ASSESSING THE STATUS OF WATER POINT SOURCES

CASE STUDY: EJISU- JUABEN MUNICIPALITY

ASANTEWAA PATRICIA

MSc THESIS

SEPTEMBER, 2013

Kwame Nkrumah University of Science and Technology

ASSESSING THE STATUS OF WATER POINT SOURCES

CASE STUDY: EJISU-JUABEN MUNICIPALITY

By

Asantewaa Patricia BSc (Hons)

A Thesis submitted to

The Department of Civil Engineering,

Kwame Nkrumah University of Science and Technology

In Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

In

(Water Supply and Environmental Sanitation)

Civil Engineering Department

CERTIFICATION

I hereby declare that this thesis is my own work towards the Master of Science (MSc) degree in Water Supply and Environmental Sanitation and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Asantewaa Patricia	………………….	....
(PG 5853411)	Signature	Date

Certified by:

Prof. Samuel Nii Odai	………………….	…..………….
(Principal Supervisor)	Signature	Date
Dr. Sampson Oduro Kwarteng	………………….	………………..
(Second Supervisor)	Signature	Date
Prof. M. Salifu	………………….	……………...
(Head of Department)	Signature	Date

ACKNOWLEDGEMENT

To God be the Glory; great things He has done and greater things He will do. What shall I say unto the Lord? All I have to say is thank you Lord for this far your grace, mercies, guidance and favour have brought me.

My utmost appreciation goes to my Supervisors Prof. S.N. Odai and Dr. S.K. Oduro-Kwarteng for their unfathomable corrections and guidance. It is my prayer that the good Lord locates and blesses you abundantly beyond measure. To Mr. K. Akwodwaa-Boadi, may God richly bless you and replenish you a hundred fold for your constructive corrections and guidance. I am sincerely indebted to SNOWS for their financial support.

This research work wouldn't have been complete without the selfless assistance and help of Mr. K. Bonsu (Technician) and the rest of the people in the Environmental Quality Laboratory during my Laboratory analyses. May the good God richly bless you a thousand times.

My sincere gratitude goes to the following members of CWSA Mr. Amankwa (Drilling Unit, Regional Office Kumasi), Mr. Mills (Planning officer), Mr. Dupe (Drilling Unit) Godfred and Osei (all of Ejisu-Juaben Municipal Assembly) and Mr. B.K. Baryeh (GWCL Drilling Unit) for their assistance during my data collection. I am also very grateful to Hayford (a Taxi Driver) and my siblings: Raymond and Bismarck for helping me in the field during my field data collection. May God's favour and mercy follow you the rest of your lives.

My heartfelt gratitude is rendered onto Mr. Gikunoo for training and assisting me in my data analysis. To my friends in WRESP especially Sharon, Rashid Amo-Larbi and Kobea, thank you very much for your friendship and moral support. God bless you all. I am also very grateful to my roommate, Marian and the Headmaster and Staff of Mpatapo JHS. May God bless you for standing in the gab for me during my absence.

Last but not the least; I will love to appreciate my loving husband Mr. Tannor for his immense support both in kind and in cash. May you never lack anything good as long as the God I serve lives. To my mother in law Comfort Yeboah, thank you for taking care of my husband in my absence. Finally, to my most adorable family, my mum; Theresa Tannor, my dad; Mr. Adu Amoako and my Siblings; Desmond and Raymond; I am proud to be a part of this family. God bless you all.

DEDICATION

This research is dedicated to my most loving and cherished husband; Mr. Tannor Kofi for his unflinching support, encouragement and prayers.

ABSTRACT

Ghana and the world at large have committed themselves to attaining universal water coverage by the year 2015. Since the advent of this target, the focus has been on provision of water and increase in coverage rather than on type of water point sources; their location, quality, functionality and sustainability and for that matter little or no data exist on these factors.

This study therefore sought to achieve these by mapping the water point sources within chosen study area, Ejisu-Juaben municipality, to provide technical information for sustainable management. In order to attain this objective, water point sources within the study area were identified and mapped, their quality as well as functionality was assessed. Finally factors affecting the sustainability of the water point sources were also identified.

A period of three months was used for data collection and sampling within fifty four (54) communities out of eighty eight (88) based on four municipal zones (division). A total of 415 water point sources were identified and mapped using a Global Position System (GPS, DR Garmin) and water point mapper. The results showed that Boreholes (60%) and hand dug wells (39%) are the main water point sources within the municipality with 1% rain harvesting. Also, 54% of the water point sources are privately owned and managed (constituting 59% funding) and the remaining 46% being community owned with 34% funding from Government, 1% from NGOs and the remaining (6%) by the communities themselves. In terms of functionality, 11% of the water point sources were not functioning as a result of low yield, faulty pumps and high iron concentrations. A total of 114 water samples were analysed for physico-chemical and bacteriological quality. Bacteriologically only 6 (3 hand dug wells and 3 boreholes) of the sampled water point sources were within WHO guideline and this poses a threat to health. Generally, the average pH of 5.41 (indicating acidity) was not within WHO guideline of 6.5-8.5. However, Bowohomoden, Juaben, Peminase, Kwaso and Kubease recorded traces of iron and high levels of turbidity. From the interviews conducted, Community participation (community ownership), private partnership, managerial practices (water boards and unit committees) constitute the positive factors enhancing sustainability whereas lack of spare parts, technical experts and lack of financial support for operation and maintenance were identified as the negative factors affecting sustainability of water point sources. It is however recommended that CWSA should educate the people on how to disinfect their water point sources to avoid any future outbreak of water related diseases.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF IMAGES

LIST OF ACRONYMS

AMCOW	African Ministers' Council on Water
AWWA	American Water Works Association
BGS	British Global Survey
BH	Borehole
CWSA	Community Water and Sanitation Agency
DA	District Assembly
DNA	De-oxyribonucleic Acid
DWST	District Assembly Water and Sanitation Teams
FCP	Freshwater Country Profile
FLOW	Field Level Operation Watch
GDHS	Ghana Demographic Health Survey
GDP	Gross Domestic Product
GFT	Google Fusion Tables
GIS	Geographical Information System
GUWL	Ghana Urban Water Limited
GWCL	Ghana Water Company Limited
GWSC	Ghana Water and Sewerage Corperation
HDW	Hand Dug Well
JMP	Joint Monitoring Programme
MDG	Millennium Development Goal
MWRWH	Ministry of Water Resources, Works and Housing
NGO	Non-governmental Organisation
NPC	National Water Policy
PURC	Public Utility Regulation Unit

SDWF	Safe and Drinking Water Foundation
SEA	Strategic Environmental Assessment
SPSS	Statistical Package for Social Scientists
TDS	Total Dissolved Solids
UNICEF	United Nations International Children Education Fund
VDH	Vermont Department of Health
WPM	Water Point Mapper
WPS	Water Point Source
WATSAN	Water and Sanitation
WHO	World Health Organisation
WMSP	Water Monitoring and Sanitation Platform
WRC	Water Resources Commission
WSDB	Water and Sanitation Development Boards

1. INTRODUCTION

1.1 Background

The increasing global population has placed a lot of demand on water supply. Researchers have thus envisaged that if care is not taken the next world war would occur as a result of water crisis (Annor, 2011). Though there is an increase in population, the world through the Millennium Development Goal (MDG) 7 has committed itself to attaining universal water coverage by 2015. Since the advent of this commitment, measures have been put in place by countries to help achieve the set target of 75% water coverage. This has resulted in a significant increase in water supply coverage over the past 12 years (2000-2012) in that the MDG set target was met in March 2012 (JMP, WHO, UNICEF, 2012). This increase has been attained with the concerted efforts by the Governments of countries worldwide of which Government of Ghana (GoG) forms a part. Available records show water supply coverage in Ghana as at March 2012 was 75 % (JMP, WHO, UNICEF, 2012) and this has been attained with concerted effort of the main water stakeholders; Ghana Water Company Limited (GWCL), Ghana Urban Water Limited (GUWL) and Community Water and Sanitation Agency (CWSA) and some Non-Governmental Agencies (NGOs).

Though there seem to be increasing water coverage nationwide, the situation on ground lives much to be desired since majority of the people living in both urban and rural areas have limited access to water. These people are therefore left with no other choice than to find their own means of getting water. Since most of the surface waters are polluted by the anthropogenic activities of humans, majority of these people rely on groundwater by drilling boreholes and hand dug wells for their sustenance. Over the past decade the drilling of boreholes has been on the ascendency in Ghana such that about 60,000 boreholes and 45,000 hand dug wells exist in the nation (Anornu *et al*., 2009; Agyekum, 2002; Kortasi, 1994). Ejisu-Juaben is one of such urban areas that still has some deficit with respect to water coverage and so rely solely on hand dug wells and boreholes. This study therefore seeks to assess water point sources to provide technical information for sustainable development in the municipality.

1.2 Problem Statement

Recent data shows that about 130 boreholes and 300 hand dug wells exist in Ejisu-Juaben municipality (Anornu *et al*., 2009) but little or no data exist on their current functionality (pump functionality, reliability), water quality characteristics, accessibility, coverage and factors affecting sustainability (such as management, acceptability, Operation and maintenance) at both local and national levels. Mapping of these water point sources will provide the needed data to measure the progress towards the MDG on a Municipal platform.

1.3 Justification

In a country where the government aims at attaining 78% water coverage by the year 2015 (Addai *et al*., 2011), there is the need to create a database on local and national water point sources to help planners and water managers in their decision making concerning water provision. Mapping of water point sources within Ejisu-Juaben Municipality will help in creating such a database since mapping will reveal the number of water point sources, numbers that are functioning, community access levels, coverage and factors affecting their sustainability. It will depict whether the quality of the water is safe for consumption. Mapping of water point sources will help reveal areas which have limited access to water and require immediate attention; thus enhancing equity and fair distribution of water supply.

1.4 Objectives

The main objective of the study is to assess water point sources to provide technical information for sustainable development.

The specific objectives of the study are to:

- To locate and map water point sources in Ejisu-Juaben municipality.
- To assess the water quality and functionality of the water point sources.
- To identify the factors that affect sustainability of the water point sources.

1.5 Scope of Study

The study is limited to Ejisu-Juaben municipality because it is the closest municipality to KNUST, the institution in which the study took place. This will allow effective data collection and movement to and fro during the research phase.

1.6 Structure of the Report

Chapter one presents the introduction, problem statement, justification, objectives, scope of work and report structure. Available literature on the research topic is reviewed in chapter two. Description of the study area and the methodology employed is presented in chapter three. Chapter four is centered on the Data Analysis and Discussion of Results. Finally, Conclusions and Recommendation is presented in chapter five.

2. LITERATURE REVIEW

This chapter focuses on the management of water resources and supply, present water supply and coverage situation of the country, Ghana. Other areas considered in this chapter include water point sources, contamination of water point sources, quality of water point sources and types of pumps used in abstracting water from water point sources. Accessibility, coverage, factors affecting sustainability and functionality of water point sources were also reviewed. Finally, various tools used for mapping of water point sources were reviewed.

2.1 Management of Water Resources and Supply in Ghana

Ghana’s water resource potential is divided into surface and groundwater. In order to manage these water resources, a whole ministry (Ministry of Water Resources, Works and Housing (MWRWH)) has been allocated to the water sector to take charge of all the affairs related to water. From this ministry, many other bodies such as Water Resource Commission (WRC), Ghana Water Company Limited (GWCL), Ghana Urban Water Limited (GUWL) and Community Water and Sanitation Agency (CWSA) have been reinforced to work efficaciously towards the attainment of the MDG set target and to enhance sustainability of the water resources. The WRC however, was established by Act 522 in 1996 and has the mandate to regulate and manage the utilization of the country’s water resources and to coordinate any policy in relation to them (WRC, 1996 and Nyarko, 2009).

In terms of water supply, Ghana Water and Sewerage Cooperation (GWSC) now GWCL was established by ACT 310, 1965 and was mandated with the provision, distribution, conservation and management of water supply and to set the criteria for all water supply development and installation and to coordinate all activities related to water supply in the country (Gyau-Boakye *et al*., 2000). GWCL was to provide water to both urban and rural sectors but due to financial constraints and break down of pipe network (GWCL, 2012); it could not meet the water demand of the urban let alone the rural communities. This led to a lot of reforms in the water sector and one of such reforms led to the establishment of a new body to take care of the rural water supply as well as sanitation. An autonomous agency called Community Water and Sanitation Agency (CWSA) was set up by an Act of Parliament in 1994 (FCP, 2004). Its main function is to facilitate the provision of safe drinking water and related sanitation services to rural communities and small towns. The agency is also required to provide technical assistance, enhance collaboration between communities and stakeholders, planning and execution of projects and charging reasonable fees for goods and services provided. In order to attain these objectives, CWSA operates in all the ten regions of Ghana and it works through District Assembly (DAs), WATSAN and Water and Sanitation Development Boards (WSDB).

The DAs are responsible for the planning, implementation, operation and maintenance of water and sanitation facilities and legal owners of communal infrastructure in rural communities and small towns. In order to carry out these responsibilities, each District Assembly has Water and Sanitation Teams (DWST) (the main government body at the DA level) who are responsible for water supply and sanitation delivery to communities (NWP, 2002 and Fielmua, 2011). The DAs through the DWSTS and in collaboration with CWSA set WATSAN and WSDB within communities. The WATSAN and WSDB, on the other hand are responsible for the preparation and executing of plans for the provision of water supply and sanitation facilities, setting of tariffs, mobilizing of funds, building of requisite human resource capacity for operation and maintenance, preparing and presenting of managerial report to the community and auditing of financial reports at the community and rural levels, (see Appendix F).

In order to ensure that these water bodies attain efficiency, there must be a policy to guard their activities and so the National Water Policy (NWP) was prepared in 2002. The NWP sought to address issues relating to quality of work, sufficiency, accessibility, affordability and continuity of water supply (NWP, 2006). There are other regulatory bodies like the Public Utility Regulatory Commission (PURC) which is responsible for regulating all the affairs of public utilities of which water is paramount and the Environmental Protection Agency (EPA). The EPA plays the key role in providing guidelines for developments that affect the environment and public health, and setting standards for emissions and discharges that are likely to affect water bodies into the environment (Fuest *et al*., 2005).

In spite of the existence of all these bodies with their laid down mandates and functions, there are extensive pollution of the country's water resources (Amuzu, 1999; Boadi and Kuitunen, 2002; Suraj, 2004; Ansa-Asare *et al*., 2008).

2.2 Water Supply and Coverage Situation in Ghana

Since the advent of GWCL and CWSA as well as the sector ministry (MWRWH), there has been a significant and tremendous increase in water supply and improved drinking water coverage in the country. The increase in water supply coverage cuts across the various regions in Ghana which bulges down to the municipal and district levels through to rural and small towns. Records also show that between the periods of 1990 and 2008, there has also been an increase in the population of improved drinking water in the country (Table 2.1) bringing Ghana close to attaining the modified MDG set target of 78% (WSP, 2009).The figures in Table 2.1 represent the coverage on the broader side but the coverage is as a result of general increase in coverage within the ten regions of the country. Figure 1 shows the general water coverage within the Regions with Upper West recording the highest of 97% with the lowest of 61% recorded by Greater Accra.

Table 2.1: Water Supply Coverage, Ghana. (Source: JMP 2008, GDHS 2008)

Year	**Improved drinking water (%)**		
	Total	Rural	urban
1990	56	39	86
2008	83.3	76.6	93

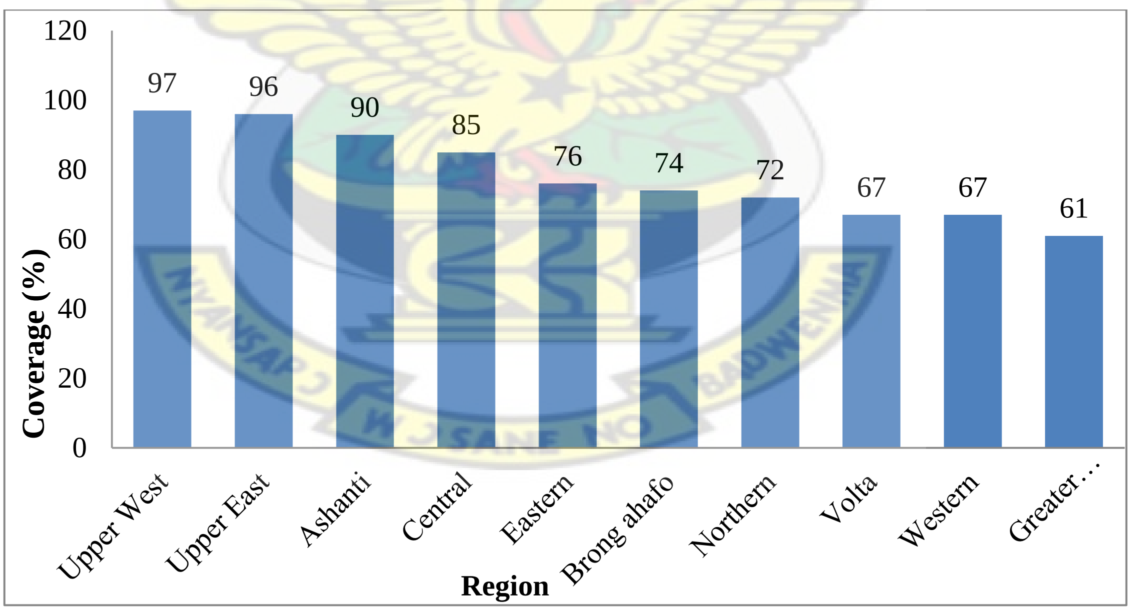

Figure 2.1: Regional Improved Water Coverage. (*Source: GDHS 2008*)

However, the water supply coverage in Ghana as at March 2012 was 75 % (JMP, WHO, UNICEF, 2012). GWCL, urban water coverage is about 59% as at March 2012 and CWSA, small town and rural areas water coverage is about 60%. Though these percentages are clearly spelt out on the international front as well as in any available document and literature, the actual situation on the ground leaves much to be desired. For instance, in cities like Accra and Kumasi, people have to carry containers around in search of water due to the inability of GWCL to provide continuous flow of water (Justin *et al.*, 2012 cited in Oteng, 2008). Many people are coping with the situation by drilling boreholes in their homes at exorbitant prices (Anornu *et al.*, 2009). Others depend on water tankers and sachet water for their day to day activities (Monney, 2011).

2.3 Water Point Sources

Groundwater is less susceptible to pollution and for that matter it is often recommended for usage as drinking water (Kortarsi, 1994). The means by which groundwater can be tapped is either by wells or boreholes, spring and infiltration galleries (Kpordze, 2010). Wells and springs are most commonly used by developing countries as a source of drinking water. Springs occur naturally whereas wells are dug, drilled or bored.

