KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

GROUNDWATER QUALITY WITHIN KWESIPRAH, CAPE COAST, CENTRAL REGION, GHANA

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

BY

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DECLARATION

I hereby declare that this Thesis is the result of my own field work towards the MSc. and has been composed under supervision. It has not been submitted previously either wholly or partially for a degree in the Kwame Nkrumah University of Science and Technology or elsewhere, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this work to the almighty God Jehovah and my beloved late father; Mr. Albert Mensah and my Sweet mother Agnes Bannerman.

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I wish to express my heartfelt gratitude and profound appreciation to a number of people who have been extremely helpful to me in accomplishing this piece of research.

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ABSTRACT

Kwesiprah is a suburb of Cape Coast faced with the perennial shortage of tap or treated water for drinking as a result of seasonal rainfall variations resulting in the drying of the Kakum River which serves as a source of raw water for the Brimso Water Treatment Plant. Consequently, the inhabitants of Kwesiprah rely on groundwater (well) which have septic tank sited closed to them for their domestic activities. This study sought to find the potability of the hand-dug wells by subjecting the collected water samples (49) from seven selected hand-dug wells in Kwesiprah to physico-chemical and bacteriological analysis using standard analytical procedure. The results showed that chloride and total iron for some selected sites were above the WHO limit. Also, total coliform and faecal coliform were positive for almost all of the sites sampled with an exception of MAH2. The principal nutrients, nitrogen and phosphorus which are potential indicators of groundwater septic tank contamination by effluents were found to be below the WHO recommended guideline indicating that groundwater has not been contaminated by septic tank effluents. However, pH, Total dissolved solids, Magnesium, Calcium, Manganese, Sulphate, Fluoride, Total hardness, Alkalinity and Zinc were all below the WHO limit. Salinity levels at sampling sites were also found to be insignificant and hence the possibility of sea water intrusion and may be negligible. These low and high values obtained for some of these parameters might have their health implications with the exception of Nitrite and Zinc. The distance of wells from septic tanks were also found to be below the limits set by the Ghana District Schedules (30 m) and USEPA (15.42 m) which poses a cause for concern. Hence the need to improve upon the quality of this water source was suggested if it is to be used as a drinking water source.

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LIST OF ABBREVIATIONS

UN	-	United Nations
WHO	-	World Health Organisation
FAO	-	Food and Agricultural Organisation
WRI	-	World Resources Institute
DALYs	-	Disability Adjusted Life Years

UNESCO	-	United Nations Education, Scientific and Cultural Organisation
UNEP	-	United Nations Environmental Programme
GOG	-	Government of Ghana
GWCL	-	Ghana Water Company Limited
TDS	-	Total Dissolved Solids
EC	-	Electrical Conductivity
EPA	-	Environmental Protection Agency
GAMA	-	Groundwater Ambient and Monitoring Assessment
APHA	-	American Public Health Association
CCMA	-	Cape Coast Metropolitan Assembly
NTU	-	Nephrometric Turbidity Unit
EDTA	-	Ethylenediaminetetraacetic acid
USEPA	-	United States Environmental Protection Agency
NPDES	-	National Pollutant Discharge Elimination System
NPDWR	-	National Primary Drinking Water Regulations
DST	-	Distance of well from Septic Tanks
DOW	-	Depth of Well

CHAPTER ONE

INTRODUCTION

1.1 Introduction

One of the most important resources for the sustenance of ecosystem, agriculture and human settlements is water. However, a serious problem to the worlds‘ drinking water sources results from climate change. This is leading to most Sub-Saharan African countries becoming water stressed as has been documented by the United Nations (UN) ―International Decade for Action _Water for Life‘ 2005 – 2015‖ programme. According to the UN Water for Life programme, Sub-Saharan Africa has the largest number of water-stressed countries of any region and with the existing climate change scenario, almost half the world's population will be living in areas of high water stress by 2030, including between 75 million and 250 million people in Africa. In addition, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people (UN, 2014).

One of most important natural resources in Ghana includes groundwater. Very large volumes of groundwater are pumped each day for industrial, agricultural, and commercial use. The World Water Day 2007 was dedicated to the theme "Coping with water scarcity". It highlighted the increasing significance of water scarcity worldwide and the need for increased integration and cooperation to ensure sustainable, efficient and equitable management of scarce water resources, both at international and local levels.

One important source of drinking water is groundwater and its quality is currently threatened by a combination of over-abstraction and microbiological and chemical contamination (Kolbel *et al*., 1988). Periodic changes in groundwater quality may result from change in the origin and constitution of the recharged water, hydrologic and human factors. According to Aksu and Vur (2004), the source of raw water may contain a wide variety of harmless heterotrophic

microorganisms such as *Flavobacterium* spp., *Pseudomonas* spp., *Acinetobacter* spp., *Moraxella* spp., *Chromobacterium*, *Achromobacter* spp. and *Alcaligenes* spp., as well as numerous unidentified or unidentifiable bacteria.

The Ghanaian citizen will always consider the quality and availability of groundwater as an important environmental issue. Long-term conservation, prudent development, and management of this natural resource are critical for preserving and protecting this priceless national asset.

In the WHO (2006) report, if per capita water availability is less than 1700 m^3 per year then the country is categorized as water stressed and if it is less than 1000 m^3 per capita per year then the country is classified as water scarce. Acute water shortages in Ghana linked to climate change could see the country become one of the world's water-stressed nations by 2025 (Deshpande and Gupta, 2004). The figure below shows the freshwater availability in cubic metres per person and per year in 2007.

According to Ashbolt *et al.* (2001) and Edberg *et al.* (2000), disease-causing microorganisms transmitted via drinking water are predominantly of faecal origin and referred to as enteric pathogens. It has been estimated by World Health Organization (WHO) that about 1.1 billion people globally drink unsafe water (Hunter *et al*., 2002) and the vast majority of diarrhoeal disease in the world (88 %) is attributable to unsafe water, sanitation and hygiene (Obire *et al*., 2005). Ashbolt (2004) reports that, poor water quality, sanitation and hygiene accounts for 1.7 million deaths a year worldwide (3.1 % of annual deaths) and 3.7 % of the annual health burden (disability adjusted life years [DALYs]) world-wide (54.2 million) mainly through infectious diarrhoea and nine out of ten such deaths are in children and virtually all of the deaths are in developing countries.

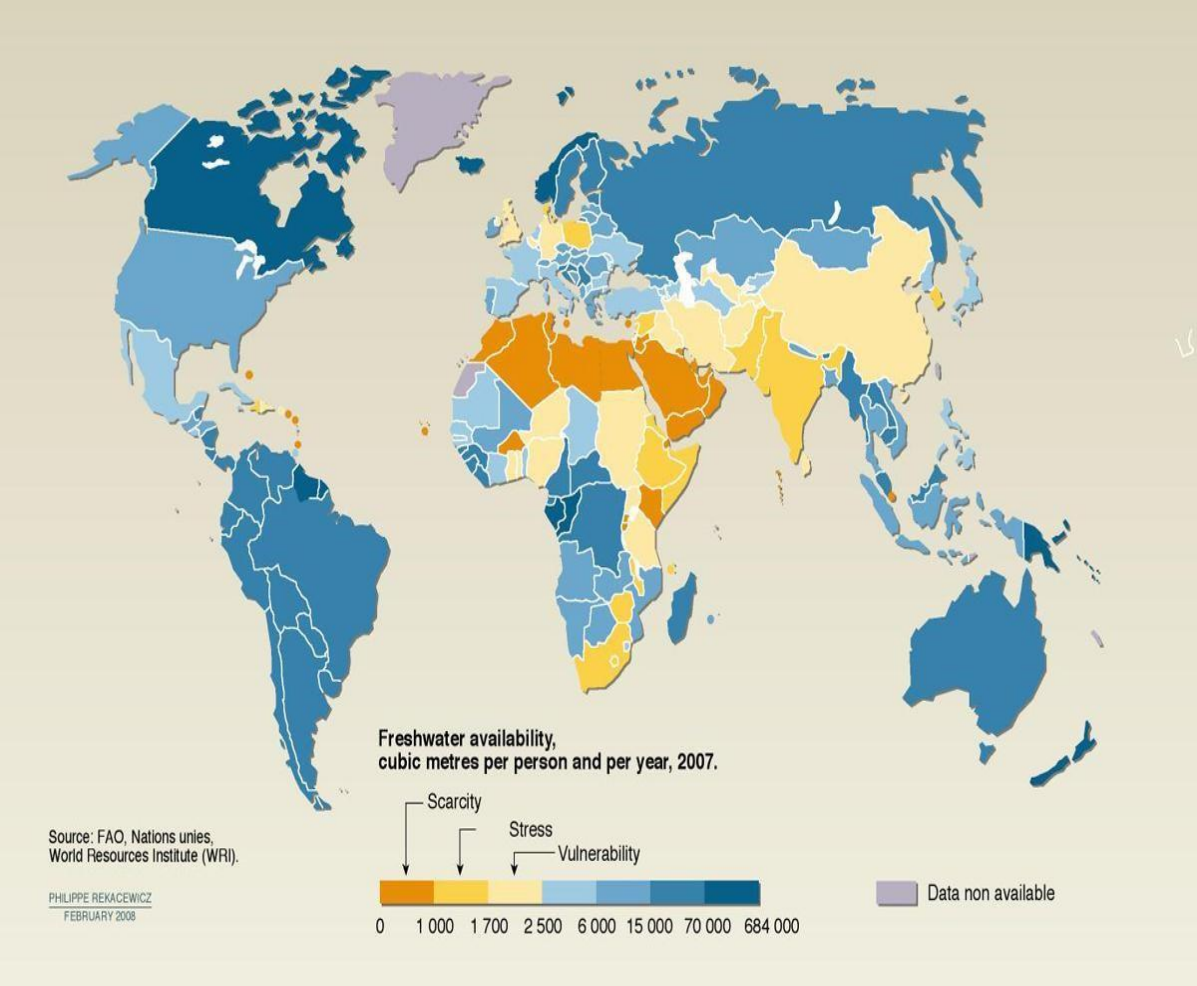

Figure 1: Map of freshwater availability in cubic metres per person and per year, 2007 Source: FAO, Nations unies, World Resources Institute (WRI).

1.2 Problem Statement:

Due to climate changes, water shortage is arising almost all over the world with Kwesiprah a community in Cape Coast North, Central Region of Ghana not being an exception. Due to perennial water shortages and closure of tap systems, most of the inhabitants within the community rely on underground or hand-dug well water for their domestic use.

Changing land use is also a threat to the quality of groundwater since most involves building construction which is mostly hostels that house students of the University of Cape Coast that do not take into consideration the siting of septic tanks. Since the water table within the community is quite high, the potential for faecal pollution is high and hence non-pathogenic

faecal organisms are best indicators of faecal pollution. In all cases however, faecal coliform contents and *Escherichia coli* is used as the major tool in the assessment of the health risk borne by pathogen in water (Byamuka *et al*., 2000).

Most of these hostels also have wells that serve their tenants with water supply when the taps go off. There are virtually no drainage systems within the community. The use of hand-dug wells to contain waste effluent is often common. This may result in reducing the percolation distance that the waste effluent would have filtered before getting to the under groundwater thereby increasing the possibility of groundwater contamination by surface water.

Also, the location of the community leaves much to be desired. The closeness of the community to the sea side requires the need to verify whether there is sea water intrusion which will render groundwater unusable for other domestic activities.

As a result of these issues, it is imperative to test the water quality of the groundwater to ensure its potability for domestic use and make recommendations for regular monitoring of the wells located within this community.

1.3 Significance of the study

The results of the study will help to establish whether there is groundwater pollution as a result of reliance on dugout wells to discharge of effluents and closeness of septic tanks to dugout wells. The results of the study will serve as baseline information on groundwater quality in terms of some selected physico-chemical parameters. The data obtained may also assist in advising government on policy regarding regulation for private groundwater provision in the

country and also advise on monitoring of groundwater quality for both domestic and commercial use in the country.

1.4 Objective

Main Objective

The study seeks to determine the groundwater quality in relation with distance from septic tanks.

Specific Objectives

The specific objectives are to determine;

1. Some physicochemical quality parameters of groundwater such as pH, conductivity, chloride, sulphate, phosphate, nitrite, nitrate and calcium;
2. Faecal coliform count as an indicator of microbial quality in groundwater;
3. Salinity levels in groundwater based on estimation using chloride levels in groundwater; and
4. If there is a correlation between the distance of well from septic tank and faecal coliform count;

1.5 Organisation of Study

The second chapter reviewed literature on the research mainly concerning factors that indicate groundwater contamination by effluent from septic tanks and some parameters that contribute to groundwater quality. The section also reviewed literature on the effect of over abstraction of groundwater in relation to salinity as a result of sea water intrusion.

Chapter three presents the methodology adopted for this study. It also describes the study area in terms of; climate and vegetation, topography and drainage, geology and soil, sampling and sampling procedures.

The fourth chapter reports the results of the comparative analysis of groundwater sample parameter value and their respective World Health Organisation guidelines as outlined in chapter three.

Chapter five discusses the results of the various parameters with reference to the purpose of study and previous findings as reviewed in chapter two. The discussion is presented according to the specific objectives. Chapter six presents the conclusions and recommendations.

CHAPTER TWO – LITERATURE REVIEW

2.1 Introduction

An important water resources issue in groundwater quality includes rapid increase of population, rapid industrialization, unplanned urbanization and excessive use of fertilizers and

pesticides in agriculture (Joarder *et al*., 2008). The major source of drinking water in both urban and rural areas is groundwater. The significance of groundwater for the existence of human society cannot be over emphasized. Natural factors are not the result of groundwater crisis. Groundwater crisis has been caused by human action; much of ill health which affects humanity, especially in the developing countries can be traced to safe and wholesome water supply **(**Shyamala *et al*., 2009). Continued discharge of industrial effluents, domestic sewage and solid waste dump causes the groundwater to become polluted and caused health problems **(**Raja *et al*., 2002).

Lamikarna (1999) noted that, man's continued existence depends very much on the availability of water of good drinking quality which is of basic importance to human physiology. With the total availability of fresh water of good drinking quality, only 1 % part is available on land for drinking, agriculture, domestic power generation, industrial consummation, transportation and waste disposal (Mishra *et al*., 2002, Gupta *et al*., 2008, Tahir *et al.,* 2008). The physical, chemical and biological characteristic of water is what is meant by water quality **(**Diersing, 2009). During the last century our dependence on fresh water resources has acceralated due to rapid growth in world population and economic development **(**Postel, 1992) which has resulted in increasing numbers of cases of water borne diseases and other health hazards **(**Mishra and Bhatt, 2009). High amount of various ions, salts etc. contained in groundwater leads to various water-borne diseases provided we were using such type of water **(**Arvnabh *et al*., 2010). Numerous health problems resulting from unsafe drinking water in developing countries contributes to one billion or more incidents of diarrhoea that occur annually **(**Mark *et al*., 2002). According to World Health Organization (2000), there were estimated 4 billion cases of diarrhoea and 2.2 million deaths annually. One of the major causes of this disease is as a result of the consumption of unsafe water resulting from the gradual deterioration of water quality

due to the increase in human population and urbanization **(**Chan *et al.,* 2007). According to the United Nation Report (1978) consumable water level is up to 2 – 7 % of the total water content. 1 % of the groundwater level is threatened either directly or indirectly by pollution **(**Davis and Cornwell, 1991). Nonpathogenic faecal organisms are the best indicators of faecal pollution. However in all cases faecal coliform contents and *E.coli* is used as the major tool in the assessment of the health risk borne by pathogen in water **(**Byamuka *et al.,* 2000).

2.2 Groundwater

According to Chapman (1992), groundwater occurs in many different geological formations. Nearly all rocks in the upper part of the Earth‘s crust possess openings called pores or voids. In unconsolidated, granular materials the voids are the spaces between the grains which may become reduced by compaction and cementation. In consolidated rocks, the only voids may be the fractures or fissures, which are generally restricted but may be enlarged by solution.
The percentage of these openings or pores in a given volume of the rock determines the volume of water contained in the rock. This is referred to as the porosity of the rock. More stored water results from more pore spaces which result in higher porosity
(UNESCO/WHO/UNEP, 1996).

An aquifer is a unit of rock or an unconsolidated deposit that can yield a significant quantity of water. A rock unit or unconsolidated medium which can yield up to 13 litres per minute in Ghana constitutes an aquifer (Harvey, 2004). The limit to which soil pore spaces or fractures and voids in rock become fully saturated with water is called the water table (Harvey, 2004). Ground water recharge is the phenomenon by which water percolates down from the land surface adding to the groundwater. Sources of groundwater recharge includes rain water and snowmelt or from water that leaks through the bottom of lakes and rivers. Groundwater may be found by drilling or digging wells and may also appear on the surface as spring. A well is

usually an opening created to be able to gain access to groundwater. This may be in the form of a tube or bore lined with protective material or a shaft created by digging into the earth until the water table is reached. This water can then be brought to the land surface by a pump or a bucket and a rope (WHO, 2014). Groundwater can run out if more water is discharged than recharged. For example, during periods of dry weather, recharge to the aquifers decreases. If too much groundwater is abstracted during these times, the water table can fall and wells may go dry.

2.3 Groundwater Pollution

According to the Texas Groundwater Protection Committee (2012), groundwater contamination is defined as the detrimental alteration of the naturally occurring physical, thermal, chemical, or biological quality of groundwater. This may result from many sources, including current and past oil and gas production and related practices, agricultural activities, industrial and manufacturing processes, commercial and business endeavours, domestic activities, and natural sources that may be influenced by, or may result from, human activities. The process of industrialization and urbanization as a contributing factor to groundwater pollution has progressively developed over time without any regard for environmental consequences (Longe and Balogun, 2010) which eventually results in the deterioration of physical, chemical and biological properties of water (Isikwu *et al*., 2011). Any substance that is placed or injected in the ground has the potential to affect groundwater quality. Dry cleaners, photographers and hair salons are all businesses that serve as examples of potentially hazardous land uses due to the types of chemicals they routinely use. If these businesses operate on individual well and septic service, the chance of groundwater contamination, through an accidental spill or mishandling, is especially high. Other businesses normally considered environmentally sound, such as golf courses, can actually threaten groundwater. These

businesses often use relatively large amounts of lawn chemicals and can cause temporary "drawdowns" of the water table, affecting nearby uses. Directly applying these chemicals to the ground presents an uninterrupted opportunity for groundwater contamination. Such groundwater contamination could cost a community millions of dollars to remedy or destroy a primary water source. A report by the Geophysics

Study Committee of the Commission on Physical Sciences, Mathematics, and National Research Council, 1984 noted that, groundwater contamination may be localized or spread over a large area, depending on the nature and source of the pollutant and on the nature of the groundwater system. A problem of growing concern is the cumulative impact of

contamination of a regional aquifer from nonpoint sources (i.e., those that lack a well-defined single point of origin), such as those created by intensive use of fertilizers, herbicides, and pesticides. In addition, small point sources, such as numerous domestic septic tanks or small accidental spills from both agricultural and industrial sources, threaten the quality of regional aquifers.

For many communities, groundwater is the only possible source of fresh water for drinking. Clean-up of groundwater contamination sites is expensive and slow, and often creates hardships for the persons affected. Groundwater protection will become increasingly important as population densities in areas not served by public utilities continue to increase. In a watershed, contaminated groundwater has a potentially devastating effect. As a result, maintaining appropriate densities of development and proper disposal of sanitary sewer wastes are critical factors in ensuring the adequacy and quality of domestic water sources. The disposal of solid or liquid wastes in pits, abandoned boreholes or even stream channels and landfills may also cause groundwater pollution (Onunkwo and Uzoije, 2011).

2.4 Septic tanks and Groundwater Pollution

The largest sources of wastewater to the ground are subsurface sewage disposal systems and this are the most frequently reported causes of groundwater contamination (Miller, 1980).

The total volume of waste disposed of via septic tanks has been estimated as approximately 800 million gallon per year, virtually all of which is disposed in the subsurface (USEPA, 1977). This makes septic tanks the leading contributor to the total volume of waste discharged directly to groundwater. In order to safeguard public health and the environment the assessment of groundwater has become very crucial (Lin *et al.,* 2010).

Drinkable water is one that does not contain chemical substances or microorganisms in amount that can cause hazards to health (Alonge, 2005). According to Hancher (1991), the likelihood of groundwater contamination by these systems is greatest where septic tanks are closely spaced as in subdivided tracts in suburban areas and in areas where the bedrock is covered by little or no soil.

Alexander Boehm, a professor in the department of Civil and Environmental Engineering at Stanford University conducted a project which was published and revised in March 11, 2009, to show how groundwater polluted by effluent from septic tanks could impact on marine ecosystems that this groundwater discharges into. Although nutrient level that was increasing the proliferation of algal blooms along coastal line could be attributed to fertilizers spread on lawns and crops, the scientist ruled out that possibility because of the concomitantly high levels of human faecal indicator bacteria detected in groundwater samples collected between the septic systems and shorelines.

Faecal and chemical (from industries and farms) contamination, combined with the failure to adequately treat water, have been incriminated in many water borne epidemics (CDC, 1993;

Bridgman *et al*., 1995). In 2004, the risk of contaminated water for people was manifested in Lake Erie, Ohio, USA when 1450 people became ill as a result of a pathogen in the well water (Fong *et al*., 2007).

The transport and contamination of groundwater by bacteria can be affected by climatic conditions, land use patterns, vegetative cover, topography, soil and geologic characteristics, well condition, location of potential pollution sources, and agricultural management practices (Bourne, 2001). Several factors affect the microbiological quality of groundwater.

Hancher (1991) reported that, concentrations of ions such as calcium, chloride, sulphate and sodium which are commonly used as indicators of sewage contamination were typical of uncontaminated groundwater. The principal nutrients reported by Miller (1980) are nitrogen and phosphorus which are potential indicators of groundwater, septic tank contamination by effluents. In places where the depth to bedrock is shallow, there is little interaction with the soil and, therefore, contaminants are not effectively removed (Conboy and Goss, 2000). Not all sites are suitable for septic systems. Of major concern is the soil at the site. Soils that are too coarse or too fine can limit the efficiency of the treatment system. A shallow, seasonally high water table or bedrock can also cause problems. Some of these problems can be overcome by altering the design of the septic system. According to the Ghana Districts Schedules (2006), a septic tank should be at least 30 m from any well, water-hole, spring or stream water used or likely to be used, by man for drinking and other domestic purposes and shall also be at an approved position which will not render any such water liable to pollution. However, USEPA (1997) sets a distance of 15.24 m between the siting of septic tank and well to avoid contamination of groundwater by septic tanks.

Where, they are properly sited, such as in sparsely populated areas and in soils with good drainage above the water table, septic tanks generally pose little or no hazard. However, even where septic systems are well drained, they may eventually pollute the groundwater. An improperly sited, designed, installed or operated septic system can pollute drinking and surface water. In such situations, sewage may contaminate wells in the area or move to the land surface, or both.

2.5 Water Policy

It is the responsibilities of the Ghana Water Company limited to ensure the overall planning, managing and implementation of urban water supply. However, only 41.4 % of people living in the urban areas have piped water in their homes whilst 42.6 % purchase water from a public tap or neighbour‘s residence (GOG, 2007). This shows that urban water supply by GWCL is insufficient for the urban community and there must be adjustments in policy implementation of urban water supply to ensure sustainable development as spelt out in Growth and Poverty Reduction Strategy II, New Partnership for African Development and the Millennium Development Goals, to which Ghana is signatory.

2.6 Groundwater Quality

Groundwater quality comprises the physical, chemical, and biological qualities of groundwater. Temperature, turbidity, colour, taste, and odour make up the list of physical water quality parameters. Groundwater is mostly colourless, odourless, and without specific taste, hence its chemical and biological qualities are of typical concern. Although spring water or groundwater products are often sold as ―pure,‖ their water quality is different from that of pure water.

Naturally, groundwater contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer. A list of the dissolved solids in any water is long, but it can be divided into three groups: major constituents, minor constituents, and trace elements. The total mass of dissolved constituents is referred to as the total dissolved solids (TDS) concentration. In water, all of the dissolved solids are either positively charged ions (cations) or negatively charged ion (anions). The total negative charge of the anions always equals the total positive charge of the cations. A higher TDS means that there are more cations and anions in the water. With more ions in the water, the water‘s electrical conductivity (EC) increases. By measuring the water‘s electrical conductivity, we can indirectly determine its TDS concentration. At a high TDS concentration, water becomes saline. Water with TDS above 500 mg/L is not recommended for use as drinking water (EPA secondary drinking guidelines). Water with a TDS above 1,500 to 2,600 mg/L (EC >2.25 to 4 mmho/cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance.

Except for natural organic matter originating from top soils, all of these naturally occurring dissolved solids are inorganic constituents: minerals, nutrients, and trace elements, including trace metals. In most cases, trace elements occur in such low concentrations that they are not a threat to human health. In fact many of the trace elements are considered essential for the human metabolism. In Europe, water from springs and wells with certain levels of trace elements has long been considered a remedy for ailments. Popular health spas usually are located near such areas. High concentrations of trace metals can also be found in groundwater near contaminated sources, however, posing serious health threats. Some trace constituents that are associated with industrial pollution, such as arsenic and chromium, may also occur in

completely pristine groundwater at concentrations that are high enough to make that water unsuitable as drinking water.

Microbial matter is also a natural constituent of groundwater. Just as microbes are ubiquitous in the environment around us, they are very common in the subsurface, including groundwater. Hydrogeologists increasingly rely on these, for instance, for subsurface bioremediation of contaminated groundwater.

Human activities can alter the natural composition of groundwater through the disposal or dissemination of chemicals and injection of wastes directly into groundwater. Groundwater pollution (or groundwater contamination) is defined as an undesirable change in groundwater pollution from agricultural activities. Improving the quality of groundwater resources offers an important economic opportunity for the gradual improvement of the quality of life (Valenzuela *et al*., 2009). Therefore, it has become necessary to monitor water quality to observe the pollution level of groundwater. The present work is a primary attempt to examine the groundwater in and around Kwesiprah.

2.7 Physico-chemical Indicators for Water Quality

The dissolved constituents in groundwater, including calcium, magnesium, sodium, potassium, bicarbonate, nitrite, sulphate and chloride occur in the form of electrically charged ions. Many minor constituents such as; iron, manganese and fluoride. Zinc and Lead are trace elements which may be found in groundwater. The pH measures the acidity or alkalinity of the water while the conductivity is the ability of the groundwater to conduct an electrical current. Conductivity is a function of temperature, types of ions present and the concentrations of the ions.

According to WHO (2006), fluoride, when present in drinking water at a concentration of about 1 milligram per litre (mg/L), helps prevent dental cavities. However, exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.

