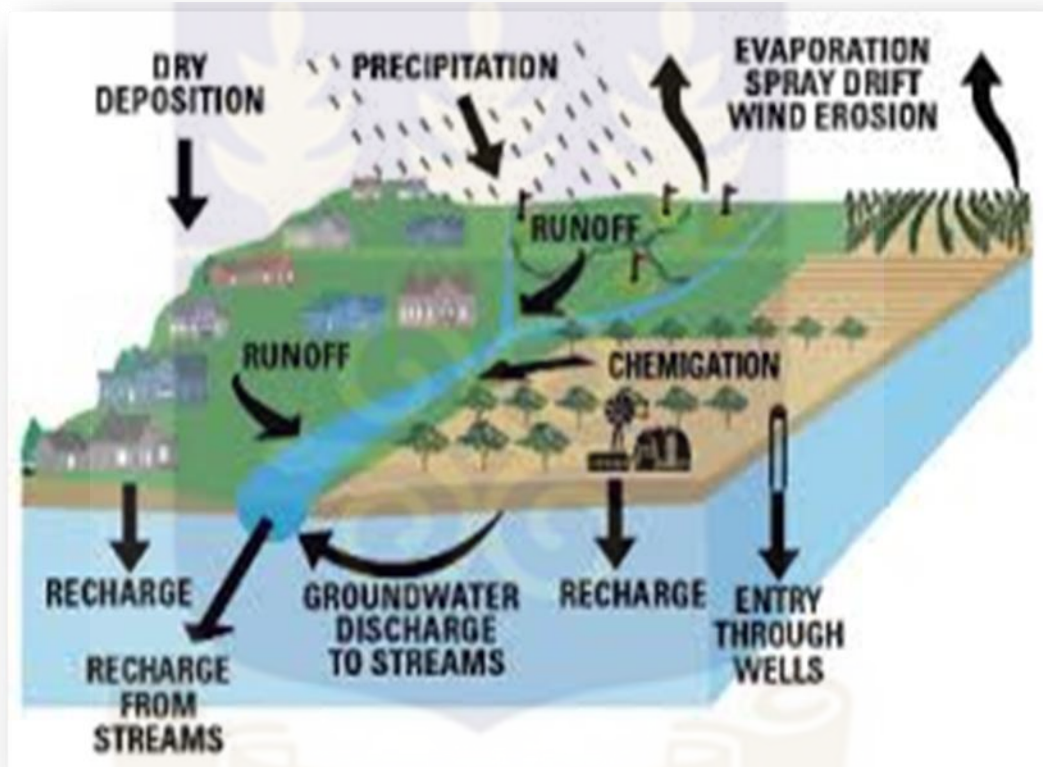


Figure 2.2: The Hydrologic Cycle

Dry season flow is dependent on evapotranspiration and the infiltration ability of soil. According to Calder (1998), the effect of evapotranspiration on water availability is localized. Afforestation can result in reduced flow during the dry season due to higher evapotranspiration during the dry season. It was reported that afforestation led to

shortage of water in a watershed in Thailand which led to the closure of a water supply facility and decreased water availability for irrigation purposes (Chomitz and Kumari, 1996). Studies have shown that replacement of plants that use high amount of water to those that use less amount of water increased dry season flow rates (Brooks et al., 1991). However, deforestation may cause reduced flow during the dry season when the land is compacted (Bruijnzeel, 1990).

Different land use methods that affect the soil capacity to hold water and the evapotranspiration process of forest cover can reduce or increase groundwater recharge. It is usually discharged into surface waters like rivers and influences dry season flow rate. Reduction in evapotranspiration through loss of forest cover may lead to rise in the water table while recharge may also increase through high rate of infiltration especially through afforestation (Tejwani, 1993). On the other hand, reduced soil infiltration through compaction and farming practices may decrease the ground water table (Tejwani, 1993). In addition; reduction in forest cover may also lead to decrease in infiltration into the aquifers (Chomitz and Kumari, 1996) which may affect water availability during the dry seasons, even in areas with enough water (FAO, 1999). According to Calder (1998), deep rooting trees can also reduce ground water recharge.

2.5 EFFECTS OF CHANGES IN LAND USES ON WATER QUALITY

The impact of land use activities on water quality is of importance because it can have dire consequence on the health of consumers. The negative impacts are changes in sediment load of streams, increase in concentrations of nutrients, salts, metals as well as introduction of agrochemicals, pathogens and variations in water temperature.

Erosion is a naturally occurring process whose effect depends on land use pattern. Forests protect the land from soil erosion and according to Bruijnzeel (1990) vegetation cover can prevent erosion. Erosion is increased by urbanization and can lead to degradation of water resources. In Malaysia, surface water was observed to have greater sediment loads when vast forests were logged (Falkenmark and Chapman, 1989). Sedimentation loads of rivers are directly affected by erosion and have lots of implications on water resources. Sedimentation may accelerate drying up of streams and rivers, loss of aquatic life and increases the cost of water treatment. The sedimentation load increases with increase in erosion resulting from different land uses such as run off from farming areas, building sites, impervious areas and stream banks. Stream bank erosion is directly influenced through developmental projects.

Improper land use may lead to eutrophication of water bodies by introducing nutrients (nitrogen, nitrate, nitrite, ammonia) and phosphorus into both surface and ground waters. When the level of nitrate in drinking water is high, it may be harmful to expectant mothers and fatal to infants (British Geological Survey, 2003). Elevated nitrogen levels in water bodies may result from decaying process of organic matter and low nutrient use by plants. Also nitrogen levels in water sources may be increased due to human activities like use of fertilizer, effluents from municipal sewage treatment facilities and human and animal wastes. Agricultural activities have been identified to contribute high levels of nitrogen through leaching into surface water and groundwater in Europe (FAO, 1996). Very high levels of $\text{NO}_3 - \text{N}$ (20 – 50 mg/L) have been detected in groundwater in Sri Lanka (BGS et al., 1996).

Phosphate is one of the major requirements for plants and which can leach into water sources, but clay particles limit its leaching into water through adsorption (BGS et al.,

1996). Direct run offs from agricultural fields and livestock farms can be a principal source of phosphate in both surface and groundwater. Fertilizers used in agriculture, lawns and gardens, livestock manure, leachates from septic systems and untreated wastewater may contribute to the phosphate load in water bodies. According to FAO (1996), wastes from livestock production alone added 30 % of phosphate to surface waters in Europe and other agricultural practices added 6 % of phosphate. High phosphate levels in sediments increases the nutrient content for plants growth in water bodies resulting in eutrophication.

Pathogens are disease causing organisms which are mainly introduced into water bodies by activities like grazing or waste from animal production and humans. The level of this disease causing organism in water sources may be increased significantly due to urbanization. Also low flow rate of surface water can serve as breeding grounds for vectors of water borne diseases like malaria (FAO, 1995). The percolation of water to aquifers through the geologic matrices dissolve minerals in them absorbs particulate matter and provides suitable conditions for pathogenic micro-organisms especially from human excreta to thrive (Onuh and Isaac, 2009).

It has been reported that groundwater which is an alternative drinking source to surface water is equally vulnerable to pollution from the same land use practices which affect surface water in Ghana (Kortatsi, 1994; Xu & Usher 2006). Synthetic chemicals such as biocides as well as fertilizer runoffs from farmlands and industrial discharges, illegal mining, runoffs from domestic houses, solid waste dumps and human wastes impact negatively on most surface water sources (Anim et al., 2010; Osei & Duker, 2008; Asante et al. 2008).

Waste disposal is one of the possible ways of land use that affects water quality. The method of dumping of solid wastes leads to leachate infiltration of contaminants into aquifers though it takes long period. The leachates contain many pollutants like nutrients, heavy metals, trace metals and organic compounds. Studies have shown that surface and groundwater are vulnerable to leachate contamination from municipal waste disposal sites in the urban centers and from fertilizer applications in rural areas respectively. (Vasanthi et al., 2008).

The level of pollutants from leachates in solid waste as well as from agricultural lands that enter groundwater depends on the nature of waste; if these pollutants enter the aquifer, they form plume that move in the direction of water flow in the aquifer. The concentration of pollutants in the water is dependent on the infiltration rates of the leachates and the volume of waste. Human waste disposal systems also contribute significantly to the level of pollutants especially high nutrients levels in ground water sources.

2.6 ASSESSMENT OF LAND USE CHANGE IMPACTS ON WATER

RESOURCES

Water availability is a serious issue facing many communities and nations around the world due to rapid urbanization and population growth which is rapidly stretching to neighbouring rural communities. There are various models such as Hydrological indicators and Soil and Water Analysis Tool (SWAT) models that can be used to assess the impact of land use changes on water resources. Hydrological indicators can also be used to assess how land-use changes affect water availability resulting from rapid urbanization and other land-use changes related to population growth which alters the hydrological regime by increasing the peak flow and volume of surface

runoff, while decreasing infiltration (Sahin and Hall, 1996). Khadka in 2014 used the Hydrological Model to predicting the Effects of Different Land-Use Scenarios on Water Availability. The model's result showed the impact of five predictive land-use scenarios on water availability. He indicated that the presence of forests and vegetation reduces surface runoff by enhancing infiltration, by increasing soil water content, recharging groundwater and increases the water availability in the form of groundwater for use during the dry season. The research further revealed that the most significant hydrological improvement were due to restoration and afforestation of depleted zones.

The impact of land use change on water resources can also be assessed using the Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998). Studies have showed the suitability of SWAT to model the water fluxes in the Mula and Mutha Rivers catchment (Wagner et al., 2011, 2012). According to Wagner et al. (2013) the use SWAT together with available data can be used to successfully quantify land use change impacts on water fluxes in data-scarce regions. The research analysis indicated that an increase of agricultural area accounts for exacerbation of the imbalance of water availability and demand in dry season due to increased consumption of irrigation water, whereas urbanization results in more runoff during rainy season due to the increase of paved surface area

SWAT input parameters can be specifically optimized with regard to stream flow predictions, estimated from readily available GIS databases, chosen from the literature for the given site condition or default model parameters selected (Kirchner, 2006).

The use of satellite data from remotely sensing and Geographic Information Systems (GIS) coverage of the area under study coupled with existing historical information can also be utilized to explain the impact of land use changes on water sources.

2.7 THE IMPORTANCE OF CLEAN WATER ON HEALTH

Access to safe drinking water is essential to the development of every nation. In 1978, International Conference on Primary Health, reported that the provision of enough clean drinking water was a basic requirement for healthy living conditions because clean water plays a major role in reducing the risk associated with certain diseases. The quality of water is influenced by parameters like temperature, transparency, suspended solids, nutrients and bacteria. Increased concentrations of these parameters in water sources affect its quality which consequently affects public health (Edema et al., 2001).

Although water borne diseases have been largely eliminated in wealthier countries, it is still a challenge in many developing countries (Gleick, 2002). The major problem of water pollution in the developing countries is fecal contamination of water sources. Some of these pathogens have been reported to enter groundwater sources (DiPaola, 1998).

2.8 WATER RESOURCES DEGRADATION IN GHANA

The significance of water sources in man's development cannot be underestimated. In Ghana about 52 % of the rural populations depend on underground water as the source of their daily water (Gyau-Boakye, 2001) and an estimated 22 % of the people rely on surface water to meet their daily water needs. However, water availability and

quality challenges across the country are pronounced and water shortages have become more intense in recent years in Ghana. Most rivers in Ghana have temporal variations under natural conditions and have deteriorated in quality and reduced channels (WRC, 2003).

Many researches have been done in different parts of Ghana on the quality of water sources and its impact on human health and the economy but there is little information on the impact of urbanization on water sources in the rural communities of the Hohoe Municipality. In 2011, International Union for Conservation of Nature an natural resources reported of deteriorating water quality of both surface and groundwater in the White Volta Basin and attributed it to the presence of phosphates and nitrates from agriculture activities in the area. Asante and Ansa – Asare (2001), investigated water quality of boreholes in some parts of the Volta region including Hohoe and effects of land modifications on freshwater sources. The results showed that, the physicochemical quality of boreholes were of good quality due to the depth of the aquifers while bacteriological results were above the WHO standard for safe drinking water. The reason was that, boreholes with high coliforms were not having clean surroundings and run off infiltration contributed to the high coliform count.

The groundwater analyzed in the peri- urban areas of Kumasi was reported to contain high bacteriological levels above the WHO permissible limit of drinking water. These high pollution levels were linked to poor hygienic conditions and sanitation due to urbanization (Obiri-Danso et al., 2009).

2.9 WATER QUALITY

Water quality is one of the important issues in water resources management. In broad terms, water quality can be classified into three broad categories, namely physical, chemical and biological and each category has a number of parameters. The assessment of these three categories by field monitoring of rivers provide basic data for detecting trends, for providing water quality information to water authorities, and for making recommendations for future actions. This assessment is usually conducted by referring to natural water quality, human health and intended uses (WHO, 2006).

Water bodies can be fully characterized by three major components: hydrology, physico-chemistry and biology. A complete assessment of water quality is based on appropriate monitoring of these components. Water monitoring and assessment are frequently confused and used synonymously. Water quality assessment is the overall process of evaluation of the physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses, particularly uses which may affect human health and the health of the aquatic system itself; but water quality monitoring is the actual collection of information at set locations and at regular intervals in order to provide the data which may be used to define current conditions, establish trends, etc (WHO, 2010).

Water quality assessment includes the use of monitoring to define the condition of the water, to provide the basis for detecting trends and to provide the information enabling the establishment of cause-effect relationships. Important aspects of an assessment are the interpretation and reporting of the results of monitoring and the making of recommendations for future actions.

The quality of drinking water shows how safe and acceptable the water is for human use. Water quality can be influenced by natural and anthropogenic activities through pollution. It is classified by analyzing the total composition of physical, chemical and microbiological parameters of water which may pose health risk to consumers when the threshold values of these parameters are above the recommended standards. The effects of unsafe drinking water globally and locally on human health by need to be put under control and if possible eliminated by the provision of safe water (WHO, 2006)..

Anthropogenic activities normally impacts negatively on water quality. With the advent of industrialization and increasing populations, the range of requirements for water has increased together with greater demands for higher quality water. Pollution and water quality degradation interfere with vital and legitimate water uses at any scale, i.e. local, regional or international. There are several human activities which have indirect and undesirable, if not devastating, effects on the aquatic environment. Uncontrolled land use for urbanization or deforestation, accidental release of chemical substances, discharge of untreated wastes or leaching of noxious liquids from solid waste deposit, excessive use of fertilizers and pesticides has long-term effects on ground and surface water quality.