A well is defined by Tilton, (n.d.) as, a hole or shaft drilled down through the earth to a water bearing stratum of sand, gravel, or a crack in the rock. The names associated with wells are based on their mode of construction. For instance, hand dug wells are the most common method of abstracting groundwater in developing countries. Hand dug wells have relatively large diameters (often ranges from 1–2m) to allow sufficient digging space. On the other hand, depths may range from shallow wells (3-5m) to deep wells 10 to over 20 m to ensure that water table can still be reached in dry seasons (Powell, 1992;

Kpordze, 2010 and WaterAid, n.d.). A traditional hand dug well is often drawn using rope and bucket and this makes it prone to contamination since they are often not covered and the rope or bucket could be contaminated before placing it into the well. Without proper drainage, pools of water can form around the wells and these can act as breeding grounds for disease-carrying insects like mosquitoes. Also, unlined hand dug wells are liable to collapse during wet seasons (Powell, 1992 and WaterAid, n.d.). With the advancement in technology, hand dug wells can now be drawn with either hand pumps such as India Mark II, Afridev and Naira or mechanical pumps.

Other mode of construction could be in the form of drilling to deeper depths using drilling rig or augurs. The wells resulting out of this mode could be tubewells or boreholes. Boreholes are deeper (depth 20-100m and over) than tubewells. The boreholes are also drawn using hand pumps or mechanical pumps. Research has shown that though the initial costs of Boreholes are expensive, they are less susceptible to contaminations since their diameters are relatively smaller and they are also sealed with the hand pumps or mechanical pumps (WaterAid, n.d.). According to WaterAid, (n.d.) higher depths prevent boreholes from faecal matter contamination as well as disease causing pathogenic contaminations making the water safe for drinking. Most often than not boreholes do not require any form of treatment and also do not often dry out in dry seasons. Moreover, water from boreholes can be used to serve places of higher demand of water by pumping the water into raised or overhead tanks and then allow it to flow through reticulated piped systems either to households or standpipes. However, the initial cost of construction and the cost of operation and maintenance of the mechanical pumps are very expensive.

2.4 Contamination of Water Point Sources

Water point sources usually are directly tapped from groundwater and so any form of groundwater contaminations whatsoever will have a direct impact on the water point sources. For this reason, contamination of water point sources in the study is reviewed in terms of groundwater contamination. Groundwater contamination therefore can be defined as the detrimental alteration of the naturally occurring physical, thermal, chemical, or biological quality of groundwater (Zaporozec *et al.,* 2002). Groundwater contaminations can be grouped under the following headings: natural sources and artificial sources (agricultural sources, mining and industrial sources, improper water mismanagement and other miscellaneous sources) (Zaporozec *et al.,* 2002). Natural groundwater contamination sources stems from the fact that groundwater forms a part of the hydrological cycle. As rain falls it picks up every contaminant in the air on to the ground and these contaminants get into the groundwater if they are unable to be filtered out by the soil. Other natural sources include polluted surface water bodies and dissolved chemicals or elements from bedrock underlying aquifers (Powell *et al.,* 1992). Other important and direct sources of groundwater contaminations are abandoned wells (are filled with refuse), rusted pump metals, unlined septic tanks and landfill (seepage of leachates) or refuse dumps. In developing countries like Ghana where sanitation facilities such as toilets (example Kumasi Ventilated Improved Pit (KVIP)) are usually unlined, there is high level of faecal contamination of the groundwater (Oteng- Peprah, 2008; Zaporozec *et al.,* 2002). For this reason WHO (2006) proposes that water point sources (boreholes and hand dug wells) should be drilled or dug at depths 40m and beyond and about 30m away from a septic tank to avoid faecal contaminations. The use of chemicals like chlorine in the treatment of boreholes and hand dug wells serve as a point source of contamination. Agro chemicals like pesticides or weedicides and fertilizers used in agriculture, mining tailing and wastes, disposed electronic gadgets (miscellaneous sources) also play a major role in groundwater pollution Zaporozec *et al.*, 2002). All the above enumerated forms of contaminations affect the groundwater quality and for that matter affect water point sources being tapped.

2.5 Quality of Water Point Sources in Ghana

The quality of water point sources depend solely on the quality of groundwater since water drawn from these sources are directly tapped from groundwater. Available data shows that the quality of groundwater depends largely on the geological formation of the area. The geological formations of Ghana and their chemical water parameters revealed by Kortasi, (1994) are shown in Appendix E. Other factors that might influence groundwater quality are the sources of contamination discussed in section 2.4.

The term quality of groundwater refers to its physical, chemical, and biological characteristics as they relate to the intended use of water (Zaporozec *et al.,* 2002). Available data indicate that the quality of groundwater abstracted via boreholes in Ghana is generally of good chemical and microbiological quality and therefore suitable for Domestic, Agriculture and Industrial use (Amuzu, 1997 and Kortatsi, 1994).

However, there exist some water quality problems and these were revealed by Kortasi (1994). These include low pH (3.5-6.0) of waters found mostly in the forest zones of southern Ghana, high concentration of iron and manganese in many places throughout the country. High concentrations of sodium chloride and high mineralization exist in some coastal aquifers due to salt water intrusions. Total dissolved solids (TDS) in ground water the range 2000-14,584 mg/l. Health related problems include Fluoride (causes fluorosis), Arsenic (carcinogenic leads to cancer of the lungs. Fluoride is readily found in the Northern part of Ghana whereas Arsenic is traced to mining areas where arsenic-bearing minerals, particularly Arsenopyrite are found and consequently resulting in surface water pollution from the mining activities. A summary of potential groundwater-quality problems has been shown in the Table 2.2 below.

Table 2.2: Summary of potential groundwater-quality problems in Ghana

Determinant	Potential problem	Geology	Location
Iron	Excess (often significant)	All Aquifers	Many locations
Manganese	Excess	All Aquifers	Several locations
Fluoride	Excess (up to 4 mg/l)	Granites and some Birimian rocks	Upper regions
Iodine	Deficiency(<0.005mg/l)	Birimian rocks, granites, voltain	Northern Regions especially upper regions
Arsenic	Excess (>0.01mg/l)	Birimian	South west Ghana(gold belt)

(Source: (BGS, Water Aid, n.d.)

2.5.1 Physical Quality Parameters of water point sources

A book written by Peavy *et al*., (1985) defines physical quality parameters as those characteristics of water that respond to the senses of sight, touch, taste or smell. These characteristics include taste, odour, colour, turbidity and temperature. According to WHO 2006, these parameters do not pose any health threats but they may aid microbial growth and inhibit some chemical reactions for instance during disinfection. Colour, turbidity, taste and odour make the water aesthetically displeasing and sometimes objectionable to the consumer. While there are no permissible WHO guideline values for temperature, taste and odour, 5 Hazen units and 5NTU (0.1NTU for ideal water) are the permissible WHO guideline values for colour and turbidity, respectively (WHO, 2006).

2.5.2 Chemical Quality Parameters of water point sources

Water is a universal solvent and the chemical parameters are related to its solvent capabilities (Peavy *et al.*, 1985). According to Zaporozec *et al*., (2002), the chemical composition of groundwater mainly resolves from the chemical weathering of rocks in the presence of water. This process produces chemical parameters such as total dissolved solids, alkalinity, hardness, metals, non-metals and nutrients. Chemical parameters considered in the study are metals (iron, arsenic, manganese and lead), TDS, electrical conductivity (EC), hardness and non-metal (fluorides, nitrates, sulphates and chlorides). Metals like manganese and iron do not pose any health threats but rather affect the colour and taste of the water making it objectionable to the consumer (Kortasi, 1994; Peavy *et al.*, 1985; WHO, 2006; BSG, 2010; Obuobie and Boubacar, (2010). The permissible WHO guideline line values for iron and manganese are 0.3mg/l and 0.05mg/l, respectively. According to Kortasi (1994), Chapman and Kimstach, (1992) and Gray (1999), TDS and EC do not have any health effects but may cause hardness of water and increase in chemical reaction of the water, respectively. The recommended WHO guideline values for EC and TDS are 1000µS/cm and 600mS/m, respectively. Moreover, chlorides and hardness do not pose any health threats but rather affect the taste of the water. However, excessive intake of hard water may cause some laxative problems. Whereas there is no WHO guideline value concerning hardness, (it is tolerable within 100mg/l to 300mg/l), the permissible guideline value for chloride is 250mg/l. Other chemical parameters like lead, arsenic, nitrates, fluoride, pH and

Sulphate are of major health concern to WHO (Sandow *et al*., 2012; WHO, 2011). High concentrations of fluoride can lead to skeletal and dental fluorosis, insomnia and reduction in intelligent quotient levels as well causing mental retardation in children (Hillleman, 1998; WHO, 2011). WHO (2006) recommends a fluoride guideline value of 1.5mg/l. High or low levels of pH (values less than 6.5 and greater than 8.5) and sulphates may cause stomach pains and diarrhoea, respectively. The permissible WHO guideline values for sulphate and pH are 250mg/l and (6.5 to 8.5) respectively. Nitrates on the other hand have the tendency of causing haemoglobinaemia in children. Its permissible WHO guideline value is 250mg/l. Lead through studies has been proven to be a very toxic and poisonous element. Lead is associated with health effects such as convulsion, insomnia, bloody diarrhoea or constipation, lowered intelligence and cardiovascular, immunological and gastrointestinal functions (WHO, 2000, 2006; Peavy *et al*., 1985). Arsenic on the other hand is related to health problems such as bladder, liver, kidney and skin cancers, birth and reproductive defects as well as miscarriages in women at very high exposures (WHO, 2011). The permissible guideline value for arsenic and lead is 0.01mg/l (WHO, 2006).

2.5.3 Microbiological Quality Parameters

Ideally, groundwater should be free from microorganisms (VDH, 2011) but the likelihood of contamination has made groundwater vulnerable to microbes. According to WHO, (2011), the greatest source of contaminants resolve from human excreta which poses a major health risk on consumers. Faecal coliforms are found in some groundwater. The presence of faecal coliform is an indication of the presence of other bacteria as well as any disease causing pathogens (bacteria, viruses) and parasites such as protozoa and helminthes. Most of the infectious diseases associated with water are caused by pathogenic bacteria, viruses and parasites (e.g. protozoa and helminthes) (WHO, 2011). The guideline value for microbes as well as pathogenic bacteria is 0 FC/ 100 ml (WHO, 2011).

2.6 Types of Pumps Used In Abstracting Water from Water Point Sources

Until 1980s, people in the developing world used to get access to groundwater from hand dug wells using the rope and bucket system. Lifting of the bucket was aided by the provision of a windlass system. This method of drawing water though very cheap and easy to operate and repair leaves much to be desired since there was constant contamination of water from the buckets and rope or from mud or dirty hands (Wood, 1994). This really did not make the water safe for drinking. This raised a lot of concern and so led to the installment over thousand hand pumps in developing countries for that matter Ghana, during the international drinking water supply and sanitation decades of the 1980s (Wood, 1994). Hand pumps were vigorously promoted as the best option to provide safe and reliable water based on the following set of assumptions: hand pumps are relatively low cost, affordable, easy to maintain by local operators, available spare parts, efficient, easy to install, user friendly and are readily available (Wood, 1994). However, Parry-Jones *et al.*, (2001), revealed that though these assumptions may be valid, the harsh reality is that most of the hand pump water projects failed to live up to expectation. There are of course examples of successful hand pump projects around the world but the only problem with that of Africa is the fact that upon installation, knowledge and experience are not being passed on for sustainability (Habtamu, 2012). The most frequently used hand pumps in Africa for that matter Ghana are India Mark II, Afridev and Nira, (see Plates 1, 2 and 3 in Appendix G. Whereas India Mark II is used for deep wells or boreholes (over 45m), Nira and Afridev are used for relatively shallow wells or boreholes. With over 5 million installed worldwide, it could be inferred that the India Mark II was most the widely used hand pump (Wood, 1994). However, this hand pump was not much sustainable in Africa in that it was reported at the world water conference held in Nairobi in 1986 that over a million of the India Mark II pumps installed in Africa had broken down. These breakdowns were attributed to the failure of a 3 tier maintenance system associated with its design (Wood, 1994). Abdominal and waist pains were some complaints from pregnant women upon pumping. It is still a preferred and cost effective choice for depths over 45m (Wood, 1994).

Nevertheless, the rapid advancement in technology and advent of the Village Level Operation and Maintenance (VLOM) concept, brought into fore Afridev pumps. Low cost of operation and maintenance, easy installation and repairs, minimal training are the characteristics associated with this pump (Wood, 1994). Afridev pumps are recommended for depths between 16.5-30m. Beyond this depth range there is a likelihood of frequent breakdown (WaterAid, n.d.). Nevertheless, the concept of VLOM was impractical in Africa due to some technical problems like the wearing of the rod connector and difficulty in the removal of the some parts like the plunger and the foot valve and these were beyond the means of trained Caretakers (Wood, 1994).

Another type of pump been used recently is the mechanical pumps. These pumps are highly recommended for higher depths of boreholes (over 100m) and for places of high water demand (WaterAid, n.d.). Usually water pumped from these boreholes is stored in overhead tanks and then distributed through a reticulated pipe network under gravity to households or public stand pipes. However, the initial capital cost as well as the operation and maintenance cost is very high. Also, its dependence on electricity does not make mechanical pumps recommendable for rural water supply.

2.7 Sustainability of Water Point Sources

Sustainability can be pragmatically defined best as "whether or not something continues to work or function over time" (Abrams, 1998) or sustainability can be defined as the functionality of water point sources over a long period of time (Habtamu, 2012). Since the world committed itself to providing water to halve the world population without access to safe drinking water by the year 2015, the focus has been provision rather than sustainability. Every year, large sums of money are used in implementation of water supply projects but only a few are seen functioning at the end of the year or two (Gebrehivot, 2006). Thus, these huge sums of money invested often go to waste. It is estimated that 35% of all rural water supplies in sub-Saharan Africa are not functioning and despite the frequency with which it appears in development discourse, the reality of sustainability remains elusive (Habtamu, 2012).

Moreover, research has also shown that rural water supplies (often water point sources) in sub-Saharan Africa, particularly those relying on hand pumps, often demonstrate low levels of sustainability. The key causes for this include inappropriate policy or legislation; insufficient institutional support; unsustainable financing mechanisms; ineffective management systems; and lack of technical backstopping. The problem will only be solved by adopting a holistic approach to planning and implementation rather than focusing on one issue (Habtamu, 2012). No wonder sustainability lately has become a prerequisite for inclusion in a project proposal document and in the objective of every water supply and sanitation projects (Parry-Jones *et al.*, 2001).

2.7.1 Factors Affecting Sustainability of Water Point Sources

According to Habtamu, (2012) the factors affecting sustainability can be grouped under two broad categories, namely pre-implementation factors and post implementation factors. Community participation, technology selection, site selection, demand responsiveness, construction quality, population and training are some of the pre-implementation factors. On the other hand, post-implementation factors are technical support, community and social satisfaction, institutional and policy, financial management, training and willingness to sustain the water project (Habtamu, 2012; Lockwood *et al.*, (n.d) and Nkongo, (2009). With regard to the community, Lockwood *et al.*, (n.d.), further groups the factors of sustainability under two headings as internal and external. Preventative maintenance, tariff collection, management capacities, the continued involvement of women in system management, social cohesion and a willingness to support the system are the internal factors whereas access to spare parts and skilled technicians, the presence of some form of external support or funding, the presence of private sector service providers, the existence of a clear and supportive policy and legislative framework regarding the operation and maintenance of water point sources and a source that continues to produce the required quality and quantity of water are the external factors. Moreover, in practicing community participation, community members' contributions can take the form of money, labor, material, equipment, or participation in project-related decision-making and meetings. Once the community members are involved in decision making, there is always a sense of ownership and as a result contribute their quota in its sustenance (Habtamu, 2012).

In the context of water supply and sanitation, institutional (organizational), social, technical, environmental and economic or finance are the five key sustainability factors often considered (Well, 1998; Abrams, 1998; Mukherjee, 1999). All these five dimensions interact with each other and will vary considerably depending on the context. This therefore makes it difficult in measuring and understanding the factors affecting sustainability according to Parry- Jones *et al*., (2001). The study however seeks to unearth the factors affecting the sustainability of water point sources.

2.8 Functionality of Water Point Sources

The functioning and non-functioning of water point sources is termed as functionality. Studies conducted on functionality of water point sources by CARE (2012) and Habtamu (2012) place functionality under type of technology (type of hand pumps) employed, the availability of spare parts in the local market and availability of skilled personnel for operation, repairs and maintenance. From the studies factors that contribute long term functionality of technologies were enumerated as governance, diversity and inclusivity of committee members' for instance, female involvement and training for maintenance and repairs. CARE (2012) further indicates that the involvement of women in committees contributed tremendously to water point functionality in Northern Mozambique. On the other hand lack of sufficient training for operation and maintenance and lack of spare parts in the local market were the factors dwindling the functionality as well as sustainability of water point sources. Most of the spare parts are imported and are not locally manufactured and hence the reason for is unavailability in the market. Habtamu (2012) again indicates that the community participation in the choice of technology was another contributing factor enhancing long term functionality since the people felt a sense of ownership and for that matter are obligated to taking proper care of the point source. Also the community involvement in the construction of the technology coupled with the training received, equip those individual with some skill and a prior knowledge on repair and maintenance. Major faults found with the technology include broken handles (Hayson, 2006).

2.9 Water Point Sources Access Assessment

Access to water can be defined based on parameters such as population, distance, time and quantity (Moriarty *et al*., 2011). With regard to population access to safe drinking water is defined or estimated by the percentage of the population using improved drinking water sources such as protected hand dug wells, boreholes, protected springs, public stand pipes and rain water harvesting (JMP, 2011). According to WHO (2011) and CWSA (2007), a water point source must serve 200 to 300 persons. Studies conducted in Ghana shows that most often than not a water point source (borehole) serves less than 300 people at a time (Moriarty *et al.*, 2011). In WASHCost, the term “crowding” is used to describe access in terms of population (Moriarty *et al*., 2011). Access to a water point source in terms distance must be between 200m to 500m (Moriarty *et al*., 2011). According to WHO or UNICEF (2000) Joint Monitoring Programme, reasonable access to a water point source must be available to a person at least 20 litres (five gallons) per day from a source within one kilometer of the user’s dwelling. However, in Ghana, CWSA defines access to safe drinking water in rural areas to include supplies from boreholes delivering a minimum of 20 litres per person/day, serving at least 300 persons each within 500 meters of households being served (CWSA, 2007a). In terms of time, it is recommended by UN to be 30mins per a normal trip (from house to water and back to the house).

2.10 Mapping of Water Points and Mapping Tools

According to Welle (2007), mapping is the act of bringing what is hidden in the dark to light. Mapping can be in any form based on what information is required. In order to envisage information of a particular jurisdiction, a map is created at the end of any mapping exercise. A map is therefore defined as a geographical representation of a whole or a part of an area usually on a flat surface. Mapping in the water supply sector has advantages as well as disadvantages. Mapping according to Welle (2007) serves as an advocacy tool since it provides citizens as well as local government with information and arguments to demand improved services. Mapping of water point sources helps in revealing information such as coverage (number of water point sources in the system), access levels (number of population which has access to water), functionality (number of water point functioning and non-functioning), water quality (Physico-chemical and bacteriological quality) and equity (fair distribution of water points) of service delivery (WaterAid, n.d.). Information gathered from mapping is very useful for improving planning and monitoring of water service delivery nationally and locally by local government and water service providers (Welle, 2007). Welle (2007) further argues that mapping in itself is a tool that is used by water service providers and Agencies such as WaterAid (water and sanitation body) to track its projects.