Generally, chemicals occurring in drinking-water are of health concern only after extended exposure for years. The only exception is nitrate. Nitrate and nitrite in water has been associated with methaemoglobinaemia, especially in bottle-fed infants. With a methaemoglobin level of 3 – 15 %, skin can turn to a pale gray or blue. Nitrate may arise from the excessive application of fertilizers or from leaching of wastewater or other organic wastes into surface water and groundwater (WHO, 2006). Anon (1987) reported that nitrite ion contains nitrogen in a relatively unstable oxidation state and that chemical and biological processes can further reduce nitrite to various compounds or oxidize it to nitrate. Fytianos and Christophoridis (2003) also report that the solubility and anionic form of nitrate makes it very mobile in groundwater and it tends not to adsorb or precipitate on aquifer solids (Hem,
1985). High chloride and sodium contents may impart saline taste, which may affect its acceptability for potable purposes. High concentration of sulphate may give bitter taste and also cause laxative effect (USEPA, 2007).

Calcium is obtained mainly from rocks containing limestone and gypsum. Small amounts come from igneous and metamorphic rocks while potassium occurs essentially in rock-salt deposits. Wastewater from industries and agricultural practices through excessive use of potash-rich fertilizers can also increase the potassium levels in groundwater. Changes in water quality occur progressively, except for those substances that are discharged or leach intermittently to flowing surface waters or groundwater supplies, such as, contaminated

landfill sites.

Hardness is a property of water that determines its ability to easily form lather with soap. Total hardness is directly related to the concentrations of calcium and magnesium. Iron and manganese in groundwater originate when water gets into contact with mineral groups and the weathering product that contain iron or manganese. Their concentrations can also be affected by wastewater from chemical industries. Excessive amount of iron and manganese are objectionable for both domestic and industrial water supplies because of their tendency to stain laundry and plumbing fixtures. According to WHO (2006), in areas with aggressive or acidic waters, the use of lead pipes and fittings or solder can result in elevated lead levels in drinking-water, which cause adverse neurological effects.

Guideline values are derived for many chemical constituents of drinking-water. A guideline value normally represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption.

2.8 Measurement of Salinity

―Salinity‖ can include hundreds of different ions; however, relatively few make up most of the dissolved material in water: chloride (Cl^-), sodium (Na^+), nitrate (NO^{3-}), calcium (Ca^{+2}), magnesium (Mg^{+2}), bicarbonate (HCO^{3-}), and sulphate (SO_4^{-2}). The concentrations of boron (B), bromide (Br^-), iron (Fe), and other trace ions can be locally important. Groundwater overdraft (over pumping) in some locations has caused the natural groundwater gradient to reverse and has allowed seawater to intrude coastal aquifers that historically contained only fresh water. Intrusion of seawater can ruin drinking water and irrigation wells, and render some areas unsuitable for continued agriculture. Salinity (TDS) is unrelated to the clarity of water. For example, visibility in the ocean can be hundreds of feet, even though ocean water has a

very high salinity (TDS of 35,000 mg/L) whiles water with low visibility like the Mississippi River can have low TDS (~200 mg/L) because the particles that obscure visibility are not dissolved, and can be easily filtered from the water. The amount of dissolved material in natural waters is a complex function of climate, land use patterns, human activity in the watershed, and geologic make-up of the hydrologic basin (GAMA, 2010). According to a research conducted by Abyaneh and associates, it was concluded that there was a good agreement and correlation between electrical conductivity and chloride ion concentration in water samples except for EC < 3dSm^{-1} (Abyaneh *et al*., 2004).

Measurement of EC is fast and inexpensive. On the other hand, Cl^- concentration typically is measured by titration of aqueous samples using standard $AgNO_3$ solution. Compared to EC measurement, chloride analysis is time consuming and expensive (Hajrasuliha et al. 1991). Since Cl^- is a major constitute of saline waters and soils, and it directly affects EC, therefore, a close correlation between EC and Cl is expected.

Electrical conductivity (EC) is usually a representation of salinity and it can be measured with a simple device such as the LF 92 conductivity meter.

2.8.1 Electrical conductivity, EC

The ability of an electric current to pass through water is proportional to the amount of dissolved salts in the water – specifically, the amount of charged (ionic) particles. EC is a measure of the concentration of dissolved ions in water, and is reported in µmhos/cm (micromhos per centimeter) or µS/cm (microSiemens per centimeter). A µmho is equivalent to a µS. EC can be measured in a laboratory or with an inexpensive field meter, also called specific conductance or specific conductivity.

The electrical conductivity of water, or EC_w, is the principal parameter used nowadays to measure a solution's salt content. Salinity hazard which is associated with high soluble salts in

water and measured in terms of Electrical conductivity (EC) can be measured quickly and easily, either in the laboratory or in the field. The readings are temperature dependent; therefore, measurements typically are corrected to an equivalent value at 25 degrees Celsius.

The internationally accepted standard unit for reporting EC is DeciSiemens per meter (dS/m). Note that this standard unit was adopted relatively recently. An older, equivalent unit often appears in water quality reports from the 1980s or earlier: millimhos per centimeter. (Although the term "mhos" may at first appear strange, it was chosen by early researchers for reasons that involve physics. EC, as its name implies, is a type of conductivity — the opposite of resistivity, measured in ohms. Hence, for EC, researchers adopted the term "mho"

— "ohm" written backwards.)

EC works well as a proxy for total dissolved solids because water‘s ability to conduct an electrical current is directly related to the concentration of salts in solution. In other words, salty water is a good conductor of electrical current, whereas pure water is a poor conductor. Waters that have EC in excess of 0.7 dS/m (corresponding to a TDS of about 450 mg/L) must be managed a bit more carefully if salinity problems are to be held in check. An EC of 3 dS/m (equivalent to a TDS of about 2000 mg/L) is the upper limit for nearly all landscape plants. (Most plants cannot tolerate salinity higher than that). Conductivity has the greatest precision, it responds only to ionic solutes.

2.8.2 Estimation of TDS from EC

A measure of TDS includes all dissolved substances in water, including organic and suspended particles that can pass through a very small filter. TDS is measured in a laboratory and reported as mg/L. Electrical conductivity of water is a direct function of its total dissolve salts (Kim *et al.* 2000). Hence it is an index to represent the total concentration of soluble salts in water (Kim *et al.* 2003). The total dissolved solids concentration in mg/L can also be calculated by

multiplying the conductivity result by a factor between 0.55 and 0.9, which is empirically determined (APHA, 1998).

A mathematical relationship between EC_w and TDS has been devised, making it easy to correlate one type of measurement with the other. For most water, TDS, in milligrams per liter, is equivalent to approximately 640 times EC, in DeciSiemens per centimeter.

TDS (in mg/L) = EC_w (in dS/m) × 640

The coefficient of 640 in the equation above is appropriate for a fairly wide range of conditions. For waters of mixed composition, consider using a factor of 735 instead, and for concentrated solutions with EC exceeding 5 dS/m, consider using a factor of 800.

2.8.3 Salinity and Chloride

One of the major inorganic *anions*, or negative ions, in saltwater and freshwater is chloride ion. It originates from the dissociation of salts, such as sodium chloride or calcium chloride, in water.

$$NaCl_{(s)} \longrightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

$$CaCl_{2(s)} \longrightarrow Ca^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)}$$

These salts, and their resulting chloride ions, originate from natural minerals, saltwater intrusion into estuaries, and industrial pollution.

The totality of all non-carbonate salts dissolved in water, usually expressed in parts per thousand (1 ppt = 1000 mg/L) is termed as salinity. Unlike chloride (Cl^-) concentration, salinity can be thought as a measure of the *total* salt concentration, comprised mostly of Na^+ and Cl^- ions. Even though there are smaller quantities of other ions in seawater (e.g., K^+, Mg^{2+}, or SO_4^{2-}), sodium and chloride ions represent about 91 % of all seawater ions.

Salinity is an important measurement in seawater or in estuaries where freshwater from rivers and streams mixes with salty ocean water. The salinity level in seawater is fairly constant, at about 35 ppt (35,000 mg/L), while brackish estuaries may have salinity levels between 1 and 10 ppt. Since most anions in seawater or brackish water are chloride ions, salinity can be determined from chloride concentration. A Chloride Ion-Selective Electrode can be used to determine the chloride concentration, which is converted to a salinity value using the above formula. The following formula is used:

Salinity (ppt) = 0.00180665 Cl^- (mg/L)

Salinity can also be measured in freshwater. Compared to seawater or brackish water, freshwater has much lower levels of ―salt ions‖ such as Na^+ and Cl^-; in fact, these ions are often lower in concentration than hard-water ions such calcium (Ca^{2+}) and bicarbonate (HCO_3^-). Because salinity readings in freshwater will be significantly lower than in seawater or brackish water, readings are often expressed in mg/L instead of ppt (1 ppt = 1000 mg/L).

2.9 Microbial Indicators for Water Quality

Consumption of drinking-water that is contaminated with human and animal excreta presents the greatest risk from microbes in water, although other sources and routes of exposure may also be significant. A combination of point and diffuse sources may increase the susceptibility of groundwater contamination from a shallow origin (Fuest *et al*, 1998; Nolan and Stoner, 2000).

Faecal indicator bacteria, including *E. coli*, are important parameters for verification of microbial quality. Analysis for faecal indicator bacteria provides a sensitive, although not the most rapid, indication of pollution of drinking-water supplies. Generally, faecal coliform count is done by using the MacConkey agar which allows the growth of gram-negative bacteria as a result of the ability to ferment the sugar lactose. Bacteria that ferment lactose cause the pH of the media to drop and the resultant change in pH is detected by neutral red, which is red in colour at pH‘s below 6.8. As the pH drops, neutral red is absorbed by the bacteria, which appear as bright pink to red colonies on the agar. The colour of the medium surrounding Gram-negative bacteria may also change. Strongly lactose fermenting bacteria produce sufficient acid to cause precipitation of the bile salts, resulting in a pink halo in the medium surrounding individual colonies or areas of confluent growth. Bacteria with weaker lactose fermentation growing on MacConkey agar will still appear pink to red but will not be surrounded by a pink halo in the surrounding medium. Gram-negative bacteria that grow on MacConkey agar but do not ferment lactose appear colourless on the medium and the agar surrounding the bacteria remains relatively transparent. Lactose can be replaced in the medium by other sugars and the abilities of gram – negative bacteria to ferment these replacement sugars is detectable in the same way as is lactose fermentation (Microbe library, 2012). Total coliforms are generally measured in 100 ml samples of water. A variety of relatively simple procedures are available based on the

production of acid from lactose or the production of the enzyme β-galactosidase. The procedures include Pour plate method followed by incubation of the media at 35 – 37 °C and counting of colony forming units after 24 hours (WHO, 2006).

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Study Area

The study area, Kwesiprah, is a newly created community that shares boundary with Amamoma, located at the northern side of Cape Coast in the Central Region. The community is bound to the east by Apeosika, north by Amamoma, to the south by the sea and to the west by Vegetation. The town has a population ranging from 280 to 1000 with fluctuation dependent on students residency during academic semesters.

The major economic activity within the community is hostel or room rental for non-resident students of the University of Cape Coast. The community lies closer to the wetlands or flood prone areas of Northern Cape Coast. Access to the community is mainly by feeder road and there are no commercial vehicles that ply the route hence residents have to walk long distances to the University Taxi Rank at North Campus for vehicular transport to their destinations. The drainage system within the community is totally absent resulting in residents resorting to dugout wells to empty their domestic waste effluents.

3.2 Climate and Vegetation

Kwesiprah is to the north of Cape Coast Municipality which lies in the littoral anomalous zone of Ghana which makes the municipality experiences high temperatures year round. The hottest months are February and March, just before the main rainy season, while the coolest months are between June and August.

The invariability in climate in the municipality is influenced more by rainfall than temperature. Cape Coast experiences relatively high temperatures throughout the year and is humid. Natural vegetation consists of shrubs, grasses and a few scattered trees (CCMA, 2006).

The original dense vegetation has been displaced, as a result of clearing for farming, charcoal burning, bush fires and other human activities. However, the northern part still has secondary forest, occurring due to the lower population densities. The municipality has a double maximal rainfall, with annual rainfall total between 750 mm and 1,000 mm (CCMA, 2006).

The present vegetation of the municipality consists of shrubs of about 1.5 meters high, grass and a few scattered trees. The original vegetation of dense shrubs, which the rainfall supported,

has been replaced by secondary vegetation as a result of clearing for farming, charcoal burning, bushfires and other human activities. Presently, trees are less dense in the area compared with the interior forest areas, except the occasional acacia plantations and bamboo shrubs found in a few sanctuaries not yet completely deforested.

The northern parts of the municipality are an exception to what has been described above. Here, secondary forests can be found and have survived mainly due to lower population densities and relatively little disturbance of the ecosystem (CCMA, 2006). However, this situation is changing due to increase in population density and changing land use mainly influenced by students‘ population influx during academic semesters at the University of Cape Coast.

3.3 Water Supply Situation

The Central Region of Ghana uses four (4) rivers (Kakum River, Arrissa River, Ochi Nakwa River and Ayensu River) as water resource for domestic water supply and irrigation. The Central Region has a total of about 8 operational water supply systems (WSS) with the Cape Coast (Brimsu) WSS being the second largest with a production capacity of 4 million gallons of water a day with more than 70 % of its consumers live in 5 towns with population more than 10,000, but can now barely produce 1 million gallons for the people of Cape Coast resulting in perennial water shortage within its distribution area. The Brimsu WSS obtains its raw water from the Kakum River for treatment and onward distribution to some coastal towns including Cape Coast and its environs. There is a short fall in water supply by 53 %, thus considering the design capacity and actual production of the dam at Brimsu. The shortfall in water supply worsens, particularly during the dry season when Brimsu dam capacity is further reduced by 35 % (Kumah, 2006).

However, the Cape Coast Supply project and Baafikrom water expansion project were inaugurated at Sekyere-Heman in 2008 to mitigate the perennial water shortage that was experienced in Cape Coast Municipality at the time but the Ghana Water Company said the projects were not completed to halt the problem entirely. This resulted in the water problem reaching a crisis level in the Cape Coast Municipality in May, 2013.

The drinking water delivery systems works perfectly when students are on vacation but when the academic semesters begin, the taps could be off for almost a semester with residents resulting to underground wells for their water supply for domestic chores. This problem is often associated with rapid population increase due to the influx of students who rent rooms within the community during the academic semester.

Also the demand for water by the halls (University of Cape Coast) account for this shortage in water supply by the Ghana Water Company.

3.4 Geological and Hydrological Background

3.4.1 Geology

The rock type of the district is of the Birrimian formation and consists of schist and introduced granites and pegmatite. The hills are generally overlain by sandy and clayey silts while the valleys are overlain by clayey gravel with lateritic soils exposed in a number of areas (Ghana Districts, 2013).

3.4.2 Soil

The dominant soils of the District are lateritic in nature and are derived mainly from the weathered granite and schist. Along the slopes the soil profiles have top soils with depths of

about 0.33 m while on the hills, loose to dense sandy soil of about 2.36 m in depth frequently occur. In the valleys and swampy areas, find sandy deposits occur extensively (Ghana Districts, 2013).

3.4.3 Topography & Drainage

The landscape of Cape Coast Municipality is dominated by batholiths interspersed with valleys. Located in the valley are several streams, the largest of which is the Kakum. Many of the steams end in wetlands and the Fosu Lagoon at Bakaano. The wetlands serve as barriers to physical development. In the northern parts of the district, however, the landscape is generally low lying and is suitable for the cultivation of various crops (Ghana Districts, 2013).

3.5 Pre-sampling Preparations

Groundwater samples (total 49) were collected from seven sampling sites from Dec 2012 – March 2013. The seven sampling sites were chosen because they were the only available sites for the study with reference to the main objective. These sampling sites were, FH (Florence Hostel), SL (Serwaa Lodge), MAH (Mr. Anane‘s Hostel), MAH2 (Mr. Anane‘s Hostel 2), MAH3 (Mr. Anane‘s Hostel 3), MBH (Macbeth Hostel) and AAH (Auntie Adwoa‘s Hostel). A map of the study area and a GPS (using the Garmin N202333 handheld GPS equipment) plot of sampling points showing the spatial distribution of wells from septic tanks are shown in figure 2 and figure 3 below. Sampling was done in the early hours of the morning (06:30 GMT) with a two week interval for resampling. The samples for physicochemical analysis were kept in an opaque container whiles that of the bacteriological analysis were kept in an ice chess containing ice packs for transportation to the Laboratory of the Department of Laboratory Technology for bacteriological analysis and Ghana Water Company at Cape Coast for the physicochemical analysis.

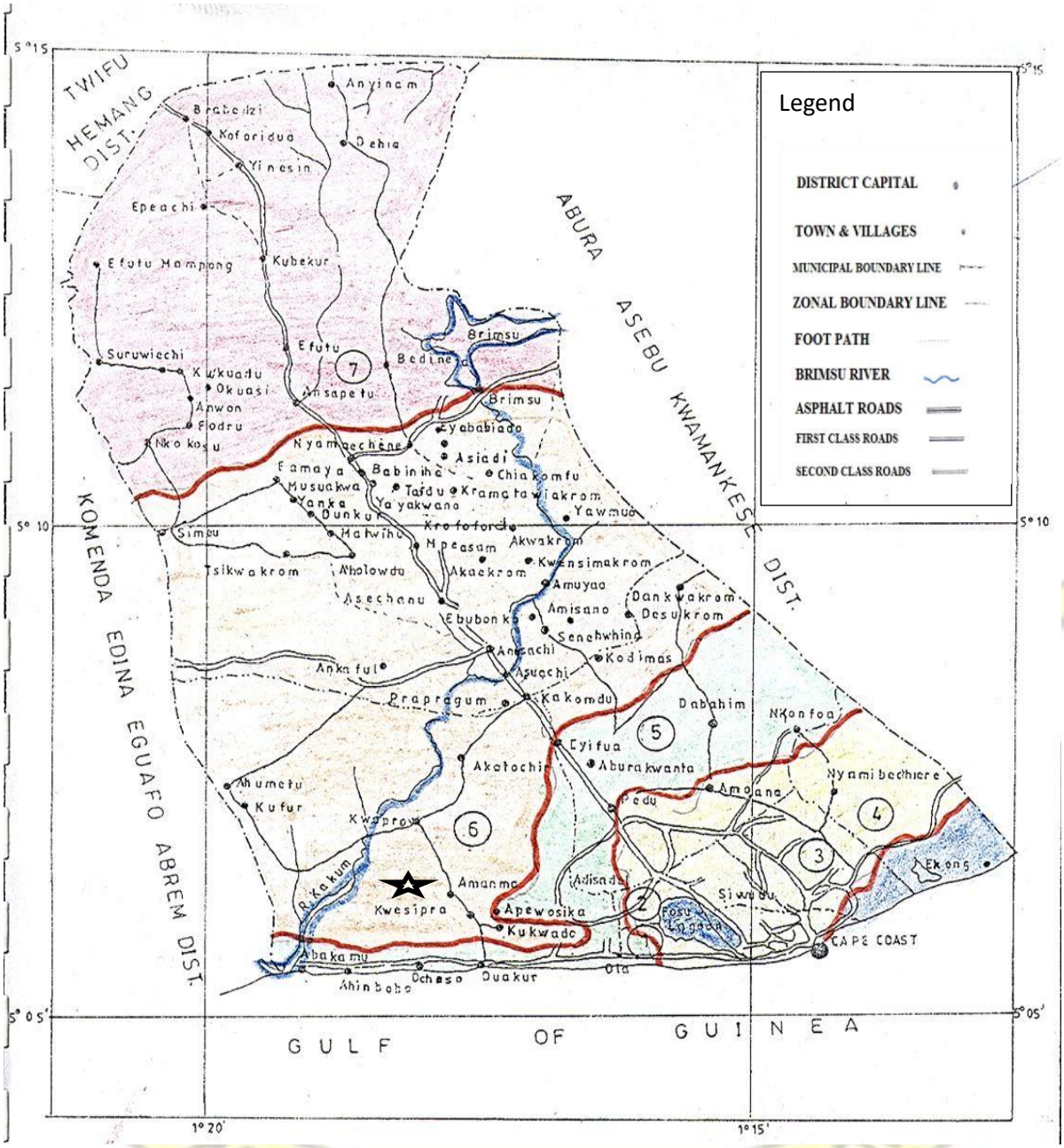

Figure 2: Map of Cape Coast North with Kwesiprah shown with the black star. Source: Cape Coast Metropolitan Development Report 2013.

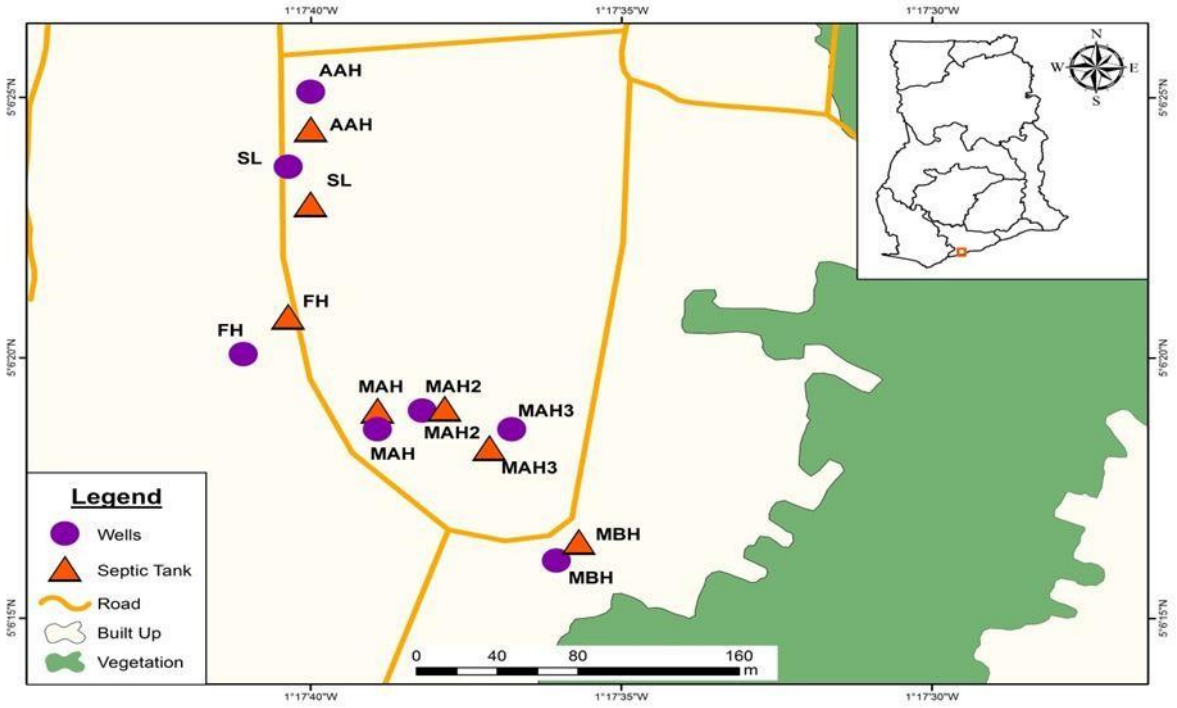

Figure 3: Map of study area showing various sampling points

3.5.1 Physico-chemical Parameters

The sample bottles of volume 1500 ml were thoroughly rinsed with distilled water. Upon reaching the sampling site, each bottle was rinsed with water from the respective well, thrice, before actual sample collection was done. Sampling at the various sampling sites was done every two weeks from December (2012) to March (2013).

3.5.2 Bacteriological Parameters

The sample bottles used for the microbial analysis were 500 ml new voltic bottles whose contents were emptied before the refilling with sample water. Resident buckets were used for the sampling from wells to avoid external contamination. The sampled water in the 500 ml voltic bottles was then kept in ice chess containing ice packs for transportation.

3.6 Sample Collection

Two samples of groundwater were collected at each site into two types of clearly labelled bottles, one for physico-chemical analysis (1500 ml) and the other for microbial analyses (500 ml). The samples were collected directly from the groundwater source with resident buckets at the wells. In all, seven samples each were collected from each of the seven sampling sites for laboratory analysis for physicochemical and faecal coliform counts. Each sample collected was preserved in a light-proof insulated box containing ice-packs to prevent possible alteration of parameters by light and also to ensure that the microorganisms remained viable though dormant.

3.7 Laboratory Analysis:

3.7.1 pH

The pH was measured with the MP125 pH meter. The electrode was first calibrated against a pH buffer of 4.01 ± 0.02, 7.00 ± 0.02 and 9.18 ± 0.02 at a temperature of 25 ^{o}C before using to read pH of the samples. The probe was placed in the sample for 3 minutes, allowing for a stable reading to be obtained and recorded on the pH on screen display.

3.7.2 Turbidity

A turbidimeter with sample cells, HACH model: HI88703 was used in reading the turbidity of the samples. The sample was shaken vigorously and 10 ml poured into the cell. The cell was wiped with a clean tissue to avoid finger prints from altering the readings. The turbidity value was read and recorded in NTU (Nephrometric Turbidity Unit).

3.7.3 Colour

The DR2800 Portable Spectrophotometer with Lithium-ion was used to check the colour of the samples obtained from the field. The appropriate program (121 LR Colour, 455 nm) was selected on the DR2800 meter and sample cells were rinsed with distilled water. The sample cell was rinsed again with the sample whose colour is to be determined before filling it. The sample cell filled with the sample to the 10 ml mark was placed into the DR2800 meter sample cell holder and then covered before the ―Read‖ button was pressed.

3.7.4 Electrical Conductivity

The conductivity was determined by means of the LF 92 conductivity meter. The conductivity cells and beaker were rinsed with a portion of the sample or distilled water. Then the beaker was filled two thirds of its volume. The probe was then inserted into the beaker containing the sample. The conductance was equilibrated to 25 ºC before the sample measurement.

3.7.5 Total Dissolved Solids (TDS)

The Total Dissolve Solids in the samples were computed by formula.

$$Total\ Dissolve\ Solids = \frac{Conductivity}{2}$$

3.7.6 Calcium (Ca) ion

The Ca ion in the samples were calculated from the formula

$$Ca^{+} = Ca\ Hardness \times \left(\frac{Atomic\ weight\ Ca}{100}\right)$$

$$Ca^{+} = Ca\ Hardness \times 0.4$$

3.7.7 Magnesium (Mg) ion

The Mg ion in the samples were calculated from the formula

$$Mg^{+} = Mg\ Hardness\ \times \left(\frac{Atomic\ weight\ of\ Mg}{100}\right)$$

$$Mg^{+} = Mg\ Hardness\ \times 0.243$$

3.7.8 Alkalinity

The sample was prepared by measuring 50 ml of the sample into a 250 ml Erlenmeyer flask and adding three drops of methyl orange to the sample aliquot. The prepared sample was then titrated against 0.02 N HCl until an end point was reached indicated by a yellow to orange colour change. The titre value was then multiplied by 20 (equivalent for the 1000 ml sample required for titration) to obtain the alkalinity of the sample.

3.7.9 Chloride ion

The sample was prepared by measuring 40mls of the sample into a 250 ml conical flask. One pillow of Chloride 2 indicator powder (equivalent to 10 ml) was mixed with the sample and swirled to get a yellow colour. The prepared sample was then titrated against Silver Nitrate (AgNO3) with 0.0010 N until an end point colour change of yellow to brown was reached. The titre value was then multiplied with 0.25 according to the Cartridge Number 0.2256 (This number determines volume of sample to use and number to multiply with the titre value).