2.10 PHYSICO - CHEMICAL WATER QUALITY PARAMETERS

The features of water determined by human senses namely sight, smell, taste and touch are referred to as the physical parameters of water while the chemical parameters are dissolved minerals and nutrients. The physical parameters are often related to chemical parameters and of aesthetic concern. The measurable physicochemical parameters include Temperature, Colour, Electrical Conductivity,

Turbidity, pH, Alkalinity and Total Suspended Salt (TSS). The physicochemical parameters are outlined in table 2.2



Table 2.2: The physicochemical quality parameters of water

PARAMETERS	DEFINITION AND EFFECTS ON WATER QUALITY AND HEALTH
Temperature	Temperature is described as "a catalyst, a depressant, an activator, a restrictor, a stimulator, a controller, and a killer, one of the most important and most influential water quality characteristics to life in water." (Federal Water Pollution Control Administration, 1967). It generally affects the chemical and biological rates of reactions in water because increase in water temperature increases the solubility of solids which increases toxicity of different parameters. The factors that influence water temperature are air temperature, storm-water runoff, groundwater inflows, turbidity, and sunlight exposure (Sharon, 1997). The most common unit for temperature measurement is degree Celsius.
Taste, Odour and Colour	A change in the appearance, taste, odour and colour of water is an evidence of contamination. These qualities of water are basically of an aesthetic concern. Human sense detects odour easily in water than taste. Highly coloured water stains clothes and fixtures causing permanent damage and cannot support aquatic life because it prevents penetration of light leading to high algal growth causing eutrophication. Colour is measured in Hazen units (HU).
Turbidity	A measure of the ability of lights penetration through water. Particles in water cause dispersion and absorption of light through it. Poor land management can cause high turbidity (Sharon, 1997) which can enhance the growth of pathogens to cause diseases like diarrhea, dysentery and typhoid. Its unit of measurement is Nephelometric Turbidity Unit (NTU), the turbidity of potable drinking water should not exceed 5 NTU's as a standard.
Electrical Conductivity (EC)	EC is waters ability to transmit charges. It indicates the amount of total dissolved salts (Dahiya and Kaur, 1999). High conductivity results from high concentrations of ions indicating the pollution of water with different ions like nutrients, salts and ions. Factors that can affect conductivity are the levels of ions, flow of ions, valency of ions and the temperature of the water. Increase in temperature causes higher conductivity by producing more kinetic ions. The unit of measurement of conductivity is microsiemens per centimeter ($\mu\text{S}/\text{cm}$).
Total Dissolved Solids (TDS)	It is a measure of dissolved salts in water when suspended particles are removed through evaporation. It is the residues of dissolved solids like minerals, salts, metals, anions and cations after evaporation. Its unit of measurement is milligram per liter (mg / L). TDS is of aesthetic concern such as making the water acidic, salty taste and formation of scales in cooking utensils. However TDS beyond the acceptable limit makes water unsafe and can cause gastrointestinal irritation.
pH	It is the measurement of a solution's acidity or basicity. When the molecules of water disassociate, it forms hydrogen ions (H^+) and hydroxide ions (OH^-). These ions bond with other compounds which enter the water and alter the equilibrium state of the ions. If

	more hydroxide (OH^-) ions react with the compound, then more hydrogen (H^+) ion will remain making the water acidic and if more hydrogen ions also react, more hydroxide ions will remain making the water basic. The recommended range of pH values by W.H.O and G.S.A for drinking water must be between 6.5 and 8.5.
Alkalinity	Alkalinity is defined as the "acid-neutralizing" ability of water. The ability of natural water to act as buffer is partly due to the presence of calcium carbonate or magnesium carbonate which releases free carbonate ions that control the changes in pH. The major source of alkalinity is from rocks rich in limestone (CaCO_3); if the alkalinity is high, it causes hardness in water. On the other hand, lower alkalinity makes the water soft and also makes it susceptible to rapid changes in pH from acid pollution.

2.11 MAJOR CHEMICAL IONS IN WATER

The most abundant chemical ions in water are the major cations and anions which are positively and negatively charged respectively. The cations are Calcium, Magnesium, Sodium, Potassium and the anions are Chloride, Sulphate, Flouride and Bicarbonate.

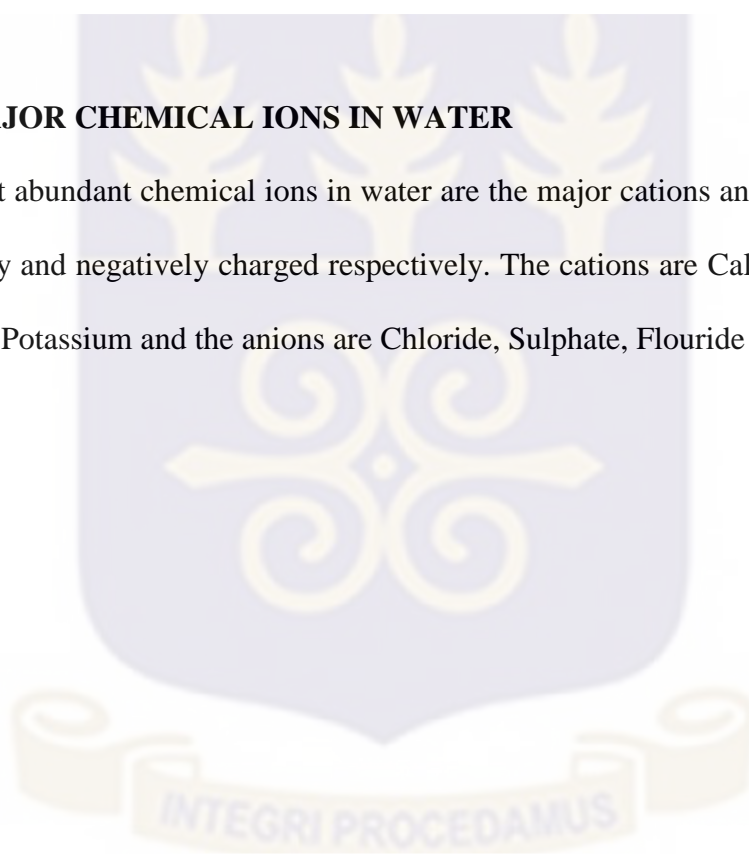


Table 2. 3: Major Chemical Ions in Water

PARAMETERS	EFFECTS ON WATER QUALITY AND HEALTH
Calcium:(Ca ²⁺)	Calcium is the main cation that causes hardness in water. (Chandra et al., 2013). The source may be natural from geological formations or anthropogenic from sewage and some industrial waste. Excessive amounts in both domestic and industrial water may affect human health and cause damage to industrial processes respectively.
Magnesium:(Mg ⁺²)	It also causes hardness in water but not abundant in rocks as calcium. High magnesium in water when taken can cause digestive problems. (Chandra et al., 2013). Magnesium is widely distributed in ores and minerals
Sodium: (Na ⁺)	The Sodium level in water is low compared to the level in food. However it can be of significance to the health of people with high blood pressure
Potassium :(K ⁺)	It occurs widely in the environment and in drinking water through potassium permanganate in water treatment. Although Potassium level in water is small, solubility of KCl in water treatment can lead to significant increased exposure. (Powell et al., 1987).
Chloride: (Cl ⁻)	Human activities contribute to high Chloride in water sources (DNHW, 1978). Excess Chloride in water causes corrosion and also gives water bad taste (WHO, 2010).
Fluoride: (F ⁻)	Fluoride ions may be present either naturally or artificially in drinking water. High Fluoride levels have been reported in parts of the upper regions of Northern Ghana. (Smedley et al., 1995) which is of health concern.
Phosphates: PO ₄ ³⁻	Phosphorus is an important nutritional element for the growth of plants and animals. Human activities contribute to high levels in water. Excessive phosphate in water causes eutrophication and digestive problems.
Sulphate: SO ₄ ²⁻	Sulphates occur naturally and through human activities such as sewage treatment plants, discharges industries and runoff from farm lands with high fertilizer applications. Excess sulphate causes a temporary laxative effect in humans and eutrophication.
Nitrate (NO ₃ ⁻) and Nitrite (NO ₂ ⁻)	Anthropogenic sources of nitrate are use of fertilizers, human and animal waste contamination of water and natural sources include geological formations, Nitrogen fixing indigenous plants and atmospheric depositions (Edmunds and Gaye, 1997). Nitrates and nitrites cause eutrophication and the main health problem of these nutrients is “blue-baby syndrome” (BGS, 2003). A condition in which the amount of oxygen supply to the brain is restricted resulting in death.

2.12 MICROBIOLOGICAL PARAMETERS OF WATER QUALITY.

This water quality basically consists of the presence of microscopic living organisms in water. They are referred to as indicator organisms in water quality analysis. The presence of pathogens in water is confirmed by fecal and total coliform counts (Okpokwasili and Akujobi, 1996). Urbanization has been reported to be associated to more fecal coliform counts in drinking water sources (Mehaffey et al., 2005). In Bangladesh, it was reported that the ascendancy in water borne diseases was as result of microbiological contamination of surface water (Sirajul et al., 2007). These indicator organisms are outlined in table 2.4

Table 2. 4: The Indicator Organisms

PARAMETERS	EFFECTS ON WATER QUALITY AND HEALTH
Faecal Coliforms	They are microorganisms in the intestines of warm- and cold-blooded organisms, which are detected at 44°C or 44.5° C. The presence of fecal coliform indicates the existence of pathogens in water (Okpokwasili and Akujobi, 1996).
Total Coliforms	Total coliforms actually indicate contamination from both fecal and other coliform bacteria sources in water (Edge and Hills, 2007). They are detected at a temperature of 35°C or 37 °C.

2.13 WATER QUALITY INDEX (WQI)

A water quality index (WQI) is a single dimensionless number expressing the water quality in a simple form by aggregating the measurements of selected parameters. A WQI has been proposed as early as in 1965, to define the state of water quality in a river (Horton 1965). Considering the easiness of their use and the scientific basis, WQIs have become important and popular tools in assessing the water quality of

water bodies worldwide, particularly of rivers. Since the birth of the concept of WQI, various indices have been formulated and developed by many researchers. WQIs have also been considered as a pivotal component of the wider environmental or natural resources indices such as the Environmental Performance Index.

The use water quality index as a tool to evaluate water quality status has been adopted by many organizations and agencies. The information gained from the WQI can be used for the following purposes:

- a) To provide an overall status of water quality to the water authorities and the wider community
- b) To study impacts of regulatory policies and environmental programs on environmental quality
- c) To compare the water quality of different sources and sites, without making highly technical assessment of the water quality data
- d) To assist policy makers and the public to avoid subjective assessments and subsequent biased opinions

The WQI has been used in United State of America, Europe, Asia and Africa (Bordalo et. al, 2001; Ramesh et.al, 2010). Water Quality Index (WQI) has generally been accepted as an important tool for measuring water quality through classification. Generally WQI categorizes the various water quality parameters into simple terms as excellent, good or bad (Hülya, 2009). The quality of water is determined by physical, chemical and microbiological characteristics of water. Water quality Index is an indispensable measure of assessing the overall water quality in a single number for classification to identify relevant treatment processes and associated problems.

Even though WQI vary from country to country, many countries have adopted an aggregated water quality data to develop their water quality indices. Currently the most common water quality parameters accepted and used widely in African, Asian and European countries are the physico – chemical and microbial parameters namely dissolved oxygen (DO), pH, coliforms, electrical conductance, alkalinity and chloride etc. (Shweta , 2013)

2.14 PREVIOUS WORKS DONE ON THE IMPACTS OF LAND USE ON WATER RESOURCES IN GHANA

Many studies have been done on the impact of land use on water resources in different parts of Ghana. The principal land uses which negatively affected river sources in the Okyeman Traditional Area in the Eastern region of Ghana (the Densu, the Birim and the Ayensu basins) were agriculture, grazing, residential, transportation, urban development, illegal mining and fishing (Ayivor et al., 2012). The consequences of the various land uses may include deforestation which lead to increased erosion, sedimentation load, high levels of nutrients and eutrophication, water shortage and pollution which affect the physicochemical quality of water (Ansah-Asare, 1995).

Studies by Ansa- Asare and Asante, (2000) revealed that there was strong correlation between Calcium and Magnesium, ($r = 0.95$ significant at $P < 0.001$) and high nutrient loads in the Birim river. They claimed it was as a result of widespread erosion due to changing land practices and influx of domestic, agricultural and industrial effluents respectively which contaminated both surface and groundwater sources threatening their sustainability. The increase in population within the catchment areas of river sources over the past four decades especially within Kade, Suhum, Asamankese and Kibi

areas has led to increased contamination of the water bodies within their catchment areas (FAO, 1999, Ansa - Asare and Asante, 2000).

The physicochemical water quality of the Ayensu River analyzed in the year 2000 was reported to be of good quality upstream while the quality degraded downstream (Appau-Attafuah, 2000). This was as result of increased human activities along the river. Atewa Forest has also been reported to be under heavy degradation which could result in the exposure of watersheds due to landscape modifications (Gunderson, 2000).

The microbiological indicator organism counts recorded along the Asukwakwa River in the Volta region was above the recommended limits of 0.0 cfu/ ml, which make it unsafe for drinking and this was due to increased human activities along the river. These parameters were recorded as fecal coliforms (minimum of 121.00 FC/100ml and maximum of 425.50 FC/100ml) and total coliforms (minimum of 497.50 TC/100ml and maximum of 1323.25 TC/100ml) (Samah, 2012). With the exception of Turbidity and Colour, many of the physicochemical parameters of the Ke – Nya stream in Brong-Ahafo region were within the WHO guidelines recommended for potable water while Heterotrophic bacteria (444 ± 3129 CFU/ml, 1341 ± 778) were higher than the WHO standard of 0.0 CFU/100 ml. The high bacterial contamination could be traced to human settlements along the stream, livestock production, poor or non-existence sewage system (Frimpong et al., 2015).

CHAPTER THREE

MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter gives an account of the various research methodologies that were employed and the materials used. it deals list of instruments used, chemicals, field reconnaissance survey, administration of questionnaires, land use change assessment, sampling of water from the major water sources within the study area, field analysis of samples involving measurement of physical parameters (temperature, pH, electrical conductivity, total dissolved solids (TDS), laboratory analysis of samples and quality control and assurance measures employed to ensure accurate results for discussion.

3.2 LIST OF EQUIPMENT, CHEMICALS AND MATERIALS USED

The list of materials, equipment and chemicals used for the analysis of the various physicochemical and microbiological parameters in this research are presented in table 3.1.



Table 3.1: List of Instrument and their models

S/N	Items	Model / Specification
1	Digital Conductivity meter	Cond 3210 SET 1
2	Ion chromatograph	SCHMADZU HPLU-HLC20A
3	Colorimeter	HACH –DR 890
4	Digital pH meter	Neuftech ATC
5	Global Position System	Garmin GPS
6	Polyethylene bottles	330 ml
7	Acetate filter papers	0.45µm
8	Acid	0.02 M HCl, 5% HNO ₃
9	Indicator	methyl orange
10	Media for incubation	Violet Red Bile (VRB) agar for total coliforms, Eosine methylene blue (EMB) for fecal coliforms and R2A agar for total viable counts
11	Burette	
12	Retort stand	
13	Conical flask	250 ml
14	Magnification Lens	(10 - 15) X
15	Blank sample	Distilled Water
16	Land use classification for 2007	Landsat 7, Enhanced Thematic Mapper
17	Land use classification for 2017	Landsat 8 , Enhanced Thematic Mapper

3.3 FIELD RECONNAISSANCE SURVEY

A field reconnaissance visit was undertaken to the entire Hohoe Municipality to identify sampling locations. The survey spanned over a three month period (September to November, 2016) and included visits to Municipal Assembly, Community Water and Sanitation Agency, Ministry of Food and Agriculture, Health Centres, Chiefs, Assembly Members and community leaders. The survey also identified major land uses within the study area, major source of drinking water in the rural communities and sanitary inspection of water sources. In all, six (6) major zonal councils in the Hohoe Municipality were selected for the study. These include Alavanyo, Lolobi, Likpe, Santokofi, Akpafu, Agumatsa and Gbi South areas.

The choice of sampling sites was due to their strategic locations, the bulk of human activities, population density and source of drinking water. Sampling locations targeted the major water abstraction points (streams, ponds, hand dug wells, drains) in the selected Zonal councils and rural communities experiencing rapid urbanization. Topographic and geological maps as well as aerial photographs and satellite images of the study area were acquired and studied. Lineaments were inferred and areas of intense anthropogenic activities were demarcated for assessment.