2.10.1 Limitations of Mapping

In as much as mapping can be advantageous, it can be misleading since changes cannot be provided on maps generated as and when they occur (Welle, 2007). For instance, after mapping a particular place, any activities like demolition that goes on cannot be factored again into the map. Again, mapping is done based on the information the mapper is looking for and so several maps are generated for various purposes. Mapping is relatively expensive based upon the information needed since primary data is often required. Welle (2007) argue that data gathered had to be entered into a compatible mapping tool that may require training, skill and experience.

2.10.2 Water Point Sources Mapping Tools

Over the years, data analysis and mapping of water supply services has been a torn in the flesh for developing countries (WaterAid, n.d.). Most often than not such countries have little or no database on their water point sources as well as water supply services thereby limiting planning and monitoring of water supply projects. This has led to the development of numerous mapping tools such as GIS (Geographical Information System), FLOW (Field Level Operation Watch), GFT (Google Fusion Tables) and WPM (Water Point Mapper). All these mapping tools have their advantages and disadvantages. That notwithstanding, they have some basic similarities such as: user friendliness, easy accessibility including free downloads and use of GPS for data collection. On the other hand, their differences are based on their individual features and uses. While GIS and FLOW require maximum training, skills and experience, others like WPM and GFT require little or no training (Hayward *et al*., 2011).

2.10.2.1 Geographical Information System

GIS is a sophisticated and mapping tool that requires a great deal of training and skills for it usage. Its features are complex for usage by local folks and since most of the water point sources are managed by local folks it is highly not recommended for usage (WaterAid, n.d). However, it can be used for all types of mapping. Out of the GIS has evolved all the other mapping tools (Hayward *et al.*, 2011).

2.10.2.2 Google Fusion Tables

Google Fusion Tables is a web service provided by Google for data management. Data is stored in multiple tables which users can view and download once they have a data account. The web service provides means for visualising data with pie charts, bar charts, line plots, scatter plots, timelines as well as geographical map (Warui, 2013 and Hayward *et al*., 2011). According Hayward *et al.*, (2011) it does not require any training as well as any software just the internet and MS office whatsoever and it is easily accessible via the net. It is user friendly and can be adopted by any service provider. The only disadvantage is its dependency on the internet.

2.9.2.3 Field Level Operation Watch

FLOW is a water point source mapping tool that uses questionnaires loaded onto an Android smartphone, linking to a powerful online database. The tool has user-friendly dashboard outputs, and data can be shown by project or across projects, districts and national (Hayward *et al.*, 2011). It is easily accessible via the internet. Collection of data is made easier with the usage of a smart android phone. Its main limitations are its dependency on the internet, other software like the SPSS for large volume of data. Again Android smartphones are very expensive in this part of the world. According to Warui, (2013), the Flow does not allow for any form of updates in case there is a change in status. For instance, a non -functional water point source upon repairs cannot be factored into the system. Newer versions of the FLOW have eliminated some features and so do not allow its usage for big survey (Warui, 2013).

2.10.2.4Water Point Mapper

The Water Point Mapper is a free and simple monitoring tool designed to generate powerful maps showing the status of water supply services. Based on a Microsoft Excel spreadsheet, it instantly converts water point data into Google Earth compatible maps without the need for any complex software like GIS software or an internet connection. These maps can be saved as images for printing or inclusion in reports. With the help of the mapper, maps showing functionality, coverage, access levels, quality, quantity and many others can be generated. The Mapper is aimed at local government planners and water, sanitation, hygiene field practitioners working on district, sub-district and village level water supply programmes (WaterAid, n.d.). The water point mapper has the following characteristics as enumerated in the water point mapper user guide: minimal training, free and user-friendly, offline usage, generation of a wide variety of different maps, ability to configure to work in different countries, compatibility with other national and international level mapping tools and the ability to work with point and shape data.

The only disadvantage is difficulty in calculating distance and changing information on the reference tables. The water point mapper is therefore the tool employed for the analysis of the water point sources data.

3. THE STUDY AREA AND RESEARCH METHODOLOGY

The location, geology and soil, water supply and sanitation of the study area as well as the methodologies employed in the research are presented in this chapter.

3.1 The Study Area

Geographically, Ejisu–Juaben Municipal Assembly lies within Latitudes 1^{o} 15’N and 1^{o} 45’N and Longitude 6^{o} 15’W and 7^{o} 00 W. Figure 3.1 shows the map of the study area. Ejisu-Juaben municipal area is one of the 27 administrative districts of Ashanti Region. Ejisu is the main capital of the municipality. The municipality has 4 main urban settlements namely: Ejisu, Juaben, Besease and Bonwire. The municipality can boast of about 88 communities. With these numbers of communities and settlements, the Municipality covers a total land area of about 637.0 Km^2 and a population of 167003. The municipality lies in the central part of the Ashanti Region and shares boundaries with six Districts in the Region. To its north east and west are Sekyere East and Afigya Kwabre respectively, to the south; Bosomtwi and Asante Akim South, to its east; Asante Akim North and to the west; Kumasi metropolitan assembly.

The municipality is rich in cultural heritage, among them is Kente weaving (the pride of Ashanti region). Its cultural heritage can also be attributed to the late queen mother of Ejisu Nana Yaa Asantewaa who fought earnestly to restore the Ashanti Kingdom and its rich Culture. The major occupation of the people in the municipality is farming. The economy of the municipality is predominantly agrarian in nature, like in most rural communities in Ghana. According to the Municipality’s Five-Year Development Plan (2000-2005), agriculture constitutes 58.55% of the districts Gross Domestic Product (GDP). The main food crops grown are plantain, cassava, maize and cocoyam. One of the major cash crops grown includes cocoa and is the driving force of the economy. Oil palm is also another cash crop that is widely grown in the district. The industrial sector is characterized by wood processing and small-scale agro processing industries and accounts for 17.58% of the labour force (Anornu *et al.*, 2009). A few communities like Bonwire engage in Kente weaving whereas others engage in trading.

Like most areas that lie in the wet semi-equatorial forest zone in Ghana, the Municipal Assembly has bi-modal rainfall pattern. The major rainfall period begins from March to July peaking in July. Mean annual temperatures in the municipality are lowest around 25^{o}C in August and highest around 32^{o} C in March (SEA, 2010). According to Anornu *et al.*, (2009), the relative humidity averages at 85% during the rainy season and 65% during the dry season. The Municipal Assembly lies in the semi–deciduous forest zone of Ghana. The flora and fauna are diverse and composed of different species of both economic and ornamental tree species with varying heights and game and wildlife. The trees shed their leaves during the dry season. The Bobiri Forest Reserve for example is renowned for its butterfly species, greenery and varied flora and fauna.

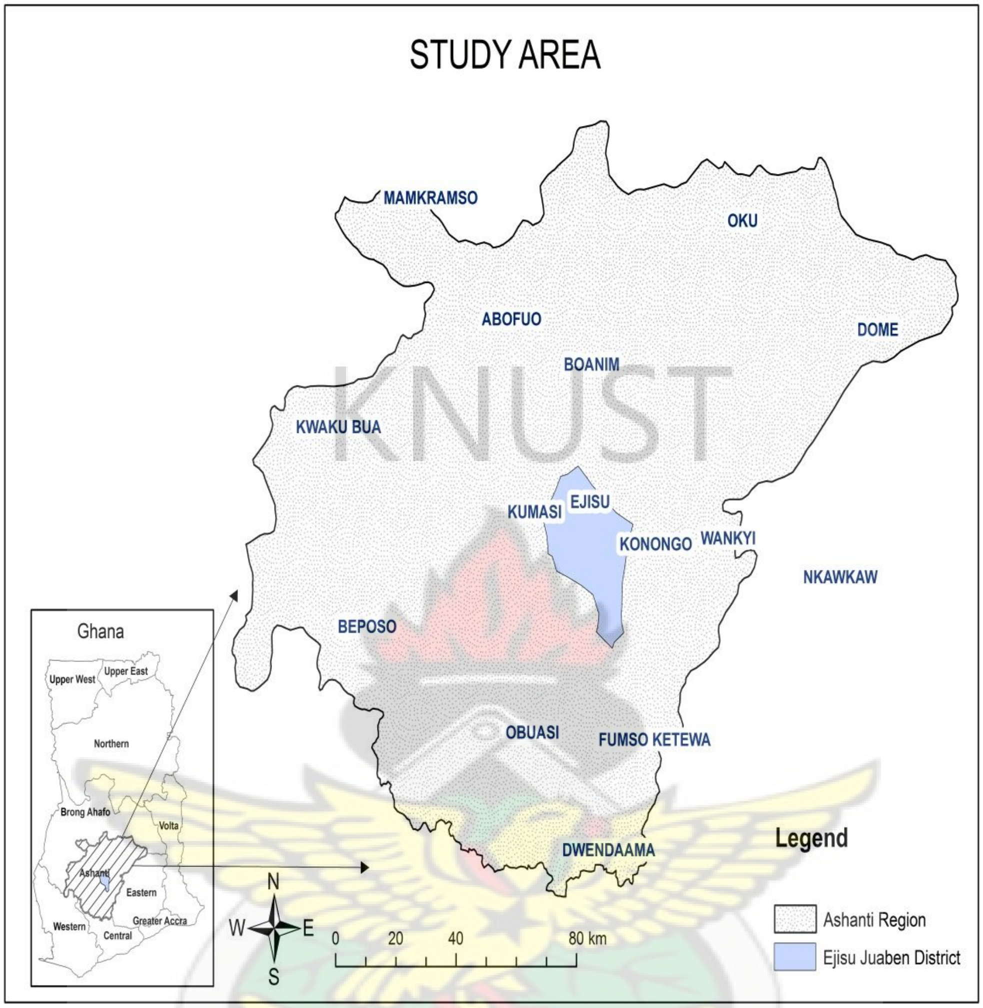

Figure 3.1: A base map of Ejisu-Juabeng *(Source: SEA, 2010)*

3.1.1 Geology and Soils

The geology of EJMA is pre-cambrian rocks of the Birimian and Tarkwaian formations which are generally suitable for agriculture. A report by Anornu *et al.*, (2009) indicates that water- bearing and yielding potential of the higher and lower Birimian is high due to the intense faults, fracturing and quartz veins imposing secondary permeability to the rocks. The soils include the associations of the Kumasi-Offin Compound, Bomso-Offin Compound, Kobeda-Esshiem-Oda Compound, Bekwai-Oda Compound and Juaso.

3.1.2 Water Supply and Sanitation Situation of The Study Area

Until 1984, GWCL was the only water supply body that supplied water to the Municipality from Barekese, a suburb of Kumasi (Anornu *et al.*, 2009). The water sector of the municipality is under the care of CWSA and they are responsible for the supply of water to the 88 communities. A report by SEA (2010), states that currently, Ejisu, the capital of the municipality has no reticulated water supply network except some few communities like Juaben and Onwe. However, recent data gathered shows that the municipality has about 300 Hand dug wells and 130 boreholes (Anornu *et al.*, 2009) and these are the main potable water facilities in the municipality. The National Water Sector Planning thresholds of 1: 300 persons and 1:150 persons for a borehole and hand-dug, respectively give EJMA potable water coverage of about 64.07% (SEA, 2010).

Sanitation of the area leaves much to be desired. Since there are no proper drains, wastewater from homes are left in the immediate surroundings. Moreover, the mode by which the people get rid of their solid waste is by open dumping. There are a few skip containers in the various dump sites and are emptied periodically when full. In the same vain not many communities have access to improved sanitation facilities and for that matter, a few toilet facilities can be found in the area and so residents, most especially those in the villages resort to open defecation.

3.2 Research Methodology

This section presents the methodology used in achieving the objectives of the study. Primarily, these include desk study, reconnaissance surveys, data collection, mapping, sampling and laboratory analysis of mapped water point sources from hand dug wells, boreholes and rain water harvesting and finally data analysis. Both primary and secondary data were collected. Primary data was collected through direct observations coupled with interviews with residents randomly selected during various field surveys. Secondary data were also collected from various stakeholders including Kumasi Metropolitan Assembly (KMA), Ejisu-Juaben Municipal Assembly (EJMA), (GWCL), CWSA (Kumasi and Ejisu).

3.2.1 Desk study

The main aim of this aspect was to gather all relevant secondary data related to the study. In view of this, both published and unpublished reports from Government Agencies, peer-reviewed journals and articles were used.

3.2.2 Reconnaissance Survey

Field visits were made on several occasions to get a general idea of the existing conditions in the study area. By this, location and referencing of sampling points, establishment of contacts with opinion leaders, brief interview of randomly selected residents of the area and an initial assessment of the existing water supply and sanitation situation were carried out.

3.2.3 Data Collection

In this study, data collection has been divided into two separate aspects; mapping of water points using GPS and random sampling of mapped water points for laboratory analysis- making up the quantitative data. The qualitative data were also collected through interviews and field observations. See Tables H-1 and H-2 in Appendix H for interview templates.

3.2.4 Sampling Design

The Ejisu-Juaben municipality can boast of about 88 communities and for this reason the municipality has been divided into four zones. In order to ensure an organized mapping exercise and a good qualitative analysis, the communities within the zones as presented by the municipal assembly was used. In order to sample the water point sources mapped, the following conditions were taken into consideration: sanitation of the area which included (the nearness of the water point source to a toilet facility like septic tanks, refuse dump, unlined drains and the cleanliness of the surroundings), history of the health conditions of the communities and sources of groundwater pollution like (farming, industrial waste). Based on any of these conditions the water point at that point is sampled. The sample space for the research was therefore obtained based on the above conditions. In all a total of 55 communities were visited with 415 water points mapped and 114 water points sampled. The mapping and sampling were done over a period of three months starting from middle of September and ending in the middle of December, 2012.

3.2.5 Mapping and Sampling Procedures, Preservation and Laboratory Analysis

As mentioned above, sampling of the water point sources were made based on conditions such as sanitation, history of health conditions of the community and sources of groundwater pollution whereas the mapping of the points were based on the zonal communities. The Global Positioning System (GPS, DNR Garmin) was used in the mapping of the water point sources. The International Standard (ISO 5667-3) for water quality sampling was adopted for the sampling. The water samples collected for metallic test were stored in a prewashed 50ml bottle and a 5ml volume of Nitric acid (HNO_3) was added to each water sample for the purpose of preservation of the metals in the water over a period of time. Water samples for microbial tests were collected and stored in a prewashed and sterilised 100 ml glass bottles. Water samples for tests like nitrate, fluoride and chloride were also collected and stored in 250ml prewashed plastic bottles. The samples were then stored in an icebox at 4ºC and transported to the Civil Engineering laboratory at KNUST, Kumasi on the same day of collection for analysis for the physical, chemical and bacteriological analysis. Parameters with extremely low stability such as temperature, pH, electrical conductivity and total dissolved solids were measured in-situ with hand-held meters. All the methodologies for laboratory analysis were according to the Standard Methods for the Examination of Water and Wastewater (APHA/AWWA/WEF, 2012). However, analyses for the presence of heavy metals such as Lead and Arsenic were undertaken with a Buck Scientific Model 210 VGP Flame Atomic Spectrometer, equipped with hollow cathode lamp and air-acetylene flame. Methods and procedures employed for the laboratory analyses are presented in Appendix C.

3.2.6 Data Analysis

This aspect is mainly concerned with analysis of results obtained from:

- Laboratory analysis of water samples from the water point sources.
- Administration of interviews with WATSAN boards and water vendors.

Results obtained from the laboratory analysis of water samples and interviews administered have been analysed with Microsoft Office Excel and the Water Point Mapper.

RESULTS AND DISCUSSIONS

4.1 Water Point Source Types

Out of the 88 communities within the study area, 55 constituting 63% of the communities were visited and a total of 415 water point sources were located with at least a water point source in each community. This is illustrated in Appendix A. From Figure 4.1 below, boreholes and hand dug wells were the major water point sources located within the municipality with 4 rain harvesting (storage reservoirs) points. See Image 4.1 (water point source type distribution within the municipality using the water point mapper). Boreholes, hand dug wells and rain harvesting storage constituted 60%, 39% and 1%, respectively.