3.7.10 Calcium Hardness

Ethylenediaminetetraaceticacid Acid (EDTA) Titration Method (APHA, 1995)

This method required two millilitres (2.0 ml) of 1M NaOH was added to 50 ml of sample. The mixture was stirred and 0.1 g of the murexide indicator was added. Titration was done immediately after the addition of the indicator. EDTA titrant was slowly added with continuous stirring until the colour changed from Salmon to orchid purple. The end point was checked by adding 2 drops of titrant in excess to make sure that no further colour change occurred.

The value was calculated using the formula:

$$Ca\ (mg/l)\ =\ A\ x\ B\ x\ 400.8\ \ ml\ of\ sample$$

Where A = ml of EDTA titrant used

B = ml of standard calcium solution ml of EDTA titrant

3.7.11 Total hardness

The sample was prepared by measuring 20 ml of the sample and adding 2 ml of Buffer solution to it. One ManVer2 Hardness indicator Powder Pillow was added to the sample aliquot and swirled to mix giving a red colour change. The prepared sample was then titrated against EDTA with 0.0004 M until an end point of a colour change from red to pure blue was obtained. The titre value was multiplied by 5.0 according to the required cartridge number of 0.800 to obtain the total hardness of the sample.

3.7.12 Magnesium Hardness

Calcium and total hardness were determined by EDTA titration method. Magnesium hardness was calculated from the difference between the total hardness and the calcium hardness which is expressed in mg/L. The magnesium concentration was obtained by multiplying magnesium hardness by 0.243.

$$Mg\ (mg/l)\ =\ magnesium\ hardness\ x\ 0.243$$

3.7.13 Total Iron

Method 8008 FerroVer® Method1 USEPA APPROVED (0.02 – 3.00 mg/L)

The DR2800 Portable Spectrophotometer with Lithium-ion was used in determination of the

Iron content in the sample. The appropriate program was selected on the DR2800 Portable Spectrophotometer with Lithium-ion for the display to show mg/L Fe. 10 ml of the sample was measured into one of the clean square sample cell. The content of one FerroVer Iron Reagent Powder Pillow was added to the sample in the sample cell. The development of an orange colour indicated the presence of iron in the sample. A reaction time of 3 minutes was allowed. A Blank preparation was made by filling a second square sample cell with 10 ml of sample, when the timer expired, the blank was inserted into the cell holder and the DR2800 was calibrated with it by pressing the zero button and waiting till the display showed 0.00 mg/L Fe. The prepared sample was then place into the cell holder after the blank was removed and the ―Read‖ button on the DR2800 was pressed to read the value of iron in the prepared sample. Results are displayed in mg/L Fe.

3.7.14 Zinc

Method 8009 Zincon Method*USEPA APPROVED (0 to 2.00 mg/L)

The DR2800 Portable Spectrophotometer with Lithium-ion was used in determination of the Zinc content in the sample. The appropriate program was selected on the DR2800 Portable Spectrophotometer with Lithium-ion for the display to show mg/L Zn. 50 ml of the sample was measured into a 100 ml beaker and the contents of one ZincoVer5 Reagent Powder Pillow was added. The beaker was swirled until the powder dissolved completely in the sample. 25 ml of the solution was poured into one sample cell (blank) and 1.0 ml of cyclohexanone was added to the remaining solution in the cylinder. The beaker was then swirled for 30 s for complete mixing. The solution was then allowed a reaction period of 3 minutes. The solution was then poured into a sample cell from the beaker. After reaction period, the blank was placed into the cell holder and the light shield closed. The absorbance meter was then zeroed with the blank for the display to show 0.00 mg/L Zn. The blank was the removed and replaced with the sample

cell and the light shield closed. The absorbance was read by pressing on the ―READ‖ button on the On Screen Display (OSD). The absorbance was read on the screen after a wait period and the value recorded. The procedure was repeated for the rest of the samples.

3.7.15 Sulphate ion

Method 8051 SulfaVer4 Method1 (2 to 70 mg/L)

The appropriate program was selected for sulphate on the DR2800 Portable Spectrophotometer with Lithium-ion. One pillow of SulfaVer4 Reagent Powder Pillow was added to 10 ml of the sample in a sample cell and the sample cell swirled until the powder dissolved in the sample. The formation of white turbidity showed the presence of sulphur. A 5 minute reaction period was allowed during which the cell was not disturbed. A second square sample cell was filled with 10 ml of the sample. The blank sample was used to zero the absorbance meter before the sample was read after the 5 minute reaction period. Results were read in mg/L SO_4^{2-}.

3.7.16 Nitrite ($\mathbf{NO_2^-}$)

Method 8153 Ferrous Sulphate Method1 HR (2 to 250 mg/L $\mathbf{NO_2^-}$)

The appropriate program was selected for reading absorbance of the samples in the cells. 10 ml of the sample was filled into a square sample cell. A square sample cell was filled with 10 ml of sample. The sample was prepared by adding the contents of one NitriVer®2 Nitrite Reagent Powder Pillow. The cell was swirled to dissolve the powder in the sample. A 10 minute reaction period was allowed. To avoid low results the sample was left on a flat surface and not disturbed. A blank was done by filling a second sample cell with 10ml of the sample. The blank cell was wiped and placed in the cell holder to zero the absorbance meter. The value shown on the display after the blank was 0 mg/L NO_2^-. After the timer expired the

sample was capped and inverted twice gently. The prepared sample was then inserted into the cell holder with the blank removed and the light shield closed before the absorbance was read in mg/L NO_2^-.

3.7.17 Nitrate (NO_3^-)

Method 8039 Cadmium Reduction Method HR (0.3 to 30mg/L NO3- -N)

The appropriate program was selected for reading absorbance of the samples in the cells.

10 ml of the sample was filled into a square sample cell. One pillow of NitraVer5 Nitrate Reagent Powder Pillow was added to the sample and stoppered. A 1 minute reaction period was allowed during which the cess as swirled until the time expired. Another 5 minute reaction period was allowed. After the sample reaction period expire, the blank wad placed in the cell holder of the absorbance meter and the meter zeroed with it. The display showed 0.0 mg/L NO_3^- -N. After this, the blank was replaced with the sample cell within 1 minute after the 5 minute reaction period expired. The ―READǁ button was pressed and after a wait period the absorbance was displayed on the screen in mg/L NO_3^- -N.

3.7.18 Phosphate (PO43-)

Molybdovanadate Method1 (Method 8114) (0.3 – 45.0 mg/L PO43-)

The program for determining phosphate was selected on the DR2800 Portable Spectrophotometer with Lithium-ion. A blank preparation was done by filling a square sample cell with 10 ml of deionize water. The sample was prepared by filling a second sample cell with 10ml of sample. 0.5 ml of Molybdovanadate Reagent was added to both the blank and the sample cell. The solutions were swirled to mix. A 7 minute reaction period was allowed. After the reaction period expired, the blank was wiped and inserted into the cell holder to zero the absorbance meter before reading the prepared sample. After the blank the absorbance meter

read 0.0 mg/L PO_4^{3-}. The prepared sample was then placed in the cell holder after the blank was removed and the absorbance read with the results recorded in mg/L

PO_{43-}.

3.7.19 Manganese (Mn)

1-(-2 Pyridylazo) -2-Naphthol PAN Method1 (Method 8149)

LR (0.006 to 0.700 mg/L)

The appropriate program for Manganese absorbance was selected on the DR2800 Portable Spectrophotometer with Lithium-ion. A blank was prepared by pouring 10 ml of deionized water into a square sample cell. The sample was prepared by pouring 10 ml of sample into another square sample cell and the contents of one Ascorbic Acid Powder Pillow were added to both the blank and sample cells each. It was then stoppered and inverted to dissolve the powder. 12 drops of Alkaline-Cyanide Reagent solution was added to each cell (both the blank and sample cell). The contents were then swirled in each cell gently to mix. A cloudy solution forms in both cells. 12 drops of PAN indicator solution, 0.1 %, was added to each sample cell and swirled gently to mix. An orange colour formation was observed in the samples showing the presence of manganese. A 2 minute reaction period was allowed. After the reaction period expired, the blank was wiped dry and inserted into the cell holder and the absorbance meter zeroed with it. The sample was then read by placing it in the cell holder after the blank was removed. The ―READǁ button was pressed and after a wait period the result was displayed on the screen reading in mg/L Mn.

3.7.20 Fluoride

Method 8029 USEPA SPADNS METHOD1 (0.02 to 2.00 mg/L F-)

The appropriate program is selected on the DR2800 Portable Spectrophotometer with Lithium-ion. 10 ml of sample was measured into a dry sample cell. A blank was done by measuring 10

ml of deionized into a second dry sample cell. 2.0 ml of SPADNS Reagent was carefully pipetted into each cell (both blank and prepare sample) and swirled to mix. A 1 minute reaction period was allowed. After the reaction period was expired, the blank was inserted in the cell holder to zero the instrument. The display showed 0.00 mg/L F^-. The prepared sample was then placed into the cell holder after removing the blank and the absorbance read in mg/L F^-.

3.7.21 Bacteriological Analysis of Groundwater samples

The pour plate method was used in determining two parameters, namely; Total Coliform and Faecal Coliform.

3.7.21.1 Total Coliform Determination of Groundwater samples

One ml of sample was pipetted into a sterile Petri dish and mixed with 15 – 20 ml of Plate Count Agar after being autoclaved and allowed to cool for sterilisation. The content of the Petri dish was allowed to solidify before incubating at 43 ^oC for 48 hours. After 48 hours, the plates were removed and the colony forming units counted for total coliform. All colonies on plates appeared as pale yellow with a foul smell confirming the presence of lactose fermenting microbes. The plates were replicated for each sample before incubating to allow for cross referencing.

3.7.21.2 Faecal Coliform Determination of Groundwater samples

One ml of sample was pipetted into a sterile petri dish and mixed with 15 – 20 ml of Mac Conkey Agar after being autoclaved and allowed to cool for sterilisation. The mixture was then allowed to cool in the plates and solidify before incubating at 44 ^oC for 48 hours and replicated. After 48 hours, the plates were removed and the colony forming units were counted for faecal

coliform. All colonies on each plate appeared as pink with yellowish spots with a foul smell indicating the presence of lactose fermenting microbes.

3.7.21.3 Procedure for Bacteriological Analysis

The inoculating bench was cleaned with detergents and wiped with 70 % ethanol before placing the sterile plates on it. A sterilised micro pipettes were used, making sure fresh pipette tips were used for each sample.

In all, fourteen sterile plates for both the faecal and total coliform were prepared for the pour plate method with one replicate for each sample. 1 ml of the sample was pipetted into respective plates and 15 to 20 ml of the appropriate growth medium was poured onto it. Each plate was swirled to ensure proper mixing of the sample with the agar and then allowed to cool in order to solidify. To avoid contamination, the mouth of the beaker was flamed after each pour. After it had cooled and solidified, it was then placed in the incubating chamber and the temperature regulated to 37 ^{O}C for 48 hrs.

For *Escherichia coli* identification, the plates with the Mac Conkey Agar were incubated again after the faecal coliform count at a temperature of 44 ^{O}C for another 24 hrs. After which the surviving colonies were counted for the presence of *E. coli*. After 48 hrs, the plates were observed and the microbial colony counts were made. Results of both the faecal and Total Coliform count are made available at the results page.

3.7.22 Data Analysis

The data of the physicochemical and faecal coliform analysis was entered in Microsoft Excel 2010 and transported to SPSS 16.0 for analyses. The summary statistics for mean, range and

standard deviation were generated but the mean and standard deviation were reported at the appendix.

The patterns of the variation of the water quality parameters in relation to the sampling sites were also generated using the Turkey Honest Significant Difference Post Hoc One Way Anova.

CHAPTER FOUR – RESULTS

4.1 Comparative Analyses of the Groundwater Sample Parameter Values and their respective W.H.O guideline values

4.1.1 pH results at sampling sites

The pH values which are shown in Figure 4 indicated that all the water samples tested were slightly acidic falling below the minimum WHO guideline of 6.5 for drinking water. In the research conducted, the pH of the underground water at the various site of sampling were acidic

and below the WHO recommended guideline for pH of drinking water. The underground sample from MAH2 well had the lowest pH level of 5.54 followed by sample from FH which recorded pH level of 5.66. The other five samples had pH levels ranging from 6.01 to 6.32. However, Anova test showed significant difference between sampling sites and a further detailed analysis using Turkey HSD Post Hoc analysis revealed significant difference between the sets of sampling sites categories i.e. MAH2 and FH did not show any significant difference between them ($p = 0.763$) but were significantly different from MAH,

AAH, and MAH3 ($p < 0.05$) which were also significantly different from MAH3 SL and MBH ($p < 0.05$) for all values of pH taken at those sampling sites. For the appropriate p values place refer to the appendix.

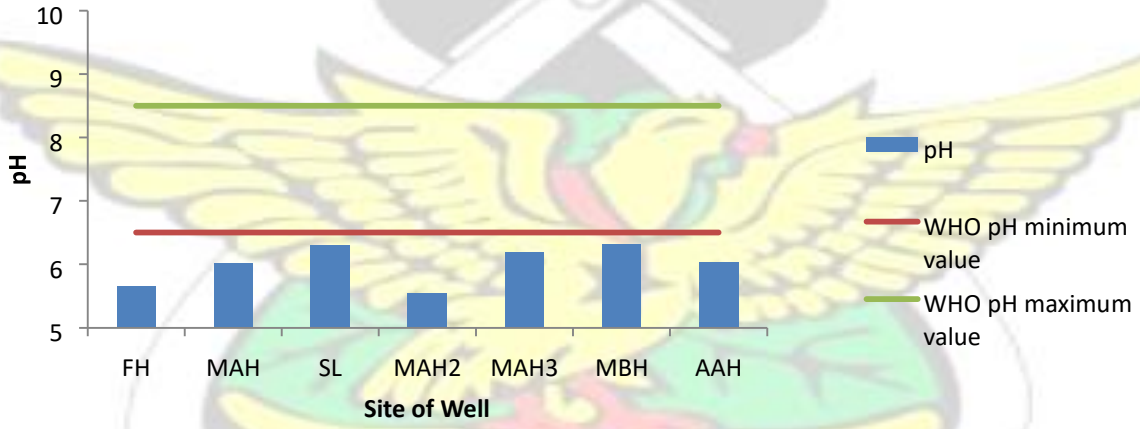

Figure 4: pH levels at various sampling sites compared with WHO standards.

4.1.2 Turbidity results at sampling sites

Figure 5 shows the comparison between turbidity at the seven sampling sites. The WHO limit for turbidity is also indicated. All the values were within the WHO safety guideline except for the value obtained for MAH. The turbidity values ranged from 0.43 NTU to 6.45 NTU. One Way ANOVA showed significant difference at all sites of sampling ($p < 0.05$). Post hoc analysis using Turkey HSD showed significant difference between AAH, SL, FH and MAH2, MAH3, MBH ($p < 0.05$). The appropriate p values are listed at the appendix.

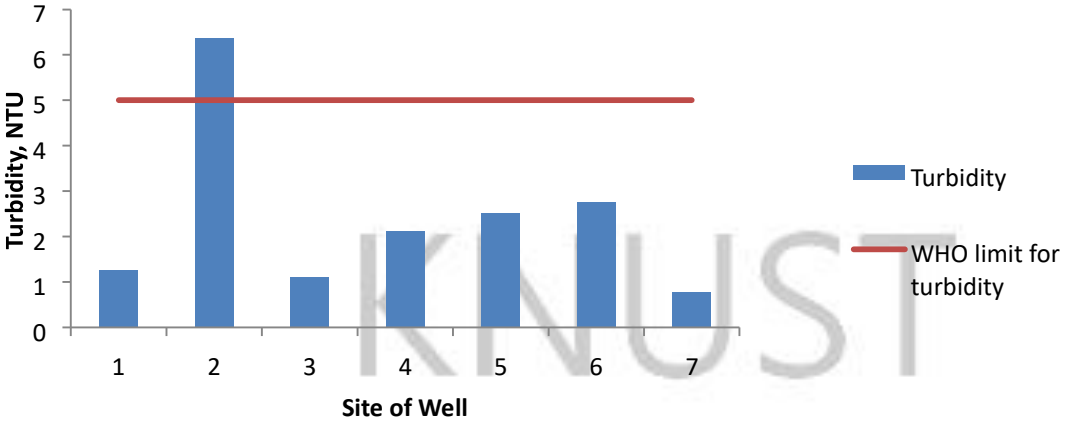

Figure 5: Turbidity levels at various sampling sites compared with WHO standards.

4.1.3 Chloride levels at sampling sites

Four of the sampling sites (MAH, MAH2, MAH3 and MBH) exceeded the WHO guideline for chloride levels of 250 mg/L as shown in Figure 7. These could have raised a concern for salinity check but the values were below 520 mg/L WHO standard for water to be considered saline. Sampling site AAH also recorded the lowest chloride level of 81 mg/L with the other two sampling sites FH and SL recording 183 mg/L and 191 mg/L respectively. The sites that were of concern for drinking water usage were MAH, MAH2, MAH3 and MBH which respectively recorded the following values 416 mg/L, 271 mg/L, 345 mg/L and 519 mg/L for chloride ion.

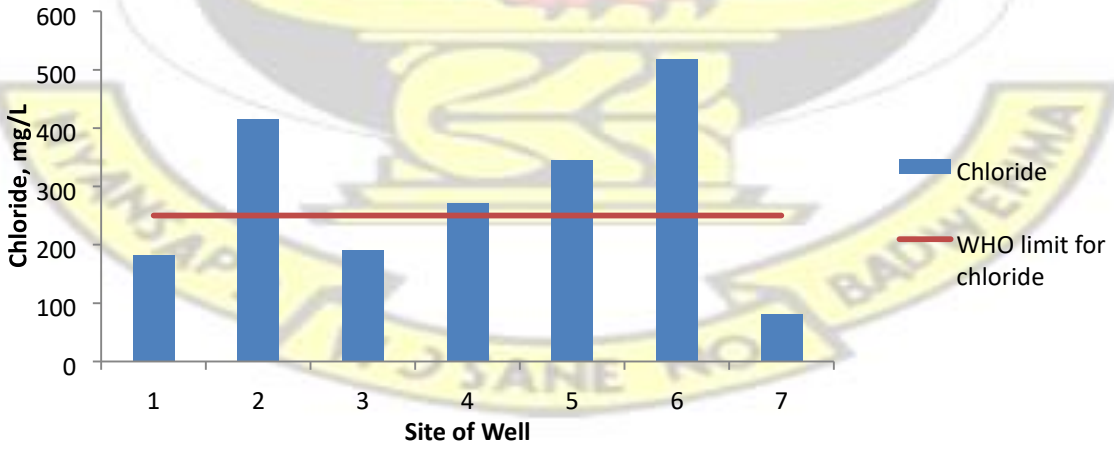

Figure 6: Chloride ion levels at various sampling sites compared with WHO standards

4.1.4 TDS levels at sampling sites

MBH recorded the highest TDS value of 776.5 mg/L with AAH recording the lowest value of 249.4 mg/L as shown below. AAH was significantly different from SL (p = 0.038)

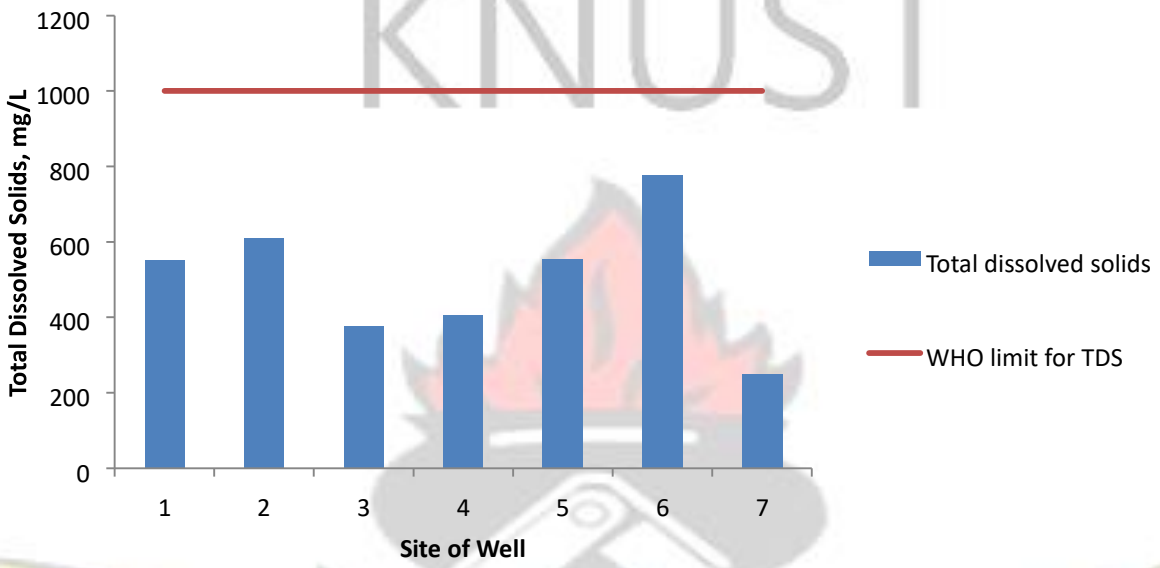

Figure 7: Total dissolved solids at various sampling sites compared with WHO standards.

4.1.5 Calcium levels at sampling sites

Calcium levels, a proponent for hardness of water recorded values below the WHO guideline of 200 mg/L with FH recording the highest of 126.76 mg/L. AAH recorded the lowest value of 36.34 mg/L. Also, Ca readings for sampling sites showed AAH being significantly different from MBH (p = 0.006) and MAH3 (p = 0.001) whiles MAH2 (p = 0.009) and SL (p = 0.031) showed significant difference with FH. All readings for Ca were below the WHO guidelines for drinking water.

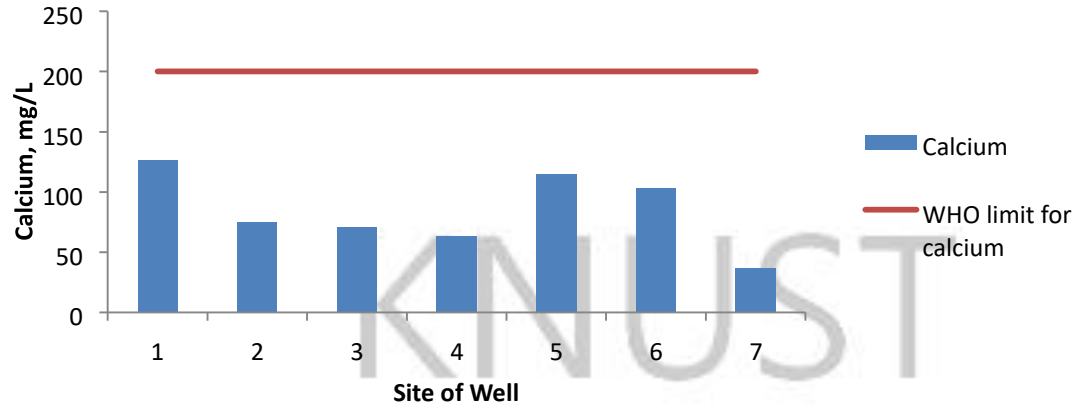

Figure 8: Calcium levels at various sampling sites compared with WHO standards.

4.1.6 Manganese levels at sampling sites

Manganese showed varying degrees of concentration with almost all within the WHO limits, except MAH3 falling on the WHO limit as shown in Figure 9. Manganese levels at the seven sampling sites were all below the WHO guideline of 0.5 mg/L with the closest recorded by MAH3 with a value of 0.49 mg/L. The other sites ranged from 0.05 mg/L (SL) to 0.21 mg/L (FH).

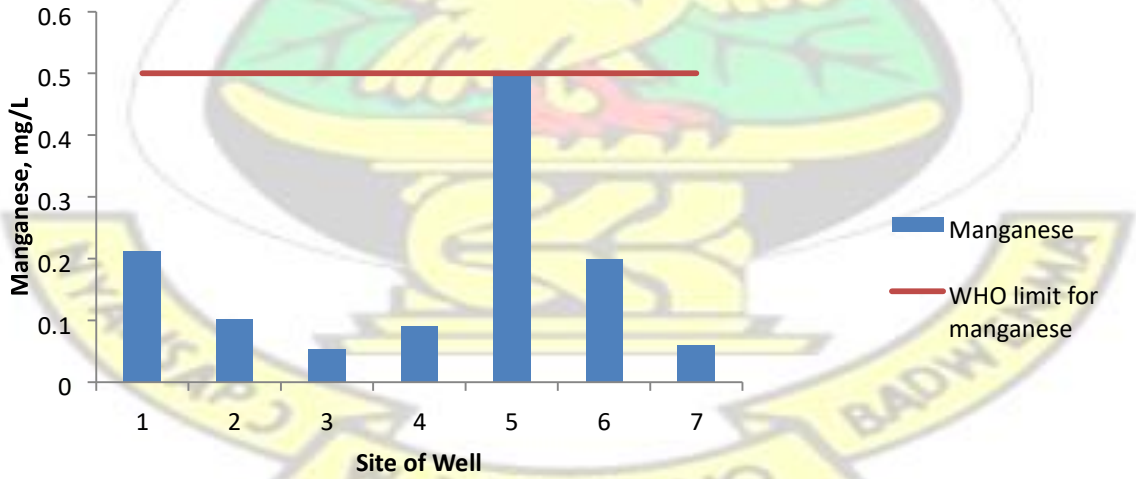

Figure 9: Manganese levels at the various sampling sites compared with WHO standards.

4.1.7 Magnesium levels at sampling sites

Magnesium, another compatriot for hardness of water was also not significant for the seven sampling sites compared to the WHO underground water which is 150 mg/L (see Figure 10). The highest value was however recorded by MAH3 with 12.49 mg/L and the lowest recorded by AAH with 3.05 mg/L.

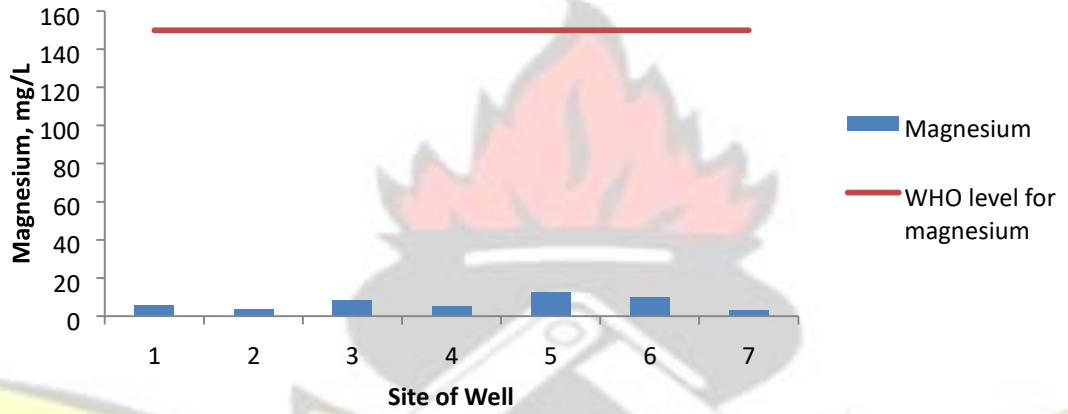

Figure 10: Magnesium levels at various sampling sites compared with WHO standards

4.1.8 Total Iron levels at sampling sites

The WHO guideline for total iron concentration of 0.30 mg/L were exceeded by two of the sampling sites (MAH and MAH3) with values of 0.37 and 0.35 mg/L respectively as shown in Figure 11. The rest of the samples from the other five sampling sites fell below the WHO guideline with the highest recording 0.27 mg/L for FH and the lowest 0.04 mg/L for SL. At levels greater than 0.3 mg/L because iron in water stains plumbing fixtures, stains cloths during laundering, incrusts well screens and clogs pipes (Deutsch, 2003).