3.4 ASSESSMENT OF LAND USE CHANGES

Data for the classification of land use in the study area was derived from analysis of remotely sensed (Landsat 7, Enhanced Thematic Mapper) satellite image for the year 2007 and (Landsat 8, Enhanced Thematic Mapper) satellite image for the year 2017 spanning ten years covering the entire Hohoe Municipality from the Centre for Remote Sensing and Geographic Information Systems (CERSGIS), located at the Department of Geography and Resource Development of the University of Ghana.

The data generated by the center showed a detailed land use maps which were classified into the following categories; unclassified, built ups, grassland, forest and bare land for analysis in combination with existing historical information to explain the impact of urbanization on land uses and how these affect water sources especially surface water within the neighbouring rural communities.

Additional data was derived from the existing literature on land use, land use change and land cover change from both published and unpublished sources including scientific journals, books and internet sources. The analysis of the data was mainly through qualitative means involving descriptions, and in-depth explanations.

3.5 ADMINISTRATION OF QUESTIONNAIRE

Primary data for the assessment was collected through field survey, observations, questionnaires (Appendix A), one- on -one interview and focus group discussions. Multiple – stage sampling techniques were used for the field survey and these were simple random, purposeful and accidental sampling. The targeted population was assembly men, chiefs, opinion leaders and households who were randomly and accidentally selected. Officials from relevant institutions (Ministry of Food and Agriculture, Community Water and Sanitation Agency, Environmental Protection Agency, Ministry of Local Government and Rural Development) and leadership of the Municipal Assembly who were purposively selected also formed part of the respondents. The random selection for the households was done using the lottery method. This was done by giving households numbers written on pieces of paper, folded and shuffled very well in a container. If the household number was picked then that household was served with a questionnaire to answer.

Accidental sampling methods were employed for Assembly members, chiefs and opinion leaders in the selected Zonal Councils. In the accidental sampling method the first person to be contacted in each selected group was interviewed. If the first person contacted was not ready, the next available person was interviewed. The convenient sampling method was used based on the following criteria:

- i. Willingness to participate,
- ii. Availability for interview, and
- iii. Even spatial selection.

The questionnaire (Appendix A) was distributed to all respondents selected for the study and the purpose of study explained to them. The respondents were assured that all responses would be treated with utmost confidence. The researcher sought permission from the Municipal Assembly to administer the questionnaires to assembly members.

The researcher distributed the questionnaires himself and this gave the researcher the opportunity to explain the purpose of the study and appealed for their co-operation. Since some respondents did not understand the English language people who understood both the English language and the local languages were employed to assist in the administration of the questionnaires and interview sessions.

In line with the research objectives, unstructured interview and focus group discussion on land use changes and its effect on water availability was scheduled with officials from key institutions (Ministry of Food and Agriculture, Community Water and Sanitation Agency, Environmental Protection Agency, Ministry of Local Government and Rural Development and leadership of the Municipal Assembly) in the study area because of their capacities as policy makers and implementers.

3.6 PRETESTING OF QUESTIONNAIRE

A pilot-testing of the questionnaire was done in Alavanyo before the final questionnaire was sent to the respondents. Twenty five questionnaires were administered randomly among adults between the ages of 45 to 70 years under the leadership of the assemblyman for Alavanyo. The test was conducted to enable the researcher make all the necessary corrections in the questionnaire. It also enabled the researcher to make sure the questionnaire was devoid of any ambiguities. After the pre-testing, the questionnaire was revised in order to solicit the exact responses.

3.7 COLLECTION OF WATER SAMPLES

3.7.1 Treatment of Sample Containers

The water samples were collected using 330 ml high density polyethylene containers for the physicochemical analysis. These containers were immersed in warm soap bath for 48 hours, rinsed with deionized water and immersed in 10 % HNO₃ at room temperature for 72 hours. The containers were rinsed three times with deionized water and immersed in 50 % HNO₃ bath at 80 °C for a day. The containers were again rinsed with deionized water and dried overnight in a clean oven at 60 °C. The containers were then removed and allowed to cool before they were capped tightly and doubled bagged in new re- sealable polyethylene bags and stored.

The same volume of sample bottles were washed thoroughly with soap and rinsed with distilled water and sterilized in the Gallenkamp autoclave at 170 °C for three hours to collect samples for microbiological analysis.

3.7.2 Labeling of Sampling Bottles

The sample bottles for boreholes were labeled by the name of the communities as Dzogbedze, Agome, Agoxoe etc. and bottles for the streams were also labeled by the name of the streams as Tsatsadu stream, Nubui stream and Obiankasa stream etc. Masking tape was fixed on the bottles before the labeling with a permanent marker to prevent the erasure of the labels.

3.7.3 Sampling

The sampling was done to cover all the major abstraction points (streams, rivers, hand dug wells, boreholes) used by the rural communities within the municipality in December 2016, January and February 2017. Water samples were collected on monthly intervals. They were collected from a total of 34 locations and this is made up of ten (10) surface water samples, three (3) hand dug wells and twenty one (21) boreholes from the rural areas of the Hohoe Municipality.

Surface water was sampled from a depth of 20 – 30 cm into the prepared containers adhering strictly to sampling protocol as described by APHA (2005) standard methods. Water samples from rivers were taken at the exact points the people fetch water using a plastic bucket and a rope. The sample container was rinsed with distilled water three times at each sampling point and immersed into the stream with the mouth upright until the water filled it and was covered instantly (fig. 3.1). Groundwater samples (hand dug wells and boreholes) were collected using existing infrastructure (hand pumps mounted on the boreholes and hand dug wells) (fig. 3.2). Prior to sampling, the boreholes were purged by pumping water out for at least 5 minutes. Four (4) samples were taken at each point for major ions and microbial analysis.

The samples for microbial analysis were collected into the sterilized containers and covered with aluminium foil. Sampling containers were rinsed three (3) times with the water sample before the samples were taken into the containers. The samples were carried on ice in an ice cooler from the field and stored in a refrigerator at 4 °C prior to analysis. A Garmin GPS (Global Position System) device was used to log spatial data of the various locations, where surface and ground water samples were collected.



Figure 3.1: Sampling of surface water at Alavanyo Kutorgble stream





Figure 3.2: Sampling Groundwater using the existing infrastructure

3.8 SAMPLE ANALYSIS

3.8.1 Field Analysis

Water samples collected were analyzed by both classical and automated instrumental standard methods for the analysis of water and wastewater (APHA, 2005). Water Temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity, and pH were measured at each sampling site using portable (field-type) instruments (3210 SET 1 conductivity meter and digital ATC Neuftech - pH meter). Alkalinity was determined on the field by titrating 0.02 M HCl against 50 ml of the water sample using methyl orange as indicator (fig. 3.3). The end points were recorded as soon as the colour changed from orange to pink. It was repeated twice to find the average titre values. The following equation was used to calculate for total alkalinity;

$$\text{Total Alkalinity mg (CaCO}_3\text{) / L} = \frac{(A \times M \times 50000)}{V}$$

where

A= volume of acid used

M= molarity of standard acid used

V = volume of samples.

A Garmin GPS (Global Position System) device was used to log spatial data of the various locations, where streams and boreholes were collected. The GPS readings were used to plot the map of the sampling points.



Figure 3.3: Simple titration for determining alkalinity

3.8.2 Laboratory Analysis

3.8.2.1 Turbidity, Total Suspended Solids (TSS) and Colour

The HACH –DR 890 Colorimeter (fig. 3.4) was used to measure the Turbidity, Total Suspended Solids and Colour of water samples in the laboratory. For turbidity measurement, the colorimeter was programmed at ‘94’. The turbidity of water samples was determined by measuring 10 ml of distilled water and 10 ml of water sample separately using the sample cell. Distilled water was first measured as a control. The distilled water was used to standardize the colorimeter after which the water sample was placed in the colorimeter and its turbidity measured. For total suspended solids measurement, the colorimeter was programmed at ‘95’. Blank sample (distilled water) was first measured after which a 20 ml of water samples was placed in the colorimeter and TSS measured. The colorimeter programme for the measurement of colour is ‘19’. The colour of the samples was then read after standardization of the colorimeter with a blank (distilled water).



Figure 3.4: HACH –DR 890 Colorimeter

3.8.2.2 Major Ions

The concentrations of fluoride, nitrate, sulphate, chloride, phosphate, calcium, magnesium, sodium and potassium in water samples were determined using ion chromatographic techniques (SHIMADZU HIC - 20A model ion chromatograph) (fig. 3.5). Before the samples were analysed, the SHIMADZU HIC - 20A model ion chromatograph was calibrated using a standard solution. The samples were filtered with a 0.45 μm size pore filter paper. Samples with conductivity above 700 $\mu\text{S}/\text{cm}$ and salinity above 0.1mg/L were diluted. Aliquot of water samples (5 ml) was pipetted into a labeled vial, interspersed with analytical standards of interest and placed on auto sampler with standards at the start, between every 15 samples and the last on the ion chromatograph sample run. The major ion components were identified by comparing their retention times with those of the standard mixture. Quantification was based on comparison with calibration curves drawn with the standards.





Figure 3.5: Ion analysis using the SCHMADZU HPLU-HLC20A at GAEC Hydrology Laboratory.

3.8.2.3 Microbiological Analysis

The membrane filtration method (fig. 3.6) was used to determine Total Coliform and Fecal Coliform. The porous plate of the membrane filtration unit and the membrane filter forceps were sterilized with 98 % alcohol which was burnt off in a Bunsen

flame. The sterilized forceps were then used to transfer the sterile membrane filter onto the porous plate of the membrane filtration unit with the grid side up and a sterilized meshed funnel placed over the receptacle and locked in place. Water sample (100 ml) was added to the membrane filtration unit using the funnel measure. The flame from the Bunsen burner was kept on throughout the whole analyses and the forceps was flamed intermittently to keep it sterilized.

The sample was filtered through the membrane filter under partial pressure created by a syringe fitted to the filtration unit. The filtrate was discarded and the funnel unlocked and removed. The forceps were then used to transfer the membrane filter onto labeled Petri plates of Violet Red Bile (VRB) agar for total coliforms, Eosine methylene blue (EMB) for fecal coliforms and R2A agar for total viable counts. The membrane filter was placed on the medium by rolling action to prevent air bubbles from forming at the membrane- medium interface. After this, a flamed forceps was used to aseptically transfer the filter papers unto a well labeled Petri plate and incubated at $36\text{ }^{\circ}\text{C} \pm 1$ for total coliforms and $44\text{ }^{\circ}\text{C} \pm 1$ for fecal coliforms for 48 hours. After incubation, typical colonies were identified and counted under 10 - 15 X magnification lens and the results expressed as colony forming units per 100 ml of sample analyzed (cfu / 100 ml). Results were computed using the relation

$$\text{Bacterial coliform/100ml} = \frac{\text{Number of bacterial coliform colonies}}{\text{Volume of sample filtered (ml)}} \times 100$$



Figure 3.6: Membrane filtration process in the Laminar Flowhood

3.9 CALCULATING THE WATER QUALITY INDEX (WQI)

Water quality index is the total combined score of number of chemical, physical and biological tests that show the actual quality of a particular water source. For the purpose of drinking water, the additive water quality method was chosen to determine the quality of the various sources of water (Cude, 2001).

The three basic steps involved are;

Step1: The quality rating scale Q_i for each parameter was determined using the equation

$$Q_i = \left\{ \frac{V_a - V_i}{V_s - V_i} \times 100 \right\} \text{ Where}$$

Q_i – the quality rating of each parameter

V_a – actual measured parameter obtained from physical or chemical measurement.

V_i – ideal value of the water quality parameter that can be obtained from standard tables, the ideal value of pH = 7.0 and for other parameters it is equal to zero,

V_s – Recommended WHO or GSA standards of the water quality parameter.

Step 2: Calculation of the relative weight (W_i) for each parameter using the following equation; $W_i = \frac{1}{S_i}$, where

W_i – relative weight for each parameter and S_i – standard permissible value for each parameter

Step 3: The total water quality index is calculated using the equation;

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}, \text{ Where}$$

Q_i – Quality rating and W_i – relative weight.

The water quality index WQI values are classified as shown in the Table 3.2

Table 3.2: Water Quality Index classification

Water Quality Values	Classification
< 50	Excellent
50 - 100	Good water
100 - 200	Poor water
200 - 300	Very poor water
> 300	Unsuitable for drinking

Source: (Ramakrishniah et al., 2009)

The Table 3.3 shows an example of how the Water Quality Index was computed for the surface water sampled at SW 4 (Fodome Helu – Nubui stream).

Table 3. 3: Example of water quality index calculation

S/ N	Parameters	Units	SW 4	WQ Standard (Si)	Wi =1/Si	Qi	Wi Qi
1	pH		7.2	8.5	0.1177	13.3333	1.5687
2	Temp	°C	22.8	30.0	0.0333	76	2.5333
3	Turb.	NTU	1.0	5.0	0.2	20	4
4	EC	µS/cm	32.2	1000	0.001	3.220	0.003
5	TDS	mg/L	16.1	600	0.002	2.683	0.004
6	Col	Hz	0.0	15	0.0667	0	0
7	Alk.	mg/L	72.0	400	0.0025	18	0.045
8	F⁻	mg/L	0.0	1.5	0.667	0	0
9	Cl⁻	mg/L	43.29	250	0.004	17.3144	0.0693
10	NO₃⁻	mg/L	3.27	50	0.02	6.544	0.1309
11	PO₄³⁻	mg/L	0.846	0.4	2.5	211.5	528.75
12	SO₄²⁻	mg/L	2.596	250	0.004	1.0384	0.00416
13	Na⁺	mg/L	11.86	100	0.01	11.86	0.1186
14	K⁺	mg/L	4.017	10	0.1	40.17	4.017
15	Ca²⁺	mg/L	1.984	50	0.02	3.968	0.0794
16	Mg²⁺	mg/L	0.122	50	0.02	0.244	0.00488
					∑= 3.767		∑= 541.373

$$WQI = 143.696$$

3.10 QUALITY CONTROL/ QUALITY ASSURANCE

The quality control and quality assurance measures applied were;

1. Contamination control procedures (strict washing and cleaning procedures)
2. Equipment calibrations, validation of method, analysis of reagent blanks and analysis of procedural blanks
3. Monitoring of instrument response, linearity and quality of analysis.

4. During analysis, blanks and duplicates were included and re-calibration standards ran frequently to check the integrity of the calibration.
5. Analysis of all blank samples showed no inherent bias in the method of analysis of analytes of interest.
6. All differences measured in concentrations between replicate pairs were within the precision of the method for all analytes of interest.



CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The results of the survey, field observations, sample location, questionnaire, land use classifications and laboratory analysis are presented for discussion in the form of tables and figures in this chapter. This chapter also focuses on the vegetation, sources of drinking water, land use changes, physico – chemical and microbial constituents of water sources in the study area. The results of the water quality are compared with recommended guideline values for raw water and the concentrations that are below and above the guideline values are identified and discussed.

4.2 LAND USE CATEGORIES OF THE STUDY AREA

The municipality falls within the forest – savanna transitional ecological zone of Ghana, with the forest part at its northern and eastern sectors tapering into the middle of the municipality. Hohoe municipality is characterized by semi-deciduous forest cover, savanna, mountainous and hilly vegetation with streams and rivers draining through many communities within the rural areas.

The vegetation of the area can be divided into three, reflecting the rainfall distribution and the altitude. These are the Moist-deciduous Forest, Savanna and Mountain Vegetation. Moist semi-deciduous forest once existed on the lower slopes of the highland but crop cultivation has reduced this to secondary forest. Patches of Wooded Savannah can also be found (Hohoe Municipal Agricultural Development Directorate, 2014).

The land use maps of the study area for 2007 and 2017 (Fig. 4.1 and 4.2) show the changes in land cover spanning for 10 years.