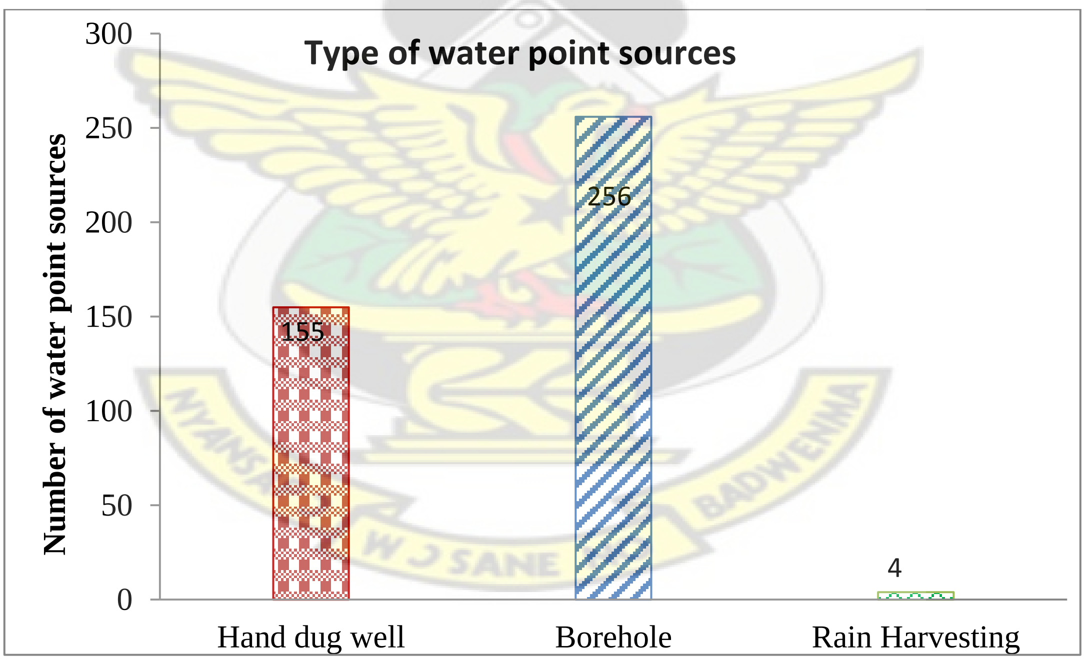

Figure 4.1: Types of Water Point Sources

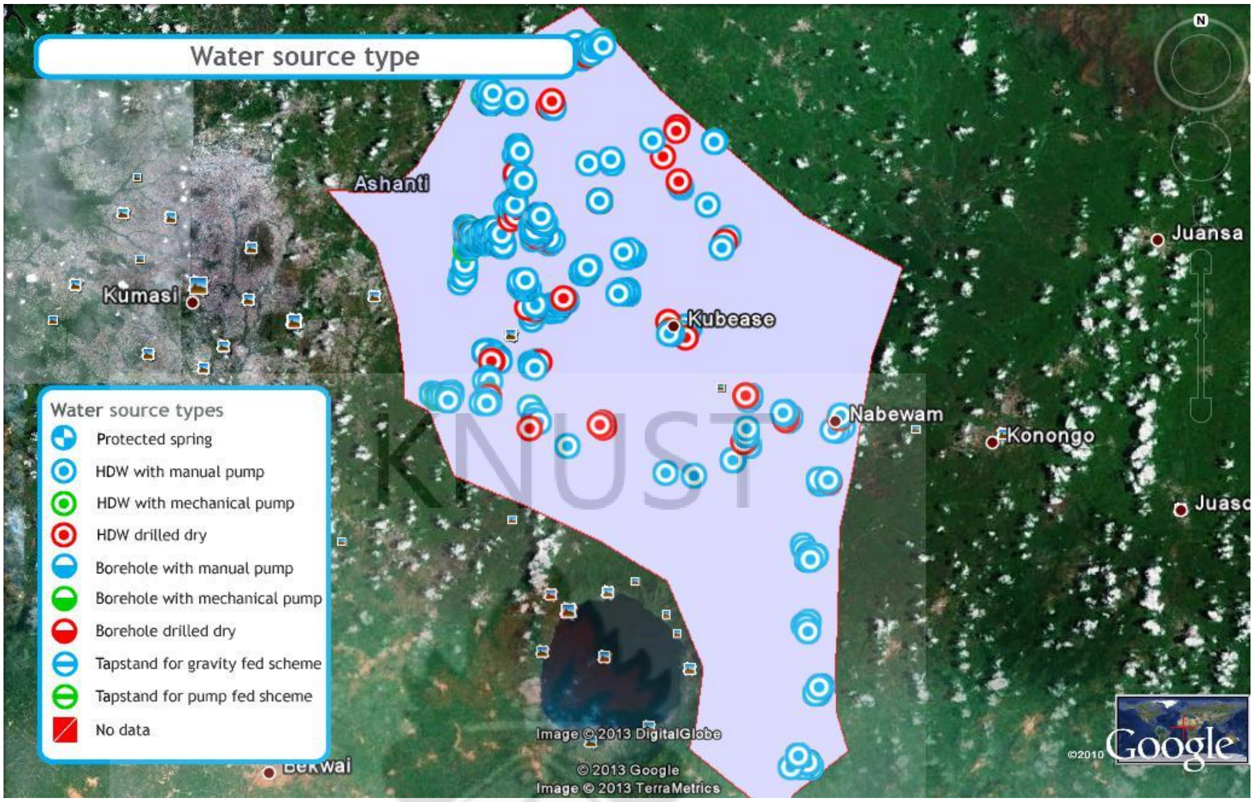

Image 4.1: A map of water point source types

4.2 Ownership, Funding and Cost of Construction of Water Point Sources

Out of the 415 water point sources located and mapped, 54% are privately owned and managed with the remaining 46% being community owned and managed. Data gathered further revealed that 59% were funded by individuals (private), 34% funded by the government, 6% by the community and the remaining 1% by NGO, (see Figures 4.2 and 4.3). Information gathered revealed that prior to the intervention of the Government to provide water to the communities, the leaders of the communities used to provide their people with hand dug wells and even now some of the communities still provide their people with water as a result of community participation and a regulated tariff structure for the sales of water and hence the 6% funding by the community.

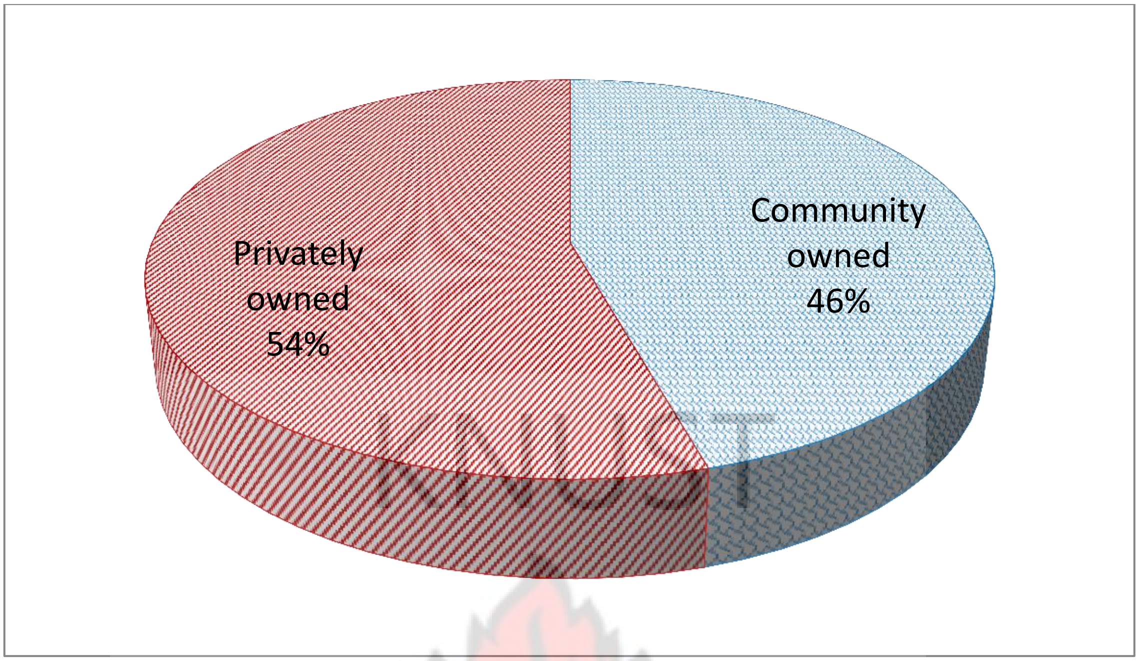

Figure 4.2: Ownership of Water Point Sources

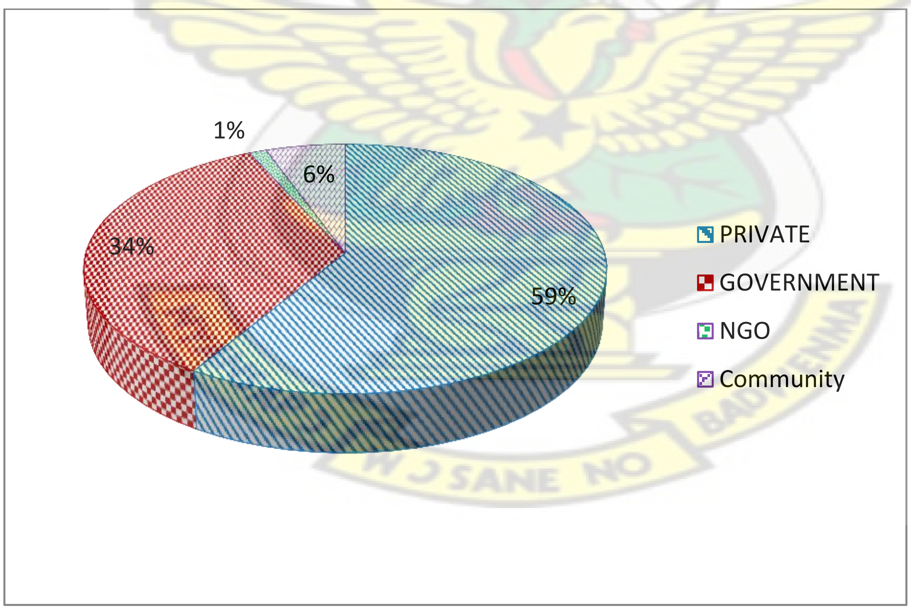

Figure 4.3: Types Funding or Support of Water Point Sources

The study also showed that 38% of the privately owned water point sources have been commrecialised. The study also revealed that four communities: Onwe, Juaben, Kwaso and some part of Ejisu Township are practicing small town water supply systems.

Furthermore, the interviews conducted with owners of water point sources revealed an average cost GH₵5000 (equivalent to $2500) for drilling or constructing a borehole. To the people in the community who are basically farmers, this cost is very high and for that matter resort to digging of hand dug wells which are relatively cheaper in construction. The average cost of constructing a hand dug well is GH₵1000 ($500) if it is just abstracted with mechanical pump (that is if mechanised) but GH₵200 ($100) to GH₵500 ($250) if not mechanized. The range in the cost of constructing a hand dug well solely depends on depth.

4.3 Construction of Water Point Sources

Figure 4.4 below represent the number of water points constructed each year in the municipality. The year 1981 recorded the highest number of boreholes construction followed by 2008 and this same year (2008) still recorded the highest number of hand dug well construction. An interview with the CWSA planning officer revealed that, in 1981, there was a nationwide assignment carried out to construct 2000 wells within towns and villages and a top up of 1000 wells later in1982 and this can be attributed to the high borehole numbers recorded in 1981. 75% of the total boreholes constructed in 1981 were provided by the government and this indeed confirms what the officer said. Between 1983 and 1990 there were not such projects and so there were no boreholes recorded but hand dug wells which were either privately owned or community owned. The construction of water point sources began to shoot up again in 2000 through to

2012. Information gathered revealed that this shoot up was a result of the quest of individuals to get water within their premises. 66% of the water point sources located within the municipality from 2000 to 2012 are privately owned and this may be a confirmation.

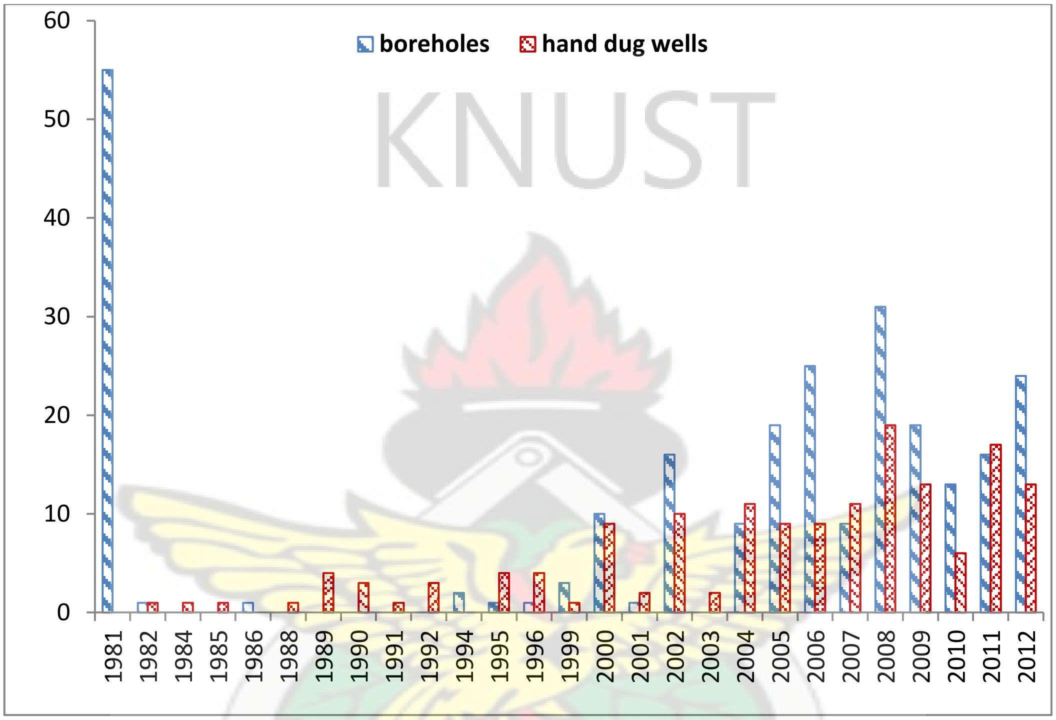

Figure 4.4: Yearly distributions of water point sources

However, to buttress the fact that individuals are constructing water point sources within their premises, 99.7 % of the water point sources belonging to individuals were located within households. 93% of the private owners interviewed said they didn’t want to walk long distances to public stand pipes and queue to get water and so they prefer to have their own. Reliability of the water point source was the reason given by the remaining 7%. However the studies revealed that on the average, 8 BH and 5 HDW are being constructed per annum over the past 3 decades.

4.4 Accessibility of Water Point Sources

From the data gathered the average distance between a water point source and the house of residence was about 400m. Though this average value is within the CWSA standard and that estimated from the studies of Moriarty *et al.* (2011) (refer to section 2.9), the maximum distance was 1200m. Out of the 55 communities mapped, 30% fell within this maximum value. Interviews conducted reveal that the water point sources are usually sited at places where there is enough groundwater yields and most often than not, these sites are at the outskirts or middle of the community. For instance, the people of Ofoase community walk about 1200m to the outskirt of the community to fetch water from a pond due to low yield and high iron concentrations of the boreholes drilled. Other communities such as Brahabebome, Timeabu and Bowohomoden had their water points located either in the middle or at the outskirt making accessing the water very difficult and so the people at par with the water point resort to alternative sources like surface water or some long abandoned hand dug wells. At the time of data collection, two communities; Brahabebome and Ofoase were in serious water crisis because the only boreholes that were serving the communities had broken down. Plates 4 and 5 show a non-functioning borehole and pond at Brahabebome and Ofoase communities, respectively.

Plate A: Pond at Ofoase

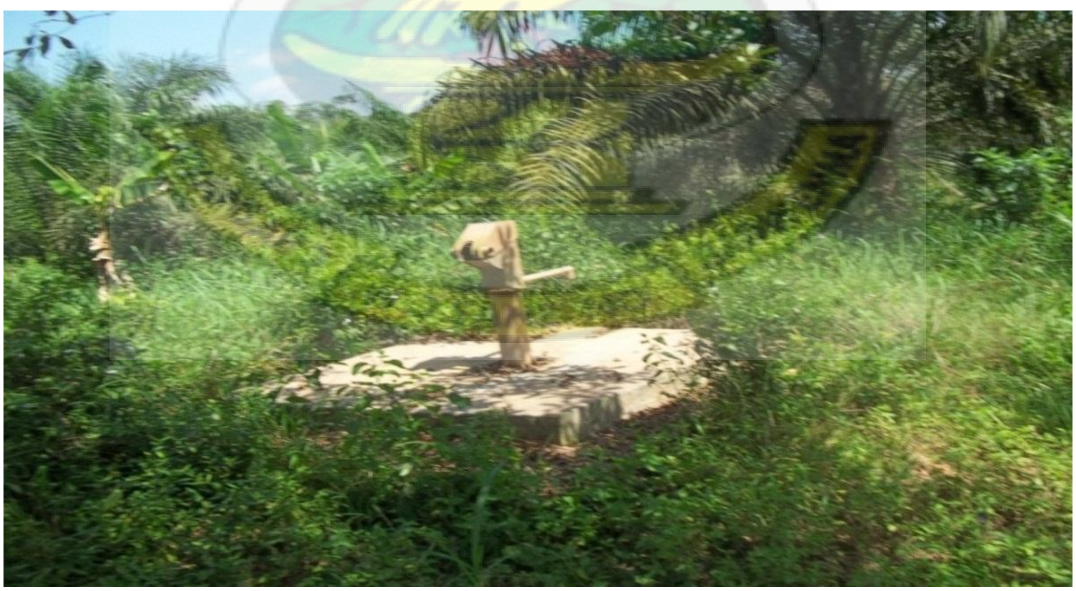

Plate B: Brahabebome; non-functioning borehole (broken handle (Afridev)

4.5 Coverage of Water Point Sources

Figure 4.4 in section 4.3, depicts an annual increase in the coverage of water point sources provision throughout the entire municipality. This has indeed translated into increase in water point sources coverage in the municipality over the past three decades. Images 4.2, 4.3 and 4.4 show the increase in 3 decades: 1981-9190, 1991-2001 and 2002-2012, respectively.

Image 4.2: Cumulative Water Point Coverage within 1980-1990

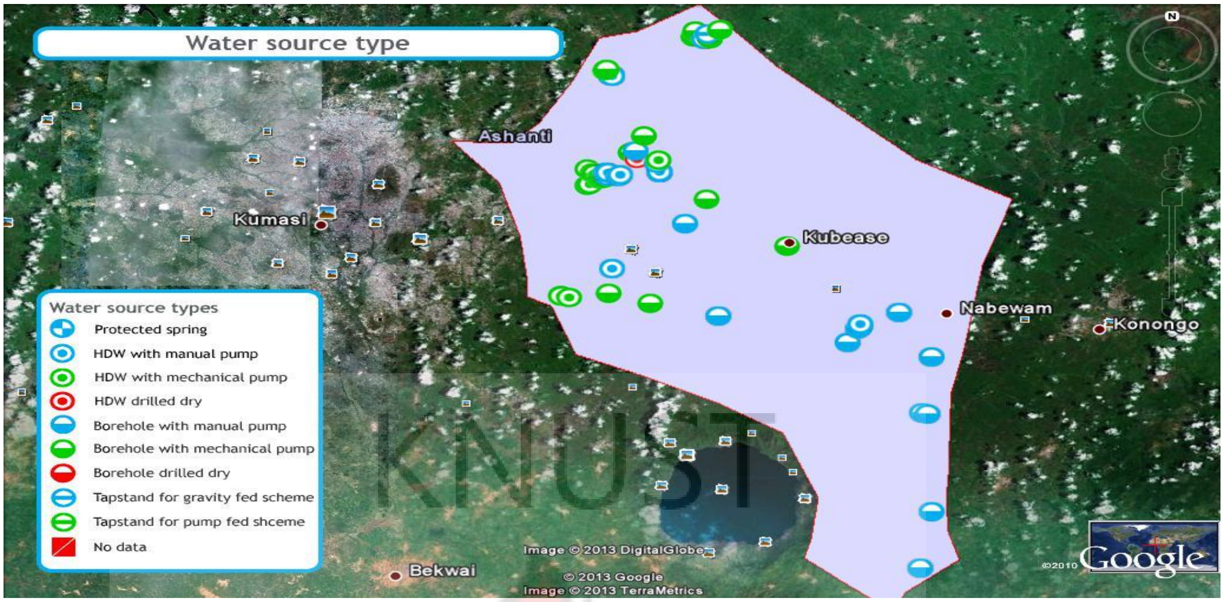

Image 4.3: Cumulative Water Point Sources Coverage within 1991-2001

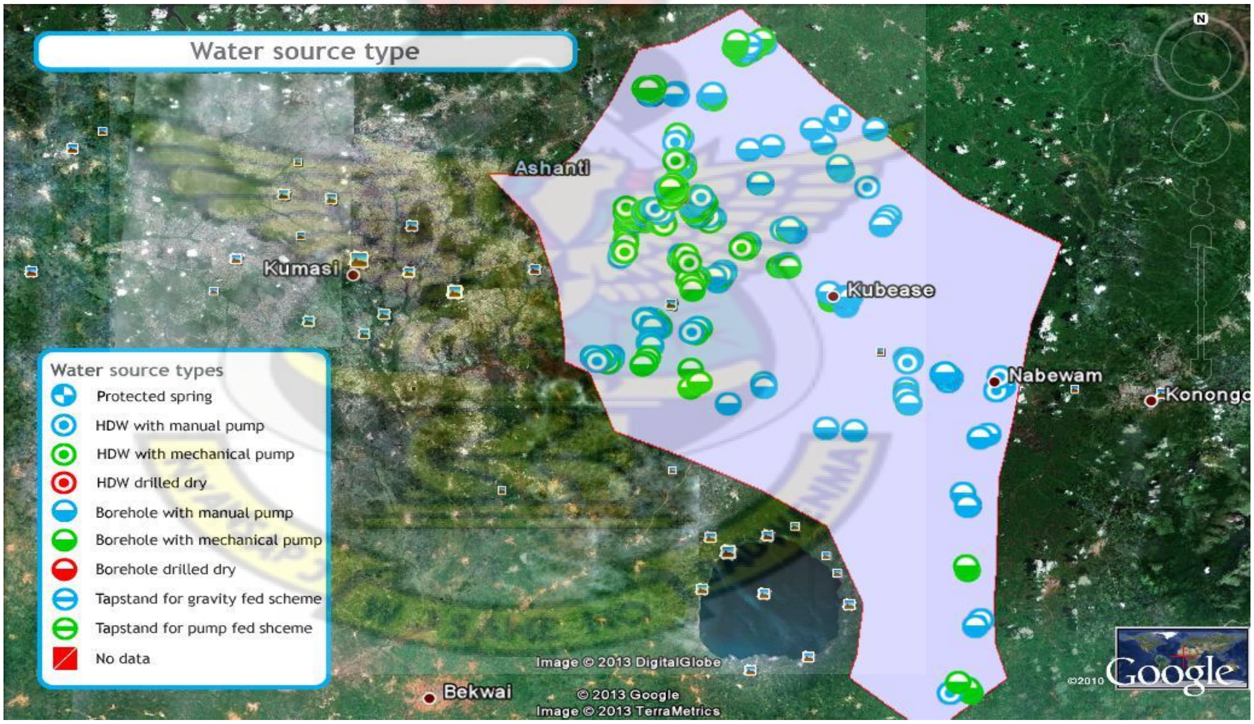

Image 4.4: Cumulative Water Point Coverage within 2002-2012

Representing the water point sources coverage in terms of numbers added each decade gives a clearer picture and this is illustrated in Table 4.1 below.