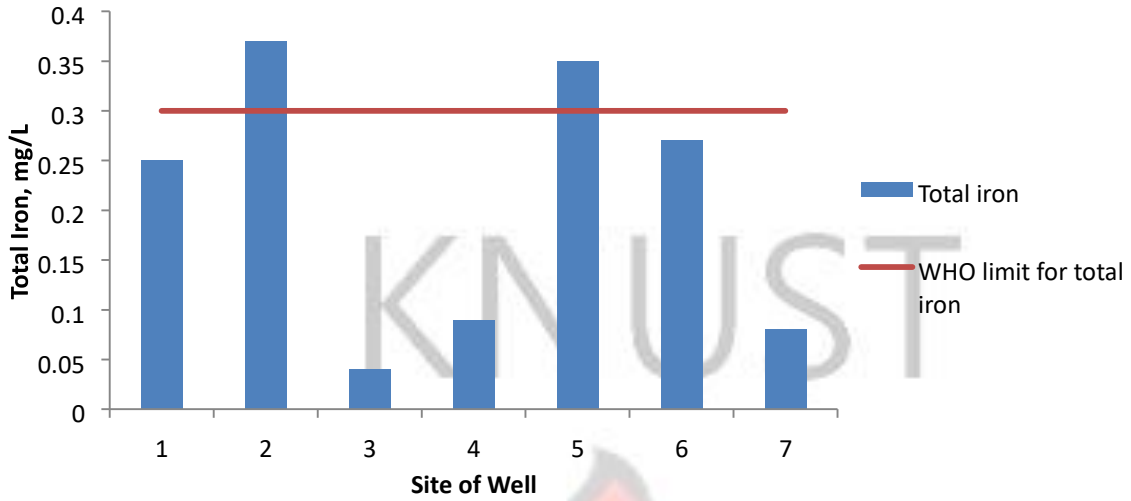

Figure 11: Total iron levels at various sampling sites compared with WHO standards.

4.1.9 Nitrite levels at sampling sites

The values of nitrite ranged from 0.00 mg/L (MAH) to 0.04 mg/L (MAH3). Nitrite readings for the sites did not show any significant difference between sampling sites except for MAH and MAH3 ($p = 0.04$). However, all nitrite levels at the various sampling sites were below the WHO guideline.

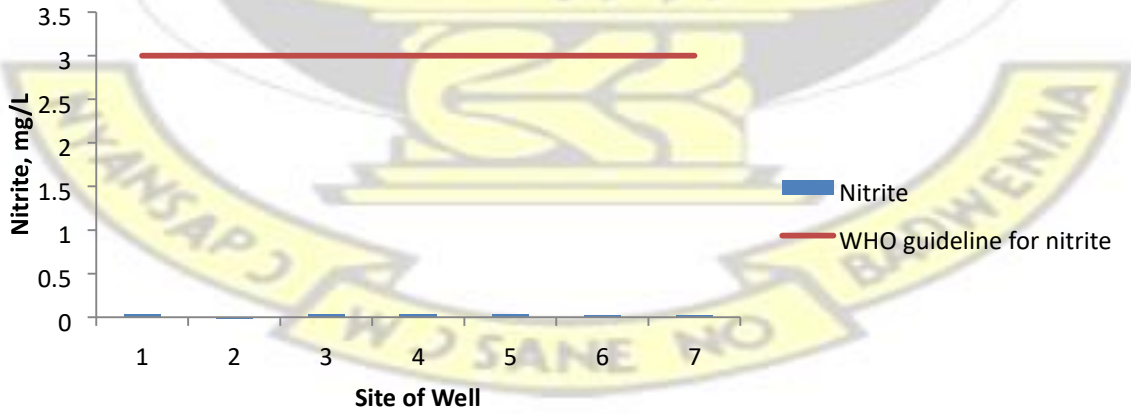

Figure 12: Nitrite levels at various sampling sites compared with WHO standards.

4.1.10 Nitrate levels at sampling sites

Nitrate levels shown in Figure 13 did not also show any cause for concern as values from seven sampling sites ranged well below the WHO guideline of 10 mg/L with the highest recorded by FH with 5.69 mg/L and the lowest 0.69 mg/L by MAH. Significantly, MAH, MBH and MAH2 did not show any difference between them but were significantly different from SL ($p < 0.05$) which was also significantly different from MAH3 and AAH ($p < 0.05$) which did not show any significance between them but were also significantly different form FH ($p < 0.05$).

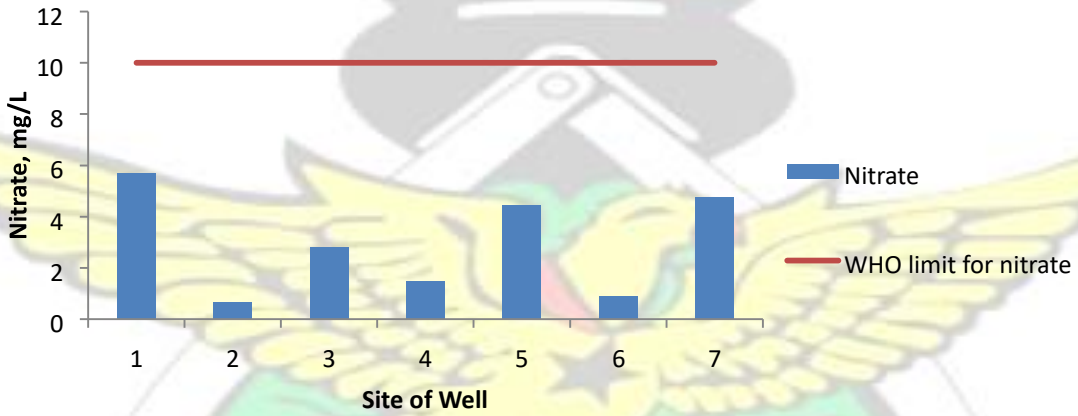

Figure 13: Nitrate levels at various sampling sites compared with WHO standards.

4.1.11 Total hardness levels at sampling sites

The level of hardness was within normal limits of 500 mg/L as shown in Figure 14. The WHO guideline for total hardness of 500 mg/L was not exceeded by all with the highest value recorded by FH (340 mg/L and the least recorded by AAH (99.66 mg/L).

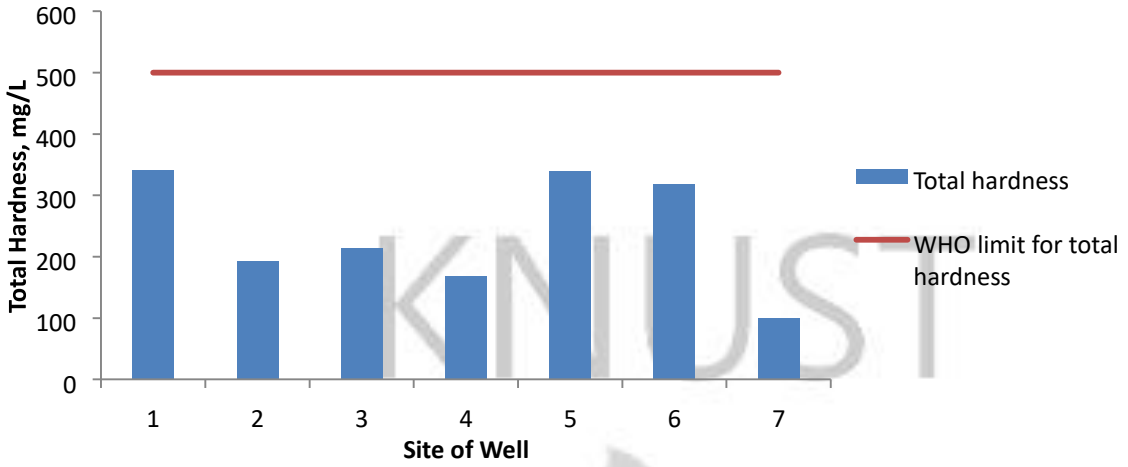

Figure 14: Total hardness levels at various sampling sites compared with WHO standards.

4.1.12 Fluoride levels at sampling sites

Fluoride levels for all seven sampling sites were below the WHO guideline of 1.5 mg/L as shown in Figure 15, had the highest level recorded by MBH with 0.35 mg/L and the least by AAH with 0.00 mg/L. AAH was significantly different from MAH ($p = 0.008$) with the rest of the significant differences shown in the appendix.

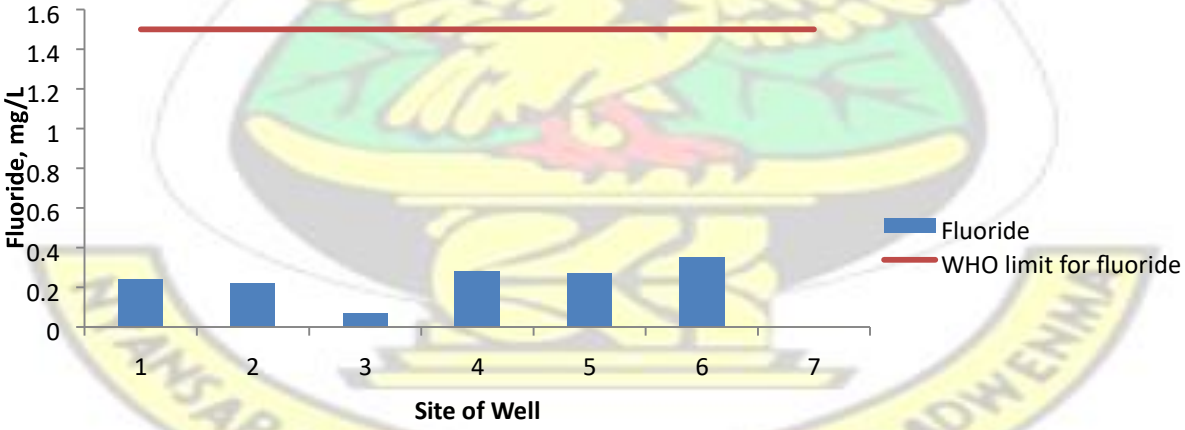

Figure 15: Fluoride levels at various sampling sites compared with WHO standards.

4.1.13 Alkalinity levels at sampling sites

Alkalinity levels indicated at the various sampling sites were all below the WHO limit of 120 mg/L with sampling site SL showing the highest increase though it fell below the WHO limit as shown in Figure 16.

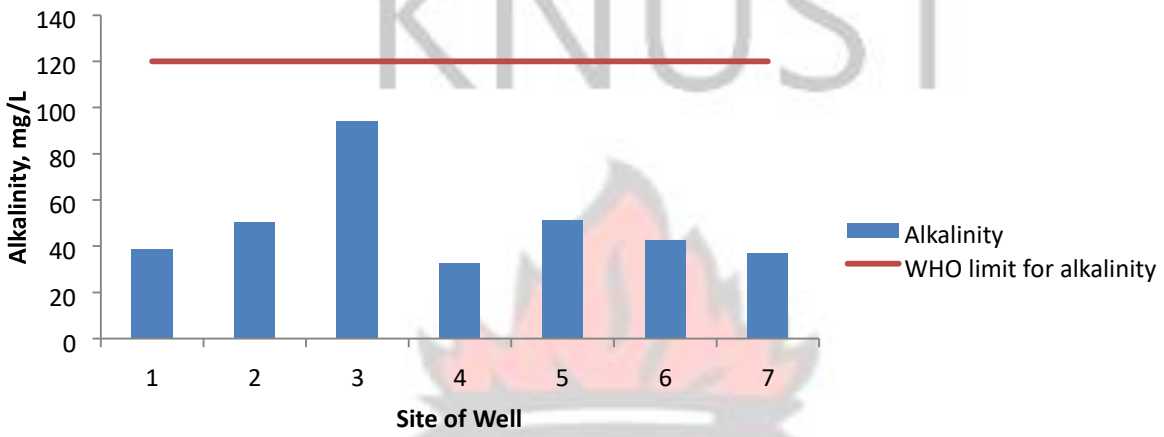

Figure 16: Alkalinity levels at various sampling sites compared with WHO standards.

4.1.14 Phosphate levels at sampling sites

All seven sampling sites had phosphate values well below the WHO guideline of 0.70 mg/L with the highest measurement being recorded by MBH with 0.28 mg/L and the least by MAH3 with 0.13 mg/L as shown in Figure 17. Phosphate readings did not show any significant readings between sites of sampling.

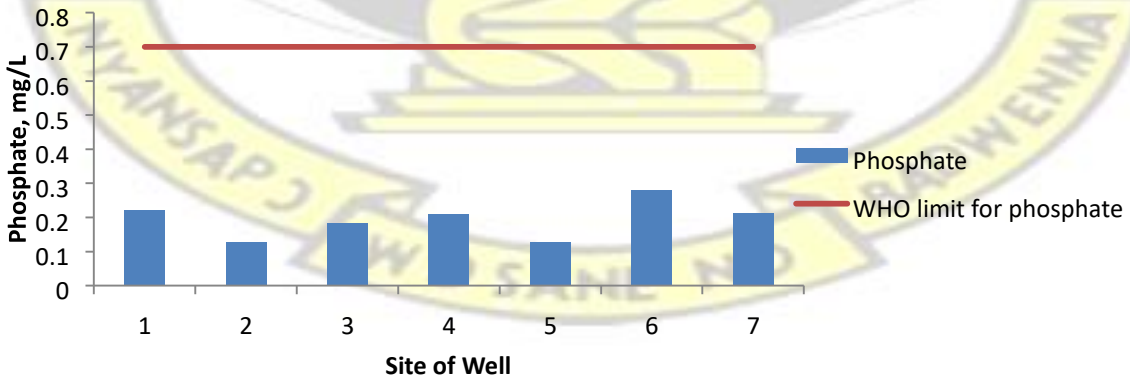

Figure 17: Phosphate levels at various sampling sites compared with WHO standards.

4.1.15 Zinc levels at sampling sites

The WHO guideline for zinc (5 mg/L) was not exceeded by any of the seven sampling sites with readings ranging from 0.00 mg/L to 0.10 mg/L for MBH and MAH3 respectively as shown in Figure 18.

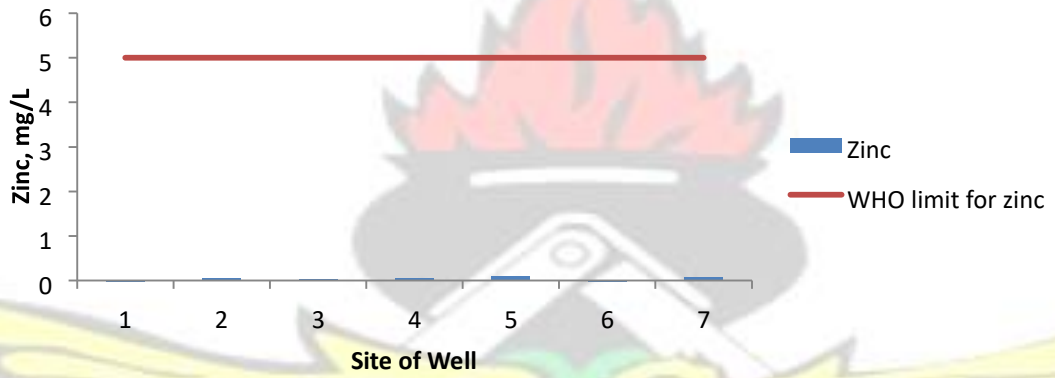

Figure 18: Zinc levels at various sampling sites compared with WHO standards.

4.1.16 Total and Faecal Coliform Count at sampling sites

All the seven sampling sites had their Total and Faecal coliform count exceeding the WHO limit with MAH2 recording the highest for both Total and Faecal coliform count per ml (Figures 19 and 20).

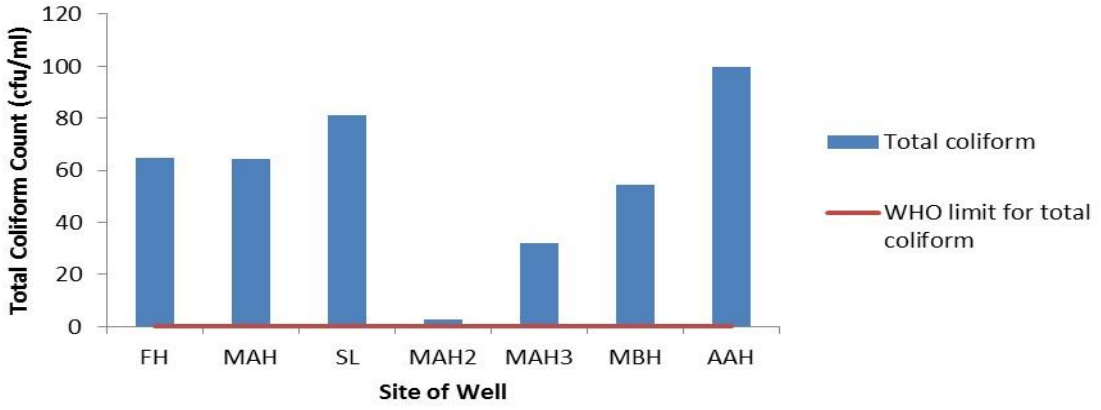

Figure 19: Total coliform counts at various sampling sites compared with WHO standards.

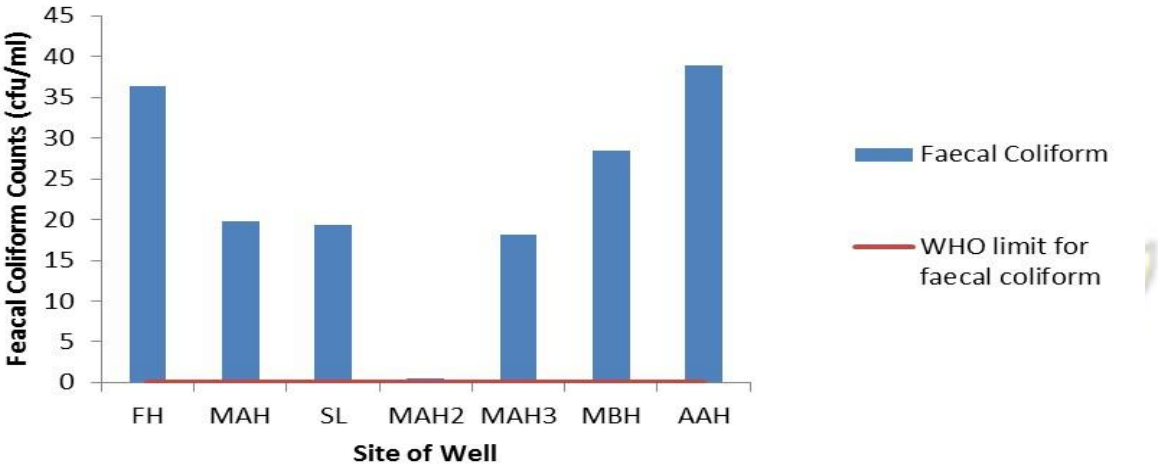

Figure 20: Faecal coliform counts at various sampling sites compared with WHO standards.

4.1.17 Sulphate levels at sampling sites

The WHO guideline for sulphate levels was not exceeded by any of the sampling sites with their results falling well below the WHO guideline of 400 mg/L. The values range from 29 mg/L (AAH) to 88 mg/L (MAH). AAH values showed significant difference with all the means of sulphate values for sampling sites at ($p < 0.05$). The rest is as shown in the table for Turkey HSD Sulphate at the appendix. FH showed significant difference with MBH and MAH values when subjected to the Turkey HSD Post Hoc analysis for analysis of variance as shown in the appendix. However, all reading for sulphates at sampling sites were below the WHO guideline as shown in Figure 21.

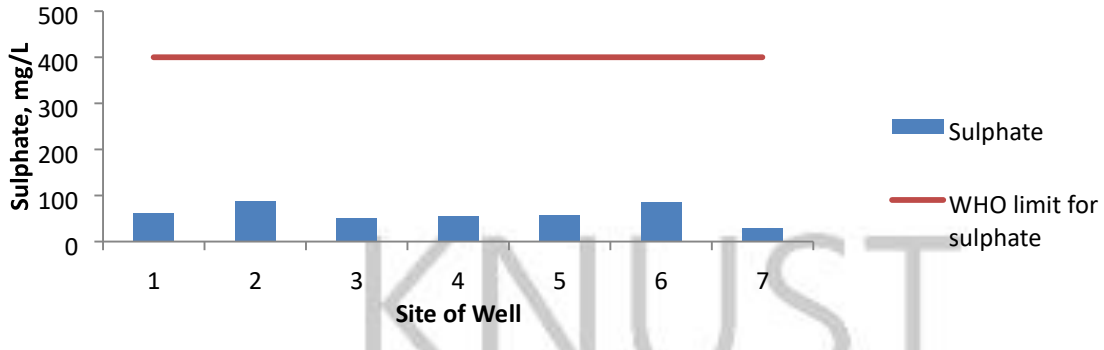

Figure 21: Sulphate levels at various sampling sites compared with WHO standards.

4.1.18 Salinity levels at sampling sites

Salinity levels that were estimated did not show any significant concern in areas of sea water intrusion with results ranging from 0 to 1 ppt. The salinity values for AAH, FH and SL did not show any significant difference between them. The salinity value for AAH was significantly different from MAH2 ($p = 0.0001$). The means of MAH2 was significantly different to the means of MAH ($p = 0.01$). There was no WHO guideline for salinity with respect to drinking water but for irrigation and agricultural purposes it was recommended that salinity levels should not exceed 10 ppt for brackish waters. However, salinity levels for all sites ranged from 0 to 1 ppt and hence there was no cause for concern since this is an indication that sea water has not intruded into underground water. This was also confirmed from conductivity readings which fall below the required level or readings for water to be used for irrigation on farms, gardens and lawns.

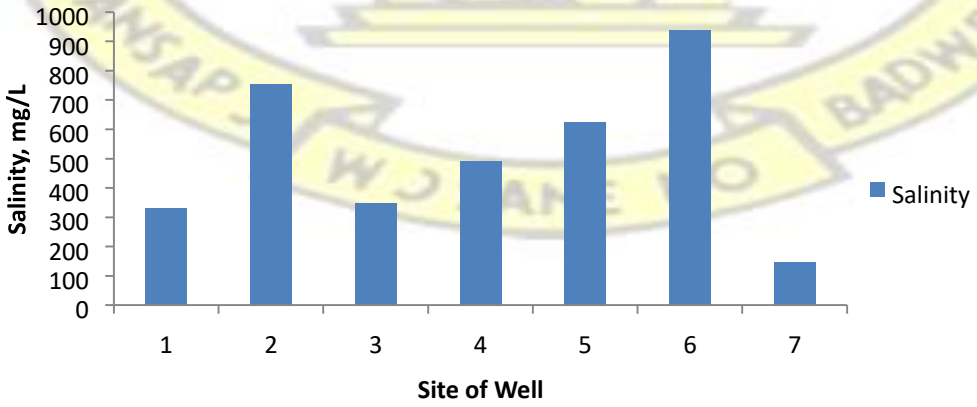

Figure 22: Salinity levels at various sampling sites

4.1.19 Distance of Septic tank from Well at sampling sites

Measurement of distance of septic tank from wells (DST) showed that all the sampling sites did not meet the minimum distance limit set by the Ghana District Schedules (GDS). However, sampling site FH exceeded the limit set by the United States Environmental Protection Agency (USEPA) with just 2.18 m whiles the rest fell below the limit even though the USEPA limit was also below the GDS limit. The lowest distance was recorded by MAH with 2.62 m.

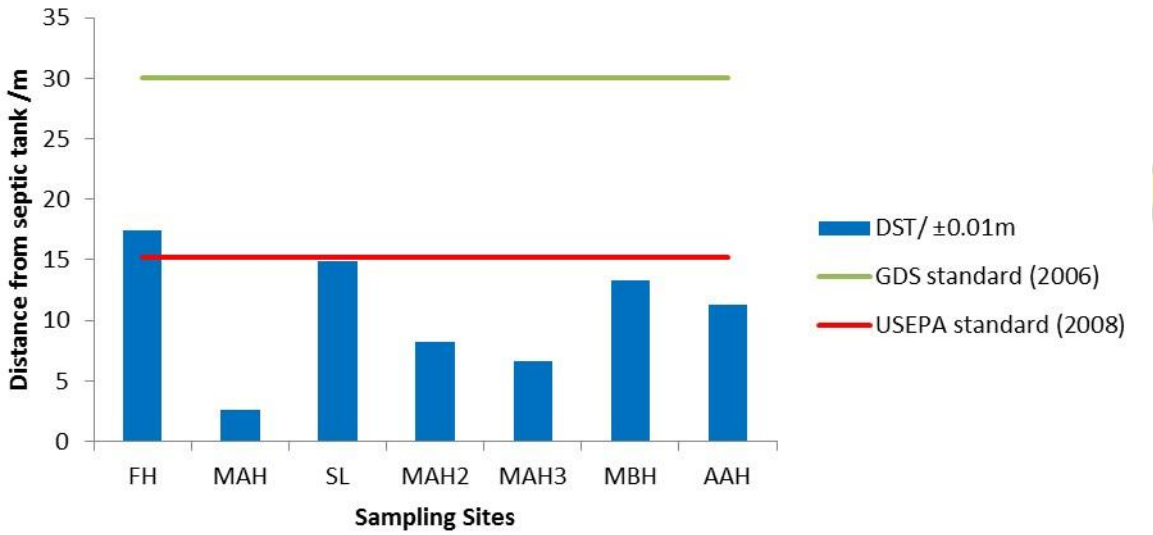

Figure 23: Distance between septic tank and well (DST) compared to Ghana District Schedules standard (GDS) and the United States Environmental Protection Agency standard (USEPA).

4.1.20 Distance of Septic tank and Faecal Coliform Count at sampling sites

A graph of distance of well from septic tank (DST) with faecal coliform count (FC) showed in Figure 24 that, although sampling site FH had the highest recorded distance of separation (17.42 m), its faecal coliform count (36.29) was second to the highest faecal coliform count recorded by sampling site AAH (38.86). Also sampling site MAH2 recorded a DST (8.27 m) which was below the USEPA guideline of 15 m but still recorded the lowest faecal coliform

count (0.57). Sampling site MAH recorded the lowest DST (2.62 m) and yet recorded the fourth highest faecal coliform count (19.71). All sampling sites recorded DST below the USEPA guideline except sampling site FH.