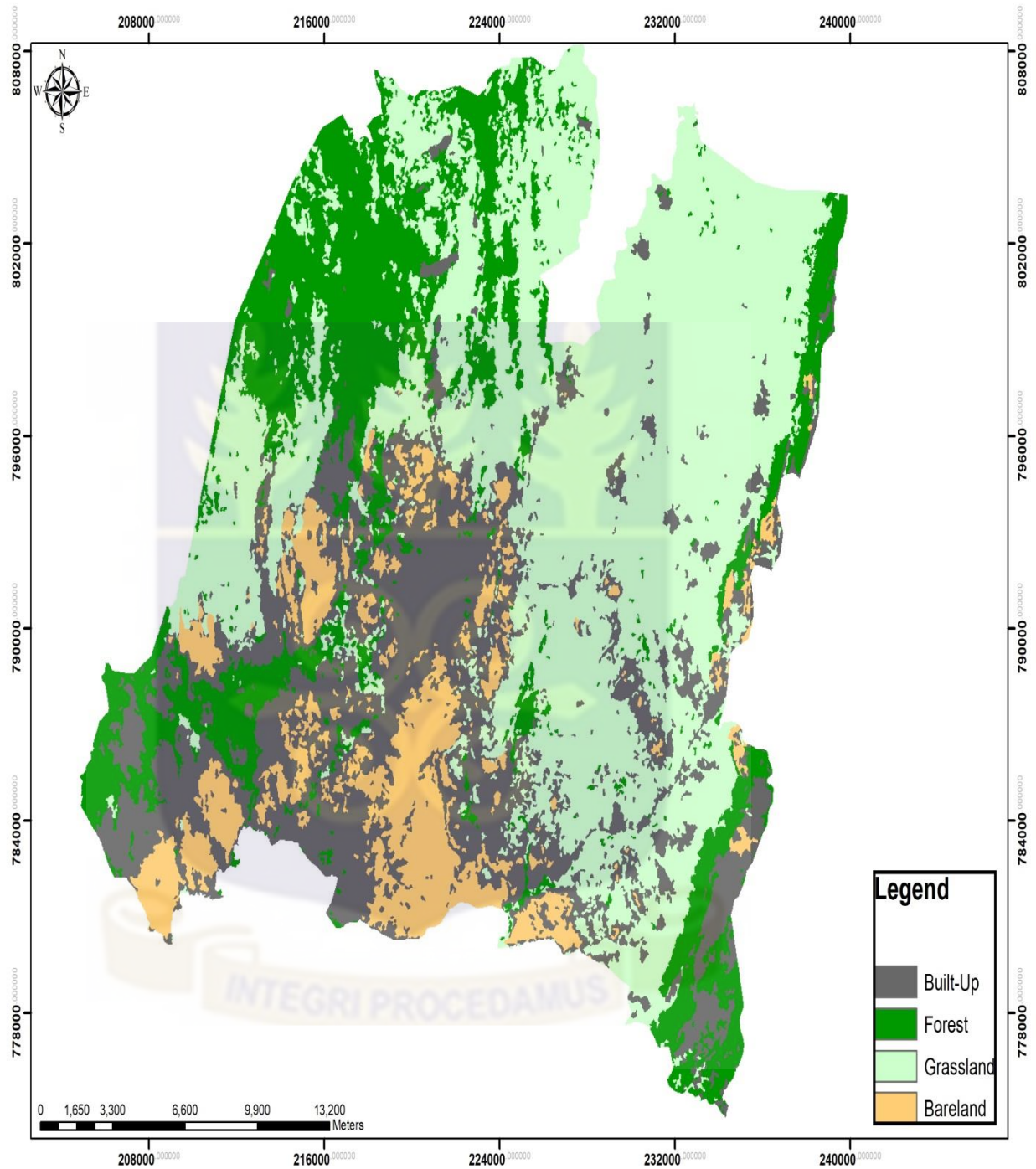


Figure 4.1: Land use map of Hohoe Municipality, 2007

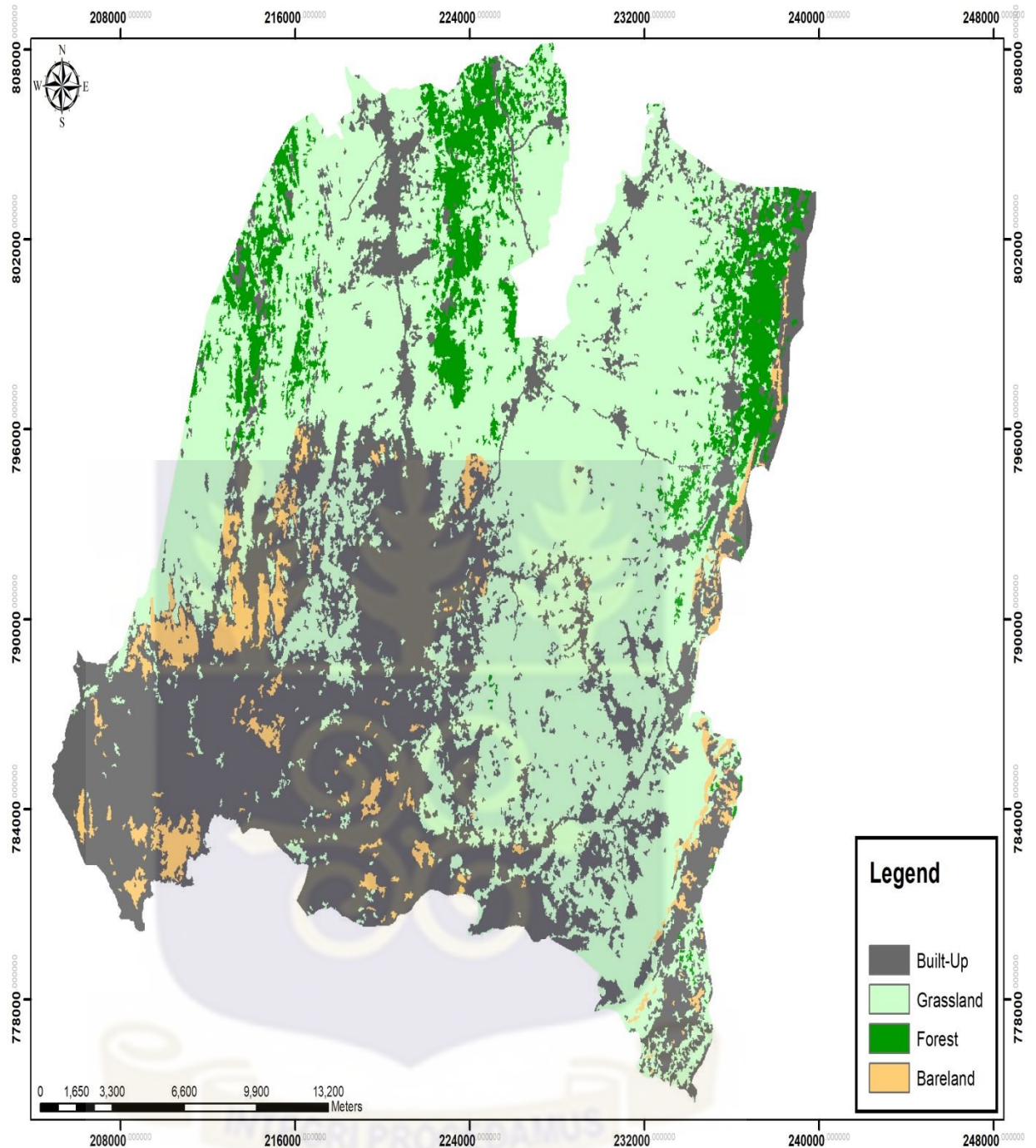


Figure 4.2: Land use map of Hohoe Municipality, 2017.

The land use changes from 2007 to 2017 were classified into four categories which are built - up, forest, grassland and bare lands. These categories have been summarized in Fig. 4.3 and 4.4 with their percentage coverage.

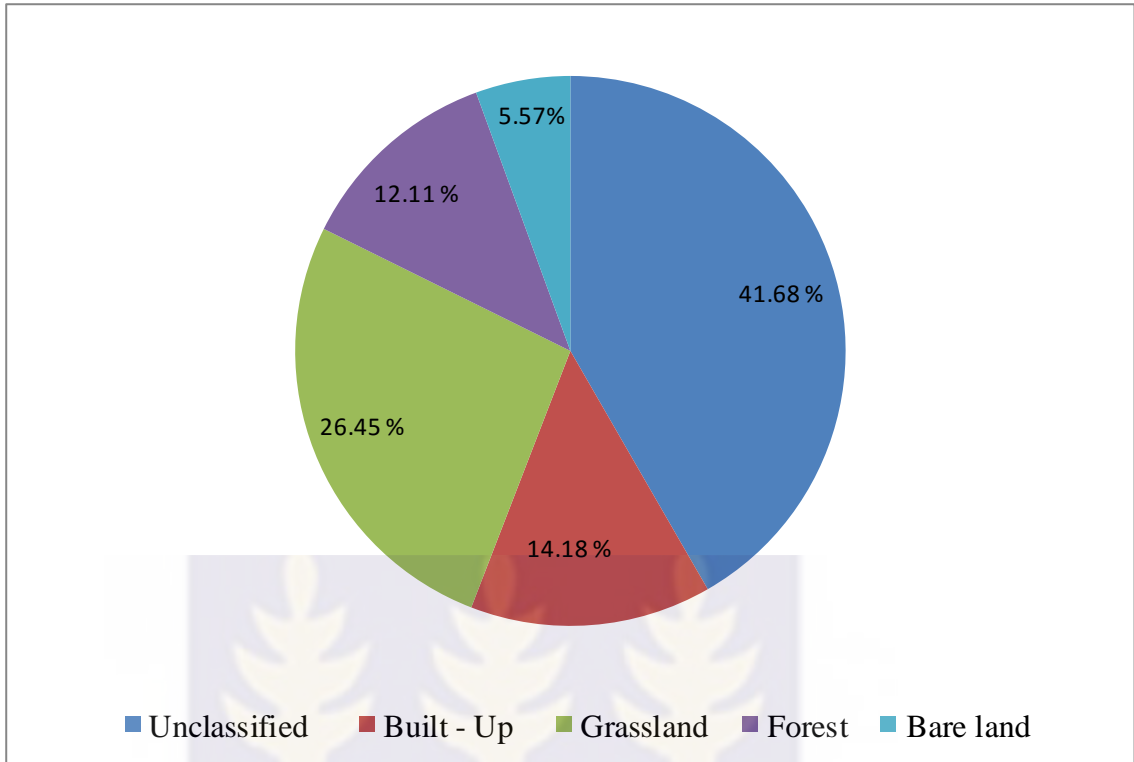


Figure 4.3: Classification of Land Use as at 2007

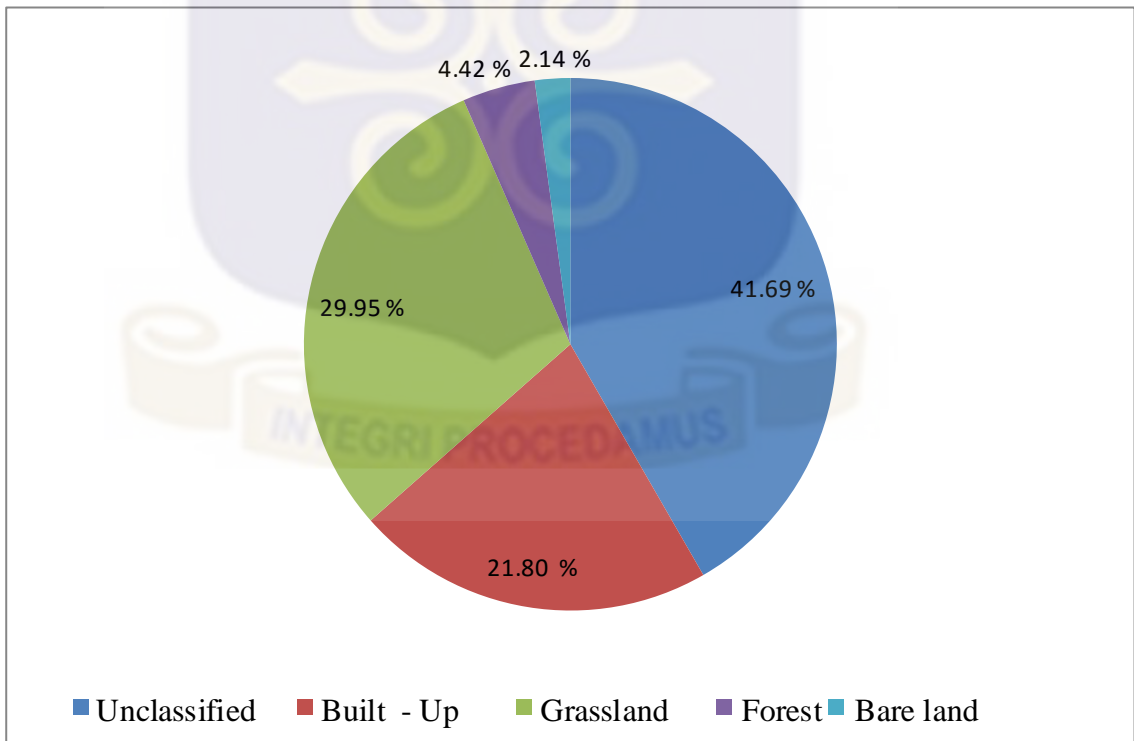


Figure 4.4: Classification of Land Use as at 2017

4.3 ANALYSIS OF LAND USE CHANGES

The major changes in land use within the Hohoe Municipality for the past 10 years from 2007 to 2017 are clearly indicated by two land use maps (Fig. 4.1 and fig. 4.2). Satellite images of land use changes are categorized as built up, grassland, forest and bare lands. The percentage coverage's of these categories are also shown in (Fig. 4.3 and fig. 4.4) respectively from 2007 to 2017.

From the land use maps and the categorization, the data clearly showed marginal increase in urbanization within the municipality over the last ten years, built up has increased from 14.18 % to 21.80 %, grassland coverage has also extended from 26.45 % to 29.95 % while forest areas and bare lands have dwindled drastically from 12.11% to 4.42 % and 5.57 % to 2.14 % respectively from 2007 to 2017. This analysis clearly shows that bare lands and forest zones are being converted to build up lands due to urbanization and industrial development such as the operation of a plywood factory along Hohoe - Lolobi road.

Illegal lumbering activities are rampant in the forest areas and this is reducing the forest cover thereby exposing water bodies to extensive erosion and evaporation which affects the water availability and quality of water. The result vividly confirms the work done by the Water Resources Commission of Ghana in the River Dayi Basin of which Hohoe Municipality constitute about 72 % in 2011, which reported that indiscriminate lumbering, industrial logging and poor farming practices leads to deforestation in the area (WRC, 2011).

Specific activities under the broad land use types are conversion of lands into croplands leading to deforestation, conversion of tree crop farms into food crop farms, livestock grazing, slash-and-burn farming practice and urban sprawl. Apart from

agricultural activities, other land use activity in the study area is the conversion of arable land to residential areas to meet the growing needs of human settlements. Rapid developing rural areas include Sanko, Kpoeta, Likpe, Lolobi Alavanyo and Fodome with high potential to negatively affect both surface and groundwater sources.

The springing up of new settlements as a result of increase in population is also on the increase as virgin lands are being sold for developmental projects. Urbanization cause significant changes in land scape such as compaction of soil through constructions. An impervious surface lowers water infiltration into aquifers and increases runoffs into surface water. The challenges of urbanization in the municipality include insanitary conditions such as open defecation along the banks of surface water sources, washing and bathing in water bodies, farming along river banks and indiscriminate waste disposal. All these human activities affect the quality and availability of both ground and surface waters by increasing sedimentation, increasing concentrations of nutrients, metals and pathogens.