Table 4.1: Water Point Sources Coverage based total WPS within the municipality

Year(decade)	Population	Number of water point sources mapped	Functional water point sources mapped	Estimated Number of water point sources required	Excess/ Deficit
1980-1990	97007	75	74	486	-412
1991-2001	126399	58	129	632	-503
2002-2012	167003	282	378	836	-458
total	**167003**	**415**	**378**	**836**	**-458**

Between 1980 and1990, there were 75 water point sources in the municipality. 58 were added between 1991 and 2001 whereas 282 were added between the period 2002 and 2012. The total functional water points of 378 recorded comprise of both community and private owned water point sources. However, analysis carried based on two different assumptions revealed that more water point sources will have to be provided within the municipality in order to attain full coverage.

Assumption 1; assuming that all the water point sources in the municipality serve the entire population and ignoring the fact that some are owned by private individuals; and using the WHO guideline of 200 people to a water point source and the population per decade, it was realized that 458 water point sources will have to be provided in the municipality to meet the current population of 167003, refer to Table 4.1. The deficit in the Table depicts the number of water point sources that should have been provided in the past years or should be provided in the subsequent years to meet the population demand of the entire municipality. Applying assumption 1 at the community levels reveal the communities that require more water point sources and those communities that have attained full coverage, see Appendix B. The negative and positive values in Appendix B show the excess and inadequate water point sources respectively. For instance, Akyawkrom recorded excess of (8); it means that the water point sources in the Akyawkrom are more than enough for the community. This excess is occurring because the privately owned outnumber the ones provided by the Government. It is same for all the communities with positive values. Also, there are other communities with deficits though the privately owned out numbers that of the Government and it means there is the need to increase coverage in such communities.

Assumption 2; using the regional figure of 5 persons per household (GSS, 2010 census), current population, only community water point sources (WPS), and using still WHO guideline of 200 persons to a WPS, a deficit of 673 was obtained. This implies that to meet the current population demand 673 WPS should be provided see Table 4.2.

Table 4.2: Coverage based on community water point sources

population	community functional WPS	private functional WPS	population served by private WPS	population to be served by community WPS	estimated number of WPS required	Deficit
167003	157	221	1105	165898	830	673

4.5.1 Factors Contributing to Increase in Water Coverage

The main factors that have contributed to the water point source coverage are the government interventions such as the 3000 wells projects (1981-1982), 20,000 boreholes nationwide (2010 to date) and such other projects. According to an interview conducted with a CWSA Planning Officer, these are part of measures embarked upon by the Government to extend water coverage (its quest to meet its MDG set target of 78% by 2015) and this has translated into the provision of 152 water point sources constituting 39% of the total water point sources identified. The other contributing factors to water coverage are: the quest of individuals to have water at their door steps (constituting 60% of the water point sources identified), management systems (such as WATSAN, Unit committees and WSDB) and a regulated tariff structure. With the help of the management, the profit accrued from the sales of water from existing water point sources are used to either construct new ones or review (revise or replace a hand pump with and mechanical pump) and maintain older ones. Akyawkrom, Achinakrom, Adumasa, Bonwire, Ampabame, Esienimpong and Achiase are examples of such committees. At Yaw Nkrumah, a private partnership is practiced on the bases of maintenance and repairs in that an individual repairs a water point source with his own money. The community sells and pays the person back. This particular practice has helped in reducing delay in maintenance (said by water source manger) thereby enhancing functionality.

4.6 Functionality of Water Point Sources

Out of the 415 water points sources mapped, non-functional water points sources were 46 and this constituted only 11%, (See Image 4.5). 26.1% out of the non-functional water point sources were as result of low yield (dry wells or boreholes) which often resulted in frequent breakdowns (broken handles and faulty plunges) due to the fact that a lot of pressure is exerted on the handle as a results of continuous pumping (about 30 minutes) and this problem is beyond the control of the community since it is a natural occurrence. 50% (constitute 23 water point sources) of the non-functional water point sources were as a result of faulty pumps. High cases of iron content constituted 2.2% of the non-functionality. For instance communities like Adumasa, Bomfa and Ofoase recorded high iron content cases. No money for operation and maintenance, lack of spare parts and technical experts and high electricity bill charges (in cases where water point source is mechanised) were the remaining factors contributing to non-functioning of water point sources in the municipality.

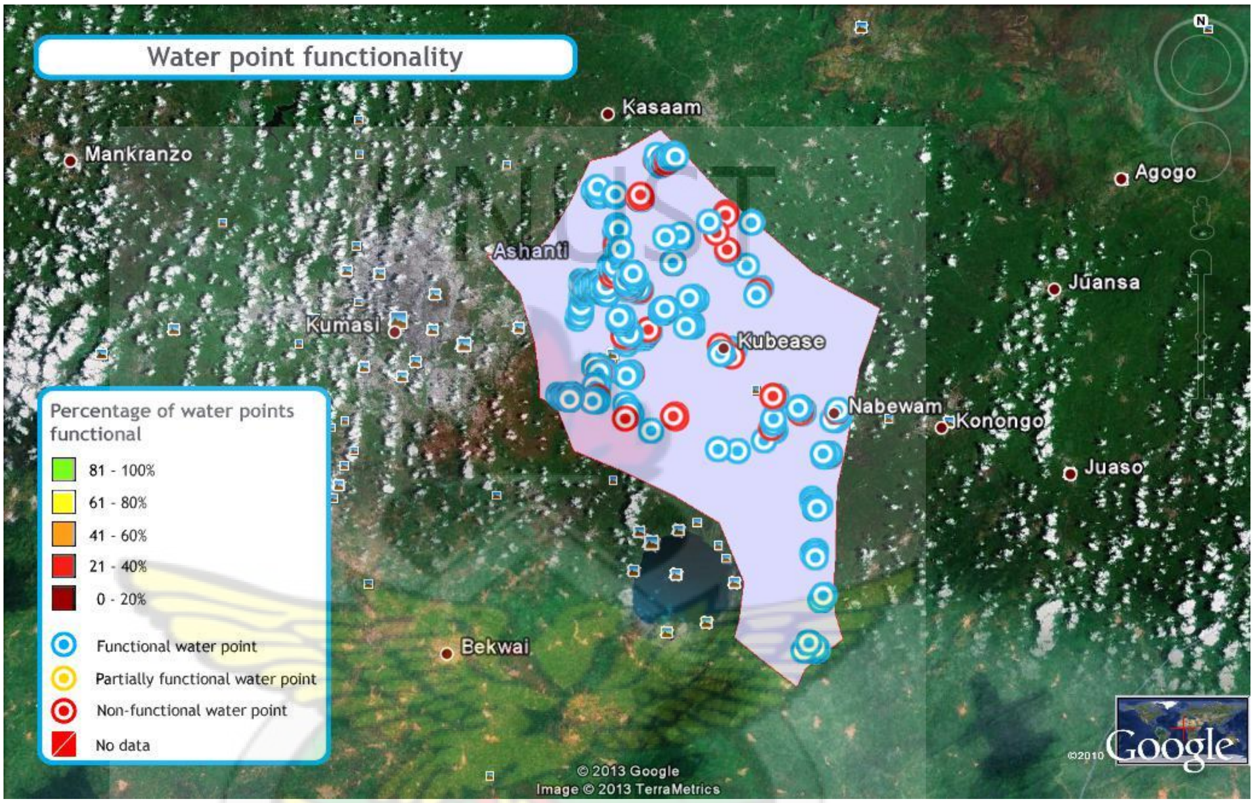

Image 4.5: Water Point Functionality Map

4.6.1 Factors Contributing to Functionality

Data gathered reveal that, all the communities visited have some form of management systems (such as WATSAN, Unit committees and WSDB). One of the responsibilities of the management system (refer to section 2.1.2) is to set a regulated tariff structure for the community. 95% of the communities visited for that matter have a regulated tariff structure and are practicing "pay as you fetch system." For this very reason, there are always available funds for maintenances and repairs and this has translated into high increase in functionality (89% functional water point sources). Also, with the help of the management, the profit accrued from the sales of water from existing water point sources are used to either construct new ones or review and maintain older ones; thereby contributing to functionality. The practice of public private partnership by some communities on the basis of maintenance and repairs such that an individual repairs a water point source with his own money and the community sells and pays the person back. This particular practice has helped in reducing delay in maintenance (said by water source manger) thereby enhancing functionality.

4.6.2 Functionality of Pump Type

Per observation, four (4) types of pumps are being used in the abstraction of ground water in the municipality. India Mark II hand pump, Afridev hand pump, Nira hand pump and mechanical pumps, (See Figure 4.5 below).

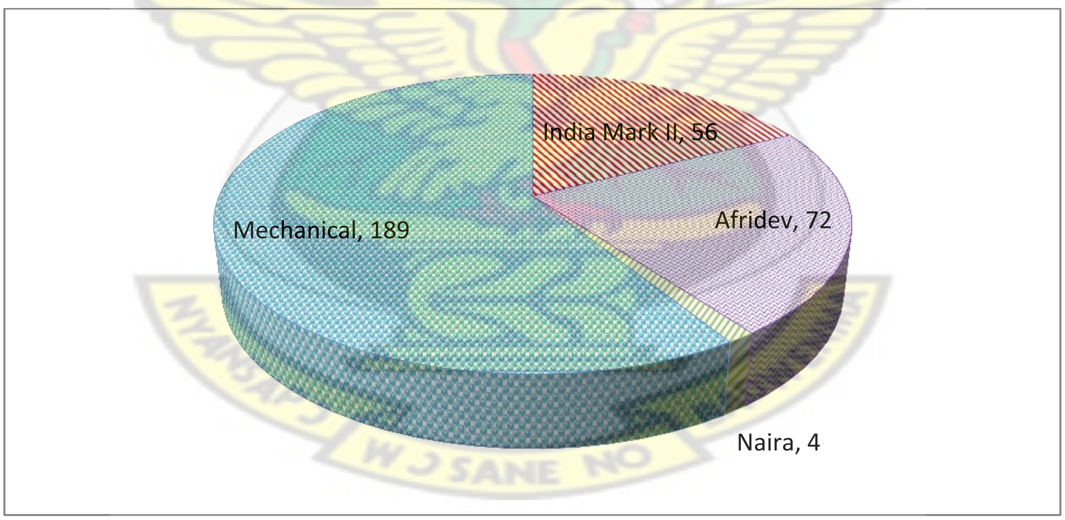

Figure 4.5: Number and Types of pumps

Among the 4 pump types identified, Afridev hand pumps were the most recently installed (age of installment ranges from 1990–2012) but these hand pumps recorded the highest percentage of non-functionality, see Figure 4.6 below.

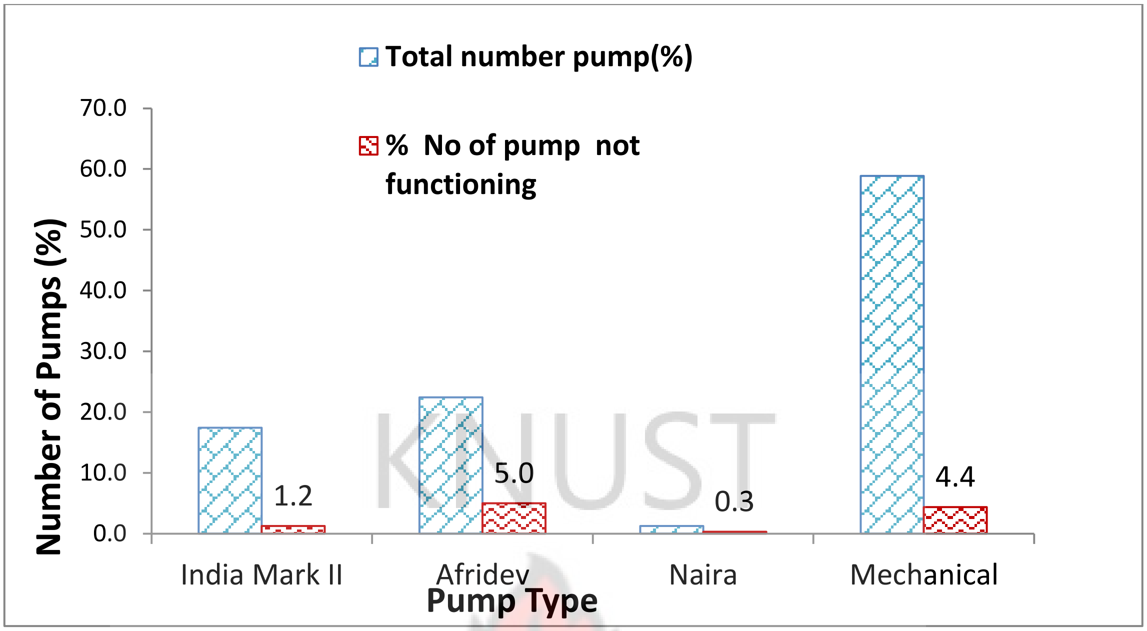

Figure 4.6: Pump Types and Functionality

The non-functionality of the Afridev pumps was as result of broken handles as observed during the field visits. Water point sources managers (WATSAN, CWSDB and Unit committee) and vendors also complained of frequent breakdown of handles of Afridev hand pumps thereby confirming the observation on the field. They complained that the handle breaks at most 3 times a year and at least once a year. Lack of technical experts and spare parts often delay repairs. According to WaterAid (n.d.), Afridev hand pumps are recommended for abstraction from depths ranging from 16.5m to 45m. From the study, it was found out that the pumps were installed on depths outside this range, instead the depth range were 50m and beyond. The pumps could not abstract the water and so the people exert more pressure on the handle while pumping and hence the frequent breakdown of handles. On the other hand, Indian Mark II hand pump which has been in the system for over the past 32 years (since 1981) are still strong and efficient and hence only 1.2% was not functioning. The non-functionality of the India

Mark II resulted from faulty plunges, and for lack of spare parts, they have been abandoned. Unlike the Afridev hand pumps, the Indian Mark II hand pumps were installed at the right depths (50m and beyond). However, the use of mechanical pump is on the ascendency such that 58.9% of the pumps identified were mechanical. 82.5% of the Mechanical pumps installed were privately owned water points and the remainder; community owned. The non-functionality of the mechanical pumps was as a result of the owners' inability to pay electricity bills and lack of money for maintenance. For instance, Onwe community which has all its boreholes connected to a reticulated pipe network system throughout the town was not functioning as at the time of the research visit due to the community's inability to pay electricity bills.

Lack of spare parts and technical experts (area mechanics), lack of money for maintenance and wrong installation depth were the major causes identified for the non-functionality of the hand pumps.

4.7 Water Quality of the Water Point Sources

This comprises of physical, chemical and bacteriological parameters of the water point sources. For the water to be wholesome and safe for drinking, it must meet the water quality standards set both locally (GSA/EPA standards) and internationally (WHO standards). The water quality of the water point sources identified within the municipality is discussed in this section.

4.7.1 Physico-chemical Quality of Water from Point Sources

These are the quality parameters that respond to the senses of sight, touch, taste or smell (Howard *et al.*, 1985; WHO, 2011). They are often called the acceptable parameters.

The acceptable parameters considered were colour, taste, odour, turbidity and temperature as specified by WHO/GSA for drinking water. From the interview with water managers like the WATSAN, WSDB, unit committee members as well as individual private owners and water vendors, colour, taste, and odour were acceptable except in few communities such as Doyina (two boreholes), Krapa1 (hand dug well), Bomfa (Borehole) and Ejisu New Town (Hand dug well). This is illustrated in Table 4.3.

Table 4.3: Community with complains on water point sources physical quality

Name of community/ water point source	**Taste**	**Colour**	**Odour/ Smell**
Doyina (boreholes)	Salty	Clear	acceptable
Krapa 1 (HDW)	Salty	Cloudy	bad
Bomfa	Metallic	Clear	Bad (rotten egg)
Ejisu Newtown(HDW)	Salty	Clear	Acceptable

With an average turbidity of 3.25 NTU, it can be inferred that almost all the water point sources sampled had their turbidity values below the WHO Guideline value of 5 NTU. However, the following water point sources did not meet the guideline value: Nobewam (HDW {71.7 NTU}), Bowohomoden (Borehole {93.8 NTU} and HDW {5.65 NTU}), Juaben (Borehole {17 NTU} and HDW {20.8NTU}), Doyina (HDW {7.35 NTU}), Boankra (HDW {11.8 NTU}) and Kwaso (borehole {8.8 NTU}) whose turbidities were alarming. At Bowohomoden, the water becomes turbid after pumping for some few minutes. This may be attributed to the fact that the right aquifer was not hit because a unit committee member complained of dryness during the dry season. However, data gathered revealed that the main cause of the high turbidity in the wells is due to their shallow depths.

Though, there is no guideline value for temperature, it influences biological activities as well as chemical reactions. The average temperature recorded was 29.4ºC for hand dug wells and 29.8 ºC for boreholes (Table D1 in Appendix D).

4.7.1.1 pH

On the average, neither boreholes nor hand dug wells met the pH guideline value of 6.5-8.5 (WHO, 2011), that is the pH values of all the water point sources fell outside of this guideline value. The pH values of hand dug wells range between 3.56 and 6.62 with a mean value of 5.15. The pH of the boreholes also recorded an average value of 5.41 and ranged between 4.41 and 6.9; see Figure 4.7 and Table D1 in Appendix D. According to Kortasi, (1994), the pH of groundwater in Ghana is often acidic and therefore the average values recorded may be a true confirmation, refer to Appendix E. On the other hand, the acidity of the water point sources may be attributed to the disinfection practices embarked on by the owners. Refer to Figure 4.11 in section 4.7. During disinfection, the addition of disinfectant such as chlorine reduces the pH of the water rendering it acidic. An interview with the residents revealed the usage of chlorine tablet to disinfect the water before drinking. Though the disinfection is not on any regular pattern since the people disinfected as and when they get the disinfectant, the continual usage of the disinfectant may be contributing to the acidity of the water (Zaporozec *et al.*, 2002).