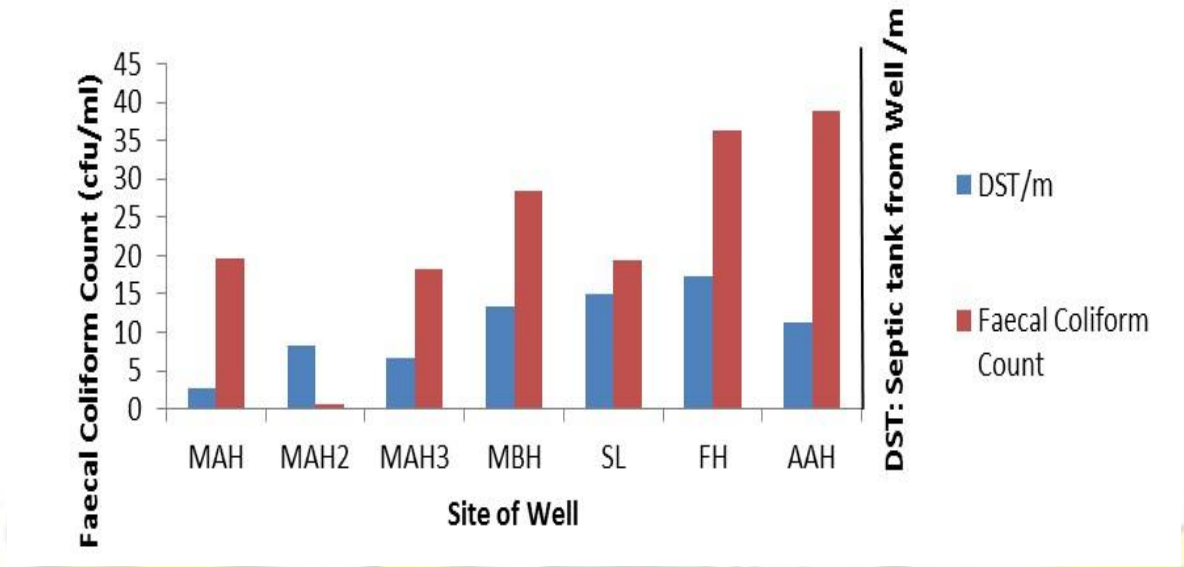

Figure 24: Distance between well and septic tank (DST) with faecal coliform counts at various sampling sites.

4.1.21 Depth of Well and Faecal Coliform Count at sampling sites

A graph of depth of well (DOW) with faecal coliform count (FC) in Figure 25 showed that, although sampling site MAH3 had the lowest depth recorded, it did not record the lowest FC but rather, sampling site MAH2 recorded the lowest FC with DOW 4.35 m being the second lowest depth recorded for all sampling sites as shown in Figure 25 below.

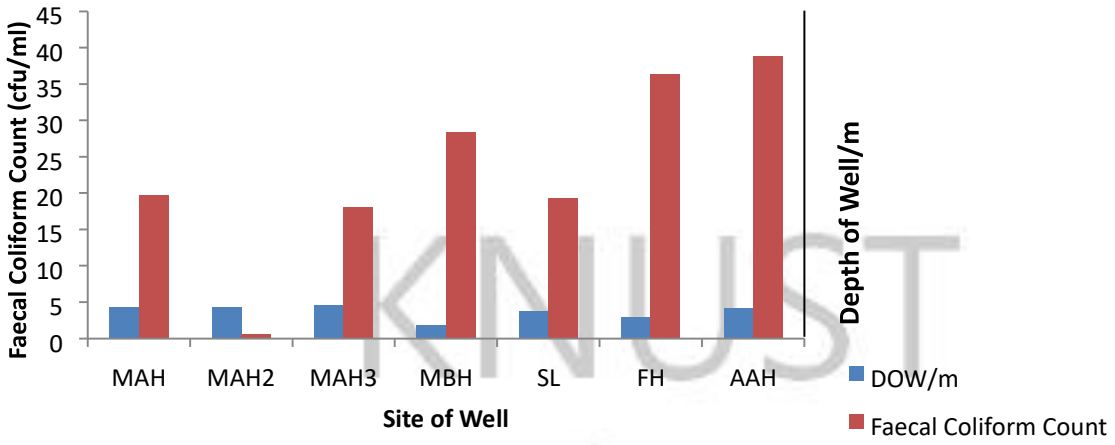

Figure 25: Depth of well with faecal coliform counts at various sampling sites.

4.1.22 Distance of Septic tank and Total Coliform Count at sampling sites

The Figure below (Figure 26) which is a graph of distance of well from septic tank and total coliform count also shows a similar trend discussed earlier with Figure 24 of the graph of distance of well from septic tank and faecal coliform count but with higher coliform counts as compared to that in Figure 24.

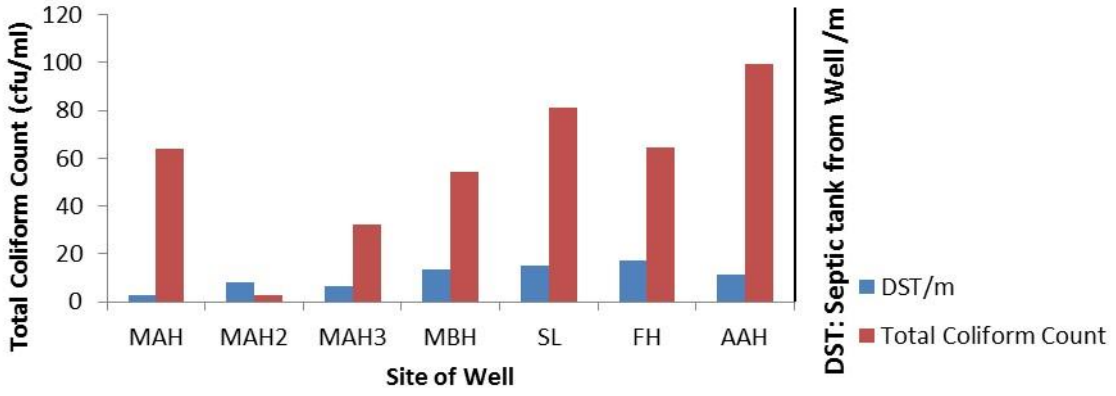

Figure 26: Distance between well and septic tank and level of total coliform count at various sampling sites.

4.1.23 Depth of Well and Total Coliform Count at sampling sites

Figure 27 show the relationship between the depth of well and total coliform count with similar trend discuss earlier with Figure 25 of the graph of depth of well and faecal coliform count but with higher coliform counts as compared to that in Figure 25.

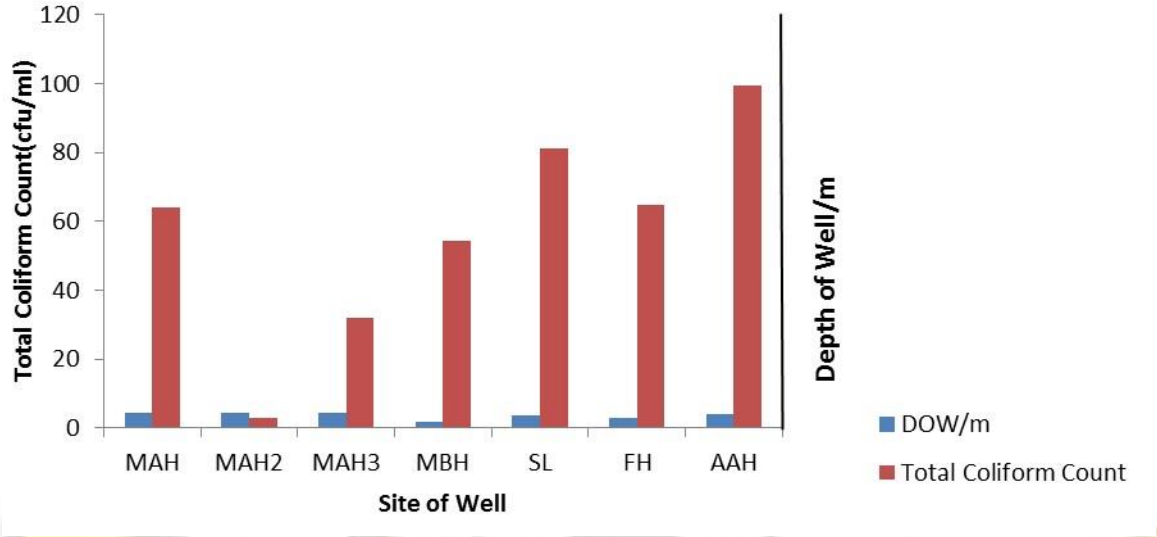

Figure 27: Depth of well and level of total coliform counts at the various sampling sites.

4.1.24 Pearson's Correlation between Chloride and Conductivity at sampling sites

Pearson's Correlation of chloride and conductivity showed a significant positive correlation of (r = 0.8969). This is shown in the Figure below;

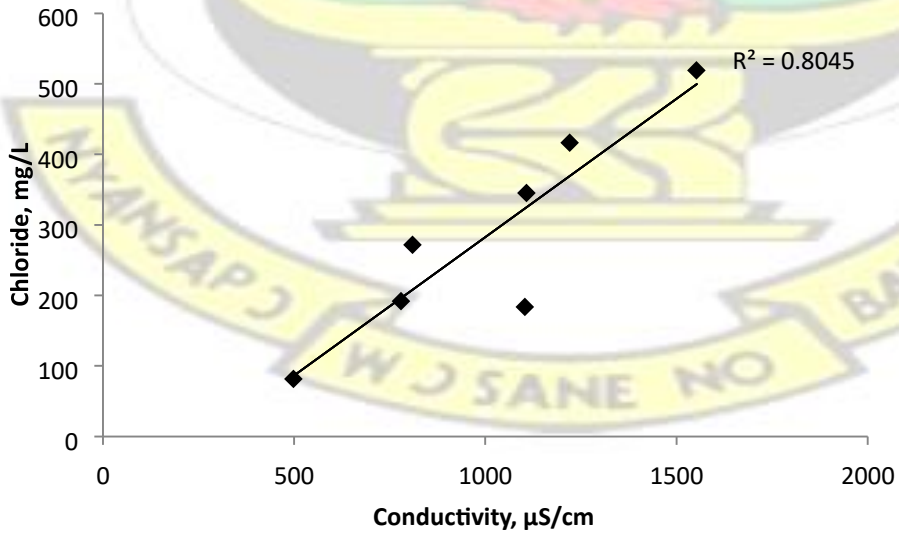

Figure 28: Pearson‘s Correlation between Chloride levels and Conductivity readings.

4.1.25 Pearson’s Correlation between Depth of Well and Faecal Coliform Count at sampling sites

Pearson‘s Correlation of faecal coliform (FC) and depth of well (DOW) show any significant correlation (r = -0.4428). This is shown in the Figure below;

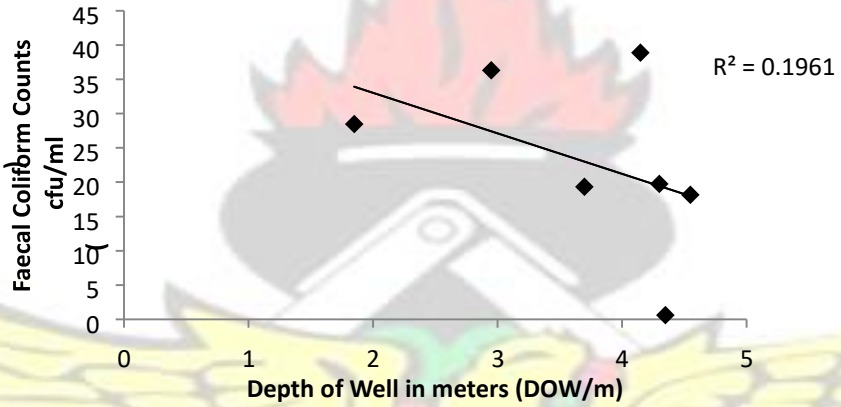

Figure 29: Pearson‘s Correlation between Faecal Coliform Count (FC) and Depth of Well (DOW).

4.1.26 Pearson’s Correlation between Distance of Septic tank from Well and Faecal Coliform Count at sampling sites

Pearson‘s Correlation of faecal coliform (FC) and distance of well from septic tank (DST) did not show any significant correlation (r = 0.4951). This is shown in the Figure below;

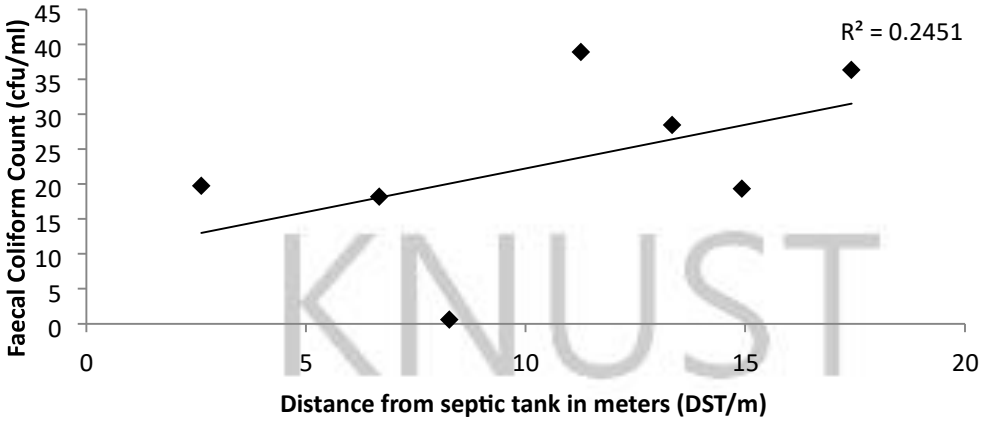

Figure 30: Pearson‘s Correlation between Faecal Coliform Count (FC) and Distance from Septic tank (DST)

4.1.27 Pearson’s Correlation between Depth of Well and Total Coliform Count at sampling sites

Pearson‘s Correlation of Total coliform (TC) and depth of well (DOW) did not show any significant correlation (r = 0.532). This is shown in the Figure below;

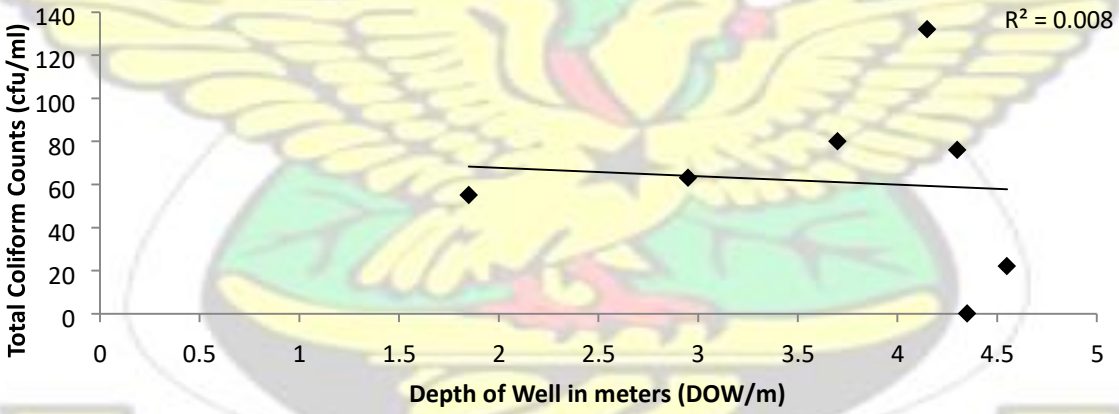

Figure 31: Pearson‘s Correlation between Total Coliform Count (TC) and Depth of Well (DOW).

4.1.28 Pearson’s Correlation between Distance of Septic tank from Well and Total Coliform Count at sampling sites

Pearson‘s Correlation of total coliform (TC) and distance of well from septic tank (DST) did not show any significant correlation (r = 0.588). This is shown in the Figure below;

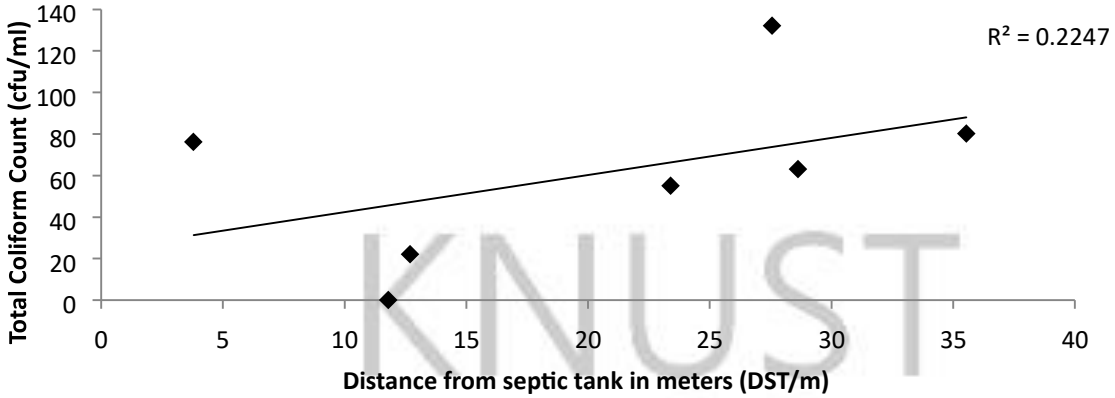

Figure 32: Pearson's Correlation between Faecal Coliform Count (FC) and Distance from Septic tank (DST).

CHPATER FIVE – DISCUSSION

5.0 PYSICO-CHEMICAL PARAMETERS AND WATER QUALITY

The minimum WHO guideline for drinking water is 6.5 for pH below which the water is said to be acidic and not recommended for drinking due to the health implications that might arise from drinking such water. In the study conducted, the pH of the underground water at the various site of sampling was acidic and below the minimum WHO recommended guideline for pH of drinking water. This may be due to waste effluent discharge; microbial decomposition of organic matter in the groundwater (Patil *et al.,* 2012) or partly attributed to the fact that the rock/soil type in the area is of the Birrimian formation, hence affecting the pH of the groundwater. The underground sample from MAH2 well had the lowest pH level of 5.54 and this could be attributed to the depth of the well and continuous covering of the well reducing contact of well water with atmospheric oxygen which leads to increase concentration in carbon dioxide by anaerobic microorganisms that find themselves in the water hence reducing the pH level of the water.

Turbidity values for underground water samples from six of the sample sites were well below the WHO recommended guideline of 5.00 NTU. This might be probably due to the fact that

most of these wells had good cover and were not sited near toilets, thereby prevented suspended particles and other contaminants from entering the well from the surface or through leaching, however, result obtain at site MAH was 6.38 NTU which is above the permissible limit could be due to not covering well or possible leaching (Mishra *et al.,* 2009). Water with a TDS above 1,500 to 2,600 mg/L is generally considered problematic for irrigation use on crops with low or medium salt tolerance in agriculture. Also, high levels of TDS in water used for drinking purposes lead to many diseases which are not water-borne but due to excess salt (Parihar *et al.,* 2003). However, the TDS values for all wells were below the WHO guideline of 1000 mg/L for drinking water with MBH recording the highest TDS value of 776.5 mg/L and AAH recording the lowest of 249.4 mg/L. This might be attributed to the low pH of the well water which is responsible for releasing cations and anions into solution and the invariably low chloride levels recorded at almost all of the sites of sampling. This implies that the underground water could be used for both domestic and irrigation purposes without any significant concerns.

Calcium and magnesium concentrations as well as total hardness were within normal WHO limits while total iron was also within normal limits with the exception of two sites (MAH and MAH3) with values of 0.37 mg/L and 0.35 mg/L respectively. But this is not surprising because of the generally high levels of iron in Ghanaian waters (Pelig-Ba *et al*., 1991). High concentrations of iron in groundwater occur in many places in Ghana and can be as high as 21.50 mg/L (Adzaku, 1989). The World Health Organization recommends that the iron content of drinking water should not be greater than 0.3 mg/L because iron when present in well water, stains plumbing fixtures, stains cloths during laundering, incrusts well screens and clogs pipes (Deutsch, 2003). Its paramount to note that, excessive amount of iron and manganese are objectionable for both domestic and industrial water supplies because of their tendency to stain laundry and plumbing fixtures. Hence, groundwater from MAH and MAH3 should be avoided

when it comes to laundry work since their iron concentration exceeded the WHO guideline. However, both iron and manganese can be kept in solution by adding a small amount of sodium hexameta-phosphate to the water (Wilham *et al.,* 2005).

Four of the sampling sites exceeded the WHO guideline for chloride levels of 250 mg/L, which could have raised a concern for salinity check but the values were below 520 mg/L which did not call for concern. High chloride contents may impart saline taste, which may affect its acceptability for potable purposes. The importance of chlorine in drinking water cannot be overemphasized. It gives a measure of protection against any contamination which may occur. The low state of this ion in the other water samples according to Suleiman (2006) implies that they cannot be kept for a long period before consumption because there are chances of them being polluted. The sites that were of concern for drinking water usage were MAH, MAH2, MAH3 and MBH with values of chloride as 416 mg/L, 271 mg/L, 345 mg/L and 519 mg/L respectively. However, salinity levels that were estimated did not show any significant concern in areas of sea water intrusion with results ranging from 0 to 1 ppt. This could partly be that groundwater resources within the community has not been heavily depended upon until recent time and hence its recharge capability is still normal and mainly from surface water.

High concentration of sulphate may give bitter taste and also cause laxative effect (USEPA, 2007). However, the WHO guideline for sulphate levels was not exceeded by all the seven sampling sites with their results falling well below the WHO guideline of 400 mg/L. The values range from 29 mg/L (AAH) to 88 mg/L (MAH). This could be attributed to the fact that the area is not a farming community which can be a possible source of sulphate leaching into underground water from fertiliser usage.

Nitrate and nitrite in water has been associated with methaemoglobinaemia, especially in bottle-fed infants (Kempster *et al*., 1997). With a methaemoglobin level of 3 – 15 %, skin can turn to a pale gray or blue Nitrite levels is a cause for concern for eutrophication and dissolved oxygen levels, however, all the seven sampling sites recorded nitrites levels that were far below the WHO guideline of 3 mg/L. This did not show any significant concern and hence nutrient levels within sampling sites could not be a cause for concern when it came to Biological Oxygen Demand or Dissolve Oxygen levels. The values of nitrite ranged from 0.00 mg/L (MAH) to 0.04 mg/L (MAH3). Nitrate levels did not also show any cause for concern as values from all sampling sites were well below the WHO guideline of 10 mg/L with the highest recorded by FH with 5.69 mg/L and the lowest 0.69 mg/L by MAH and as reported by Adeyemo *et al.* (2002) that natural nitrate concentrations in groundwater range from 0.1 to 10 mg/L . Possible sources of nitrate pollution in groundwater and streams include wastewater treatment plants, runoff from fertilized lawns and farmland, failing septic systems, runoff from animal feedlots and animal manure storage areas. However, traces of nitrate and nitrite in groundwater could be attributed to failing septic systems.

The level of hardness was within normal limits of 500 mg/L. The WHO guideline for total hardness of 500 mg/L was not exceeded by any of the seven sampling sites with the highest value recorded by FH (340 mg/L and the least recorded by AAH (99.66 mg/L). This implies that underground water can be used for domestic activities such as laundry.

Fluoride, when present in drinking water at a concentration of about 1 milligram per litre (mg/L), helps prevent dental cavities. However, exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis

(WHO, 2006). Fluoride levels for all seven sampling sites were below the WHO guideline of 1.5 mg/L with the highest level recorded by MBH with 0.35 mg/L and the least by AAH with 0.00 mg/L.

The WHO guideline for alkalinity of 120 mg/L was not exceeded by all the seven sampling sites with the highest measurement recorded by SL (94 mg/L) and the least by MAH2 (32 mg/L). This is an indication that wastewater has not contaminated groundwater since wastewater can have higher alkalinity because it typically has higher concentrations of nutrients and ions, some with acid buffering properties, such as silicates and phosphates (VCCS, 2014).

All seven sampling sites had phosphate readings well below the WHO guideline of 0.70 mg/L with the highest measurement being recorded by MBH (0.28 mg/L) and the least by MAH3 (0.13 mg/L). Phosphate readings did not show any significant readings between sites of sampling. Possible sources of phosphate contamination in the environment include industrial and municipal wastewater discharges, runoff from fertilized lawns and farmland, failing septic systems and from animal feed lots and animal manure storage areas (CEES, 2014). In addition, phosphorus can be derived from disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations. However, phosphate readings for various sampling sites cannot be attributed to any of the following except failing septic system. The WHO guideline for zinc (5 mg/L) was not exceeded by any of the seven sampling sites with readings ranging from 0.00 mg/L (MBH) to 0.10 mg/L (MAH3).

There was no WHO guideline for salinity with respect to drinking water but for irrigation and agricultural purposes it was recommended that salinity levels should not exceed 10 ppt for brackish waters. One of the reasons for salinity is the high concentrations of cations such as

sodium, calcium and magnesium whereas chloride, phosphate and nitrates as anions (Chauhan *et al.*, 2012). However, salinity levels for all seven sites ranged from 0 to 1 ppt and hence there was no cause for concern since this is an indication that sea water has not intruded into underground water. This was also confirmed from conductivity readings which fall below the required level or readings for water to be used for irrigation on farms, gardens and lawns.

5.1 EFFECT OF BACTERIOLOGICAL AND SEPTIC TANK DISTANCE FROM WELL ON GROUNDWATER QUALITY

Pollution indicator bacteria, (faecal coliforms and total coliforms) were present in all the groundwater sampling sites. This could be due to both human and animal waste in the vicinity. Clapham (1993) reported that the risk of contracting diseases from Private Water Supplies was 22 times more probable than from a mains supply. Galbraith *et al*., (1987), however, suggested that the figure was more likely to be 50 times. According to van Derslice and Briscoe (1995), in areas with poor environmental sanitation, improved drinking water would have little or no effect. However, in areas with good community sanitation, reducing faecal coliform counts by two orders of magnitude would reduce the incidence of diarrhoea by 40 %.

Total and Faecal Coliform counts at six of the sites were above the WHO. The sampling site AAH had the highest coliform count and this can be attributed to the poor management of the well as it is at the mercy of unsuspecting clients who rely on the well for their domestic water supply.

Observations made with relation to distance of well from septic tanks showed that all the sampling sites except FH were below the distance of separation (15.24 m or 50 ft) set by the United States Environmental Protection Agency (USEPA) in the siting of septic tanks and wells but were all below the standard set by the Ghana District Schedules of 30 m separation distance

between wells and septic tank distance. Reasons could be due to inadequate space (as siting of wells were an after taught) or simply ignorance by owners of the need for the separation distance. The faecal coliform count for these sites were all above the WHO permissible limit of 0 counts per 100 ml.

The faecal counts for the sampling site FH was also above the WHO guideline even though the distance of separation from the septic tank was above the USEPA guideline for septic tank and siting of well separation distance but below the 30 m separation distance sited by the Ghana Districts Schedules. This could partly be attributed to anthropogenic activities, wells not being properly covered and also its accessibility to public use leading to contamination from unsuspecting victims and also not meeting regulated standard stipulated by the Ghana Districts Schedules.