The quality of groundwater sources can be affected by these different pollution sources. For example, Hamilton and Helsel (1995), revealed the relationship between agricultural land use and groundwater pollution. The increase in the use of nitrogen-phosphorous-potassium (NPK) fertilizers has resulted in high concentration of $\text{NO}_3\text{-N}$ in groundwater sources in Karachi – Pakistan (Mahmood et al., 1997) and in a rural setting of developing countries (Essumang et al., 2011) and also high levels of physicochemical parameters contributed to poor quality of groundwater in the Accra Plains (Quist 1976; Akiti 1986)

4.4 LAND USE CATEGORIES

The major land uses from respondents during the administration of questionnaire and focus group discussions in the study are agriculture, urban development, housing, lumbering and sand winning (Table 4.1). Sand winning is extensive at Fodome, Wli and Alavanyo areas. Sand winning activities in the Municipality at times involve diverting the course of rivers or winning sand in the rivers which introduce pollutants directly into water bodies thereby affecting its availability and quality. According to Owusu – Sekyere, (1993) sand winning activities contribute significantly to erosion. It was observed during the field survey that most of the streams have dried up and the respondents attributed it to land use changes especially infrastructural development.

Sand winning sites closer to the few surface water sources visited revealed high brown colouration. Human activities such as bathing, washing and defeacating during the sand winning introduce pollutants directly into the surface water bodies thereby affecting its quality along their courses. Respondents were of the view that the erosion level along the banks of streams in the study area has deteriorated due to illegal lumbering, sand winning and bush fires.



Table 4.1: Land use categories in Hohoe Municipality

S/N	Communities	Land uses	Water Sources in the communities
1	Alavanyo and Akplamafu	Forest / farming/ sand winning/ house hold waste management	Boreholes / streams
2	Lolobi and Likpe	Forest / farming / logging / built ups / household waste management	Boreholes / streams
3	Sankotrokofi and Akpafu	Farming/built ups/household waste management	Boreholes / streams
4	Fodome and Wli	Forest / farming / household waste management / sand winning	Boreholes / hand dug well / stream
5	Bla and Zongo	Urban areas	Hand dug well / borehole/river

The Municipality is agrarian with about 76 % of the active labour force engaged in agriculture (Hohoe Municipal Agricultural Development Directorate, 2014). The Municipality has vast suitable land for both upland and lowland rice cultivation and the bimodal rain pattern is an added potential for crop production. About 55,000 ha (47 %) of the 117,200 ha of land area of the Municipality is suitable for crop production (Table 4.2).

Table 4.2: SRID Estimated Major Crop Production in the Municipality

S/N	Crops	Cultivated Area (Ha)	Total Production (M. Tons)
1	Maize	7,225	15,714
2	Rice	6,520	19,560
3	Cassava	8,650	74,390
4	Cocoyam	1,455	12,076
5	Yam	205	656
6	Plantain	645	37,410

The major activities are crop farming such as vegetables; yam, maize, cassava, plantain and paddy rice (Table 4.3). Other crops grown in the study area are Cocoa, Coffee, Oil palm, Banana, Cassava, Groundnut, Mango, Pineapple, Citrus and Papaya (Hohoe Municipal Agricultural Development Directorate, 2014). Many of the farms are on subsistence basis except cocoa production which is on large scale in some areas like Likpe, Lolobi, Wli and Alavanyo. From the field survey, many of these farms use fertilizers and pesticides to boost production. Remnants of these agrochemicals may find their way into surface water through run offs or leach into ground water (FAO, 1999).

Table 4.3: Major Crop Production Locations in the Municipality

S/N	Crops	Locations
1	Maize	Fodome, Wli, Alavanyo
2	Rice	Akpafu, Santrokofi, Lolobi, Likpe, Godenu.
3	Cassava	Fodome, Alavanyo, Akpafu,
4	Cocoyam	Likpe, Lolobi, Akpafu, Alavanyo
5	Yam	Alavanyo
6	Plantain	Likpe, Alavanyo, Lolobi, Akpafu
7	Fruits	Lolobi, Likpe

Livestock production and fish farming also takes place at specific areas of the Municipality (Table 4.4). The identifiable livestock are goats, sheep, piggery and poultry. Local pigs are located in particular communities and largely kept on free – range and there are few commercial poultry farms located in municipal with layers between 200 and 1500.

Table 4.4: Major Livestock production and locations

S/N	Species	Population	Locations
1	Sheep	10,287	All over the municipal
2	Goats	32,070	All over the municipal
3	Poultry (Local)	73,490	Local breeds all over the municipal
4	Poultry (Exotic breeds)	2,633	Wli Afegame, Hohoe, Alavanyo,
5	Pigs (Local breeds)	52	Hohoe,
6	Pigs (Exotic)	610	Mostly Akpafu-Mempeasem

4.5 LAND USE CHANGES AND ITS IMPACT ON WATER AVAILABILITY AND QUALITY

The main sources of water for drinking and other household chores within the Hohoe Municipality are surface water (streams, rivers, ponds) and groundwater (boreholes and hand dug wells) and pipe borne water. Water supply has always been a basic problem of the Municipality with a limited number of communities having access to potable water. According to District Analytical Report of the Hohoe Municipality, higher proportions of households in urban locality (55.40 %) use pipe-borne water and 18.4% uses protected well compared to proportions of rural households which are 12.7 % and 2.2 % respectively. The proportions of rural households that use river or stream are 38.3 %, public tap or standpipe 21.3 % and borehole/hand dug well 17.3 % (GSS, 2014).

Observation by the researcher revealed that pipe-borne water is supplied mainly to urban areas in the Municipality while majority of the rural communities depend on untreated surface and groundwater as their sources of water for drinking, cooking, washing, bathing and other household chores. Interviews from the Municipal

Assembly indicated that potable water supply in the peri-urban and rural areas of the Municipality has been a major challenge to the Assembly since the Assembly has no direct control over urban water supply.

Opinion leaders in the various rural communities gave the historical background of surface water sources in the municipality during the focus group discussions and the outcome of questionnaires. Respondents involved in the study included 65 % females and 35 % males who were within the age range of 40 to 70 years (Fig. 4.5). Majority of the respondents (85%) during the interviews, focus group discussions and questionnaires administration agreed that there has been a strong impact of land use changes on water availability and quality within the study area over the past decades. They indicated that the Hohoe Municipality was well endowed with water resources, but the amount of water available changed remarkably from season to season as well as from year to year.

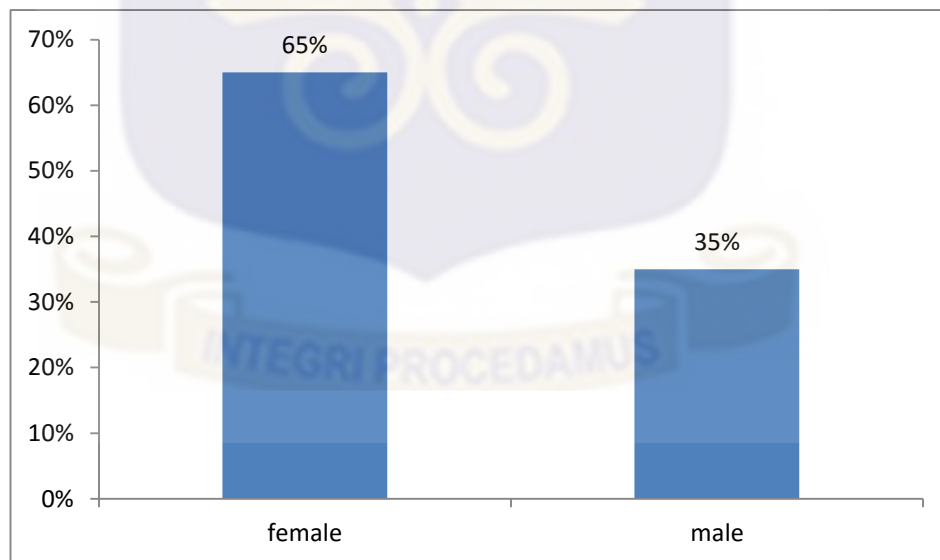


Figure 4.5: Respondents to the questionnaires

River Dayi is the main river that drains the whole of the Municipality and flows through Semi-deciduous forest, savannah, and mountain vegetation covering the low-

lying portion and extends to the Detu highlands in the south of the Municipality. Other important rivers which drain the Hohoe Municipality are Agumatsa, Tsatsadu and Aflabo. These rivers make it possible for small scale irrigation farming especially for seasonal cultivation of vegetables. Some of the low-lying areas have swamps that are used for rice cultivation. They include Akpafu Odomi, Akpafu Mempeasem, Santrokofi and Godenu. The respondents asserted that because of the increasing destruction of vegetative cover mostly due to poor farming practices and indiscriminate lumbering and the degradation of the environment, there has been frequent flooding during the rainy season and drying of rivers during the dry season in the Municipality.

The respondents were of the view that the prevailing extensive agriculture land use and increasing population results in erosion, increased peak flow and loss of biodiversity in the Municipality. A progression in land degradation and unchecked waste disposal in the rural community impacts negatively on the water availability and quality. They also indicated that management of waste in the rural communities in the municipality is based on individual households and most inhabitants dispose – off their waste into open drains which eventually lead to degradation of natural water bodies. Increase use of agrochemicals (fertilizer and pesticides) in farming activities, sprawling of new settlements, farming along the banks of river bodies, sand winning and illegal logging in forest areas degrade water resources.

The degradation of the water resources within the Municipality is envisaged to cause shortages of potable water in the municipality in support of sustainable agriculture. Studies have shown that different land uses contribute significantly to soil erosion, nutrient depletion, loss of vegetation and water resources degradation (Ayivor and Gordon, 2012). The consequences of the various land uses are a threat to water

availability and quality (Ansah-Asare, 1995). Though natural features such as geology, topography and, hydrology within a drainage basin changes seasonal runoff volumes, weather conditions and water levels which may affect the quality and availability of both surface and groundwater, anthropogenic sources of pollution have been shown to significantly influence the availability and quality of both ground and surface water sources (Alvani et al. 2011).

According to 70% of households who are in peri- urban communities in the Municipality, groundwater (hand dug wells and boreholes) serve as the main source of water for all their domestic needs. Most of these water sources normally dry up especially in the dry season. They were of the view that land use changes (urbanization, lumbering, deforestation) in recent times might contribute to the drying up of the wells and low recharge. The groundwater recharge may be increased or decreased as a result of changing land use practices. The major driving forces are removal of the vegetative cover and the infiltration capacity of the soil. The water table may change as a result of decreased evapotranspiration, logging or conversion of forest to grassland for grazing. Recharge may also increase due to an increased infiltration rate through afforestation of degraded areas (Tejwani, 1993).

Other land uses may be of some significance to water availability and quality but the expansion of human settlement in the area has had a greater impact on the water resources in the Municipality. Associated with human settlements is human population which has also been on the increase. The spiral impact of population growth on water resource occurs as a result of farming, indiscriminate waste disposal and livestock grazing (Ansah-Asare and Asante, 2000).

As part of the field investigations, a survey was undertaken at the Hohoe Municipal Health Directorate on most water related cases reported at the outpatient departments in the Municipality. A four year report from the directorate indicated the prevalence of water related diseases especially intestinal worm infections in the study area which was attributed to the degradation of water. Communities most affected were Lolobi, Likpe, Fodome and Wli areas (Tables 4.5, 4.6 and 4.7).

Water related diseases are caused by pathogenic micro-organisms most commonly transmitted in contaminated fresh water. Infections normally occur during drinking, bathing, washing and in the preparation of food. According to (WHO, 2014) various forms of diarrhoeal diseases and gastrointestinal problems affect mainly children in developing countries and cause about 1.5 million human deaths annually.

Table 4.5: Water Related Diseases within Lolobi Sub Area of the Municipality

Years	Diarrhoea Diseases	Intestinal Worms Infections
2012	281	342
2013	264	751
2014	264	806
2015	264	1217

Source: Hohoe Municipal Health Directorate

Table 4.6: Water Related Diseases within Likpe Sub Area of the Municipality

Years	Diarrhoea Diseases	Intestinal Worms infections
2012	409	184
2013	548	442
2014	855	387
2015	681	881

Source: Hohoe Municipal Health Directorate

Table 4.7: Water Related Diseases within Fodome/ Wli Sub Area of the Municipality

Years	Diarrhoea Diseases	Intestinal Worms infections
2012	561	398
2013	912	646
2014	990	624
2015	671	1052

Source: Hohoe Municipal Health Directorate

4.6 PHYSICOCHEMICAL CHARACTERISTICS OF SURFACE WATER

The sample locations, measured values of physicochemical parameters of surface water and groundwater (boreholes and hand dug wells) of all thirty four (34) water samples within the communities are presented in Tables 4.8, 4.9 and 4.10 respectively. The physical characteristics of water samples analyzed did not deviate from what one would expect from natural water bodies. The pH ranged from 5.3 at SW 1 (Alavanyo Agome - Kutorgble stream) to 7.5 at SW 8 (Lolobi Kumasi -River Dayi), it is slightly acidic to basic. The pH readings of the surface water were normal and within the recommended guideline values of 6.5 to 8.5 for pH (GSA, 2006; WHO, 2006).

Apart from the pH of 5.3 at SW 1 (Alavanyo Agome - Kutorgble stream), all the pH values recorded were within the permissible limit of 6.5 – 8.5 for potable water. pH generally plays an important role in metal bioavailability, toxicity and leaching capability. At low pH metals ions such as iron, manganese, copper, lead, and zinc could leach from the aquifer into drinking water (Stumm and Morgan, 1981). This low pH may be the result of the presence of organic matter (dried leaves), the

decomposition leads to releases of carbon dioxide which combines with water molecules to form weak carbonic acid resulting in lowering the pH.

The temperature ranged from 21.40 °C at SW8 (Lolobi Kumasi – Dayi) to 25.8 °C recorded at SW 10 (Gbi – Kledzo) and within the maximum recommended limit of 30°C (GSA, 2006; WHO, 2006). The vegetation cover upstream along the Lolobi – Kumasi Dayi River may be attributed to the low temperature of 21.40 °C as compared to the high value of 25.8 °C recorded at SW 10 (Gbi – Kledzo) River Dayi downstream with degraded vegetation along its banks due to the construction of a bridge over it and springing up of new settlements. The Federal Water Pollution Control Administration (1967) described temperature as a catalyst. It generally affects the rates of chemical and biological reactions in water, because increase in water temperature increases the solubility of solids which increases levels of different parameters.

The colour of the water samples ranged between 0 and 23 HU. Values recorded at SW 1 (Alavanyo Agome – Kutorgble stream), SW2 (Alavanyo Abehenasi – Tsatsadu River) and SW 6 (Likpe - Mate – Nguan stream) were 21 HU, 23 HU and 18 HU respectively which were above the recommended standards of 15 HU (GSA, 2006; WHO, 2006). The colour of water is basically of an aesthetic concern of water quality because it changes the appearance even though the water may be perfectly safe for public use. Clean water should be clear with no observable colour. Colour in water can be caused by a number of contaminants such as iron which changes the oxygen to yellow or red sediment and organic matter in the soil through which the water interact. It can be used to quantify the presence of potentially hazardous substances in water.

Highly coloured water cannot support aquatic life because coloured water prevents penetration of light leading to high algal growth causing eutrophication. Also in our homes coloured water stains our clothes and fixtures causing permanent damage. The high colour values recorded may be attributed to presence of dissolved organic matter and minerals.