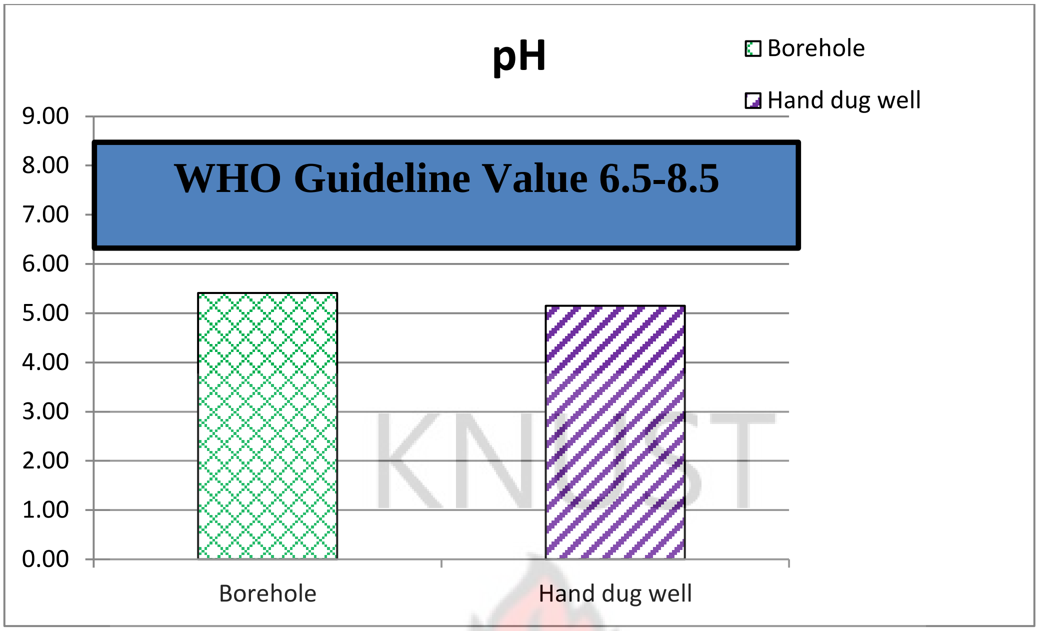

Figure 4.7: Average pH of water point sources

4.7.1.2 Electrical Conductivity and Total Dissolved Solids

The average EC and TDS values for both boreholes and hand dug wells were below the WHO guideline value of 1000µs/cm and 600µs/cm respectively (Figures 4.8, 4.9 and Tables D2 and D3 in Appendix D). Comparatively the boreholes ECs were higher than hand dug well and whiles the later ranged from 30.9 to 569 µS/cm with a parametric mean of 238 µS/cm and the former ranged from 15.5 to 795 µS/cm with a mean of 162 µS/cm. The higher average value of boreholes may be due to the deeper depth at which they are drilled in that the elements in the bedrock may have dissolved into the groundwater. The maximum EC borehole value was recorded in only one community (Achiase). Peminase, Adumasa and Kwaso were the other communities which showed high EC values for boreholes of 633µs/cm, 501µS/cm and 565µS/cm respectively. On the other hand, the highest EC value for hand dug well was recorded in Ejisu Newtown followed by Ejisu Bafo with 528µS/cm.

TDS on the other hand ranged from 15.5 to 309 mS/m with a mean of 83 mS/m and 15.5 to 397 mS/m with a mean of 120.44 mS/m for hand dug wells and boreholes, respectively.

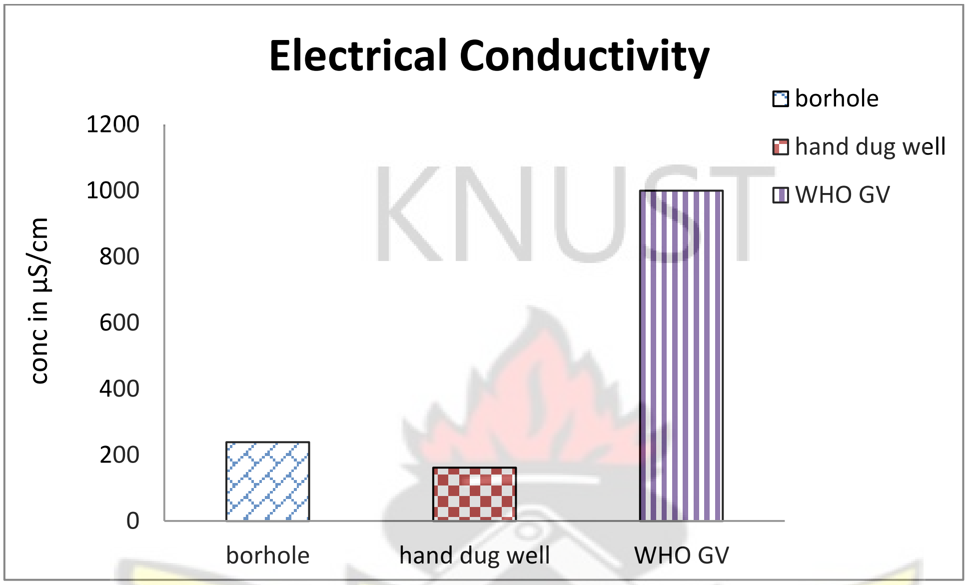

Figure 0.8: EC of Boreholes and Hand Dug wells, units in µS/cm

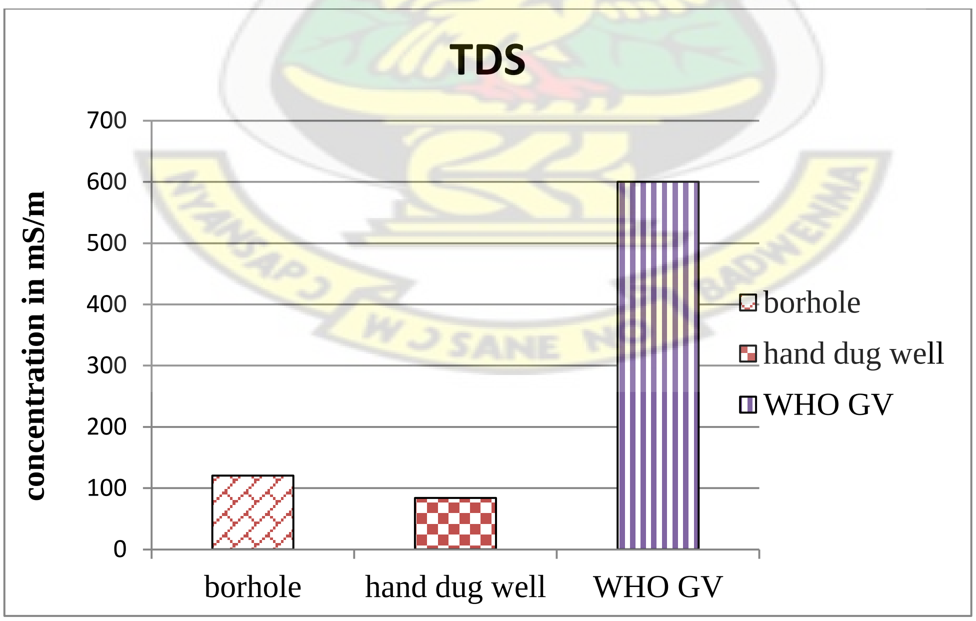

Figure 0.9: TDS of Hand dug wells and boreholes

4.7.1.3 Iron and Manganese

With an average of 0.21mg/l concentration of iron, it can be inferred that all the boreholes sampled are below the WHO guideline value of 0.3mg/l. However some communities recorded high levels of iron; Bowohomoden (5.37mg/l), Juaben (1.05mg/l), Peminase (0.56mg/l), Kwaso (0.37mg/l) and Kubease (0.34 mg/l). The water vendor at Peminase complained about the rusting of the metal bucket used for measuring the water for selling. Per observation, a stream that lay in the middle of Peminase had turned brownish. At Bowohomoden, it was observed that upon pumping, some brownish particles were seen in the water and this may account for the high concentration. At Juaben, it was observed that the metal pipe that carries water to the main distribution line has rusted and this might have leached into the water. However, all the boreholes sampled showed low concentrations of Manganese with an average of 0.032mg/l and this is below the guideline value of 0.05mg/l. The hand dug wells recorded an average iron concentration of 0.074mg/l and an average manganese concentration of 0.026mg/l. Only 2 communities; Manhyia and Nobewam revealed Iron concentrations of 0.34mg/l each. This is illustrated in Tables D2 and D3 in Appendix D.

4.7.1.4 Lead

The average concentration of lead in the boreholes and hand dug wells sampled are 0.064mg/l and 0.065 mg/l, respectively. These values are within the WHO guideline value of 0.1 mg/l. Only 9 communities had lead concentrations ranging from 0.10 to 0.45 mg/l and these were above the guideline value. Bowohomoden community recorded the maximum lead concentration of 0.45mg/l, See Tables D2 and D3 in Appendix D.

4.7.1.5 Chloride, Nitrates and Sulphates

On the average, both borehole and hand dug water sampled were below the guideline value (250mg/l) of chloride, (see Tables D2 and D3 in Appendix D). The averages of chloride for the water sampled from boreholes and hand dug wells are 25.69mgl and 25.67 mg/l, respectively. Only one hand dug well in Ejisu Newtown recorded a high chloride concentration of 275.5mg/l. The owner of the facility complained of the saltiness of the water and for that matter it is only used for cooking. Also, the concentrations of the nitrates in the water sampled were within the WHO guideline value of 250mg/l. On the average both boreholes and hand dug wells recorded 0.5mg/l and 0.51mg/l of NO_3, respectively.

The concentration of Sulphates was also below the guideline value of 250mg/l. The averages of sulphate for both boreholes and hand dug wells were 15.73mg/l and 13.17mg/l respectively.

The main occupation of the people is farming (this indicates the use of chemicals like fertilizers, weedicides and pesticides), yet there were little or no traces of sulphates and nitrates because the water point sources are not located in the farm areas but within the communities.

4.7.1.6 Total Hardness and Calcium Hardness

None of the water sampled, be it borehole or hand dug well had high concentrations of either total or calcium hardness. All the water sampled were below the WHO guideline value of 100-300mg/l for both total and calcium hardness. No community complained of hardness of water during sampling and so the laboratory result confirms that. The average total hardness for boreholes and hand dug wells are 58.47mg/l and 50.74mg/l, respectively. In the case of calcium hardness, the averages are 37.26mg/l and 28.1 mg/l for boreholes and hand dug wells respectively, (see Table D2 andD3 in Appendix D).

4.7.2 Bacteriological Water Quality of Water Point Source

Out of the 114 water point sources sampled only 6 (3 hand dug wells and 3 boreholes) met the WHO guideline value of 0 FC/100ml faecal coliform (e-coli and salmonella) and for that matter are safe for drinking. With the remainder, hand dug wells relatively recorded higher microbial loads on the average; e-coli (19 FC/100ml) and salmonella (69 FC/100ml) whereas the boreholes recorded an average of (3 FC/100ml) and (24 FC/100ml salmonella) and e- coli respectively, (see Figure 4.10 below).

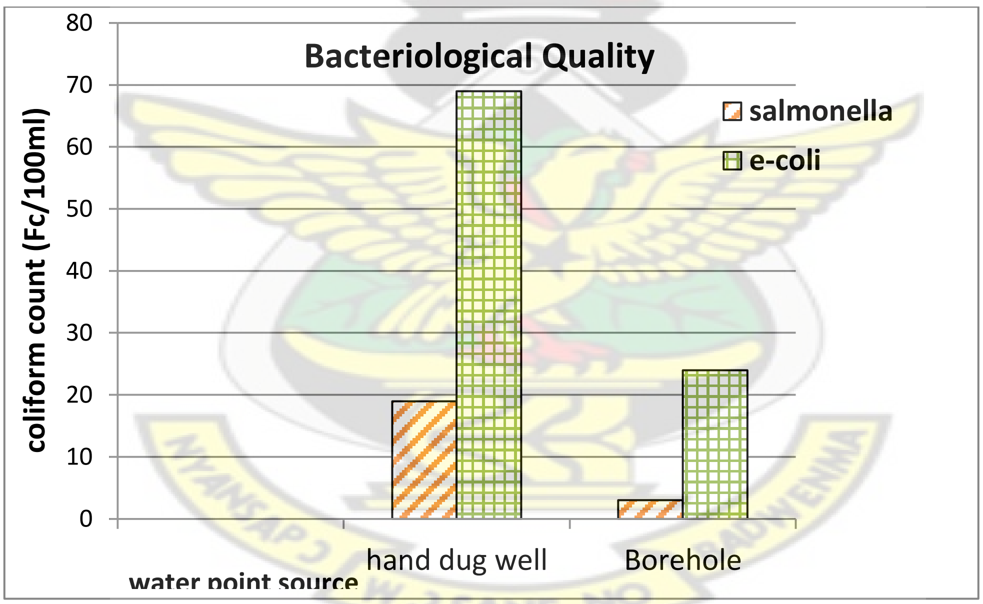

Figure 4.10: Bacteriological Quality of water point sources

4.7.2.1 Factors Contributing Faecal Contaminations

As mentioned in section 4.1.1, majority of the water point sources mapped are located within households and these households have either a septic tank or a toilet facility within it. This could contribute to the high faecal contaminations of the water point sources if the distance between them does not exceed 20m to 30m (Verstraeten *et al.*, 2004). In Ejisu and Bonwire, a commrecialised borehole was located right beside a public toilet (see Plate 6 in Appendix G) and this for instance may be a confirmation of the high faecal contaminations. Some of the boreholes fitted with hand pumps had a pool of stagnant water on the stance and this may also be a point source for faecal contaminations in the boreholes in case there are loosened bolts or cracks on any part of the borehole (see Plate 6 in Appendix G). On the other hand, the hand dug wells are mostly drawn using rope and bucket, and for that matter most of the hand dug wells are uncovered. Per observation, there was always a pool of mud around the wells and this could be possible point source of faecal contamination of the rope and bucket before they are dropped into the water; (see Plate 5 in Appendix G). Also, an interview conducted with the water managers and vendors revealed that the public boreholes are not disinfected even after a major maintenance or repairs and this could be a major point source for faecal contamination. Moreover, some of the hand pumps have been in operation for over 30 years and so there could be accumulation of biofilms which may provide an optimum substrate for these opportunistic bacteria to survive and hence the high fecal contamination of the boreholes. Again, abandoned hand dug wells were used as a source of refuse damp by some private owners. Essentially, this was confirmed by the 2010 report of the Ejisu- Juaaben Municipal Hospital, recording high incidence of diarrhoea (5565 cases), typhoid and other water related diseases. Interestingly, 39% of the water point sources sampled are being treated; however, the treatment does not follow any regular pattern and also it does not really show any reduction in faecal contamination.

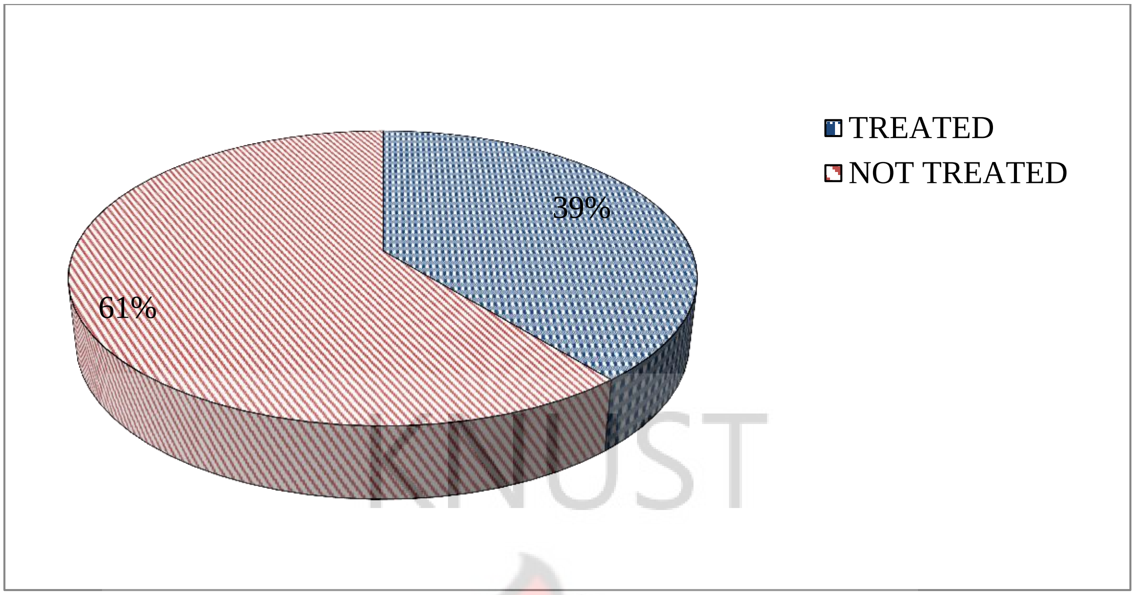

Figure 4.11: Treatment of water point sources

4.8 Factors Affecting Sustainability of Water Point Sources

Community participation, institutional arrangement in the form of management (committees and Boards), technical assistance in the form of training and community initiative and funding are the main factors of sustainability identified. Each of these factors is elaborated in this section.

4.8.1 Community Participation

One of the important factors affecting sustainability is community participation and for that matter considered a pre-implementation factor of sustainability (refer to section 2.7.1). From the interviews conducted with CWSA and the water managers, it was found out that the opinions of the community are sought during the implementation stage of each government funded project. Usually, the water point is constructed in a community based on the request made by the community and so when there is any government project such communities are considered first. Also, some communities as part of community initiative do pay part of the construction cost or even the full cost of a water point source and for this reason such water point sources are sustained in the community. Communities, out of their initiative have borne water the cost of borehole construction by themselves and this constituted 7.2%. Examples of such communities are Akyawkrom, Achinakrom and New Bomfa. In trying to ensure sustainability, the water point source is sited at the exact location approved by the community except under circumstances where the groundwater yield is not enough to serve the community; a CWSA officer reiterated.

4.8.2 Institutional Arrangement

Out of the 55 communities visited, 18 had WATSAN committees, 3 CWSDB and 34 had unit committees, (see Figure 4.12 below and Appendix A).