MAH2 recorded a distance of 8.27 m between septic tank and a depth of well of 4.32 m well and had a total faecal coliform count (mean) of approximately 1 (0.57) count per ml, the lowest in all the seven sampling sites. This might be as a result of the hygienic way in which this well is kept. It is well covered, and at all times closed unless the taps goes off before they are open for public usage. They have a dedicated bucket for drawing water from the well. There is no vegetation covering it and it is isolated from the busy portions of the hostel. All this practices must be a reason for its low faecal contamination.

Statistical analysis of Pearson‘s correlation between the variables chloride and conductivity gave a coefficient of correlation (r) to be 0.8969 which shows a perfect correlation between these variables and hence one can help predict the levels of the other without necessary taking measurements for the other values with 95 % confidence interval as stated by Abyaneh and associates in the conclusion of their research i.e. there was a good agreement and correlation

between electrical conductivity and chloride ion concentration in water samples except for EC < 3dSm^{-1} (Abyaneh *et al.* 2004).

Correlational analysis between depth of well and faecal coliform count, depth of well and total coliform count, distance of septic tank from site of well and faecal coliform count, and distance of septic tank from site of well and total coliform count did not show any correlation, with Pearson‘s correlation generating correlation coefficient (r) to be -0.443, -0.182, 0.4951, and 0.3533 with 95 % confidence interval.

Concentrations of some ions such as Ca, Cl and Sulphate, which are commonly used as indicators of sewage contamination, did not indicate any relationship with siting of septic tanks when subjected to Pearson‘s correlation analysis as shown in Table 9. Concentrations of the principal nutrients, nitrogen and phosphorus which are also potential indicators of groundwater, septic tank contamination did not also show any relationship when subjected to Pearson‘s correlation with siting of septic tanks as shown in Table 9.

In the discussion, the various indicators for groundwater contamination by failing septic systems and wastewater effluents, that are directly discharged into hand dug wells; with calcium, chloride, sulphate and sodium commonly used as indicators for sewage contamination were typical of uncontaminated groundwater (Hancher, 1991) and the principal nutrients which are potential indicators (nitrogen and phosphorus) of groundwater and septic tank contaminations by effluents (Miller, 1980), were all within acceptable limits of WHO guidelines indicating that groundwater has not been contaminated by failing septic tanks or waste water effluents discharged into hand dug wells. However, bacteriological analysis showed faecal and total coliform counts at all sites of sampling but this could not be an indication of wastewater or failing septic tank contamination but anthropogenic activities, wells

not being properly covered or sited, also accessibility to public use leading to contamination from unsuspecting victims and also not meeting regulated standard stipulated by the Ghana Districts Schedules.

CHAPTER SIX:

CONCLUSION AND RECOMMENDATION

6.0 Conclusion

The physicochemical quality parameters of underground water were all found to be below or within the WHO guideline for drinking water at all sites of sampling except parameters such as chloride ion which exceeded the WHO guideline at some sampling sites (MAH, MAH2, MAH3 and MBH) and pH values which fell below the WHO guideline limit for all sampling sites, hence making the water acidic.

Faecal coliform counts for all sampling sites were found to be above the WHO guideline giving an indication of microbial contamination of wells.

Salinity levels for all sampling sites were within the acceptable limit giving an indication that there has not been sea water intrusion into underground water.

Based on some selected parameters subjected to statistical analysis of Pearson‘s correlation, it was found that there was no relationship or pattern between distance between septic tank and well and faecal coliform count of groundwater within Kwesiprah. Hence faecal coliform count could be as a result of other factors other than the distance between septic tanks and wells within Kwesiprah.

In concluding, faecal coliform count for all sites were above the WHO guideline. Hence groundwater within Kwesiprah is not recommended for drinking except treated but can be used for domestic chores.

6.1 Recommendations

A research into the pedology of the community with particular attention into the edaphic properties will help inform the residents on how to site septic tanks from wells and the depth to which hand dug wells are made to contain waste effluent in order to avoid groundwater contamination in the future.

A research into the water quality index of groundwater with time will help inform residents on impact of hand dug wells used to contain wastewater and effluents on groundwater quality and measures put in place to find alternate ways of disposing of wastewater and effluents.

The Environmental Protection Agency in Cape Coast should educate residents within Kwesiprah on acceptable standards for siting of septic tanks from wells and enforce such guidelines.

The Ghana Water Company within Cape Coast should endeavour to include monitoring of wells within Kwesiprah into their monitoring programs and support owners in disinfecting the wells periodically to sanitize it.

The University of Cape Coast should also include monitoring of wells within Kwesiprah so as part of their quality assurance and cross check their data periodically with the Ghana Water Company.

The University of Cape Coast should make it mandatory for hostels housing students to provide alternate source of water in the form of boreholes or wells to serve students who rent such hostels.

Landlords within Kwesiprah involve in hostel management should at least have wells within their hostels to serve their student tenants when the tap goes off.

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APPENDIX

Table shows results of mean and standard deviation of some physical parameters at various sites of sampling. Note that various abbreviations for sampling site are defined as follows: (FH=FLORENCE HOSTEL, MAH=MR. ANANE'S HOSTEL (2, 3), SL=SERWAA LODGE, MBH=MACBETH HOSTEL, AAH= AUNTIE ADWOA'S HOSTEL)

Sample	pH	Conductivity µS/cm	Alkalinity mg/L	Turbidity (NTU)	Colour Pt.Co	Salinity mg/L
FH	5.66 ± 0.14	1103.71 ± 3120	38.86 ± 2.54	1.26 ± 0.01	3.71 ± 2.87	331.29 ± 29.80
MAH	6.01 ± 0.09	1221.14 ± 6.12	50.29 ± 6.37	6.38 ± 0.05	25.71 ± 10.92	751.86 ± 257.88
SL	6.30 ± 0.13	780.43 ± 3.21	94 ± 5.77	1.10 ± 0.01	2.00 ± 1.63	345.71 ± 78.16
MAH2	5.54 ± 0.32	809.86 ± 5.49	32.57 ± 9.78	2.14 ± 0.30	8.57 ± 4.12	490.43 ± 141.06
MAH3	6.18 ± 0.05	1108.28 ± 2.29	51.14 ± 6.20	2.52 ± 0.90	11.43 ± 8.06	623.43 ± 145.85
MBH	6.32 ± 0.10	1552.86 ± 179.37	42.86 ± 3.44	2.77 ± 0.31	2.29 ± 2.36	937.29 ± 117.52
AAH	6.03 ± 0.06	498.86 ± 6.36	37.14 ± 4.45	0.77 ± 0.22	0.86 ± 1.57	147.14 ± 9.03

Table below shows results of mean and standard deviation of some chemical parameters at various sites of sampling. Note that various abbreviations for sampling site are defined as follows: (FH=FLORENCE HOSTEL, MAH=MR. ANANE'S HOSTEL (2, 3), SL=SERWAA LODGE, MBH=MACBETH HOSTEL, AAH= AUNTIE ADWOA'S HOSTEL)

Sample	Ca Hardness	Mg Hardness	Ca ion	Mg ion	Phosphate	Chloride	NO2
FH	316.86 ±143.75	23.37 ±20.40	126.71 ±57.54	5.68 ±4.96	0.22 ±0.02	183.43 ±16.26	0.037 ±0.046
MAH	187.43 ±7.98	14.49 ±19.21	75.00 ±3.06	3.52 ±4.67	0.13 ±0.02	416.14 ±142.87	0.007 ±0.001
SL	177.00 ±53.27	33.89 ±51.331	71.00 ±21.42	8.24 ±12.48	0.18 ±0.04	191.43 ±43.27	0.034 ±0.011
MAH2	157.14 ±34.04	21.99 ±28.60	63.00 ±13.69	5.34 ±6.95	0.21 ±0.07	271.69 ±78.11	0.033 ±0.012
MAH3	287.29 ±99.70	51.41 ±72.64	115.00 ±39.83	12.50 ±17.65	0.13 ±0.03	345.00 ±80.64	0.039 ±0.003
MBH	257.57 ±96.11	40.21 ±60.49	103.00 ±38.41	9.77 ±14.70	0.28 ±0.37	519.00 ±65.10	0.026 ±0.008
AAH	91.00 ±19.65	12.53 ±20.00	36.46 ±7.84	3.05 ±4.86	0.21 ±0.05	81.43 ±4.96	0.025 ±0.002

All units are in mg/L.

Continuation of the table above

Sample	Total Hardness	NO3	Sulphates	Fluoride	Manganese	Iron	Zinc
FH	340.27 ±137.34	5.69 ±0.63	61.43 ±2.15	0.251 ±0.111	0.212 ±0.004	0.247 ±0.087	0.013 ±0.008
MAH	192.26 ±9.06	0.67 ±0.05	88.43 ±1.62	0.221 ±0.098	0.102 ±0.007	0.367 ±0.036	0.059 ±0.073
SL	214.60 ±40.68	2.81 ±0.24	51.14 ±0.69	0.086 ±0.110	0.054 ±0.013	0.044 ±0.005	0.027 ±0.011
MAH2	168.11 ±43.00	1.47 ±1.07	56.29 ±1.25	0.280 ±0.088	0.090 ±0.009	0.086 ±0.013	0.057 ±0.030
MAH3	338.77 ±79.12	4.47 ±0.74	57.14 ±0.69	0.280 ±0.127	0.495 ±0.275	0.349 ±0.057	0.097 ±0.038
MBH	318.57 ±47.26	0.90 ±0.24	86.14 ±4.60	0.357 ±0.161	0.199 ±0.005	0.269 ±0.007	0.023 ±0.010
AAH	99.66 ±22.19	4.74 ±0.05	29.29 ±1.25	0	0.060 ±0.017	0.081 ±0.043	0.073 ±0.016

All units are in mg/L.

Table below shows results of mean and standard deviation of bacteriological parameters at various sites of sampling. Note that various abbreviations for sampling site are defined as follows: (FH=FLORENCE HOSTEL, MAH=MR. ANANE'S HOSTEL (2, 3), SL=SERWAA LODGE, MBH=MACBETH HOSTEL, AAH= AUNTIE ADWOA'S HOSTEL)

Sample	Total Coliform Count (cfu)	Faecal Coliform Count (cfu)
FH	64.71 (6.45)	36.29 (7.78)
MAH	64.14 (10.35)	19.71 (4.34)
SL	81.29 (4.11)	19.29 (3.04)
MAH2	2.86 (1.77)	0.57 (0.79)
MAH3	32.14 (6.31)	18.14 (3.98)
MBH	54.43 (4.12)	28.43 (6.65)
AAH	99.57 (17.19)	38.86 (7.31)

Table 9 shows coefficients of correlation (r) values for some selected chemical parameters that are indicators of sewage or faecal pollution in underground water with faecal coliform count, total coliform count, distance of well from septic tank and depth of well.

Table 9: Summary of Pearson's Correlation Coefficients for some selected parameters

	Ca	**Cl**	**SO_4^{2-}**	**NO_2**	**NO_3**	**PO_4^{2-}**
Faecal Coliform	0.128	-0.288	-0.182	0.193	0.555	0.310
Total Coliform	-0.288	-0.422	-0.282	-0.165	0.324	0.058
Distance from Septic Tank	-0.018	-0.541	-0.491	0.498	0.480	0.497
Depth of Well	-0.437	-0.372	-0.425	-0.188	0.127	-0.817

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	3.866	6	.644	27.453	.000
	Within Groups	.986	42	.023		
	Total	4.852	48			
Conductivity	Between Groups	4982187.551	6	830364.592	174.703	.000
	Within Groups	199626.000	42	4753.000		
	Total	5181813.551	48			
TDS	Between Groups	1270140.993	6	211690.166	152.896	.000
	Within Groups	58150.557	42	1384.537		
	Total	1328291.550	48			
Total Hardness	Between Groups	376342.691	6	62723.782	13.968	.000
	Within Groups	188603.026	42	4490.548		
	Total	564945.717	48			
Ca Hardness	Between Groups	267437.061	6	44572.844	7.045	.000
	Within Groups	265720.571	42	6326.680		
	Total	533157.633	48			
Mg Hardness	Between Groups	8475.485	6	1412.581	.728	.629
	Within Groups	81440.476	42	1939.059		
	Total	89915.961	48			
Ca ion	Between Groups	42680.119	6	7113.353	7.023	.000
	Within Groups	42538.206	42	1012.814		
	Total	85218.325	48			
Mg ion	Between Groups	500.726	6	83.454	.729	.629
	Within Groups	4809.637	42	114.515		

	Total	5310.363	48			
Phosphate	Between Groups	.121	6	.020	.949	.471
	Within Groups	.893	42	.021		
	Total	1.014	48			

		Sum of Squares	df	Mean Square	F	Sig.
Chloride	Between Groups	953631.918	6	158938.653	28.228	.000
	Within Groups	236481.429	42	5630.510		
	Total	1190113.347	48			
NO2	Between Groups	.005	6	.001	2.283	.054
	Within Groups	.015	42	.000		
	Total	.019	48			
NO3	Between Groups	172.274	6	28.712	90.554	.000
	Within Groups	13.317	42	.317		
	Total	185.591	48			
Sulphates	Between Groups	17664.980	6	2944.163	634.592	.000
	Within Groups	194.857	42	4.639		
	Total	17859.837	48			
Fluoride	Between Groups	.650	6	.108	9.053	.000
	Within Groups	.502	42	.012		
	Total	1.152	48			
Alkalinity	Between Groups	18061.551	6	3010.259	85.625	.000
	Within Groups	1476.571	42	35.156		
	Total	19538.122	48			
Turbidity	Between Groups	151.814	6	25.302	169.802	.000

	Within Groups	6.258	42	.149		
	Total	158.073	48			
Colour	Between Groups	3245.388	6	540.898	17.203	.000
	Within Groups	1320.571	42	31.442		
	Total	4565.959	48			
Manganese	Between Groups	1.011	6	.169	15.494	.000
	Within Groups	.457	42	.011		
	Total	1.468	48			
Iron	Between Groups	.756	6	.126	61.783	.000
	Within Groups	.086	42	.002		
	Total	.842	48			
Zinc	Between Groups	.039	6	.006	5.492	.000
	Within Groups	.049	42	.001		
	Total	.088	48			
Salinity	Between Groups	3111111.265	6	518518.544	28.232	.000
	Within Groups	771399.429	42	18366.653		
	Total	3882510.694	48			

Table 8: Statistical Analysis of means of parameters taking at various sampling sites using ANOVA to compare significance between sampling sites and within sampling sites for readings of various parameters

Anova Post Hoc Analysis for Physico-chemical parameters analysed

Multiple Comparisons

pH

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-.35142857*	.08189092	.002	-.6049256	-.0979315
	SL	-.63857143*	.08189092	.000	-.8920685	-.3850744
	MAH2	.12000000	.08189092	.763	-.1334971	.3734971
	MAH3					
	MBH	-.52142857*	.08189092	.000	-.7749256	-.2679315
	AAH	-.66000000*	.08189092	.000	-.9134971	-.4065029
		-.36714286*	.08189092	.001	-.6206399	-.1136458
MAH	FH	.35142857*	.08189092	.002	.0979315	.6049256
	SL	-.28714286*	.08189092	.017	-.5406399	-.0336458
	MAH2	.47142857*	.08189092	.000	.2179315	.7249256
	MAH3	-.17000000	.08189092	.385	-.4234971	.0834971

	MBH	-.30857143*	.08189092	.008	-.5620685	-.0550744
	AAH	-.01571429	.08189092	1.000	-.2692114	.2377828
SL	FH	.63857143*	.08189092	.000	.3850744	.8920685
	MAH	.28714286*	.08189092	.017	.0336458	.5406399
	MAH2	.75857143*	.08189092	.000	.5050744	1.0120685
	MAH3	.11714286	.08189092	.782	-.1363542	.3706399
	MBH	-.02142857	.08189092	1.000	-.2749256	.2320685
	AAH	.27142857*	.08189092	.029	.0179315	.5249256
MAH2	FH	-.12000000	.08189092	.763	-.3734971	.1334971
	MAH	-.47142857*	.08189092	.000	-.7249256	-.2179315
	SL	-.75857143*	.08189092	.000	-1.0120685	-.5050744
	MAH3	-.64142857*	.08189092	.000	-.8949256	-.3879315
	MBH	-.78000000*	.08189092	.000	-1.0334971	-.5265029
	AAH	-.48714286*	.08189092	.000	-.7406399	-.2336458
MAH3	FH	.52142857*	.08189092	.000	.2679315	.7749256
	MAH	.17000000	.08189092	.385	-.0834971	.4234971
	SL	-.11714286	.08189092	.782	-.3706399	.1363542
	MAH2	.64142857*	.08189092	.000	.3879315	.8949256
	MBH	-.13857143	.08189092	.625	-.3920685	.1149256
	AAH	.15428571	.08189092	.502	-.0992114	.4077828
MBH	FH	.66000000*	.08189092	.000	.4065029	.9134971
	MAH	.30857143*	.08189092	.008	.0550744	.5620685
	SL	.02142857	.08189092	1.000	-.2320685	.2749256

	MAH2	.78000000*	.08189092	.000	.5265029	1.0334971
	MAH3	.13857143	.08189092	.625	-.1149256	.3920685
	AAH	.29285714*	.08189092	.014	.0393601	.5463542
AAH	FH	.36714286*	.08189092	.001	.1136458	.6206399
	MAH	.01571429	.08189092	1.000	-.2377828	.2692114
	SL	-.27142857*	.08189092	.029	-.5249256	-.0179315
	MAH2	.48714286*	.08189092	.000	.2336458	.7406399
	MAH3	-.15428571	.08189092	.502	-.4077828	.0992114
	MBH	-.29285714*	.08189092	.014	-.5463542	-.0393601

*. The mean difference is significant at the 0.05 level.

pH

Turkey HSD

	Subset for alpha = 0.05		
Sample	1	2	3
MAH2	5.5400000E0		
FH	5.6600000E0		
MAH		6.0114286E0	
AAH		6.0271429E0	
MAH3		6.1814286E0	6.1814286E0
SL			6.2985714E0
MBH			6.3200000E0
Sig.	.763	.385	.625

Multiple Comparisons

Conductivity

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-1.17428571E2*	3.68510515E1	.040	-2.3150268E2	-3.3544634
	SL	3.23285714E2*	3.68510515E1	.000	209.2116062	437.3598223
	MAH2	2.93857143E2*	3.68510515E1	.000	179.7830348	407.9312509
	MAH3	-4.57142857	3.68510515E1	1.000	-1.1864554E2	109.5026795
	MBH	-4.49142857E2*	3.68510515E1	.000	-5.6321697E2	-3.3506875E2
	AAH	6.04857143E2*	3.68510515E1	.000	490.7830348	718.9312509
MAH	FH	1.17428571E2*	3.68510515E1	.040	3.3544634	231.5026795
	SL	4.40714286E2*	3.68510515E1	.000	326.6401777	554.7883938
	MAH2	4.11285714E2*	3.68510515E1	.000	297.2116062	525.3598223
	MAH3	1.12857143E2	3.68510515E1	.054	-1.2169652	226.9312509
	MBH	-3.31714286E2*	3.68510515E1	.000	-4.4578839E2	-2.1764018E2
	AAH	7.22285714E2*	3.68510515E1	.000	608.2116062	836.3598223
SL	FH	-3.23285714E2*	3.68510515E1	.000	-4.3735982E2	-2.0921161E2
	MAH	-4.40714286E2*	3.68510515E1	.000	-5.5478839E2	-3.2664018E2
	MAH2	-29.42857143	3.68510515E1	.984	-1.4350268E2	84.6455366
	MAH3	-3.27857143E2*	3.68510515E1	.000	-4.4193125E2	-2.1378303E2
	MBH	-7.72428571E2*	3.68510515E1	.000	-8.8650268E2	-6.5835446E2
	AAH	2.81571429E2*	3.68510515E1	.000	167.4973205	395.6455366
MAH2	FH	-2.93857143E2*	3.68510515E1	.000	-4.0793125E2	-1.7978303E2

	MAH	-4.11285714E2*	3.68510515E1	.000	-5.2535982E2	-2.9721161E2
	SL	29.42857143	3.68510515E1	.984	-84.6455366	143.5026795
	MAH3	-2.98428571E2*	3.68510515E1	.000	-4.1250268E2	-1.8435446E2
	MBH	-7.43000000E2*	3.68510515E1	.000	-8.5707411E2	-6.2892589E2
	AAH	3.11000000E2*	3.68510515E1	.000	196.9258920	425.0741080
MAH3	FH	4.57142857	3.68510515E1	1.000	-1.0950268E2	118.6455366
	MAH	-1.12857143E2	3.68510515E1	.054	-2.2693125E2	1.2169652
	SL	3.27857143E2*	3.68510515E1	.000	213.7830348	441.9312509
	MAH2	2.98428571E2*	3.68510515E1	.000	184.3544634	412.5026795
	MBH	-4.44571429E2*	3.68510515E1	.000	-5.5864554E2	-3.3049732E2
	AAH	6.09428571E2*	3.68510515E1	.000	495.3544634	723.5026795
MBH	FH	4.49142857E2*	3.68510515E1	.000	335.0687491	563.2169652
	MAH	3.31714286E2*	3.68510515E1	.000	217.6401777	445.7883938
	SL	7.72428571E2*	3.68510515E1	.000	658.3544634	886.5026795
	MAH2	7.43000000E2*	3.68510515E1	.000	628.9258920	857.0741080
	MAH3	4.44571429E2*	3.68510515E1	.000	330.4973205	558.6455366
	AAH	1.05400000E3*	3.68510515E1	.000	939.9258920	1.1680741E3
AAH	FH	-6.04857143E2*	3.68510515E1	.000	-7.1893125E2	-4.9078303E2
	MAH	-7.22285714E2*	3.68510515E1	.000	-8.3635982E2	-6.0821161E2
	SL	-2.81571429E2*	3.68510515E1	.000	-3.9564554E2	-1.6749732E2
	MAH2	-3.11000000E2*	3.68510515E1	.000	-4.2507411E2	-1.9692589E2
	MAH3	-6.09428571E2*	3.68510515E1	.000	-7.2350268E2	-4.9535446E2
	MBH	-1.05400000E3*	3.68510515E1	.000	-1.1680741E3	-9.3992589E2

*. The mean difference is significant at the 0.05 level.

Conductivity

Tukey HSD

	Subset for alpha = 0.05				
Sample	1	2	3	4	5
AAH	4.9885714E2				
SL		7.8042857E2			
MAH2		8.0985714E2			
FH			1.1037143E3		
MAH3			1.1082857E3	1.1082857E3	
MAH				1.2211429E3	1.5528571E3
MBH					1.000
Sig.	1.000	.984	1.000	.054	

Multiple Comparisons

TDS

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-58.69285714	1.98892439E1	.071	-1.2026092E2	2.8752029
	SL	1.76000000E2*	1.98892439E1	.000	114.4319400	237.5680600
	MAH2	1.46928571E2*	1.98892439E1	.000	85.3605114	208.4966314
	MAH3	-2.27142857	1.98892439E1	1.000	-63.8394886	59.2966314

	MBH	-2.24571429E2*	1.98892439E1	.000	-2.8613949E2	-1.6300337E2
	AAH	3.02500000E2*	1.98892439E1	.000	240.9319400	364.0680600
MAH	FH	58.69285714	1.98892439E1	.071	-2.8752029	120.2609172
	SL	2.34692857E2*	1.98892439E1	.000	173.1247971	296.2609172
	MAH2	2.05621429E2*	1.98892439E1	.000	144.0533686	267.1894886
	MAH3	56.42142857	1.98892439E1	.092	-5.1466314	117.9894886
	MBH	-1.65878571E2*	1.98892439E1	.000	-2.2744663E2	-1.0431051E2
	AAH	3.61192857E2*	1.98892439E1	.000	299.6247971	422.7609172
SL	FH	-1.76000000E2*	1.98892439E1	.000	-2.3756806E2	-1.1443194E2
	MAH	-2.34692857E2*	1.98892439E1	.000	-2.9626092E2	-1.7312480E2
	MAH2	-29.07142857	1.98892439E1	.765	-90.6394886	32.4966314
	MAH3	-1.78271429E2*	1.98892439E1	.000	-2.3983949E2	-1.1670337E2
	MBH	-4.00571429E2*	1.98892439E1	.000	-4.6213949E2	-3.3900337E2
	AAH	1.26500000E2*	1.98892439E1	.000	64.9319400	188.0680600
MAH2	FH	-1.46928571E2*	1.98892439E1	.000	-2.0849663E2	-85.3605114
	MAH	-2.05621429E2*	1.98892439E1	.000	-2.6718949E2	-1.4405337E2
	SL	29.07142857	1.98892439E1	.765	-32.4966314	90.6394886
	MAH3	-1.49200000E2*	1.98892439E1	.000	-2.1076806E2	-87.6319400
	MBH	-3.71500000E2*	1.98892439E1	.000	-4.3306806E2	-3.0993194E2
	AAH	1.55571429E2*	1.98892439E1	.000	94.0033686	217.1394886
MAH3	FH	2.27142857	1.98892439E1	1.000	-59.2966314	63.8394886
	MAH	-56.42142857	1.98892439E1	.092	-1.1798949E2	5.1466314
	SL	1.78271429E2*	1.98892439E1	.000	116.7033686	239.8394886

	MAH2	1.49200000E2*	1.98892439E1	.000	87.6319400	210.7680600
	MBH	-2.22300000E2*	1.98892439E1	.000	-2.8386806E2	-1.6073194E2
	AAH	3.04771429E2*	1.98892439E1	.000	243.2033686	366.3394886
MBH	FH	2.24571429E2*	1.98892439E1	.000	163.0033686	286.1394886
	MAH	1.65878571E2*	1.98892439E1	.000	104.3105114	227.4466314
	SL	4.00571429E2*	1.98892439E1	.000	339.0033686	462.1394886
	MAH2	3.71500000E2*	1.98892439E1	.000	309.9319400	433.0680600
	MAH3	2.22300000E2*	1.98892439E1	.000	160.7319400	283.8680600
	AAH	5.27071429E2*	1.98892439E1	.000	465.5033686	588.6394886
AAH	FH	-3.02500000E2*	1.98892439E1	.000	-3.6406806E2	-2.4093194E2
	MAH	-3.61192857E2*	1.98892439E1	.000	-4.2276092E2	-2.9962480E2
	SL	-1.26500000E2*	1.98892439E1	.000	-1.8806806E2	-64.9319400
	MAH2	-1.55571429E2*	1.98892439E1	.000	-2.1713949E2	-94.0033686
	MAH3	-3.04771429E2*	1.98892439E1	.000	-3.6633949E2	-2.4320337E2
	MBH	-5.27071429E2*	1.98892439E1	.000	-5.8863949E2	-4.6550337E2

*. The mean difference is significant at the 0.05 level.