Alkalinity values measured at SW 3 (Fodome Dzenana- Dzenana stream) and SW 7 (Fodome Kodzeto - Torgame stream) as 505.0 mg/L and 742.0 mg/L respectively (Table 4.9) were slightly above their recommended standards of 500 mg/L for safe drinking water (GSA, 2006; WHO,2006). Generally, low level of alkalinity of surface water is good for safe drinking water. The major source of alkalinity is from rocks rich in limestone (CaCO_3); if the alkalinity is high, it causes hardness in water. On the other hand, lower alkalinity makes the water soft and also makes it susceptible to rapid changes in pH from acid pollution.

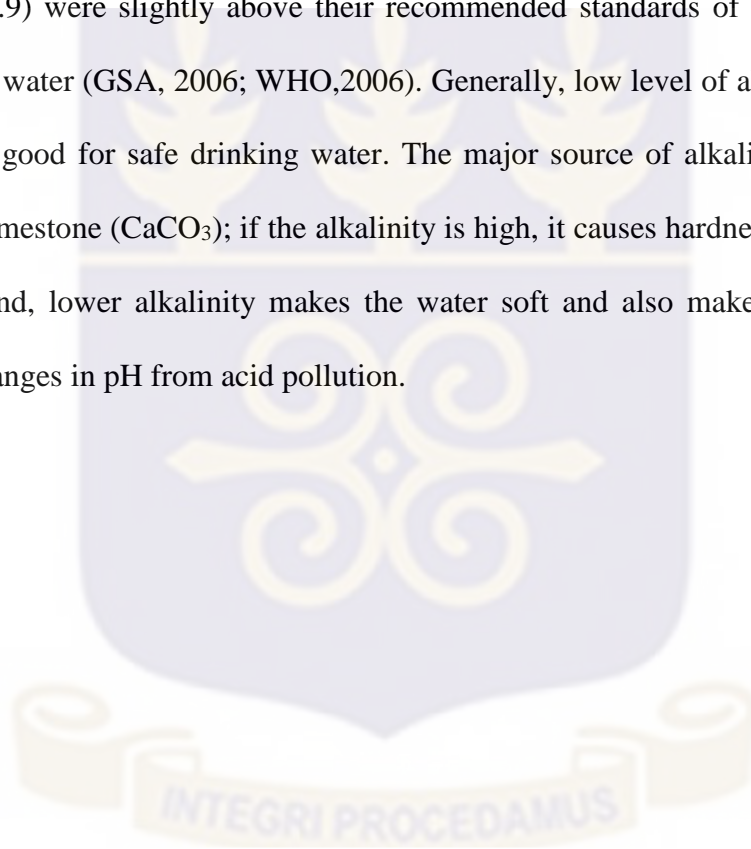


Table 4.8: Sample Locations and GPS coordinates

a. Groundwater samples

S/N	CODE	COMMUNITIES	LATITUDE	LONGITUDE
1	BH A1	ALAVANYO DZOGBEDZE	N07°04.574'	E000°21.051'
2	BH A2	ALAVANYO AGOME	N07°06.192'	E000°21.129'
3	BH A3	ALAVANYO KPEME	N07°07.261'	E000°20.939'
4	BH A4	ALAVANYO AGOXOE 1	N07°07.240'	E000°22.392'
5	BH A5	ALAVANYO AGOXOE 2	N07°07.203'	E000°22.460'
6	BH A6	ALAVANYO WUDIDI	N07°07.204'	E000°21.870'
7	BH A7	GBI AKPLAMAFU	N07°06.831'	E000°24.519'
8	BH F 1	FODOME DZENANA	N07°06.857'	E000°29.282'
9	BH F 2	FODOME TORMEGBE	N07°03.733'	E000°30.799'
10	BH F 3	FODOME WOE	N07°04.283'	E000°30.875'
11	BH F 4	FODOME HLORMA	N07°04.282'	E000°31.399'
12	BH F 5	FODOME AMELE	N07°05.064'	E000°33.330'
13	BH F 6	WLI AFEGAME	N07°07.195'	E000°35.406'
14	BH L 1	LISEC	N07°10.966'	E000°36.523'
15	BH L 2	LIKPE AGBOZOME	N07°11.921'	E000°33.648'
16	BH L 3	LOLOBI HYUASEM	N07°12.171'	E000°32.468'
17	BH L 4	LOLOBI KUMASI	N07°12.578'	E000°31.580'
18	BH L 5	LOLOBI ASHAMBI	N07°12.078'	E000°31.158'
19	BH S	SANTROKOFI BENUA	N07°11.921'	E000°28.439'
20	BH K	KPOETA	N07°08.499'	E000°27.778'
21	BH Z	HOHOE ZONGO	N07°09.563'	E000°28.674'
22	HD 1	FODOME DZENANA	N07°06.802'	E000°29.292'
23	HD 2	LOLOBI KUMASI	N07°12.451'	E000°31.936'
24	HD 3	BLA	N07°09.439'	E000°29.188'

b.: Surface Water Samples with their names

S/N	CODE	SURFACE WATER	LONGITUDE	LATITUDE
1	SW 1	ALAVANYO AGOME - KUTORGBLE	N07°06.248'	E000°21.225'
2	SW 2	ALAVANYO ABEHENASI - TSATSADU	N07°07.243'	E000°23.344'
3	SW 3	FODOME DZENANA- DZENANA	N07°06.857'	E000°29.282'
4	SW 4	FODOME HELU- NUBUI	N07°03.911'	E000°30.690'
5	SW 5	LIKPE BAKUA - OBIANKASA	N07°09.736'	E000°35.490'
6	SW 6	LIKPE MATE - NGUAN	N07°10.720'	E000°36.401'
7	SW 7	FODOME KODZETO - TORGAME	N07°05.986'	E000°30.064'
8	SW 8	LOLOBI KUMASI - DAYI	N07°12.577'	E000°31.379'
9	SW 9	AKPAFU MEMPEASEM - KATUKALA	N07°14.776'	E000°28.603'
10	SW 10	GBI KLEDZO - DAYI	N07°07.716'	E000°26.717'

Table 4.9: Physicochemical parameters values with their statistical summary of Surface water

	pH	Temp	Turb.	TSS	EC	TDS	Col	Alk.	F ⁻	Cl ⁻	NO ₃ ⁻ -N	PO ₄ ³⁻ -	SO ₄ ²⁻	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
CODE		°C	NTU	mg /L	µS/cm	mg /L	HU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
SW 1	5.30	25.30	2.00	3.00	35.30	17.65	21.00	36.00	0.00	28.11	2.95	0.00	8.94	8.93	2.09	2.21	0.43
SW 2	7.00	23.90	2.00	3.00	44.10	22.05	23.00	105.00	0.00	52.17	4.08	0.00	5.75	8.67	3.19	1.01	0.20
SW 3	7.30	25.00	0.00	2.00	340.00	170.00	0.00	505.00	0.00	81.50	3.50	0.00	6.01	9.67	0.36	0.63	0.27
SW 4	7.20	22.80	1.00	2.00	32.20	16.10	0.00	72.00	0.00	43.29	3.27	0.85	2.60	11.86	4.02	1.98	0.12
SW 5	7.00	25.30	1.00	2.00	42.00	21.00	0.00	50.00	0.00	26.53	2.94	0.00	0.53	5.82	2.94	0.98	0.05
SW 6	6.70	24.90	4.00	2.00	18.20	9.10	18.00	23.00	0.00	48.23	2.73	0.92	2.10	9.28	2.83	1.17	0.01
SW 7	7.30	23.90	2.00	2.00	476.00	238.00	0.00	742.00	0.00	84.55	4.53	0.00	10.92	8.39	2.12	0.96	1.10
SW 8	7.50	21.40	1.00	1.00	35.50	17.75	6.00	25.00	0.00	35.41	1.91	0.82	6.86	7.29	3.21	0.67	0.23
SW 9	6.60	22.70	3.00	1.00	102.90	51.45	0.00	130.00	0.00	88.78	2.33	0.00	4.89	9.39	2.95	0.98	0.03
SW 10	7.40	25.80	1.00	1.00	46.00	23.00	0.00	24.00	0.00	46.87	2.29	0.00	4.85	8.38	3.02	2.04	3.84
MEAN		24.10	1.70	1.90	117.22	58.61	6.80	171.20	0.00	53.54	3.05	0.26	5.34	8.77	2.67	1.26	0.63
STDV		1.35	1.10	0.70	150.02	75.01	9.31	234.76	0.00	22.07	0.78	0.39	2.98	1.49	0.93	0.56	1.11
MAX	7.50	25.80	4.00	3.00	476.00	238.00	23.00	742.00	0.00	88.78	4.53	0.92	10.92	11.86	4.02	2.21	3.84
MIN	5.30	21.40	0.00	1.00	18.20	9.10	0.00	23.00	0.00	26.53	1.91	0.00	0.53	5.82	0.36	0.63	0.01
WHO/GSA	6.5 - 8.5	30	5	0	1000	600	15	500	1.5	250	10	0.3 - 0.5	250	100	50	50	50

4.7 THE PHYSICOCHEMICAL QUALITY OF GROUNDWATER

The physicochemical parameters of the groundwater analyzed are presented in Table 4.10. The pH at BH A1 (Alavanyo Dzogbedze), BH A5 (Alavanyo Agoxoe 2), BH F6 (Wli Afegame), BH L5 (Lolobi Ashambi) and BH S (Santrokofi Benua), HD 1 (Fodome Dzenana) and HD2 (Lolobi Kumasi) were below the minimum limit of 6.5. This is an indication of the slight acidic nature of groundwater in these areas which may be due to the geology of the area which consists of thick series of shale, sandstone, and volcanic rocks, with different highlands and adjacent lowlands. pH generally plays an important role in metal bioavailability, toxicity and leaching capability. Geological areas rich in metal could leach metal ions like iron, copper and manganese into aquifers and eventually into streams and rivers (Stumm and Morgan, 1981). The temperature readings ranged from 26.3 °C to 29.7 °C. The highest value of 29.7 °C was due to the time of the day the sample was taken. The small variations in the mean temperature (28.2 °C) indicate some uniformity of the groundwater temperature in the study area.

At BH A1 (Alavanyo Dzogbedze), the turbidity (6.0 NTU) was slightly above the recommended standard of 5 NTU while 32.0 HU of colour was recorded at HD3 (Gbi - Bla). High EC value of 1140.0 $\mu\text{S}/\text{cm}$ and alkalinity value of 2702.5 mg/ L were measured at BH A7 (Gbi Akplamafu). This shows the presence of high dissolved ions from the geological matrix into the water sample in that area.

Table 4.10: Physicochemical Parameter Values with their Statistical Summary of Groundwater

CODE	pH	Temp °C	Turb. NTU	TSS mg/L	EC µS/cm	TDS mg/L	Col HU	Alk. mg/L	F ⁻ mg/L	Cl ⁻ mg/L	NO ₃ ⁻ -N mg/L	PO ₄ ³⁻ -P mg/L	SO ₄ ²⁻ mg/L	Na ⁺ mg/L	K ⁺ mg/L	Ca ²⁺ mg/L	Mg ²⁺ mg/L
BH A1	5.60	29.20	6.00	2.00	216.00	108.00	0.00	140.00	0.00	62.47	4.72	0.01	2.81	10.08	3.97	0.08	0.69
BH A2	6.80	28.40	0.00	1.00	415.00	207.50	0.00	195.00	0.00	67.19	3.45	0.91	28.47	8.94	3.12	0.10	0.16
BH A3	6.60	28.40	1.00	1.00	395.00	197.50	0.00	172.00	0.00	76.22	3.08	0.00	20.70	14.96	5.65	4.10	5.99
BH A4	6.60	28.00	2.00	1.00	257.00	128.50	0.00	191.00	0.00	90.30	1.31	0.52	7.87	7.38	2.04	1.85	0.01
BH A5	6.10	28.70	1.00	2.00	351.00	175.50	0.00	300.00	0.00	71.97	4.05	0.28	4.99	19.46	0.46	0.57	0.49
BH A6	6.40	28.30	1.00	1.00	239.00	119.50	0.00	185.00	0.00	76.85	0.93	0.19	8.74	10.19	2.73	0.18	0.63
BH A7	6.90	28.60	0.00	1.00	1140.00	570.00	0.00	2702.50	0.00	141.90	2.50	0.00	8.64	24.07	6.56	2.78	2.10
BH F1	7.30	28.70	1.00	0.00	300.00	150.00	0.00	390.00	0.00	68.34	4.38	0.01	2.28	12.06	6.61	0.82	0.10
BH F2	7.20	28.00	0.00	0.00	821.00	410.50	0.00	1490.00	0.00	86.30	7.09	0.00	6.61	15.48	4.98	0.01	0.95
BH F3	7.30	28.70	1.00	0.00	723.00	361.50	0.00	967.50	0.00	97.44	5.41	0.27	7.14	17.09	7.94	2.74	0.94
BH F4	7.40	29.00	0.00	0.00	930.00	465.00	0.00	887.50	0.00	74.42	8.75	0.00	6.83	13.39	0.17	4.33	2.06
BH F5	6.90	29.00	1.00	0.00	742.00	371.00	0.00	893.00	0.00	86.61	3.52	0.21	6.87	12.97	5.09	0.89	0.08
BH F6	6.10	29.10	2.00	1.00	248.00	124.00	0.00	223.00	0.00	69.37	2.71	0.00	9.69	16.95	3.10	4.99	2.10
BH L1	6.50	27.40	0.00	1.00	236.00	118.00	0.00	300.00	0.00	77.24	1.96	0.10	7.15	8.97	3.04	0.97	0.71
BH L2	6.90	26.30	0.00	2.00	573.00	286.50	0.00	707.50	0.00	85.68	2.64	0.00	8.19	18.50	0.10	0.75	2.19
BH L3	6.70	26.60	0.00	0.00	424.00	212.00	0.00	389.00	0.00	70.73	6.06	1.84	4.38	8.99	2.21	1.84	0.04
BH L4	6.70	27.40	2.00	2.00	707.00	353.50	0.00	463.50	0.00	69.48	2.32	0.00	11.19	6.95	0.08	1.74	0.95
BH L5	6.30	27.10	0.00	1.00	397.00	198.50	0.00	210.00	0.00	71.21	2.02	0.28	5.77	9.96	4.04	1.96	0.85
BH S	6.30	27.50	1.00	1.00	178.00	89.00	0.00	215.00	0.00	67.19	3.45	0.91	28.47	8.94	3.12	0.10	0.16
BH K	7.00	29.70	1.00	2.00	817.00	408.50	0.00	583.50	0.00	97.44	5.41	0.27	7.14	17.09	7.94	2.74	0.94
BH Z	7.30	28.10	2.00	0.00	776.00	388.00	2.00	947.50	0.00	84.67	5.64	0.73	8.96	13.24	3.84	4.90	1.09
HD 1	5.30	28.20	2.00	0.00	76.00	38.00	0.00	54.00	0.00	37.12	0.53	0.00	6.53	6.94	3.02	0.99	0.08
HD 2	5.30	26.20	3.00	2.00	93.00	46.50	3.00	38.00	0.00	88.86	3.63	0.00	6.16	14.69	2.49	0.91	0.41
HD 3	7.60	28.40	5.00	1.00	1390.00	695.00	32.00	982.50	0.00	167.20	6.70	0.27	11.04	23.99	8.88	6.10	5.99
MEAN		28.13	1.33	0.92	518.50	259.25	1.54	567.79	0.00	82.76	3.84	0.28	9.44	13.39	3.80	1.93	1.24
STDEV		0.90	1.52	0.76	335.51	167.75	6.39	577.79	0.00	25.26	2.02	0.43	6.68	4.88	2.46	1.75	1.58
MAX	7.60	29.70	6.00	2.00	1390.00	695.00	32.00	2702.50	0.00	167.20	8.75	1.84	28.47	24.07	8.88	6.10	5.99
MIN	5.30	26.20	0.00	0.00	76.00	38.00	0.00	38.00	0.00	37.12	0.53	0.00	2.28	6.94	0.08	0.01	0.01
WHO/GSA	6.5 - 8.5	30.00	5.00	0.00	1000	600	15.00	0 - 500	1.50	250.0	10.00	0.3	250.0	100.0	50.00	50.00	50.00

4.8 CHEMICAL CHARACTERISTICS OF WATER SOURCES

The results of the chemical analysis of the surface water and groundwater are presented in Fig.4.6 and Fig 4.7 respectively. The chemical characteristics of surface water showed Na^+ with mean of 8.8 mg/L and groundwater with mean Na^+ of 13.39 mg/ L. This showed that more sodium ions were released into groundwater than surface water and may be attributed the geology of the area consists of thick series of shale, sandstone, and volcanic rocks, with different highlands and adjacent lowlands. The fluoride (F^-) levels in both surface and groundwater samples were below the detection limit of 0.01mg/L indicating its low level in the study area. The mean chloride ion (Cl^-) in surface water is 53.5 mg/L and groundwater was 82.76 mg/L. The chemical characteristics of surface water and groundwater show the same cationic dominance of $\text{Na}^+ > \text{K}^+ > \text{Ca}^{2+} > \text{Mg}^{2+}$ and anionic dominance of $\text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{PO}_4^{3-}$. The dominance of Sodium cation (Na^+) in both ground and surface water may be due to the anthropogenic activities and the dominance of Chloride anion in both ground and surface water may also be due to anthropogenic activities.