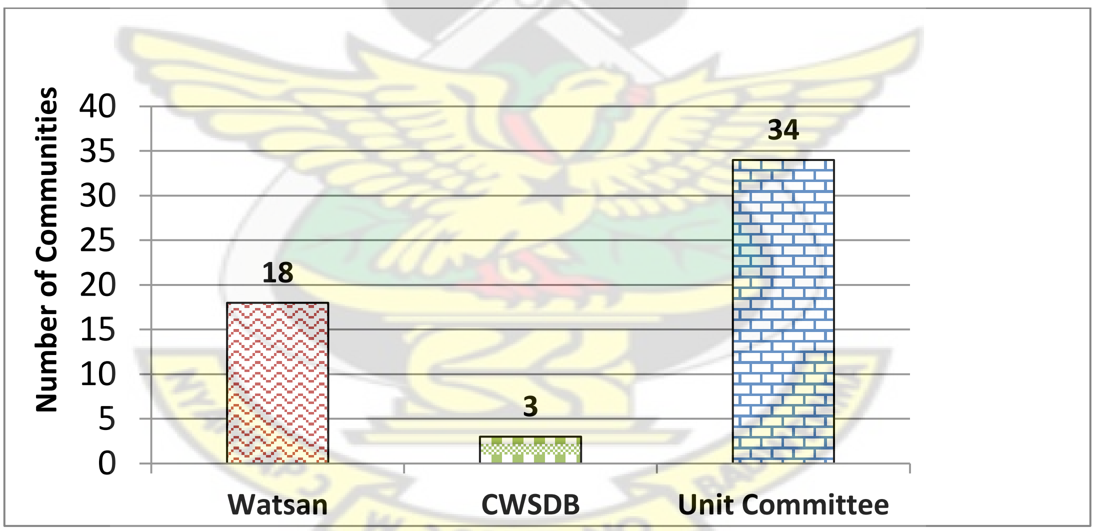

Figure 4.12: Type of Management

As part of the measures embarked upon by CWSA to enhance sustainability, water management boards such as WATSAN and CWSDB are formed in some of the communities. However, it was found out that communities which do not have either WATSAN or CWSDB are the ones with unit committees. Under the local government, every community in Ghana has a unit committee and these unit committees manage the affairs of the people in the community (NYP, 2002).

During the establishment of the water boards in the communities, some form of technical assistance in the form of training (like oiling and greasing of the hand pumps, tightening of bolts and nuts) is given to the people but no training is given upon completion of project and so committee members lack the minor skills of maintenance.

4.8.3 Cost Recovery and Financial management

With the help of the managerial systems, communities are able to sustain and recover the cost of constructing water point sources by practicing either the “fetch and pay system” or “the flat rate system.” 95% of communities practice the “fetch and pay system” such that a bucket (24L) or a 20L gallon (see Plate 7 in Appendix G) goes for 5 pesewas and about a 40L pan which goes for 20p (for three pans) and such communities are able to make average daily sales of GH ₵ 4.00 per water point source. “The flat rate system” was practiced by some communities (constituting 4%) of unit committees and WATSAN in that a household is charged to pay a specific amount either monthly or yearly. For instance at Manhyia, each household pays 50p per person every year and others charge GH₵ 20 per house yearly. In terms of financial management, only 7% out of the 55 communities mapped had bank accounts. The remaining communities, though the communities do not have bank accounts, the committees are committed to rendering accounts at the end of each year to the community by the treasurer. As the communities sell their water, some private owners do sell theirs as well and they are able to make average daily sales of approximately GH₵ 10.00, the reason being that such water point sources do not require pumping and are closer to the people than the community water point sources. As a result of this some communities, (see Table 4.3 below) have changed their hand pumps into mechanical pumps and this has really yielded good results, because some communities after changing their pumps have seen great increase in their average daily sales (Table 4.4).

Table 4.4: Increase in sales as a result of change in pump type

Name of community	**Average Daily Sales of Revised (mechanised) pump GH₵**		**Average Daily Sales of non-revised (mechanised) pump GH₵**		**Average Daily sales of private mechanised pump GH₵**	
	Sales	**Number of pumps**	**Sales**	**Number of pumps**	**Sales**	**Number of pumps**
Achiase	10	1	3.3	3	8	1
Adumasa	9	2	3.6	5		
Akyawkrom	14	3			6	1
Ampabame	8	1	2	3		
Bonwire	14	3	3	2	18.5	1

For instance, Achiase community makes an average daily sale of GH₵ 10 with 1 revised pump compared with average sales of GH₵3.3 with 3 hand pumps. However, if average daily sales and monthly operation and maintenance cost (OpEx) remain like that for five years, there is likelihood that Achiase and Ampabame could recover cost in five years. Tables 4.5 and 4.6, revealed a likelihood of all the communities to recover cost in five years if a flat rate system is employed if OpEx for all the communities remain the same in the next five years. However, charges per household might differ from one community to the other due to difference in population and number of water point sources.

Table 4.5: Cost Recovery based on daily sales

	Name of community				
	Achiase	Adumasa	Akyawkrom	Ampabame	Bonwire
Average daily sales (mechanised pump)	**10**	4.5	4.7	**8**	4.7
Yearly sales (YS) GH₵	**3650**	1642.5	1715.5	**2920**	1715.5
Capital expenditure (CapEx)	**6000**	5000	4500	**5000**	6500
monthly Operations and maintenances (OpEx) GH₵	**120**	100	75	**150**	115
yearly OpEx (YOpEx) GH₵	**1440**	1200	900	**1800**	1380
five years OpEx (FOpEx) GH₵	**7200**	6000	4500	**9000**	6900
(CapEx)+ (FOpEx) GH₵	**13200**	11000	9000	**14000**	13400
5 year baseline	**18250**	8212.5	8577.5	**14600**	8577.5
profit	**5050**	-2787.5	-422.5	**600**	-4822.5

Table 4.6: Cost Recovery based on flat rate system

	Achiase	**Adumasa**	**Akyawkrom**	**Ampabame**	**Bonwire**
Population	4260	4583	2412	1125	6840
Number of households	852	916.6	482.4	225	1368
Number of household/ Water Point Source	213	130.9	160.8	75	456
Capital Expenditure (CapEx) GH₵	6000	5000	4500	5000	6500
CapEx/20 years design life (CapEx/DL) GH₵	300	250	225	250	325
Monthly OpEx GH₵	120	100	75	150	115
Yearly OpEx (YOpEx) GH₵	1440	1200	900	1800	1380
CapEx/DL+ YOpEx GH₵	1740	1450	1125	2050	1705
Charge/household/year	8.2	11.1	7.0	27.3	3.7
Charge/household/month	**0.7**	**0.9**	**0.6**	**2.3**	**0.3**
Cost Recovery (5yrs) GH₵	8700	7250	5625	10250	8525

4.8.4 Spare Parts and Technical Expertise

Interviews conducted with water point source managers (Caretakers) and vendors revealed that most often than not, the unavailability of technical expertise (Area Mechanics) as well as spare parts delay repairs and maintenances during breakdown. For instance, at Yaw Nkrumah community, all the water point sources have been non-functional for close to three months for lack of technical expertise. One repair takes away all the savings made in a year because usually the technical expertise charge exorbitant prices for both spare parts and workmanship. The water Caretakers also complained of water charges been too low and hence the draining of account upon paying the technical experts. An interview conducted with CWSA planning officer reveal that the municipality has three Area Mechanics for the municipality but they are not enough since they work as a team and are not always readily available. This in a way confirms the reason for lack of Area Mechanics. The planning officer further revealed that lack of available spare parts in the local market is a major contributing factor to delay in repairs and maintenances.

4.8.5 Type of Funding

As shown by Figure 4.2 in section 4.2, it may be inferred that the community owned water point sources are funded by the Government and sometimes some NGOs and so once a water point is constructed; no money whatsoever is allocated for maintenance or repairs. Most often than not, the water point sources do not even last for three months before they break down and the water point source is abandoned due to lack of funds. For instance, Brahabebome and Bowohomoden WPS abandoned till date due to lack of funds for repairs of broken handles of hand pumps that broke down few days upon completion.

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

- The main water point sources identified within the municipality are boreholes, hand dug wells and storage tanks used for harvesting rain. A total of 415 water point sources were identified with boreholes constituting 60%, hand dug wells 39% and 1% rain harvesting storage tanks and these are spatially distributed within the community.
- 61% of the water point sources are privately owned whereas 39% are owned by the community. This has contributed to increase in coverage as well as accessibility thereby contributing to the attainment of the MDG.
- 59% were funded by individuals (private), 34% funded by the government, 6% by the community and the remaining 1% by NGOs. However, the average cost of constructing a borehole in the municipality is GH₵ 5000 ($2500) and that of a hand dug well is GH₵1000 ($500) if it is just abstracted with mechanical pump (that is if mechanised) but GH₵200 ($100) to GH₵500 ($250) if not mechanized.
- Cost recovery of a mechanised borehole is possible within five years.
- 12% of the water point sources mapped were not functioning as a result of dry wells, faulty hand pumps and a few cases of water quality problems.
- Bacteriologically, only 6 (3 hand dug wells and 3 boreholes) out of the 114 water point sources sampled had no traces of faecal contaminations. Physico-chemically, the averages of all the water point sources sampled were within the WHO guidelines except pH (average of 5.41 for boreholes and 5.15 for HDW.

- The main factors affecting sustainability of water point sources in the municipality can be grouped into two namely positive and negative factors. Community Participation, Private Partnership and management systems are the positive factors enhancing sustainability whereas lack of spare parts, technical experts and lack of financial capability for maintenance upon completion of projects are the negative factors affecting sustainability.

5.2 RECOMMENDATIONS

- To avoid regular contamination of hand dug wells, a simple pulley system should be used instead of rope and bucket and also water point sources should be sited at least 30m from a septic tank or toilet facility to avoid faecal contaminations.
- To reduce the point sources of faecal contaminations, communities should keep the stance of their water points clean to prevent settlement of stagnant water.
- Further studies should be conducted to ascertain the bacteriological quality of the water point sources especially boreholes.
- CWSA should begin to install mechanised pumps and allow the communities to pay within a period of five years.
- CWSA should embark on public education on disinfection to avoid the ad-hoc disinfection currently being practiced and likewise organise and provide adequate training for members of committees of minor maintenances and repairs.
- CWSA should encourage and establish WATSAN and CWSDB boards in communities which do not have them to enhance proper management of the water point sources, thereby enhancing sustainability.

REFERENCES

- Abrams, L. J. (1998). Understanding Sustainability of Local Water Services. Available online at www.thewaterpage.com/sustainability.htm. Last assessed (05-03-2013).
- Addai, E., Ampomah, B. Y., Yiadom, G. B., Agyemang, M., Ofosu, E. and Etego, R. A. (2009). Water and Sanitation Sector Performance Report. Ghana
- Agyekum, W. (2002). Groundwater Resources of Ghana with Focus on International shared Aquifer Boundaries. CSIR Water Research Institute Accra, Ghana. Pp: 77-81.
- APHA/AWWA/WEF, (2012). American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF), Standards Method for the Examination of Water and Wastewater, 22nd edition.
- Amuzu, A. T. (1997). The Impact of Urbanization and Development on Surface Waters in Ghana. Freshwater Contamination. Proceedings of Rabat Symposium S4. IAHS Publications, No. 243. 117.
- Anornu, G. K., Kortatsi, B. K. and Zango, M. S. (2009). Evaluation of Groundwater Resources Potential in the Ejisu-Juaben District of Ghana. African Journal of Environmental Science and Technology. 3 (10): 333-339, Available online at http://www.academicjournals.org/AJEST ISSN 1996-0786 © 2009 Academic Journals.

- Ansa-Asare, O. D., Mensah, E., Entsua-Mensah, M. and Biney, C. A. (2008). Impact of Human Activities on Nutrient and Trophic Status of some Selected Lagoons in Ghana. West African Journal of Applied Ecology. 12: 5-10.
- Awuah, E. and Fiakuma, E. (2007). State of Sanitation in Accra. SWITCH: Accra visioning and scenario planning workshop. Pp 1-5.
- Awuah E., Nyarko, K. B. and Ofori, D. (2008). Local Initiative in Community Water Supply: Case study in Ashanti Region, Ghana. Presented at Water and sanitation in International Development and Disaster Relief International Workshop Edinburgh, Scotland (assessed on 25/05/2012).
- British Global Survey, (n.d.). Groundwater Quality: Ghana. WaterAid, Ghana.
- Boadi, K. O. and Kuitunen, M. (2002). Urban Waste Pollution in Korle Lagoon, Accra, Ghana. The Environmentalist, Kluwer Academic Publishers, the Netherlands. 22: 301-309.
- CARE, (2012). Assessing Water Point Sustainability in Northern Mozambique. CARE water Team, United States of America.
- Chapman, D. and Kimstach, V. (1992). The Selection of Water Quality Variables in Water Quality Assessment. A Guide to the use of Biota, Sediments and Water in Environmental Monitoring. D. Chapman (Ed) published on behalf of UNESCO, WHO & UNEP, Pp. 51-119.
- CWSA (2007). Strategic Investment Plan (2008-2015). Accra, Ghana.
- Ejisu-Juaben Municipal Assembly, (2010). SEA Report.
- Fielmua, N. (2011). The Role of the Community Ownership and Management Strategy towards Sustainable Access to Water in Ghana (A Case of Nadowli

District). Research Fellow, University for Development Studies, Centre for Continuing Education and Interdisciplinary Research (CCEIR)

- Fuest, V., Ampomah, B., Haffner, S. A. and Tweneboah, E. (2005). Mapping the Water Sector of Ghana: An Inventory of Institutions and Actors. The GLOWA Volta Project. Center for Development Research, Germany. Pp. 9-12 **http://www.glowa-volta.de**
- Gebrehiwot, M. (2006). An Assessment of Challenges of Sustainable Rural Water Supply: The Case of Ofla Woreda in Tigray Region. Msc Thesis, Regional and Local Development Study (RLDS). A.A.U. Ethiopia.
- Gray, N. F. (1999). Water Technology: An Introduction for Scientists and Engineers. Arnold, London.
- Greenberg, A. E., Clesceri, L. S. and Eaton, A. D. (2012). Standard Methods for the Examination of Water and Wastewater. 20th Edition. APHA/AWWA/WEF, Washington DC.
- Gyau-Boakye, P. and Danquah-Siakwan, S. (2000). Groundwater as a Source of Rural Water Supply in Ghana. Council for Scientific and Industrial Research-Water Research Institute, Accra, Ghana.journal of Applied Science and Technology (JAST). Vol. 5, Numbers 1 and 2.
- Habtamu, A. B. (2012). Factors Affecting the Sustainability of Rural Water Supply Systems: The Case of Mecha Woreda, Amhara Region, Ethiopia. A Project Paper Presented to the Faculty of the Graduate School of Cornell University in Partial Fulfillment of the Requirements for the Degree of Master of Professional Studies.

- Hayson, A. (2006). Sustainability of Rural Water Supplies in Tanzania. Msc Water Management, Community Water Supply Option Cranfield University, Silsoe Institute of Water and the Environment.
- Hayward, T., Pearce, J., Etherington, A., Breslin,N., Norman, G., Parker, S., Tayler, K. and Bastin, G. (2011). GIS & mapping tools for water and sanitation infrastructure. AlexMusson.com. Version 1.
- JMP. (2010). Progress on Sanitation and Drinking Water. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. WHO Library cataloguing-in-publication Data.
- JMP. (2011). Definitions of Indicators. Available online at http://www.who.int/water_sanitation_health/monitoring/jmp04_2.pdf [(16-03-2013) last assessed].
- Kortatsi, B. K. (1994). Groundwater Utilization in Ghana Water Resources Research Institute Accra, Ghana. Future Groundwater Resources at Risk (Proceedings of the Helsinki Conference, IAHS Publ. no. 222)
- Kpordze, C. S. K. (2010). Source Water Development. Department of Civil Engineering; Kwame Nkrumah University of Science and Technology (KNUST). Lecture Notes Unpublished.
- Lockwood, H., Bakalian, A. and Wakeman, W. (2010). Assessing Sustainability in Rural Water Supply: The Role of Follow-Up Support to Communities. Literature Review and Desk Review of Rural Water Supply and Sanitation Project Documents.

- Monney, I. (2011). Assessing the Impacts of Sanitation in Unsewered Urban Slums and Water Resources: A Case Study of Old Fadama, Accra, Ghana, Kwame Nkrumah University of Science and Technology, College of Engineering; Department of Civil Engineering, Kumasi – Ghana. MSc Thesis Unpublished.
- Moriarty, P., Batchelor, C., Fonseca, C., Klutse, A., Naafs, A., Nyarko, K., Pezon, C., Potter, A., Reddy, R. and Snehalatha, M. (2011). Ladders for assessing and costing water service delivery. IRC International Water and Sanitation Centre Second Edition.
- Mukherjee. N. (1999). "Measuring Sustainability Recent Lessons from Indonesia". Waterlines vol.18 No.1 pg 13-16.
- National Water Policy. (2007). Government of Ghana, Ministry of Water Resources, Works and Housing. Accra, Ghana.
- Nkongo, D. (2009) Management and Regulation for Sustainable Water Supply Schemes in Rural Communities. Tanzania, WaterAid.
- Nyarko, K. B. (2009). Water and sanitation institutional arrangement. Lecture notes, unpublished.
- Obuobie, E. O. and Boubacar. B. (2010). Groundwater in Sub-Saharan Africa: Implications for food security and livelihoods. Ghana Country Status on Groundwater Final Report.
- Oteng-Peprah, M. (2008). Water Quality Problems of Community Wells in Villages around Tarkwa Goldmines. MSc Thesis Department of Civil

Engineering; Kwame Nkrumah University of Science and Technology (KNUST), unpublished.

- Parry-Jonnes, S., Reed, R. and Skinner, B. H. (2001). Sustainable Hand Pump Projects in Africa. Produced under the knowledge and Research, funded by the Department for International Development. United Kingdom.
- Peavy, S. H., Rowe, D. R. and Tchobanoglous, G., (1985). Environmental Engineering". McGraw-Hill International Editions Civil Engineering Series. Third edition.
- Powell, M. G., Black. R.D and Hickman. S. G (1992). Groundwater Quality and well Contamination Cooperate Extension Service.
- Sandow. M. Y., Duke. O., Bruce. B.Y and Abdul. A. S. (2012). A Factor Model to Explain the Hydrochemistry and Causes of Fluoride Enrichment in Groundwater from the middle Voltaian Sedimentary Aquifers in the Northern region, Ghana.
- Suraj, M. (2004). Urbanization and Water Resources Vulnerability in the Kumasi Metropolitan Area, Ghana. Linköping University, Sweden, Pp. 1-9.
- Tilton, J. (n.d). Drilling Water Wells by Hand. Ghana West Africa Missions.
- UNICEF and WHO (2011). Drinking water safety, equity and sustainability. New York.
- Vermont Department of Health, (2011). Coliform Bacteria in Water.

  http://healthvermont.gov/enviro/water/coliform.aspx#top[(20-03-2013 accessed)

- Versraeten, M. S, Fetterman, G. S., Sebree, S. K.,Meyer, M. T. and Bullllen, T. D. (2004). Is septoc waste affectingdrinking water from domestic shallow wells in Platte River in Eastern Nebraska?

- WaterAid. (n.d). Water point mapper User Guide. www.wateraid.org

- WaterAid, America. (n.d). Sustainable Technologies. http://www.wateraidamerica.org/what_we_do/how_we_work/sustainable_technologies/default.aspxSubsurface dams (10-03-13 last accessed).

- Water resource commission. (1996). Accra, Ghana.

- Water and Sanitation Monitoring Platform (WSMP). (2009 and 2011) Ghana summary sheet. Available online at www.wsmp.org[last accessed (02-11-2012)].