TDS

Turkey HSD

	Subset for alpha = 0.05			
Sample	1	2	3	4
AAH	2.4942857E2			
SL		3.7592857E2		
MAH2		4.0500000E2		

FH			5.5192857E2	
MAH3			5.5420000E2	
MAH			6.1062143E2	
MBH				7.7650000E2
Sig.	1.000	.765	.071	1.000

Multiple Comparisons

TotalHardness

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	1.48014286E2*	3.58191817E1	.003	37.1343776	258.8941938
	SL	1.25671429E2*	3.58191817E1	.017	14.7915205	236.5513366
	MAH2	1.72157143E2*	3.58191817E1	.000	61.2772348	283.0370509
	MAH3	1.50000000	3.58191817E1	1.000	-1.0937991E2	112.3799081
	MBH	21.70000000	3.58191817E1	.996	-89.1799081	132.5799081
	AAH	2.40614286E2*	3.58191817E1	.000	129.7343776	351.4941938
MAH	FH	-1.48014286E2*	3.58191817E1	.003	-2.5889419E2	-37.1343776
	SL	-22.34285714	3.58191817E1	.996	-1.3322277E2	88.5370509
	MAH2	24.14285714	3.58191817E1	.993	-86.7370509	135.0227652
	MAH3	-1.46514286E2*	3.58191817E1	.003	-2.5739419E2	-35.6343776
	MBH	-1.26314286E2*	3.58191817E1	.017	-2.3719419E2	-15.4343776

	AAH	92.60000000	3.58191817E1	.157	-18.2799081	203.4799081
SL	FH	-1.25671429E2*	3.58191817E1	.017	-2.3655134E2	-14.7915205
	MAH	22.34285714	3.58191817E1	.996	-88.5370509	133.2227652
	MAH2	46.48571429	3.58191817E1	.849	-64.3941938	157.3656224
	MAH3	-1.24171429E2*	3.58191817E1	.019	-2.3505134E2	-13.2915205
	MBH	-1.03971429E2	3.58191817E1	.079	-2.1485134E2	6.9084795
	AAH	1.14942857E2*	3.58191817E1	.038	4.0629491	225.8227652
MAH2	FH	-1.72157143E2*	3.58191817E1	.000	-2.8303705E2	-61.2772348
	MAH	-24.14285714	3.58191817E1	.993	-1.3502277E2	86.7370509
	SL	-46.48571429	3.58191817E1	.849	-1.5736562E2	64.3941938
	MAH3	-1.70657143E2*	3.58191817E1	.000	-2.8153705E2	-59.7772348
	MBH	-1.50457143E2*	3.58191817E1	.002	-2.6133705E2	-39.5772348
	AAH	68.45714286	3.58191817E1	.485	-42.4227652	179.3370509
MAH3	FH	-1.50000000	3.58191817E1	1.000	-1.1237991E2	109.3799081
	MAH	1.46514286E2*	3.58191817E1	.003	35.6343776	257.3941938
	SL	1.24171429E2*	3.58191817E1	.019	13.2915205	235.0513366
	MAH2	1.70657143E2*	3.58191817E1	.000	59.7772348	281.5370509
	MBH	20.20000000	3.58191817E1	.997	-90.6799081	131.0799081
	AAH	2.39114286E2*	3.58191817E1	.000	128.2343776	349.9941938
MBH	FH	-21.70000000	3.58191817E1	.996	-1.3257991E2	89.1799081
	MAH	1.26314286E2*	3.58191817E1	.017	15.4343776	237.1941938
	SL	1.03971429E2	3.58191817E1	.079	-6.9084795	214.8513366
	MAH2	1.50457143E2*	3.58191817E1	.002	39.5772348	261.3370509

	MAH3	-20.20000000	3.58191817E1	.997	-1.3107991E2	90.6799081
	AAH	2.18914286E2*	3.58191817E1	.000	108.0343776	329.7941938
AAH	FH	-2.40614286E2*	3.58191817E1	.000	-3.5149419E2	-1.2973438E2
	MAH	-92.60000000	3.58191817E1	.157	-2.0347991E2	18.2799081
	SL	-1.14942857E2*	3.58191817E1	.038	-2.2582277E2	-4.0629491
	MAH2	-68.45714286	3.58191817E1	.485	-1.7933705E2	42.4227652
	MAH3	-2.39114286E2*	3.58191817E1	.000	-3.4999419E2	-1.2823438E2
	MBH	-2.18914286E2*	3.58191817E1	.000	-3.2979419E2	-1.0803438E2

*. The mean difference is significant at the 0.05 level.

Total Hardness

Turkey HSD

	Subset for alpha = 0.05			
Sample	1	2	3	4
AAH	9.9657143E1			
MAH2	1.6811429E2	1.6811429E2		
MAH	1.9225714E2	1.9225714E2		
SL		2.1460000E2	2.1460000E2	
MBH			3.1857143E2	3.1857143E2
MAH3				3.3877143E2
FH				3.4027143E2
Sig.	.157	.849	.079	.996

Multiple Comparisons

CaHardness

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	1.29428571E2	4.25161491E1	.057	-2.1821041	261.0392469
	SL	1.39857143E2*	4.25161491E1	.031	8.2464674	271.4678184
	MAH2	1.59714286E2*	4.25161491E1	.009	28.1036102	291.3249612
	MAH3	-1.0203925E2	4.25161491E1	.992	-2.1821041	261.0392469
	MBH	29.57142857	4.25161491E1	.802	-72.3249612	161.1821041
	AAH	94.2464674	4.25161491E1	.000	59.28571429	190.8963898
MAH	FH	-1.29428571E2	4.25161491E1	.057	-2.6103925E2	2.1821041
	SL	10.42857143	4.25161491E1	1.000	-1.2118210E2	142.0392469
	MAH2	30.28571429	4.25161491E1	.991	-1.0132496E2	161.8963898
	MAH3	-99.85714286	4.25161491E1	.246	-2.3146782E2	31.7535326
	MBH	-70.14285714	4.25161491E1	.652	-2.0175353E2	61.4678184
	AAH	96.42857143	4.25161491E1	.283	-35.1821041	228.0392469
SL	FH	-1.39857143E2*	4.25161491E1	.031	-2.7146782E2	-8.2464674
	MAH	-10.42857143	4.25161491E1	1.000	-1.4203925E2	121.1821041
	MAH2	19.85714286	4.25161491E1	.999	-1.1175353E2	151.4678184
	MAH3	-1.10285714E2	4.25161491E1	.154	-2.4189639E2	21.3249612
	MBH	-80.57142857	4.25161491E1	.495	-2.1218210E2	51.0392469
	AAH	86.00000000	4.25161491E1	.416	-45.6106755	217.6106755

MAH2	FH	-1.59714286E2*	4.25161491E1	.009	-2.9132496E2	-28.1036102
	MAH	-30.28571429	4.25161491E1	.991	-1.6189639E2	101.3249612
	SL	-19.85714286	4.25161491E1	.999	-1.5146782E2	111.7535326
	MAH3	-1.30142857E2	4.25161491E1	.054	-2.6175353E2	1.4678184
	MBH	-1.00428571E2	4.25161491E1	.240	-2.3203925E2	31.1821041
	AAH	66.14285714	4.25161491E1	.710	-65.4678184	197.7535326
MAH3	FH	-29.57142857	4.25161491E1	.992	-1.6118210E2	102.0392469
	MAH	99.85714286	4.25161491E1	.246	-31.7535326	231.4678184
	SL	1.10285714E2	4.25161491E1	.154	-21.3249612	241.8963898
	MAH2	1.30142857E2	4.25161491E1	.054	-1.4678184	261.7535326
	MBH	29.71428571	4.25161491E1	.992	-1.0189639E2	161.3249612
	AAH	1.96285714E2*	4.25161491E1	.001	64.6750388	327.8963898
MBH	FH	-59.28571429	4.25161491E1	.802	-1.9089639E2	72.3249612
	MAH	70.14285714	4.25161491E1	.652	-61.4678184	201.7535326
	SL	80.57142857	4.25161491E1	.495	-51.0392469	212.1821041
	MAH2	1.00428571E2	4.25161491E1	.240	-31.1821041	232.0392469
	MAH3	-29.71428571	4.25161491E1	.992	-1.6132496E2	101.8963898
	AAH	1.66571429E2*	4.25161491E1	.006	34.9607531	298.1821041
AAH	FH	-2.25857143E2*	4.25161491E1	.000	-3.5746782E2	-94.2464674
	MAH	-96.42857143	4.25161491E1	.283	-2.2803925E2	35.1821041
	SL	-86.00000000	4.25161491E1	.416	-2.1761068E2	45.6106755

MAH2	-66.14285714	4.25161491E1	.710	-1.9775353E2	65.4678184
MAH3	-1.96285714E2*	4.25161491E1	.001	-3.2789639E2	-64.6750388
MBH	-1.66571429E2*	4.25161491E1	.006	-2.9818210E2	-34.9607531

*. The mean difference is significant at the 0.05 level.

Ca Hardness

Turkey HSD

	Subset for alpha = 0.)5		
Sample	1	2	3
AAH	9.1000000E1		
MAH2	1.5714286E2	1.5714286E2	
SL	1.7700000E2	1.7700000E2	
MAH	1.8742857E2	1.8742857E2	1.8742857E2
MBH		2.5757143E2	2.5757143E2
MAH3		2.8728571E2	2.8728571E2
FH			3.1685714E2
Sig.	.283	.054	.057

Mg Hardness

Turkey HSD

	Subset for alpha = 0.05
Sample	1
AAH	12.5314286
MAH	14.4880000
MAH2	21.9942857

FH	23.3720000
SL	33.8948571
MBH	40.2114286
MAH3	51.4114286
Sig.	.651

Multiple Comparisons Caion

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound

FH	MAH	51.71428571	1.70110420E1	.057	-.9441693	104.3727407
	SL	55.71428571*	1.70110420E1	.032	3.0558307	108.3727407
	MAH2	63.71428571*	1.70110420E1	.009	11.0558307	116.3727407
	MAH3	11.71428571	1.70110420E1	.993	-40.9441693	64.3727407
	MBH	23.71428571	1.70110420E1	.802	-28.9441693	76.3727407
	AAH	90.25714286*	1.70110420E1	.000	37.5986878	142.9155979
MAH	FH	-51.71428571	1.70110420E1	.057	-1.0437274E2	.9441693
	SL	4.00000000	1.70110420E1	1.000	-48.6584550	56.6584550
	MAH2	12.00000000	1.70110420E1	.992	-40.6584550	64.6584550
	MAH3	-40.00000000	1.70110420E1	.245	-92.6584550	12.6584550
	MBH	-28.00000000	1.70110420E1	.654	-80.6584550	24.6584550
	AAH	38.54285714	1.70110420E1	.284	-14.1155979	91.2013122
SL	FH	-5.57142857E1*	1.70110420E1	.032	-1.0837274E2	-3.0558307
	MAH	-4.00000000	1.70110420E1	1.000	-56.6584550	48.6584550
	MAH2	8.00000000	1.70110420E1	.999	-44.6584550	60.6584550
	MAH3	-44.00000000	1.70110420E1	.156	-96.6584550	8.6584550
	MBH	-32.00000000	1.70110420E1	.504	-84.6584550	20.6584550
	AAH	34.54285714	1.70110420E1	.412	-18.1155979	87.2013122
MAH2	FH	-6.37142857E1*	1.70110420E1	.009	-1.1637274E2	-11.0558307
	MAH	-12.00000000	1.70110420E1	.992	-64.6584550	40.6584550
	SL	-8.00000000	1.70110420E1	.999	-60.6584550	44.6584550
	MAH3	-52.00000000	1.70110420E1	.055	-1.0465846E2	.6584550
	MBH	-40.00000000	1.70110420E1	.245	-92.6584550	12.6584550

	AAH	26.54285714	1.70110420E1	.707	-26.1155979	79.2013122
MAH3	FH	-11.71428571	1.70110420E1	.993	-64.3727407	40.9441693
	MAH	40.00000000	1.70110420E1	.245	-12.6584550	92.6584550
	SL	44.00000000	1.70110420E1	.156	-8.6584550	96.6584550
	MAH2	52.00000000	1.70110420E1	.055	-.6584550	104.6584550
	MBH	12.00000000	1.70110420E1	.992	-40.6584550	64.6584550
	AAH	78.54285714*	1.70110420E1	.001	25.8844021	131.2013122
MBH	FH	-23.71428571	1.70110420E1	.802	-76.3727407	28.9441693
	MAH	28.00000000	1.70110420E1	.654	-24.6584550	80.6584550
	SL	32.00000000	1.70110420E1	.504	-20.6584550	84.6584550
	MAH2	40.00000000	1.70110420E1	.245	-12.6584550	92.6584550
	MAH3	-12.00000000	1.70110420E1	.992	-64.6584550	40.6584550
	AAH	66.54285714*	1.70110420E1	.006	13.8844021	119.2013122
AAH	FH	-9.02571429E1*	1.70110420E1	.000	-1.4291560E2	-37.5986878
	MAH	-38.54285714	1.70110420E1	.284	-91.2013122	14.1155979
	SL	-34.54285714	1.70110420E1	.412	-87.2013122	18.1155979
	MAH2	-26.54285714	1.70110420E1	.707	-79.2013122	26.1155979
	MAH3	-7.85428571E1*	1.70110420E1	.001	-1.3120131E2	-25.8844021
	MBH	-6.65428571E1*	1.70110420E1	.006	-1.1920131E2	-13.8844021

*. The mean difference is significant at the 0.05 level.

Ca ion

Turkey HSD

Sample	Subset for alpha = 0.)5

	1	2	3
AAH	3.6457143E1		
MAH2	6.3000000E1	6.3000000E1	
SL	7.1000000E1	7.1000000E1	
MAH	7.5000000E1	7.5000000E1	7.5000000E1
MBH		1.0300000E2	1.0300000E2
MAH3		1.1500000E2	1.1500000E2
FH			1.2671429E2
Sig.	.284	.055	.057

Mg ion

Turkey HSD

	Subset for alpha = 0.05
Sample	1
AAH	3.0457143
MAH	3.5205714
MAH2	5.3438571
FH	5.6802857
SL	8.2375714
MBH	9.7728571
MAH3	12.4955714
Sig.	.650

Phosphate

Turkey HSD

Sample	Subset for alpha = 0.05 1
MAH	.1285714
MAH3	.1285714
SL	.1842857
MAH2	.2100000
AAH	.2142857
FH	.2228571
MBH	.2785714
Sig.	.476

Multiple Comparisons

Chloride

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-2.32714286E2*	4.01088170E1	.000	-3.5687296E2	-1.0855562E2
	SL	-8.00000000	4.01088170E1	1.000	-1.3215867E2	116.1586694
	MAH2	-87.85714286	4.01088170E1	.322	-2.1201581E2	36.3015265

	MAH3	-1.61571429E2*	4.01088170E1	.004	-2.8573010E2	-37.4127592
	MBH	-3.35571429E2*	4.01088170E1	.000	-4.5973010E2	-2.1141276E2
	AAH	1.02000000E2	4.01088170E1	.170	-22.1586694	226.1586694
MAH	FH	2.32714286E2*	4.01088170E1	.000	108.5556164	356.8729551
	SL	2.24714286E2*	4.01088170E1	.000	100.5556164	348.8729551
	MAH2	1.44857143E2*	4.01088170E1	.013	20.6984735	269.0158122
	MAH3	71.14285714	4.01088170E1	.572	-53.0158122	195.3015265
	MBH	-1.02857143E2	4.01088170E1	.163	-2.2701581E2	21.3015265
	AAH	3.34714286E2*	4.01088170E1	.000	210.5556164	458.8729551
SL	FH	8.00000000	4.01088170E1	1.000	-1.1615867E2	132.1586694
	MAH	-2.24714286E2*	4.01088170E1	.000	-3.4887296E2	-1.0055562E2
	MAH2	-79.85714286	4.01088170E1	.435	-2.0401581E2	44.3015265
	MAH3	-1.53571429E2*	4.01088170E1	.007	-2.7773010E2	-29.4127592
	MBH	-3.27571429E2*	4.01088170E1	.000	-4.5173010E2	-2.0341276E2
	AAH	1.10000000E2	4.01088170E1	.113	-14.1586694	234.1586694
MAH2	FH	87.85714286	4.01088170E1	.322	-36.3015265	212.0158122
	MAH	-1.44857143E2*	4.01088170E1	.013	-2.6901581E2	-20.6984735
	SL	79.85714286	4.01088170E1	.435	-44.3015265	204.0158122
	MAH3	-73.71428571	4.01088170E1	.531	-1.9787296E2	50.4443836
	MBH	-2.47714286E2*	4.01088170E1	.000	-3.7187296E2	-1.2355562E2
	AAH	1.89857143E2*	4.01088170E1	.000	65.6984735	314.0158122
MAH3	FH	1.61571429E2*	4.01088170E1	.004	37.4127592	285.7300979
	MAH	-71.14285714	4.01088170E1	.572	-1.9530153E2	53.0158122

	SL	1.53571429E2*	4.01088170E1	.007	29.4127592	277.7300979
	MAH2	73.71428571	4.01088170E1	.531	-50.4443836	197.8729551
	MBH	-1.74000000E2*	4.01088170E1	.002	-2.9815867E2	-49.8413306
	AAH	2.63571429E2*	4.01088170E1	.000	139.4127592	387.7300979
MBH	FH	3.35571429E2*	4.01088170E1	.000	211.4127592	459.7300979
	MAH	1.02857143E2	4.01088170E1	.163	-21.3015265	227.0158122
	SL	3.27571429E2*	4.01088170E1	.000	203.4127592	451.7300979
	MAH2	2.47714286E2*	4.01088170E1	.000	123.5556164	371.8729551
	MAH3	1.74000000E2*	4.01088170E1	.002	49.8413306	298.1586694
	AAH	4.37571429E2*	4.01088170E1	.000	313.4127592	561.7300979
AAH	FH	-1.02000000E2	4.01088170E1	.170	-2.2615867E2	22.1586694
	MAH	-3.34714286E2*	4.01088170E1	.000	-4.5887296E2	-2.1055562E2
	SL	-1.10000000E2	4.01088170E1	.113	-2.3415867E2	14.1586694
	MAH2	-1.89857143E2*	4.01088170E1	.000	-3.1401581E2	-65.6984735
	MAH3	-2.63571429E2*	4.01088170E1	.000	-3.8773010E2	-1.3941276E2
	MBH	-4.37571429E2*	4.01088170E1	.000	-5.6173010E2	-3.1341276E2

*. The mean difference is significant at the 0.05 level.

Chloride

Turkey HSD

	Subset for alpha = 0.05				
Sample	1	2	3	4	5
AAH	8.1428571E1				

FH	1.8342857E2	1.8342857E2			
SL	1.9142857E2	1.9142857E2			
MAH2		2.7128571E2	2.7128571E2		
MAH3			3.4500000E2	3.4500000E2	4.1614286E2
MAH				4.1614286E2	5.1900000E2
MBH					.163
Sig.	.113	.322	.531	.572	

Multiple Comparisons

NO2

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	.02928571	.00998385	.074	-.0016198	.0601912
	SL	.00257143	.00998385	1.000	-.0283340	.0334769
	MAH2	.00385714	.00998385	1.000	-.0270483	.0347626
	MAH3	-.00214286	.00998385	1.000	-.0330483	.0287626
	MBH	.01014286	.00998385	.947	-.0207626	.0410483
	AAH	.01142857	.00998385	.910	-.0194769	.0423340
MAH	FH	-.02928571	.00998385	.074	-.0601912	.0016198
	SL	-.02671429	.00998385	.130	-.0576198	.0041912
	MAH2	-.02542857	.00998385	.169	-.0563340	.0054769
	MAH3	-.03142857*	.00998385	.044	-.0623340	-.0005231

	MBH	-.01914286	.00998385	.481	-.0500483	.0117626
	AAH	-.01785714	.00998385	.563	-.0487626	.0130483
SL	FH	-.00257143	.00998385	1.000	-.0334769	.0283340
	MAH	.02671429	.00998385	.130	-.0041912	.0576198
	MAH2	.00128571	.00998385	1.000	-.0296198	.0321912
	MAH3	-.00471429	.00998385	.999	-.0356198	.0261912
	MBH	.00757143	.00998385	.988	-.0233340	.0384769
	AAH	.00885714	.00998385	.973	-.0220483	.0397626
MAH2	FH	-.00385714	.00998385	1.000	-.0347626	.0270483
	MAH	.02542857	.00998385	.169	-.0054769	.0563340
	SL	-.00128571	.00998385	1.000	-.0321912	.0296198
	MAH3	-.00600000	.00998385	.996	-.0369055	.0249055
	MBH	.00628571	.00998385	.995	-.0246198	.0371912
	AAH	.00757143	.00998385	.988	-.0233340	.0384769
MAH3	FH	.00214286	.00998385	1.000	-.0287626	.0330483
	MAH	.03142857*	.00998385	.044	.0005231	.0623340
	SL	.00471429	.00998385	.999	-.0261912	.0356198
	MAH2	.00600000	.00998385	.996	-.0249055	.0369055
	MBH	.01228571	.00998385	.878	-.0186198	.0431912
	AAH	.01357143	.00998385	.820	-.0173340	.0444769
MBH	FH	-.01014286	.00998385	.947	-.0410483	.0207626
	MAH	.01914286	.00998385	.481	-.0117626	.0500483
	SL	-.00757143	.00998385	.988	-.0384769	.0233340

	MAH2	-.00628571	.00998385	.995	-.0371912	.0246198
	MAH3	-.01228571	.00998385	.878	-.0431912	.0186198
	AAH	.00128571	.00998385	1.000	-.0296198	.0321912
AAH	FH	-.01142857	.00998385	.910	-.0423340	.0194769
	MAH	.01785714	.00998385	.563	-.0130483	.0487626
	SL	-.00885714	.00998385	.973	-.0397626	.0220483
	MAH2	-.00757143	.00998385	.988	-.0384769	.0233340
	MAH3	-.01357143	.00998385	.820	-.0444769	.0173340
	MBH	-.00128571	.00998385	1.000	-.0321912	.0296198

*. The mean difference is significant at the 0.05 level.

NO_2

Turkey HSD

	Subset for alpha = 0.05	
Sample	1	2
MAH	.0072857	
AAH	.0251429	.0251429
MBH	.0264286	.0264286
MAH2	.0327143	.0327143
SL	.0340000	.0340000
FH	.0365714	.0365714
MAH3		.0387143
Sig.	.074	.820

Multiple Comparisons

NO3

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	5.01428571*	.30098639	.000	4.0825686	5.9460028
	SL	2.87142857*	.30098639	.000	1.9397115	3.8031457
	MAH2					
	MAH3	4.21428571*	.30098639	.000	3.2825686	5.1460028
		1.21428571*	.30098639	.004	.2825686	2.1460028
	MBH	4.78571429*	.30098639	.000	3.8539972	5.7174314
	AAH	.94285714*	.30098639	.046	.0111401	1.8745742
MAH	FH	-5.01428571*	.30098639	.000	-5.9460028	-4.0825686
	SL	-2.14285714*	.30098639	.000	-3.0745742	-1.2111401
	MAH2	-.80000000	.30098639	.135	-1.7317171	.1317171
	MAH3	-3.80000000*	.30098639	.000	-4.7317171	-2.8682829
	MBH	-.22857143	.30098639	.988	-1.1602885	.7031457
	AAH	-4.07142857*	.30098639	.000	-5.0031457	-3.1397115
SL	FH	-2.87142857*	.30098639	.000	-3.8031457	-1.9397115
	MAH	2.14285714*	.30098639	.000	1.2111401	3.0745742
	MAH2	1.34285714*	.30098639	.001	.4111401	2.2745742
	MAH3					
		-1.65714286*	.30098639	.000	-2.5888599	-.7254258
		1.91428571*	.30098639	.000	.9825686	2.8460028

	MBH	-1.92857143*	.30098639	.000	-2.8602885	-.9968543
	AAH					
MAH2	FH	-4.21428571*	.30098639	.000	-5.1460028	-3.2825686
	MAH	.80000000	.30098639	.135	-.1317171	1.7317171
	SL	-1.34285714*	.30098639	.001	-2.2745742	-.4111401
	MAH3	-3.00000000*	.30098639	.000	-3.9317171	-2.0682829
	MBH	.57142857	.30098639	.493	-.3602885	1.5031457
	AAH	-3.27142857*	.30098639	.000	-4.2031457	-2.3397115
MAH3	FH	-1.21428571*	.30098639	.004	-2.1460028	-.2825686
	MAH	3.80000000*	.30098639	.000	2.8682829	4.7317171
	SL	1.65714286*	.30098639	.000	.7254258	2.5888599
	MAH2	3.00000000*	.30098639	.000	2.0682829	3.9317171
	MBH	3.57142857*	.30098639	.000	2.6397115	4.5031457
	AAH	-.27142857	.30098639	.970	-1.2031457	.6602885
MBH	FH	-4.78571429*	.30098639	.000	-5.7174314	-3.8539972
	MAH	.22857143	.30098639	.988	-.7031457	1.1602885
	SL	-1.91428571*	.30098639	.000	-2.8460028	-.9825686
	MAH2	-.57142857	.30098639	.493	-1.5031457	.3602885
	MAH3	-3.57142857*	.30098639	.000	-4.5031457	-2.6397115
	AAH	-3.84285714*	.30098639	.000	-4.7745742	-2.9111401
AAH	FH	-.94285714*	.30098639	.046	-1.8745742	-.0111401
	MAH	4.07142857*	.30098639	.000	3.1397115	5.0031457
	SL	1.92857143*	.30098639	.000	.9968543	2.8602885
	MAH2	3.27142857*	.30098639	.000	2.3397115	4.2031457

	MAH3	.27142857	.30098639	.970	-.6602885	1.2031457
	MBH	3.84285714*	.30098639	.000	2.9111401	4.7745742

*. The mean difference is significant at the 0.05 level.