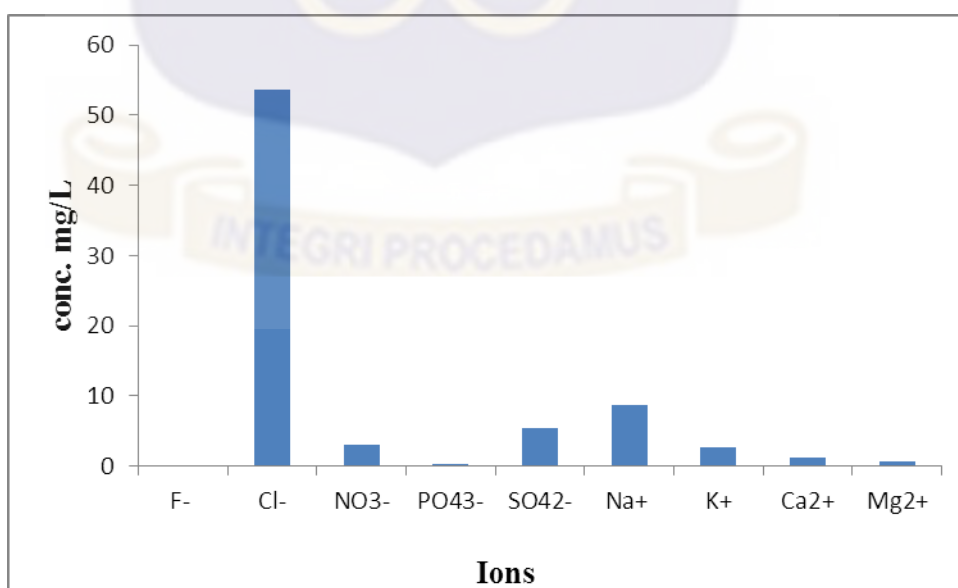


Figure 4.6: Mean concentrations of ions in surface water samples.

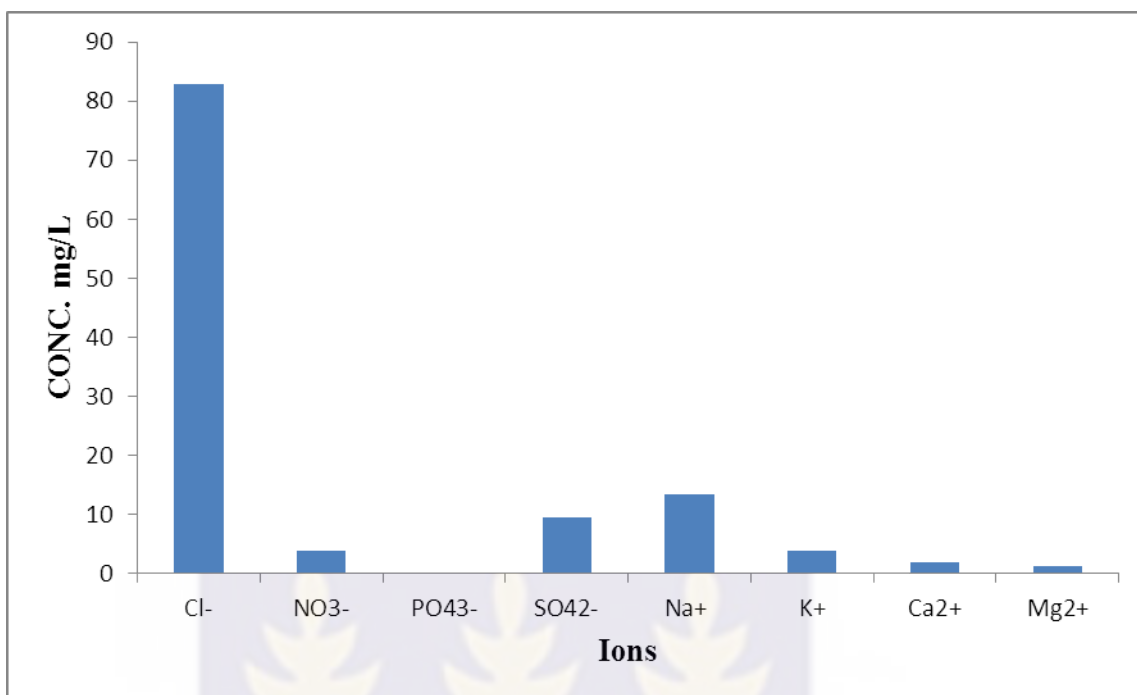


Figure 4.7: Mean concentrations of ions in groundwater samples.

4.9 NUTRIENTS

The main nutrients orthophosphate, $\text{PO}_4^{3-}\text{-P}$ and nitrate $\text{NO}_3^{-}\text{-N}$ in both surface water (Table 4.9) and groundwater (Table 4.10) in the study area were generally low and majority fell below their permissible limits of 0.3 mg/L and 10 mg/L respectively. However, high $\text{PO}_4^{3-}\text{-P}$ levels were recorded at SW8 (0.82 mg/L), SW6 (0.92 mg/L) and SW4 (0.85 mg/L). Also high level of $\text{PO}_4^{3-}\text{-P}$ was recorded in groundwater BL3 (1.84 mg/L), BH A2 (0.91 mg/L), BH L3 (1.84 mg/L) BH S (0.91 mg/L) and BH Z (0.73 mg/L). The study area is located at intensive agricultural zone and market communities. The elevated phosphate levels could therefore be attributed to the use of chemical fertilizers and effluent from agricultural, domestic and municipal sewage which could contain detergent rich phosphate. Moreover, more intensive agricultural production, poor drainage, the spreading of animal manure, sewage sludge and effluent affect nutrient leaching. High phosphorus availability is generally believed to be a critical factor in eutrophication. Nutrient enrichment in a water body is

accompanied by a high rate of production of plant material, which acts as a major cause of eutrophication problems.

4.10 MICROBIOLOGICAL CHARACTERISTICS OF WATER SOURCES.

The microbiological counts of all the surface water and groundwater are presented in Tables 4.11 and 4.12 respectively. The indicator organisms ranged from 115 to 411 Cfu/100 ml and 562 to 1203 Cfu/100 ml for the fecal coliform and total coliforms respectively. The Total Viable Counts is also high in both surface and groundwater indicating microbial contamination from other sources apart from fecal contamination.

The fecal coliform counts of 0.0 Cfu/ 100 ml was recorded at four (4) borehole locations; BH A1 (Alavanyo Dzugbedze), BH A4 (Alavanyo Agoxoe 1), BH F4 (Fodome Hlorma) and BH K (Gbi Kpoeta) which is an indication that they are free from fecal contamination. Apart from these four places, faecal coliform and total coliform at the other sampling locations were above the guideline value of 0.0 cfu / 100 ml (GSA, 2006; WHO, 2006). The coliform counts are higher in surface water as compared to the groundwater as shown in Fig.4.8 and Fig 4.9 respectively.

Table 4.11: Microbiological counts of surface water

S/N	CODE	Total Coli (Cfu/100ml)	Fecal coli (Cfu/1000ml)	Total Viable Count (Cfu/100ml)
1	SW 1	952	411	1332
2	SW 2	915	379	1220
3	SW 3	664	286	991
4	SW 4	816	323	1103
5	SW 5	562	115	1101
6	SW 6	891	321	1100
7	SW 7	788	271	1103
8	SW 8	874	213	1233
9	SW 9	1203	422	1720
10	SW 10	743	191	1132
	MEAN	840.8	293.2	1203.5
	STDEV	166	94	194
	MAX	1203	422	1720
	MIN	562	115	991
	WHO / GSA	0	0	500

Table 4.12: Microbiological parameters of groundwater (boreholes and hand dug wells)

S/N	CODE	Fecal Coliform (Cfu/100ml)	Total Coliform (Cfu/100ml)	Total Viable Counts (Cfu/100ml)
1	BH A1	0.00	51.00	417.00
2	BH A2	243.00	832.00	1125.00
3	BH A3	1.00	346.00	871.00
4	BH A4	0.00	31.00	406.00
5	BH A5	153.00	784.00	1100.00
6	BH A6	241.00	763.00	1201.00
7	BH A7	7.00	73.00	472.00
8	BH F1	162.00	420.00	1021.00
9	BH F2	5.00	25.00	788.00
10	BH F3	87.00	377.00	1201.00
11	BH F4	0.00	101.00	671.00
12	BH F5	193.00	547.00	1551.00
13	BH F6	198.00	483.00	986.00
14	BH L1	1.00	64.00	612.00
15	BH L2	531.00	1107.00	1531.00
16	BH L3	1.00	28.00	871.00
17	BH L4	92.00	281.00	981.00
18	BH L5	3.00	6.00	632.00
19	BH S	256.00	634.00	956.00
20	BH K	0.00	18.00	203.00
21	BH Z	125.00	324.00	925.00
22	HD 1	122.00	785.00	1132.00
23	HD 2	172.00	895.00	2013.00
24	HD 3	235.00	1253.00	1421.00
	MEAN	117.83	426.17	961.96
	STDEV	127.30	372.18	406.50
	MAX	531.00	1253.00	2013.00
	MIN	0.00	6.00	203.00
	WHO/GSA	0.00	0.00	500

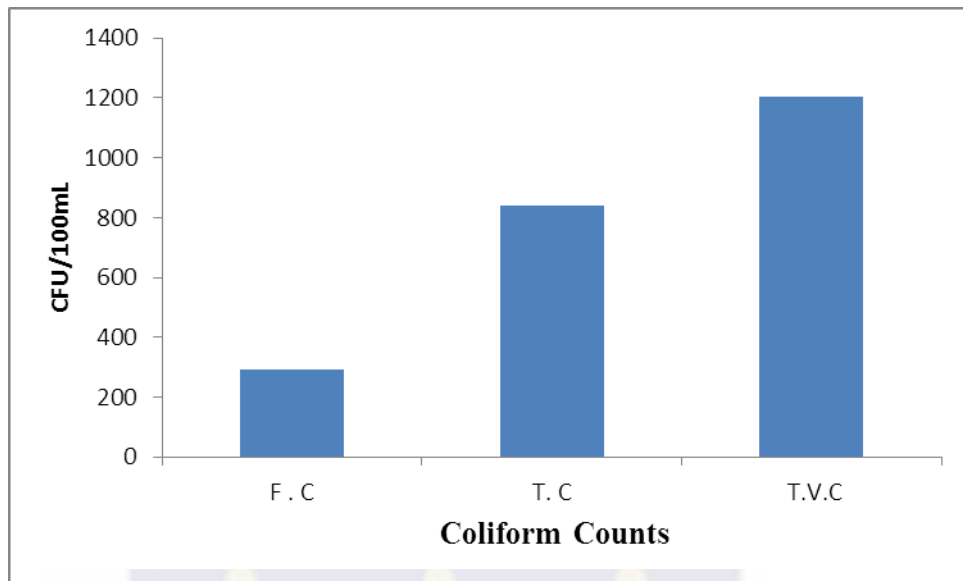


Figure 4.8: Mean Coliform counts in surface water

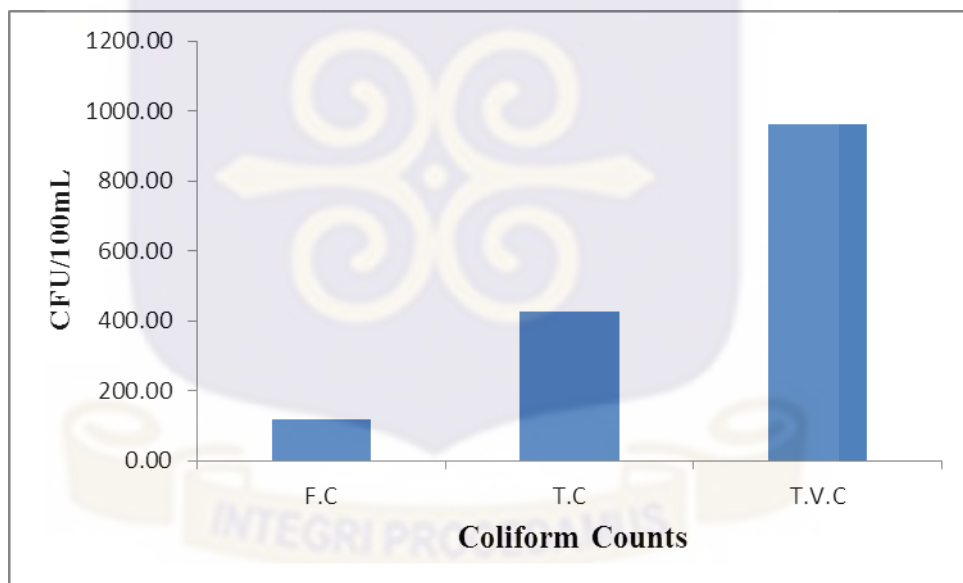


Figure 4.9: Mean coliform counts in groundwater samples

Different changes in land use directly lead to high bacteriological contamination of water through human activities such as poor hygienic and sanitary conditions. Studies have shown high counts of fecal and total coliforms in surface water in different

places (Liao et al., 2015; Frimpong et al., 2015; Samah, 2012; Obiri-Danso et al., 2009).

Although boreholes are protected sources of water, studies have shown that ground water sources are vulnerable to pollution (Kortatsi, 1994; Xu & Usher, 2006). Changes in land uses can influence the presence of pathogens in boreholes. The common types of sanitation facilities in the study area are pit latrines, KVIPs and septic tanks which can introduce bacteria into groundwater when sited improperly. The high levels of indicator organisms water sources within some of the communities may be attributed poor sanitary conditions and lack of maintenance of borehole facilities.