- WSP (n.d). Water Supply and Sanitation in Ghana. An AMCOW Country Status Overview. www.wsp.org last accessed 20-03-2013).

- Well, (1998). DFID Guidance, Manual on well water supply and sanitation programme. Available at online at **www.lboro.ac.uk.well** (03-03-2013 last assessed).

- Welle, K. (2007). WaterAid Learning for Advocacy and Good Practice: water and sanitation mapping: a synthesis of finding. WaterAid report.

- WHO (2004). Sulphate in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality.

- (WHO) (2008). Guidelines for Drinking-water Quality. Volume 1, Third Edition, Incorporating the First and Second Addenda.

- WHO / UNICEF, Joint Monitoring Programme for Water Supply and Sanitation Ghana (2012). Estimate for the use of Improved Drinking-Water Sources. Available online at www.wssinfo.org [(02-05-2013) last accessed].
- WHO (2011). Water Supply Coverage: Progress and Prospects, chapter 2. http://www.who.int/water_sanitation_health/publications/aww2.pdf [(16-03-2013].
- WHO (2011); (2006). Drinking Water Quality guidelines.
- Wood, M. (1994). Are Hand Pumps Really Affordable? Affordable Water Supply and Sanitation.20th WEDC Conference Colombo, Sri Lanka. CARE, Ethiopia. Pp. 132-133.
- Zaporozec, A., Conrad, J. E., Hirata, R., Johansson, P. O., Nonner. J. C., Romijn, E. and Weaver, J. M. C. (2002). Groundwater Contamination Inventory. Prepared for the International Hydrological Programme within Project 3.1 (IHP-V).

APPENDICES

APPENDIX A: COMMUNITY, NUMBER OF WATER POINT SOURCES AND MANAGEMENT TYPE

NAME OF COMMUNITY	TYPE OF MANAGEMENT	NO OF WATER POINTS LOCATED
Abenase	WATSAN	4
Abetrem	WATSAN	2
Achiase	WATSAN	5
Achinakrom	Unit Committee	15
Adumasa	Unit Committee	7
Afraku	Unit Committee	1
Akrome	WATSAN	4
Akyawkrom	WATSAN	16
Amangoase	Unit Committee	2
Ampabame	Unit Committee	11
Apemso	Unit Committee	2
Asotwe	Unit Committee	12
Atia	Unit Committee	5
Baman	WATSAN	4
Besease	Unit Committee	16
Boankra	Unit Committee	6
Bomfa	WATSAN	2
Bonwire	WATSAN	16
Bowohomoden	Unit Committee	1

Brahabebome	Unit Committee	1
Boamah Dumase	WATSAN	6
Deduako	Unit Committee	6
Donaso	Unit Committee	11
Doyina	WATSAN	15
Duampompo	WATSAN	6
Edwinase	Unit Committee	12
Ejisu	WATSAN	45
Esienimpong	Unit Committee	5
Hwereso	Unit Committee	4
Jamase	Unit Committee	13
Juaben	CWSDB	21
Juabenmma	Unit Committee	1
Kotei	Unit Committee	3
Krapa1	Unit Committee	2
Krapa 2	Unit Committee	2
Krapa new town	Unit Committee	20
Kubease	Unit Committee	5
Kurofrom	Unit Committee	3
Kwaso	CWSDB	5
Manhyia	Unit Committee	4
New Bomfa	WATSAN	6
New koforidua	WATSAN	8
Nkyerepoaso	Chief	2

Nobewam	WATSAN	3
Nsonyameye	Unit Committee	1
Odoyefe	WATSAN	4
Ofoase	Unit Committee	2
OKorase	Unit Committee	1
Onwe	CWSDB	10
Peminase	Unit Committee	4
Sarpe	Unit Committee	3
Timeabu	Unit Committee	3
Yaw Nkurmah	Unit Committee	7
Yeboakrom	Unit Committee	1

APPENDIX B: COMMUNITY AND WATER POINT SOURCES REQUIRED

Name Of Community	Private	Government / Community	Population	Estimated Number of Water Points	Number of Water Points From 1981-date	Excess / Deficit
Abenase		2	1944	7	4	-3
Abetrem		1	617	2	2	0
Achiase	1	1	4260	15	5	-10
Achinakrom	10	2	3156	11	15	4
Adumasa		3	4583	16	7	-9
Afraku		1	65	1	1	0
Akrome		1	2017	7	4	-3
Akyawkrom	10	1	2412	8	16	8
Amangoase		1			2	2
Ampabame	8	1	1125	4	11	7
Apemso		1	803	3	2	-1
Asotwe	8	1	3951	13	12	-1
Atia	1	3	2192	8	5	-3
Baman		3	1697	6	4	-2
Besease	12	1	5645	19	16	-3
Boankra	3	1	1241	5	6	1
Bomfa		2	3175	11		-11
Bonwire	8	1	6840	23	16	-7
Bowohomoden			88	1	1	0
Brahabebome		1	68	1	1	0
Boamah Dumase		3	1700	6	6	0
Deduako	1	1	1281	5	6	1
Donuaso	10	1	427	2	11	9
Doyina	7	2	3843	13	15	2
Duampompo	4	1	1372	5	6	1
Edwinase	10		917	3	12	9
Ejisu	15	2	14692	49	65	-4

Esienimpong	1	2	3475	12	5	-7
Hwereso		1	1327	5	4	-1
Jamase	11		594	2	13	11
Juaben	6	2	15367	51	21	-30
Juabenmma		1	230	1	1	0
Kotei		3	161	1	3	2
Krapa1	1	1	240	1	2	1
Krapa 2	1	1	1000	4	2	-2
Krapa New town	8	1	2404	8	20	12
Kubease		3	1350	5	5	0
Kurofrom			1000	4	3	-1
Kwaso		2	5389	18	5	-13
Manhyia	2	2	799	3	4	1
New Bomfa	4	1	431	2	6	4
New koforidua	1	4	3067	11	8	-3
Nkyerepoaso		1	1192	4	2	-2
Nobewam		1	4274	15	3	-12
Nsonyameye		1	274	1	1	0
Odoyefe		3	717	3	4	1
Ofoase		1	794	4	2	-2
Korase			922	4	1	-3
Onwe	2	6	5632	19	10	-9
Peminase		2	2478	9	4	-5
Sarpe		2	1075	4	3	-1
Timeabu		2	170	1	3	2
Yaw Nkurmah	5	2	415	2	7	5
Yeboakrom		1	400	2	1	-1

Negative (-) = number of water point sources required

Positive (+) = adequate water point sources

APPENDIX C: ANALYTICAL METHODS USED IN RESEARCH

(a)Parameters measured in-situ: Temperature, pH, TDS and EC

Apparatus

PC 300 Waterproof Handheld pH/Conductivity/TDS/Temperature meter

Procedure

A digital reading appears upon inserting the probes into the sample indicating first the values of pH and temperature. The sample is stirred and the digital reading allowed stabilise before recording. The "MODE" button which allows switching to other parameters was then used to read the values of TDS and EC.

(b) Chloride

The presence of chloride was determined by the Argentometric method as stipulated. The procedure used in this method involved the addition of 1.0mL K_2CrO_4 indicator solution to 20mL of wastewater. The solution was titrated with standard $AgNO_3$ titrant to a pinkish yellow end point. The procedure was repeated for an equal volume of distilled water, representing the blank. The concentration of chloride was computed using the equation below:

$$\text{mg Cl}^{-}/\text{L} = \frac{(A - B) \times N \times 34.50}{\text{mL sample}}$$

Where:

A = mL titration for sample,

B = mL titration for blank, and

N = normality of $AgNO_3$ (0.0141M)

(c). Faecal coliforms and total coliforms

Membrane filter technique using Chromocult Coliform Agar

Principle

Chromocult Coliform Agar determines the presence or absence of coliform bacteria and *E. coli, and salmonella* in water. A water sample is passed through the membrane that retains the bacteria. Following filtration, the membrane containing bacterial cells is placed on the media and incubated at 36 ± 1°C for 24 ± 1 h. Salmon to red colonies are recorded as coliforms. In contrast, dark-blue to violet colonies are recorded as *E. coli*. And green to turquoise colonies are counted as salmonella. Salmon to red, dark-blue to violet and turquoise colonies are recorded as total coliforms.

Procedure

In this method, an appropriate volume (100mL) of the water sample was filtered through a sterile micropore filter by suction, thereby capturing any coliforms. With the aid of sterile forceps, the filter membrane was placed aseptically and rolled onto the Chromocult Coliform Agar in a Petri dish. The dish was inverted, closed and incubated at 35°C

After 24 hours of incubation, the numbers of green to turquoise colonies are counted as salmonella by visual examination whiles dark-blue to violet colonies are recorded as *E. coli*. The sum of these two colonies is recorded as total coliforms.

(d)Principle Spectrophotometric analysis

A spectrophotometer is employed to measure the amount of light that a sample absorbs. The instrument operates by passing a beam of light through a sample and measuring the intensity of light reaching a detector. The beam of light consists of a stream of photons.

When a photon encounters an analyte molecule (the analyte is the molecule being studied), there is a chance the analyte will absorb the photon. This absorption reduces the number of photons in the beam of light, thereby reducing the intensity of the light beam. The fraction of light in the original beam that passes through the sample and reaches the detector (transmittance) and the amount of light absorbed by the molecules (absorbance) are used in computing the concentration of the absorbing molecule.

In this research, a DR/2400 Spectrophotometer (shown in Plate 2) was used in determining the concentration of Iron, Sulphates and Nitrates–nitrogen. The procedures involved are described below:

Plate C: DR/2400 Spectrophotometer

(d_1) Iron

FerroVer Method

Principle

FerroVer Iron Reagent converts all soluble iron and most insoluble forms of iron in the sample to soluble ferrous iron. The ferrous iron reacts with the 1.10 phenanthroline indicator in the reagent to form an orange color in proportion to the iron concentration.

Procedure

The concentration of iron was determined by initially selecting Program 265 Iron, FerroVer from the Hach Programs. A clean, round sample cell was filled with a known sample volume diluted to 10mL and the contents of one FerroVer Iron Reagent Powder Pillow added to it. The sample cell was swirled to mix the contents and the timer icon pressed to begin a three-minute reaction period. Another sample cell was filled with 10mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L Fe concentration was displayed. After the three-minute reaction period, the prepared sample was also placed in the cell holder and 'Read' button pressed. The concentration of iron was displayed in mg/L Fe.

(d_2) Sulphate

SulfaVer 4 Method

Principle

Sulphate ions in the sample react with barium in the SulfaVer 4 and form a precipitate of barium sulphate. The amount of turbidity formed is proportional to the sulphate concentration. The SulfaVer 4 also contains a stabilizing agent to hold the precipitate in suspension.

Procedure

Sulphate was determined by selecting Program 680 Sulphate from the Hach Programs. A clean, round sample cell was filled with a known sample volume and the contents of one SulfaVer 4 Reagent Powder Pillow added to it. The sample cell was swirled to mix the contents and the timer icon pressed to begin a five-minute reaction period. Another sample cell was filled with 10mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L SO_4^{2-} concentration was displayed. After the five-minute reaction period, the prepared sample was also placed in the cell holder after wiping the sample cell and the 'Read' button was pressed. The concentration of sulphate was displayed in mg/L SO_4^{2-}.

($d_{3)}$ Nitrate-nitrogen

Cadmium Reduction Method

Principle

Cadmium metal reduces nitrates in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt couples with gentisic acid to form an amber coloured solution.

Procedure

The concentration of Nitrate-nitrogen was determined by selecting Program 353 N, Nitrate MR from the Hach Programs. A clean, round sample cell was filled with a known sample volume and the contents of one NitraVer 5 Nitrate Reagent Powder

Pillow added to it. The sample cell shaken vigorously to mix the contents and the timer icon pressed to begin a one-minute reaction period. The timer icon is pressed again after the one-minute reaction for a five-minute reaction period to begin. Another sample cell was filled with 10mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The ‘Zero’ button was pressed and a 0.00 mg/L NO_3^--N concentration was displayed. After the five-minute reaction period, the prepared sample was also placed in the cell holder after wiping the sample cell and the ‘Read’ button was pressed. The concentration of Nitrate-nitrogen was displayed in mg/L NO_3^{-}N.

APPENDIX D: ANALYTICAL TABLES

Table D1: Turbidity, Temperature and pH of hand dug wells and boreholes

	Turbidity (NTU) (5)		Temperature (°C)		pH (6.5-8.5)	
	hand dug wells	**boreholes**	**hand dug wells**	**boreholes**	**hand dug wells**	**boreholes**
Mean	3.55	3.25	29.38	29.8	5.15	5.41
Standard Error	1.60	1.47	0.28	0.30	0.11	0.08
Standard Deviation	10.88	12.16	1.93	2.51	0.76	0.67
Minimum	0.18	0.12	26.00	26.60	3.56	4.06
Maximum	71.70	93.80	34.70	37.00	6.62	6.90

Table D2: Chemical Parameters of Hand Dug Wells

Hand Dug Wells	Conductivity	TDS	No_3-N	SO_4	Manganese	Iron	Lead	Total Hardness	Calcium Hardness	Chloride
WHO/EPA Guidelines Values	**125**	**0-1000**	**0-10**	**0-250**	**0.01**	**0.3**	**0.01**	**0-500**	**0-500**	**0-50**
Mean	161.802	83.872	0.507	13.179	0.026	0.074	0.065	50.739	28.075	25.674
Standard Error	18.902	9.664	0.121	2.051	0.004	0.011	0.005	5.025	3.731	6.689
Standard Deviation	128.198	65.546	0.824	13.911	0.026	0.073	0.037	34.081	25.304	45.364
Minimum	30.9	15.5	0.002	1	0.002	0.003	0.006	14	6.4128	0.9729
Maximum	569	309	3.6	69.13	0.156	0.343	0.182	144	126	275.91

All measurements are in mg/l except conductivity (µS/cm) and TDS (µS/m)

Table D3: Chemical Parameters of Boreholes

Boreholes	**EC**	**TDS**	**NO_3-N**	**SO_4**	**Chloride**	**Mn**	**Iron**	**Lead**	**Total Hardness**	**Calcium Hardness**
WHO/EPA Guideline Values	**125**	**0-1000**	**0-10**	**0-250**	**0-50**	**0.1**	**0.3**	**0.01**	**0-500**	**0-500**
Mean	238.86	120.34	0.50	15.73	23.69	0.030	0.213	0.064	66.50	36.99
Standard Error	20.72	10.40	0.11	1.40	2.07	0.001	0.083	0.008	5.77	3.80
Standard Deviation	170.93	85.76	0.91	11.53	17.03	0.040	0.683	0.066	47.55	31.30
Minimum	15.50	15.50	0.01	2.00	2.92	0.002	0.001	0.005	14.00	4.01
Maximum	794.00	397.00	6.40	65.00	85.97	0.240	5.367	0.450	260.00	142.00

All measurements are in mg/l except conductivity (µS/cm) and TDS (µS/m).

APPENDIX E: CHEMICAL ANALYSIS OF WATER SAMPLES IN THE GEOLOGICAL FORMATIONS OF GHANA

parameter	Gneiss	Granitic formation	Phyllite	Sandstone	Mudstone and shale	Sand & gravel	Limestone	Quartzite
pH	7.5	6.99	6.83	6.95	7.64	7.53	7.7	6.36
TDS	4888	387.38	211.2	533.45	424.66	632.04	946.77	398.26
calcium	595	49.38	32.09	28.08	26.10	68.72	58.08	42.06
magnesium	207.2	19.06	15.67	7.57	9.12	33.50	36.15	23.37
Sodium	720	47.99	11.67	262.55	125.39	134.45	296.77	24.53
Chloride	1790	73.48	9.90	70.42	42.04	173.56	196.86	103.61
Sulphate	1800	10.60	7.16	65.17	11.18	101.19	77.25	60.06
Bicarbonate	34	81017	104.14	97.49	189.29	154.59	149.66	67.05
Total iron	0.1	1.01	2.15	1.95	0.645	1.84	0.467	2.87
Manganese	0.05	0.44	0.39	0.17	0.10	0.22	0.16	0.45
Fluoride	0.25	0.35	0.315	0.775	0.57	0.60	1.76	0.23
Nitrate nitrogen	0.5	1.605	0.59	0.75	0.135	2.22	1.79	2.32
Total hardness	2340	172.49	123.70	70.76	222.77	230.35	229.94	179.61

(Source: Kortasi, 1994) (all values are in mg/l except pH)

APPENDIX F: Functions of WSDB or WATSANs

Terms and Abbreviations	Missions and responsibilities
Bye-laws of DAs	A DA “may make bye-laws for the purpose of any function conferred upon it by or under this Act or any other enactment” (GoG 1993: 37). Specifying as penalties fines etc. Every bye-law to be submitted to the Minister for approval or rejection
Bye-laws of WSDB or WATSANs	These organisations are advised to set up bye-laws or constitutions to regulate their cooperation. They shall be responsible for the management of the operation and maintenance of all water system in the service area of the communities within the jurisdiction of the DA’s. This mandate shall include the following specific aspects: • The preparation of plans for the establishment, rehabilitation and expansion and replacement of existing as well as new water systems in any community specified in the schedule to these bye-laws. • The determination of appropriate financial contributions by members of the community towards the capital cost of developing the community water supply; • Proposing an appropriate tariff to cover the cost of operation and maintaining the community water system, including capital depreciation, such tariff to be approved by the DA. • Recruiting and supervision qualified persons within the community to work as operators and managers of the community water system; • Contracting an outside agency where appropriate to carry out operations and maintenance or maintenance alone. • Recommending necessary byelaws (to be enacted by the DA) that would regulate water use, enforce tariff and other financial obligations and promote appropriate sanitation practices within the community; • Undertake public education and community training to promote tariff obligations and sound sanitation and hygienic behaviour within the community; • Set procedures and charges for services connection, disconnection, penalties for default and damages to the water subject to the approval of the DA. (MWH & CWSA 2003: 27f.)
Contracts)	DAs or communities are entitled to make their own contracts with private firms. To be specified: (MWH & CWSA 2000

(Source: Fuest et al (2005))

APPENDIX G: LIST OF PLATES

Plate 1: An Afridev pump at Odeyefe

Plate 2: An India Mark II pump at Abenase

Plate 3: A faulty Nira at Yaw Nkrumah

Plate 4: An interview with WATSAN members at Odoyefe

Plate 5: A BH at Kuofrom and HDW at Esienimpong showing a source of faecal contamination

Plate 6: A commrecialised borehole at Bonwire beside a toilet facility

Plate 7: A 20L gallon for fetching water

Plate 8: A 40L pan for fetching water

APENDIX H: LIST OF DATA COLLECTION TEMPLATES

Table H-1: Template for Data Collection

Date of Sampling:									
Location									
Name Of Community	**Type of Water Point**	**Latitude**	**Longitude**	**Number of Water Points**	**Type of Pump**	**Depth**	**Year of Installation**	**Functionality**	**Remarks**

TABLE H-2: Template for Data Collection

Name Of Community	Water Quality				Cost Recovery				
	pH	Turbidity	Conductivity	Temperature	Sales per day Avg	Managed by	Monthly bill maintenance	Cost of Construction/	Remarks