Even though information on the depth of boreholes was not available, research has shown that the depth can also lead to high coliform in boreholes (Tagbor et al., 2014; Moyo, 2013). The minimum depth to prevent microbial contamination is 40 m deep (Gallay et al., 2006; Maunula, 2007). The presence of indicator organisms in water renders it unsafe for human consumption because total coliforms indicate the existence of other pathogens which are causative agents of water borne diseases such as gastroenteritis, typhoid fever, hepatitis and dysentery (Maunula, 2007). A four year report from the Hohoe Municipal Health Directorate indicated the prevalence of water related diseases especially intestinal worm infections in the study area.

4.11 WATER QUALITY INDICES (WQI)

The water quality indices (WQI) classified 75 % of groundwater and 70% of surface water as excellent in terms of their physicochemical quality. The calculated water quality index of surface water revealed that WQI value of 143.696 for SW4 (Fodome

Helu – Nubui stream), WQI value of 161.579 for SW6 (Likpe Mate – Nguan stream) and WQI value of 139.9025 for SW 8 (Lolobi Kumasi – Dayi) were above 100 and therefore classified the water as having poor quality.

The WQI value of 2.6359 for SW1 (Alavanyo Agome – Kutorgble stream), WQI value of 6.677 for SW 2 (Alavanyo Abehenasi – Tsatsadu river), WQI value of 1.2313 for SW 3 (Fodome Dzenana- Dzenana stream), WQI value of 3.0705 for SW 5 (Likpe Bakua – Obiankasa) , WQI value of 4.4779 for SW 7 (Fodome Kodzeto – Torgame stream) , WQI value of 4.09875 for SW 9 (Akpafu Mempeasem –Katukala stream) and WQI value of 3.773 for SW 10 (Gbi Kledzo - River Dayi) . The WQI values are less than 50 indicating they have excellent physicochemical quality (Fig: 4.10).

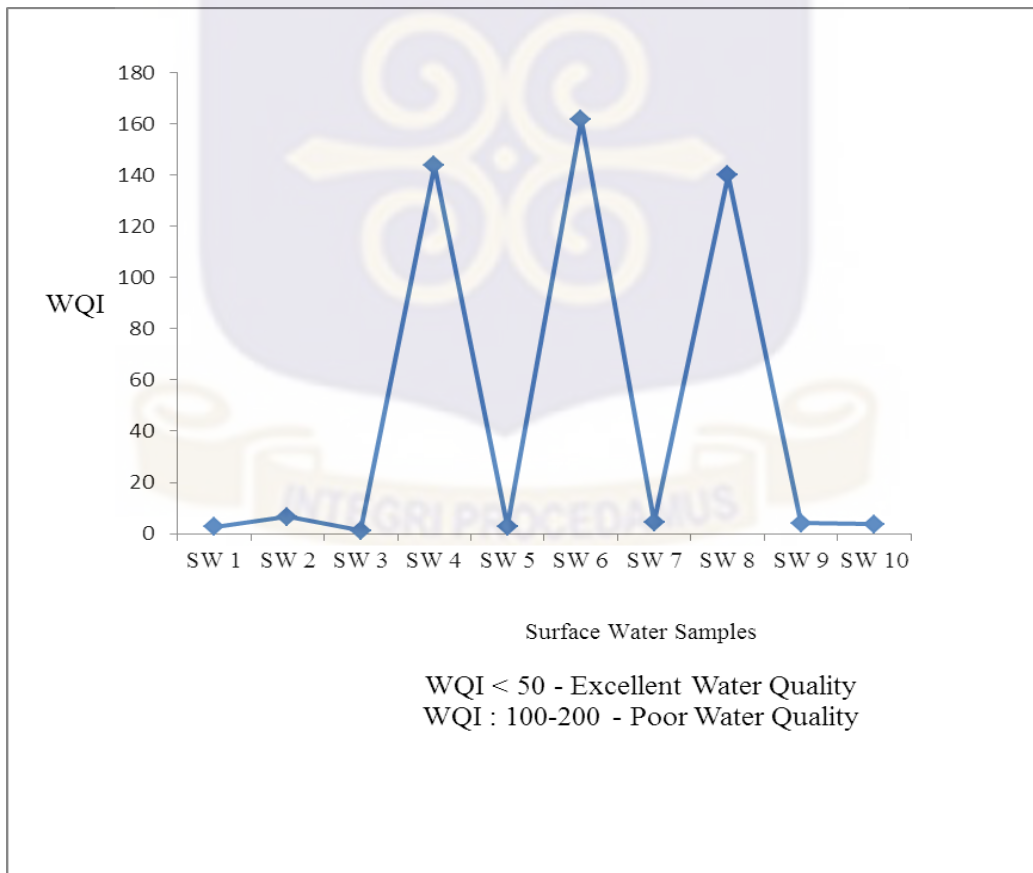


Figure 4.10: Surface quality water within the study area.

The WQI for majority of the ground water samples were less than 50 and therefore classified as excellent. Meanwhile the WQI value of 152.9619 for BH A2 (Alavanyo Agome), WQI value of 152.4726 for BH S (Santrokofi Benua) and WQI value of 128.7952 for BH Z (Hohoe Zongo) fell within the of range 100 to 200, representing poor water quality.

At BH L3 (Lolobi Hyuasem), the WQI value of 307.5645 was greater than 300 showing that it is unsuitable for drinking (Fig. 4.11). The highest rating at BH L 3 may due to the presence of high phosphate which might result from the leaching of fertilizer into the aquifer because of extensive farming activities within the catchment. This quality rating of the water possesses long term risk to the health of women and children coupled with the manual pumping of the borehole as the women complained of chest pains.

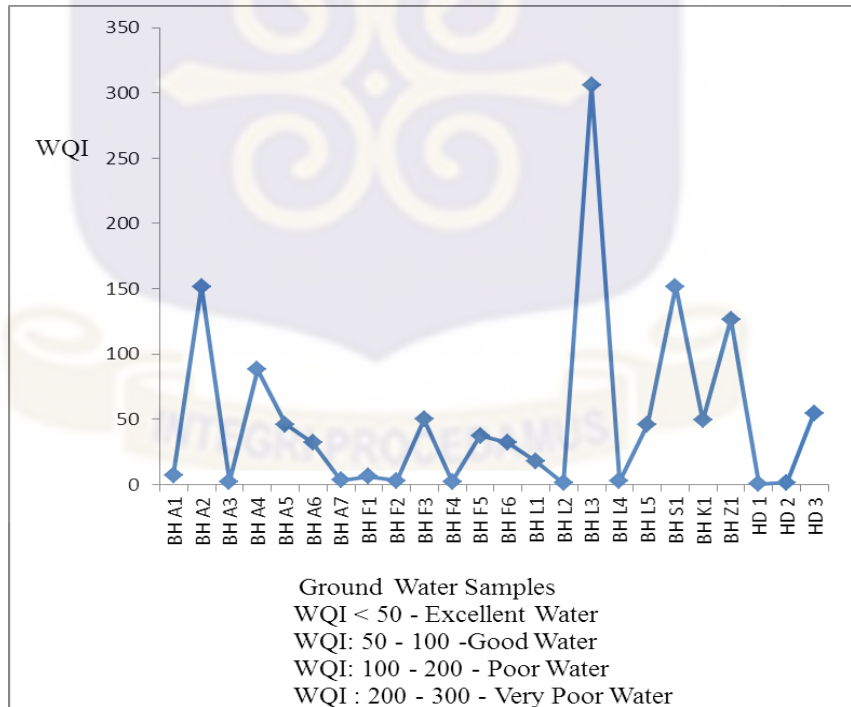


Figure 4.11: The water quality of groundwater sources.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Hohoe Municipality in the Volta Region of Ghana has abundant water resources in the form of springs, rivers, streams and groundwater from high yielding aquifers. However, increasing population and economic activities within the municipality have significant impact on the availability and quality of both surface water and groundwater sources.

The research examined the types of land uses and their impacts on ground and surface water sources within the rural areas of the Hohoe Municipality and how these impacts could be reduced to protect and make them safe and available for sustainable development.

The data collected through extensive literature research, interviews, field survey and satellite images from 2007 to 2017 highlighted the historic land uses changes that pertained in the study area which impact on water quality and availability. Data from the land use maps and its categorization clearly showed increase in urbanization within the municipality over the last ten years, built up has increased from 14.18 % to 21.80 %, grassland coverage has also extended from 26.45 % to 29.95 % while forest areas and bare lands have dwindled drastically from 12.11% to 4.42 % and 5.57 % to 2.14 % respectively .

The major land uses are agriculture, urban development, illegal lumbering and sand winning activities. Historical accounts revealed that water availability has changed over the years due to these anthropogenic influences. The result of the study further revealed that, the impact of land uses on physicochemical characteristics of both

surface and groundwater was generally low and within the regulatory guidelines. The average nutrient concentrations in the water sources were also generally low but high phosphate was identified in some areas under extensive agricultural cultivation. The major ion concentrations dominance was the same in both surface and groundwater sources; $\text{Na}^+ > \text{K}^+ > \text{Ca}^{2+} > \text{Mg}^{2+}$ for cationic dominance and $\text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{PO}_4^{3-}$ for anionic dominance.

The water quality indices (WQI) classified 75 % of groundwater and 70% of surface water as excellent in terms of their physicochemical quality. The results showed that, only four boreholes representing 31.7% of groundwater were free from fecal coliforms. This is an indication of high microbial counts which exceeded the recommended guidelines of drinking water. All the microbial counts were higher in surface water as compared to groundwater. Microbial contaminations usually correlate with poor hygienic and sanitary conditions resulting from anthropogenic factors due to changing land uses within the study area. In order to minimize the microbial pollution of the water sources within the communities, an integrated approach is required to protect the water sources through education and proper land management.

5.2 RECOMMENDATIONS.

1. The local assemblymen and community members need to be taken through educational programs, like workshops and open forums to make them aware of the importance to protect the water sources in their various communities.

2. The agricultural extension officers should intensify their education of farmers on best management practices like planting of trees, mulching, and correct applications of fertilizers and cover cropping to control erosion.
3. The water should be boiled before drinking because of the high microbial levels. Especially the vulnerable groups like pregnant women, infants and the elderly in the various communities. Also the health professionals in the communities should intensify their education about dangers associated with microbial contaminations to protect public health.
4. Future researches should consider the analysis of the following physicochemical parameters ; Arsenic, Chromium, Iron, Cyanide and Total Hardness which are equally important water quality parameter
5. Future researches should consider the impact of urbanization on water quality especially on groundwater in the Hohoe Township
6. The environmental health unit of the Hohoe Municipal Assembly should be well resourced to enforce their mandated environmental regulations to protect water sources especially in fast growing areas.
7. The impacts of pesticides on water sources can also be assessed in the future since the use of agrochemicals are on the increase in the municipality.

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APPENDICES

Appendix A: Questionnaire

SCHOOL OF NUCLEAR AND ALLIED SCIENCES, UNIVERSITY OF GHANA

A questionnaire to solicit the knowledge of Chiefs, opinion leaders and community members on the impact of land uses on the availability of water within the rural areas of Hohoe municipality in the Volta Region of Ghana.

(Please tick as applicable).

1. Name of community
2. Gender Male [] Female []
3. Physical features of the area
 - a. mountainous / hills []
 - b. forest area []
 - c. grassland []
4. Major land uses in the community
 - a. Agriculture []
 - b. Sand winning []
 - c. Lumbering []
 - d. Any other
5. If agriculture, is it
 - a. subsistence []
 - b. commercial []
6. Do farmers apply fertilizers to boost production? YES / NO

6. Do people farm along river banks? YES / NO

7. Is lumbering or sand winning done under any regulations? YES / NO

8. Water sources within the community

a. Pipe - borne []

b. Stream []

c. Boreholes []

d. Any other

9. Has there been any change in water availability over the years? YES/ NO

a. If yes, what changes are observed?

b. What are the causes of the changes?

10. How are wastes managed in the community?

a. human waste

b. solid wastes.....

c. liquid wastes.....

11. Are there any activities that go on in the community that pollutes your water sources?

.....

.....

Appendix B

**APPLICATION FOR DATA ON WATER BORNE DISEASES IN THE
SUB MUNICIPAL COUNCILS OF HOHOE MUNICIPALITY.**

I am a second year M .Phil Nuclear and Environmental Protection student of School of Nuclear and Allied Sciences University of Ghana.

I would like to apply for available data on the cases of water borne diseases (cholera, diarrhea, dysentery, typhoid and the like) recorded in the sub zonal councils of the municipality. This information is vital to assisting me in my thesis on the impact of land uses on water availability and quality within the sub zonal councils.

Researches have shown that changes in land uses introduces pollutants into water sources which impact on especially the microbial quality resulting in water related diseases.

The result of this research will reveal the level of contaminations of water borne diseases resulting from changes in land uses due to urbanization for policy making to improve the health of the people within the various communities.



Appendix C

CORRELATION BETWEEN PHYSICOCHEMICAL PARAMETERS OF WATER SOURCES

Table a: Surface water

	pH	Temp	Turb.	TSS	EC	Col	Alk.
pH	1.00						
Temp	-0.30	1.00					
Turb.	*-0.43	-0.03	1.00				
TSS	*-0.53	*0.36	0.09	1.00			
EC	0.29	0.05	-0.21	0.01	1.00		
TDS	0.29	0.05	-0.21	0.01	1.00		
Col	*-0.59	0.15	*0.49	*0.69	*-0.40	1.00	
Alk.	0.29	0.03	-0.19	0.08	*0.99	*-0.36	1.00

Significant at (* p< 0.05)

Table b: Groundwater

	pH	Temp	Turb.	TSS	EC	Col	Alk.
pH	1.00						
Temp	0.03	1.000					
Turb.	*-0.52	*0.375	1.00				
TSS	*-0.61	-0.029	*0.34	1.00			
EC	*0.68	0.193	-0.31	-0.24	1.00		
TDS	*0.68	0.193	-0.31	-0.24	1.00		
Col	0.29	-0.026	0.16	-0.27	0.21	1.00	
Alk.	*0.51	0.118	-0.30	-0.28	*0.84	0.13	1.00

Significant at (*---p<0.05)

CORRELATIONS BETWEEN CHEMICAL PARAMETERS IN WATER

SOURCES

Table c: Surface water

	Cl ⁻	NO ₃ ⁻	PO ₄ ³⁻	SO ₄ ²⁻	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
Cl ⁻	1.00							
NO ₃ ⁻	*0.36	1.00						
PO ₄ ³⁻	-0.33	*-0.34	1.00					
SO ₄ ²⁻	*0.36	*0.37	*-0.35	1.00				
Na ⁺	0.32	0.18	0.32	0.02	1.00			
K ⁺	*-0.45	-0.30	*0.47	*-0.42	0.05	1.00		
Ca ²⁺	*-0.45	-0.14	0.02	-0.02	*0.38	*0.33	1.00	
Mg ²⁺	-0.00	-0.15	-0.30	0.17	-0.10	0.03	*0.44	1.00

Significant at * p< 0.05

Table d: Groundwater.

	Cl ⁻	NO ₃ ⁻	PO ₄ ³⁻	SO ₄ ²⁻	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
Cl ⁻	1.00							
NO ₃ ⁻	-0.05	1.00						
PO ₄ ³⁻	-0.19	0.15	1.000					
SO ₄ ²⁻	-0.16	-0.20	0.272	1.00				
Na ⁺	*0.65	0.18	*-0.39	-0.21	1.00			
K ⁺	*0.46	0.12	-0.122	-0.05	0.33	1.00		
Ca ²⁺	0.23	0.23	-0.085	-0.07	*0.31	0.13	1.00	
Mg ²⁺	0.16	-0.01	*-0.41	0.21	*0.42	0.09	*0.55	1.00

Significant at (* p< 0.05)