NO_3

Turkey HSD

Sample	Subset for alpha = 0.05			
	1	2	3	4
MAH	.6714286			
MBH	.9000000			
MAH2	1.4714286E0			
SL		2.8142857E0		
MAH3			4.4714286E0	
AAH			4.7428571E0	
FH				5.6857143E0
Sig.	.135	1.000	.970	1.000

Multiple Comparisons

Sulphates

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-2.70000000E1*	1.15132914E0	.000	-30.5639918	-23.4360082
	SL	10.28571429*	1.15132914E0	.000	6.7217225	13.8497061

	MAH2	5.14285714*	1.15132914E0	.001	1.5788654	8.7068489
	MAH3	4.28571429*	1.15132914E0	.010	.7217225	7.8497061 - 21.1502939
	MBH	-2.47142857E1*	1.15132914E0	.000	-28.2782775	35.7068489
	AAH	32.14285714*	1.15132914E0	.000	28.5788654	
MAH	FH	27.00000000*	1.15132914E0	.000	23.4360082	30.5639918
	SL	37.28571429*	1.15132914E0	.000	33.7217225	40.8497061 35.7068489
	MAH2	32.14285714*	1.15132914E0	.000	28.5788654	34.8497061
	MAH3	31.28571429*	1.15132914E0	.000	27.7217225	5.8497061 62.7068489
	MBH	2.28571429	1.15132914E0	.439	-1.2782775	
	AAH	59.14285714*	1.15132914E0	.000	55.5788654	
SL	FH	-1.02857143E1*	1.15132914E0	.000	-13.8497061	-6.7217225
	MAH	-3.72857143E1*	1.15132914E0	.000	-40.8497061	-33.7217225
	MAH2	-5.14285714*	1.15132914E0	.001	-8.7068489	-1.5788654
	MAH3	-6.00000000*	1.15132914E0	.000	-9.5639918	-2.4360082 -31.4360082
	MBH	-3.50000000E1*	1.15132914E0	.000	-38.5639918	25.4211346
	AAH	21.85714286*	1.15132914E0	.000	18.2931511	
MAH2	FH	-5.14285714*	1.15132914E0	.001	-8.7068489	-1.5788654
	MAH	-3.21428571E1*	1.15132914E0	.000	-35.7068489	-28.5788654
	SL	5.14285714*	1.15132914E0	.001	1.5788654	8.7068489 2.7068489 - 26.2931511
	MAH3	-.85714286	1.15132914E0	.989	-4.4211346	30.5639918
	MBH	-2.98571429E1*	1.15132914E0	.000	-33.4211346	
	AAH	27.00000000*	1.15132914E0	.000	23.4360082	

MAH3	FH	-4.28571429*	1.15132914E0	.010	-7.8497061	
	MAH	-3.12857143E1*	1.15132914E0	.000	-34.8497061	
	SL	6.00000000*	1.15132914E0	.000	2.4360082	-.7217225
	MAH2	.85714286	1.15132914E0	.989	-2.7068489	-27.7217225 9.5639918
	MBH	-2.90000000E1*	1.15132914E0	.000	-32.5639918	4.4211346 - 25.4360082
	AAH	27.85714286*	1.15132914E0	.000	24.2931511	31.4211346
MBH	FH	24.71428571*	1.15132914E0	.000	21.1502939	28.2782775
	MAH	-2.28571429	1.15132914E0	.439	-5.8497061	1.2782775 38.5639918
	SL	35.00000000*	1.15132914E0	.000	31.4360082	33.4211346
	MAH2	29.85714286*	1.15132914E0	.000	26.2931511	32.5639918 60.4211346
	MAH3	29.00000000*	1.15132914E0	.000	25.4360082	
	AAH	56.85714286*	1.15132914E0	.000	53.2931511	
AAH	FH	-3.21428571E1*	1.15132914E0	.000	-35.7068489	
	MAH	-5.91428571E1*	1.15132914E0	.000	-62.7068489	
	SL	-2.18571429E1*	1.15132914E0	.000	-25.4211346	-28.5788654
	MAH2	-2.70000000E1*	1.15132914E0	.000	-30.5639918	-55.5788654 -18.2931511
	MAH3	-2.78571429E1*	1.15132914E0	.000	-31.4211346	-23.4360082
	MBH	-5.68571429E1*	1.15132914E0	.000	-60.4211346	-24.2931511 -53.2931511

*. The mean difference is significant at the 0.05 level.

Sulphate

Turkey HSD

Sample	Subset for alpha = 0.05

	1	2	3	4	5
AAH	2.9285714E1				
SL		5.1142857E1			
MAH2			5.6285714E1		
MAH3			5.7142857E1		
FH				6.1428571E1	8.6142857E1
MBH					8.8428571E1
MAH					.439
Sig.	1.000	1.000	.989	1.000	

Multiple Comparisons

Fluoride

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	.03000000	.05846597	.999	-.1509841	.2109841
	SL	.16571429	.05846597	.092	-.0152698	.3466984
	MAH2	-.02857143	.05846597	.999	-.2095555	.1524127
	MAH3	-.02857143	.05846597	.999	-.2095555	.1524127
	MBH	-.10571429	.05846597	.550	-.2866984	.0752698
	AAH	.25142857*	.05846597	.002	.0704445	.4324127
MAH	FH	-.03000000	.05846597	.999	-.2109841	.1509841
	SL	.13571429	.05846597	.258	-.0452698	.3166984

	MAH2	-.05857143	.05846597	.951	-.2395555	.1224127
	MAH3	-.05857143	.05846597	.951	-.2395555	.1224127
						.0452698
	MBH	-.13571429	.05846597	.258	-.3166984	.4024127
	AAH	.22142857*	.05846597	.008	.0404445	
SL	FH	-.16571429	.05846597	.092	-.3466984	.0152698
	MAH	-.13571429	.05846597	.258	-.3166984	.0452698
						-.0133016
	MAH2	-.19428571*	.05846597	.028	-.3752698	-.0133016
						-.0904445
	MAH3	-.19428571*	.05846597	.028	-.3752698	.2666984
	MBH	-.27142857*	.05846597	.001	-.4524127	
	AAH	.08571429	.05846597	.763	-.0952698	
MAH2	FH	.02857143	.05846597	.999	-.1524127	.2095555
	MAH	.05857143	.05846597	.951	-.1224127	.2395555
						.3752698
	SL	.19428571*	.05846597	.028	.0133016	.1809841
	MAH3	.00000000	.05846597	1.000	-.1809841	.1038412
						.4609841
	MBH	-.07714286	.05846597	.839	-.2581269	
	AAH	.28000000*	.05846597	.000	.0990159	
MAH3	FH	.02857143	.05846597	.999	-.1524127	
	MAH	.05857143	.05846597	.951	-.1224127	
	SL	.19428571*	.05846597	.028	.0133016	.2095555
						.2395555
	MAH2	.00000000	.05846597	1.000	-.1809841	.3752698
						.1809841
	MBH	-.07714286	.05846597	.839	-.2581269	.1038412
	AAH	.28000000*	.05846597	.000	.0990159	.4609841

MBH	FH	.10571429	.05846597	.550	-.0752698	
	MAH	.13571429	.05846597	.258	-.0452698	
	SL	.27142857*	.05846597	.001	.0904445	.2866984
	MAH2	.07714286	.05846597	.839	-.1038412	.3166984 .4524127
	MAH3	.07714286	.05846597	.839	-.1038412	.2581269
	AAH	.35714286*	.05846597	.000	.1761588	.2581269 .5381269
AAH	FH	-.25142857*	.05846597	.002	-.4324127	
	MAH	-.22142857*	.05846597	.008	-.4024127	
	SL	-.08571429	.05846597	.763	-.2666984	-.0704445
	MAH2	-.28000000*	.05846597	.000	-.4609841	-.0404445 .0952698
	MAH3	-.28000000*	.05846597	.000	-.4609841	-.0990159
	MBH	-.35714286*	.05846597	.000	-.5381269	-.0990159 -.1761588

*. The mean difference is significant at the 0.05 level.

Fluoride

Turkey HSD

	Subset for alpha = 0.)5		
Sample	1	2	3
AAH	.0000000		
SL	.0857143	.0857143	
MAH		.2214286	.2214286
FH		.2514286	.2514286
MAH3			.2800000
MAH2			.2800000
MBH			.3571429

Sig.	.763	.092	.258

Alkalinity

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-1.14285714E1*	3.16933804E0	.013	-21.2394016	-1.6177412
	SL	-5.51428571E1*	3.16933804E0	.000	-64.9536874	-45.3320269
	MAH2	6.28571429	3.16933804E0	.440	-3.5251159	16.0965445
	MAH3	-1.22857143E1*	3.16933804E0	.006	-22.0965445	-2.4748841
	MBH	-4.00000000	3.16933804E0	.865	-13.8108302	5.8108302
	AAH	1.71428571	3.16933804E0	.998	-8.0965445	11.5251159
MAH	FH	11.42857143*	3.16933804E0	.013	1.6177412	21.2394016
	SL	-4.37142857E1*	3.16933804E0	.000	-53.5251159	-33.9034555
	MAH2	17.71428571*	3.16933804E0	.000	7.9034555	27.5251159
	MAH3	-.85714286	3.16933804E0	1.000	-10.6679731	8.9536874
	MBH	7.42857143	3.16933804E0	.248	-2.3822588	17.2394016
	AAH	13.14285714*	3.16933804E0	.003	3.3320269	22.9536874
SL	FH	55.14285714*	3.16933804E0	.000	45.3320269	64.9536874
	MAH	43.71428571*	3.16933804E0	.000	33.9034555	53.5251159
	MAH2	61.42857143*	3.16933804E0	.000	51.6177412	71.2394016
	MAH3	42.85714286*	3.16933804E0	.000	33.0463126	52.6679731
	MBH	51.14285714*	3.16933804E0	.000	41.3320269	60.9536874
	AAH	56.85714286*	3.16933804E0	.000	47.0463126	66.6679731
MAH2	FH	-6.28571429	3.16933804E0	.440	-16.0965445	3.5251159
	MAH	-1.77142857E1*	3.16933804E0	.000	-27.5251159	-7.9034555

Multiple Comparisons

	SL	-6.14285714E1*	3.16933804E0	.000	-71.2394016	-51.6177412
	MAH3	-1.85714286E1*	3.16933804E0	.000	-28.3822588	-8.7605984
	MBH	-1.02857143E1*	3.16933804E0	.034	-20.0965445	-.4748841
	AAH	-4.57142857	3.16933804E0	.776	-14.3822588	5.2394016
MAH3	FH	12.28571429*	3.16933804E0	.006	2.4748841	22.0965445
	MAH	.85714286	3.16933804E0	1.000	-8.9536874	10.6679731
	SL	-4.28571429E1*	3.16933804E0	.000	-52.6679731	-33.0463126
	MAH2	18.57142857*	3.16933804E0	.000	8.7605984	28.3822588
	MBH	8.28571429	3.16933804E0	.148	-1.5251159	18.0965445
	AAH	14.00000000*	3.16933804E0	.001	4.1891698	23.8108302
MBH	FH	4.00000000	3.16933804E0	.865	-5.8108302	13.8108302
	MAH	-7.42857143	3.16933804E0	.248	-17.2394016	2.3822588
	SL	-5.11428571E1*	3.16933804E0	.000	-60.9536874	-41.3320269
	MAH2	10.28571429*	3.16933804E0	.034	.4748841	20.0965445
	MAH3	-8.28571429	3.16933804E0	.148	-18.0965445	1.5251159
	AAH	5.71428571	3.16933804E0	.554	-4.0965445	15.5251159
AAH	FH	-1.71428571	3.16933804E0	.998	-11.5251159	8.0965445
	MAH	-1.31428571E1*	3.16933804E0	.003	-22.9536874	-3.3320269
	SL	-5.68571429E1*	3.16933804E0	.000	-66.6679731	-47.0463126
	MAH2	4.57142857	3.16933804E0	.776	-5.2394016	14.3822588
	MAH3	-1.40000000E1*	3.16933804E0	.001	-23.8108302	-4.1891698

MBH	-5.71428571	3.16933804E0	.554	-15.5251159	4.0965445

*. The mean difference is significant at the 0.05 level.

Alkaline

Turkey HSD

	Subset for alpha = 0.05			
Sample	1	2	3	4
MAH2	3.2571429E1			
AAH	3.7142857E1	3.7142857E1		
FH	3.8857143E1	3.8857143E1		
MBH		4.2857143E1	4.2857143E1	
MAH			5.0285714E1	
MAH3			5.1142857E1	
SL				9.4000000E1
Sig.	.440	.554	.148	1.000

Turbidity

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-5.11285714*	.20633598	.000	-5.7515796	-4.4741347
	SL	.16571429	.20633598	.983	-.4730081	.8044367
	MAH2	-.87000000*	.20633598	.002	-1.5087224	-.2312776

Multiple Comparisons

	MAH3	-1.25142857*	.20633598	.000	-1.8901510	-.6127061
	MBH	-1.50142857*	.20633598	.000	-2.1401510	-.8627061
	AAH	.49857143	.20633598	.217	-.1401510	1.1372939
MAH	FH	5.11285714*	.20633598	.000	4.4741347	5.7515796
	SL	5.27857143*	.20633598	.000	4.6398490	5.9172939
	MAH2	4.24285714*	.20633598	.000	3.6041347	4.8815796
	MAH3	3.86142857*	.20633598	.000	3.2227061	4.5001510
	MBH	3.61142857*	.20633598	.000	2.9727061	4.2501510
	AAH	5.61142857*	.20633598	.000	4.9727061	6.2501510
SL	FH	-.16571429	.20633598	.983	-.8044367	.4730081
	MAH	-5.27857143*	.20633598	.000	-5.9172939	-4.6398490
	MAH2	-1.03571429*	.20633598	.000	-1.6744367	-.3969919
	MAH3	-1.41714286*	.20633598	.000	-2.0558653	-.7784204
	MBH	-1.66714286*	.20633598	.000	-2.3058653	-1.0284204
	AAH	.33285714	.20633598	.675	-.3058653	.9715796
MAH2	FH	.87000000*	.20633598	.002	.2312776	1.5087224
	MAH	-4.24285714*	.20633598	.000	-4.8815796	-3.6041347
	SL	1.03571429*	.20633598	.000	.3969919	1.6744367
	MAH3	-.38142857	.20633598	.524	-1.0201510	.2572939
	MBH	-.63142857	.20633598	.054	-1.2701510	.0072939
	AAH	1.36857143*	.20633598	.000	.7298490	2.0072939

MAH3	FH	1.25142857*	.20633598	.000	.6127061	1.8901510
	MAH	-3.86142857*	.20633598	.000	-4.5001510	-3.2227061
	SL	1.41714286*	.20633598	.000	.7784204	2.0558653
	MAH2	.38142857	.20633598	.524	-.2572939	1.0201510
	MBH	-.25000000	.20633598	.886	-.8887224	.3887224
	AAH	1.75000000*	.20633598	.000	1.1112776	2.3887224
MBH	FH	1.50142857*	.20633598	.000	.8627061	2.1401510
	MAH	-3.61142857*	.20633598	.000	-4.2501510	-2.9727061
	SL	1.66714286*	.20633598	.000	1.0284204	2.3058653
	MAH2	.63142857	.20633598	.054	-.0072939	1.2701510
	MAH3	.25000000	.20633598	.886	-.3887224	.8887224
	AAH	2.00000000*	.20633598	.000	1.3612776	2.6387224
AAH	FH	-.49857143	.20633598	.217	-1.1372939	.1401510
	MAH	-5.61142857*	.20633598	.000	-6.2501510	-4.9727061
	SL	-.33285714	.20633598	.675	-.9715796	.3058653
	MAH2	-1.36857143*	.20633598	.000	-2.0072939	-.7298490
	MAH3	-1.75000000*	.20633598	.000	-2.3887224	-1.1112776
	MBH	-2.00000000*	.20633598	.000	-2.6387224	-1.3612776

*. The mean difference is significant at the 0.05 level.

Turbidity

Turkey HSD

	Subset for alpha = 0.)5		
Sample	1	2	3

Multiple Comparisons

AAH	.7671429		
SL	1.1000000E0		
FH	1.2657143E0		
MAH2		2.1357143E0	
MAH3		2.5171429E0	
MBH		2.7671429E0	
MAH			6.3785714E0
Sig.	.217	.054	1.000

Colour

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-2.20000000E1*	2.99724525E0	.000	-31.2781092	-12.7218908
	SL	1.71428571	2.99724525E0	.997	-7.5638234	10.9923949
	MAH2	-4.85714286	2.99724525E0	.670	-14.1352520	4.4209663
	MAH3	-7.71428571	2.99724525E0	.160	-16.9923949	1.5638234
	MBH	1.42857143	2.99724525E0	.999	-7.8495377	10.7066806
	AAH	2.85714286	2.99724525E0	.961	-6.4209663	12.1352520
MAH	FH	22.00000000*	2.99724525E0	.000	12.7218908	31.2781092
	SL	23.71428571*	2.99724525E0	.000	14.4361766	32.9923949
	MAH2	17.14285714*	2.99724525E0	.000	7.8647480	26.4209663
	MAH3	14.28571429*	2.99724525E0	.000	5.0076051	23.5638234

	MBH	23.42857143*	2.99724525E0	.000	14.1504623	32.7066806
	AAH	24.85714286*	2.99724525E0	.000	15.5790337	34.1352520
SL	FH	-1.71428571	2.99724525E0	.997	-10.9923949	7.5638234
	MAH	-2.37142857E1*	2.99724525E0	.000	-32.9923949	-14.4361766
	MAH2	-6.57142857	2.99724525E0	.321	-15.8495377	2.7066806
	MAH3	-9.42857143*	2.99724525E0	.044	-18.7066806	-.1504623
	MBH	-.28571429	2.99724525E0	1.000	-9.5638234	8.9923949
	AAH	1.14285714	2.99724525E0	1.000	-8.1352520	10.4209663
MAH2	FH	4.85714286	2.99724525E0	.670	-4.4209663	14.1352520
	MAH	-1.71428571E1*	2.99724525E0	.000	-26.4209663	-7.8647480
	SL	6.57142857	2.99724525E0	.321	-2.7066806	15.8495377
	MAH3	-2.85714286	2.99724525E0	.961	-12.1352520	6.4209663
	MBH	6.28571429	2.99724525E0	.373	-2.9923949	15.5638234
	AAH	7.71428571	2.99724525E0	.160	-1.5638234	16.9923949
MAH3	FH	7.71428571	2.99724525E0	.160	-1.5638234	16.9923949
	MAH	-1.42857143E1*	2.99724525E0	.000	-23.5638234	-5.0076051
	SL	9.42857143*	2.99724525E0	.044	.1504623	18.7066806
	MAH2	2.85714286	2.99724525E0	.961	-6.4209663	12.1352520
	MBH	9.14285714	2.99724525E0	.056	-.1352520	18.4209663
	AAH	10.57142857*	2.99724525E0	.016	1.2933194	19.8495377
MBH	FH	-1.42857143	2.99724525E0	.999	-10.7066806	7.8495377
	MAH	-2.34285714E1*	2.99724525E0	.000	-32.7066806	-14.1504623
	SL	.28571429	2.99724525E0	1.000	-8.9923949	9.5638234

Multiple Comparisons

	MAH2	-6.28571429	2.99724525E0	.373	-15.5638234	2.9923949
	MAH3	-9.14285714	2.99724525E0	.056	-18.4209663	.1352520
	AAH	1.42857143	2.99724525E0	.999	-7.8495377	10.7066806
AAH	FH	-2.85714286	2.99724525E0	.961	-12.1352520	6.4209663
	MAH	-2.48571429E1*	2.99724525E0	.000	-34.1352520	-15.5790337
	SL	-1.14285714	2.99724525E0	1.000	-10.4209663	8.1352520
	MAH2	-7.71428571	2.99724525E0	.160	-16.9923949	1.5638234
	MAH3	-1.05714286E1*	2.99724525E0	.016	-19.8495377	-1.2933194
	MBH	-1.42857143	2.99724525E0	.999	-10.7066806	7.8495377

*. The mean difference is significant at the 0.05 level.

Colour

Turkey HSD

	Subset for alpha = 0.)5		
Sample	1	2	3
AAH	.8571429		
SL	2.0000000E0		
MBH	2.2857143E0	2.2857143E0	
FH	3.7142857E0	3.7142857E0	
MAH2	8.5714286E0	8.5714286E0	
MAH3		1.1428571E1	
MAH			2.5714286E1
Sig.	.160	.056	1.000

Manganese

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	.11057143	.05575369	.440	-.0620167	.2831595
	SL	.15800000	.05575369	.092	-.0145881	.3305881
	MAH2	.12214286	.05575369	.322	-.0504452	.2947310
	MAH3	-.28228571*	.05575369	.000	-.4548738	-.1096976
	MBH	.01357143	.05575369	1.000	-.1590167	.1861595
	AAH	.15257143	.05575369	.114	-.0200167	.3251595
MAH	FH	-.11057143	.05575369	.440	-.2831595	.0620167
	SL	.04742857	.05575369	.978	-.1251595	.2200167
	MAH2	.01157143	.05575369	1.000	-.1610167	.1841595
	MAH3	-.39285714*	.05575369	.000	-.5654452	-.2202690
	MBH	-.09700000	.05575369	.594	-.2695881	.0755881
	AAH	.04200000	.05575369	.988	-.1305881	.2145881
SL	FH	-.15800000	.05575369	.092	-.3305881	.0145881
	MAH	-.04742857	.05575369	.978	-.2200167	.1251595
	MAH2	-.03585714	.05575369	.995	-.2084452	.1367310
	MAH3	-.44028571*	.05575369	.000	-.6128738	-.2676976
	MBH	-.14442857	.05575369	.155	-.3170167	.0281595
	AAH	-.00542857	.05575369	1.000	-.1780167	.1671595
MAH2	FH	-.12214286	.05575369	.322	-.2947310	.0504452

Multiple Comparisons

	MAH	-.01157143	.05575369	1.000	-.1841595	.1610167
	SL	.03585714	.05575369	.995	-.1367310	.2084452
	MAH3	-.40442857*	.05575369	.000	-.5770167	-.2318405
	MBH	-.10857143	.05575369	.462	-.2811595	.0640167
	AAH	.03042857	.05575369	.998	-.1421595	.2030167
MAH3	FH	.28228571*	.05575369	.000	.1096976	.4548738
	MAH	.39285714*	.05575369	.000	.2202690	.5654452
	SL	.44028571*	.05575369	.000	.2676976	.6128738
	MAH2	.40442857*	.05575369	.000	.2318405	.5770167
	MBH	.29585714*	.05575369	.000	.1232690	.4684452
	AAH	.43485714*	.05575369	.000	.2622690	.6074452
MBH	FH	-.01357143	.05575369	1.000	-.1861595	.1590167
	MAH	.09700000	.05575369	.594	-.0755881	.2695881
	SL	.14442857	.05575369	.155	-.0281595	.3170167
	MAH2	.10857143	.05575369	.462	-.0640167	.2811595
	MAH3	-.29585714*	.05575369	.000	-.4684452	-.1232690
	AAH	.13900000	.05575369	.188	-.0335881	.3115881
AAH	FH	-.15257143	.05575369	.114	-.3251595	.0200167
	MAH	-.04200000	.05575369	.988	-.2145881	.1305881
	SL	.00542857	.05575369	1.000	-.1671595	.1780167
	MAH2	-.03042857	.05575369	.998	-.2030167	.1421595

	MAH3	-.43485714*	.05575369	.000	-.6074452	-.2622690
	MBH	-.13900000	.05575369	.188	-.3115881	.0335881

*. The mean difference is significant at the 0.05 level.

Manganese

Turkey HSD

Sample	Subset for alpha = 0.05	
	1	2
SL	.0542857	
AAH	.0597143	
MAH2	.0901429	
MAH	.1017143	
MBH	.1987143	
FH	.2122857	
MAH3		.4945714
Sig.	.092	1.000

Iron

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-.12000000*	.02414324	.000	-.1947365	-.0452635
	SL	.20285714*	.02414324	.000	.1281206	.2775936
	MAH2	.16142857*	.02414324	.000	.0866921	.2361651

Multiple Comparisons

	MAH3	-.10142857*	.02414324	.002	-.1761651	-.0266921
	MBH	-.02142857	.02414324	.973	-.0961651	.0533079
	AAH	.16571429*	.02414324	.000	.0909778	.2404508
MAH	FH	.12000000*	.02414324	.000	.0452635	.1947365
	SL	.32285714*	.02414324	.000	.2481206	.3975936
	MAH2	.28142857*	.02414324	.000	.2066921	.3561651
	MAH3	.01857143	.02414324	.987	-.0561651	.0933079
	MBH	.09857143*	.02414324	.003	.0238349	.1733079
	AAH	.28571429*	.02414324	.000	.2109778	.3604508
SL	FH	-.20285714*	.02414324	.000	-.2775936	-.1281206
	MAH	-.32285714*	.02414324	.000	-.3975936	-.2481206
	MAH2	-.04142857	.02414324	.610	-.1161651	.0333079
	MAH3	-.30428571*	.02414324	.000	-.3790222	-.2295492
	MBH	-.22428571*	.02414324	.000	-.2990222	-.1495492
	AAH	-.03714286	.02414324	.721	-.1118794	.0375936
MAH2	FH	-.16142857*	.02414324	.000	-.2361651	-.0866921
	MAH	-.28142857*	.02414324	.000	-.3561651	-.2066921
	SL	.04142857	.02414324	.610	-.0333079	.1161651
	MAH3	-.26285714*	.02414324	.000	-.3375936	-.1881206
	MBH	-.18285714*	.02414324	.000	-.2575936	-.1081206
	AAH	.00428571	.02414324	1.000	-.0704508	.0790222

MAH3	FH	.10142857*	.02414324	.002	.0266921	.1761651
	MAH	-.01857143	.02414324	.987	-.0933079	.0561651
	SL	.30428571*	.02414324	.000	.2295492	.3790222
	MAH2	.26285714*	.02414324	.000	.1881206	.3375936
	MBH	.08000000*	.02414324	.029	.0052635	.1547365
	AAH	.26714286*	.02414324	.000	.1924064	.3418794
MBH	FH	.02142857	.02414324	.973	-.0533079	.0961651
	MAH	-.09857143*	.02414324	.003	-.1733079	-.0238349
	SL	.22428571*	.02414324	.000	.1495492	.2990222
	MAH2	.18285714*	.02414324	.000	.1081206	.2575936
	MAH3	-.08000000*	.02414324	.029	-.1547365	-.0052635
	AAH	.18714286*	.02414324	.000	.1124064	.2618794
AAH	FH	-.16571429*	.02414324	.000	-.2404508	-.0909778
	MAH	-.28571429*	.02414324	.000	-.3604508	-.2109778
	SL	.03714286	.02414324	.721	-.0375936	.1118794
	MAH2	-.00428571	.02414324	1.000	-.0790222	.0704508
	MAH3	-.26714286*	.02414324	.000	-.3418794	-.1924064
	MBH	-.18714286*	.02414324	.000	-.2618794	-.1124064

*. The mean difference is significant at the 0.05 level.

Iron

Turkey HSD

Sample	Subset for alpha = 0.)5

Multiple Comparisons

	1	2	3
SL	.0442857		
AAH	.0814286		
MAH2	.0857143		
FH		.2471429	
MBH		.2685714	
MAH3			.3485714
MAH			.3671429
Sig.	.610	.973	.987

Zinc

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-.04571429	.01828401	.185	-.1023133	.0108847
	SL	-.01428571	.01828401	.986	-.0708847	.0423133
	MAH2	-.04428571	.01828401	.215	-.1008847	.0123133
	MAH3	-.08428571*	.01828401	.001	-.1408847	-.0276867
	MBH	-.01000000	.01828401	.998	-.0665990	.0465990
	AAH	-.06000000*	.01828401	.031	-.1165990	-.0034010
MAH	FH	.04571429	.01828401	.185	-.0108847	.1023133
	SL	.03142857	.01828401	.608	-.0251704	.0880276
	MAH2	.00142857	.01828401	1.000	-.0551704	.0580276
						.0180276

	MAH3	-.03857143	.01828401	.366	-.0951704	.0923133
	MBH	.03571429	.01828401	.458	-.0208847	.0423133
	AAH	-.01428571	.01828401	.986	-.0708847	
SL	FH	.01428571	.01828401	.986	-.0423133	.0708847
	MAH	-.03142857	.01828401	.608	-.0880276	.0251704
	MAH2	-.03000000	.01828401	.657	-.0865990	.0265990
	MAH3	-.07000000*	.01828401	.007	-.1265990	-.0134010
	MBH	.00428571	.01828401	1.000	-.0523133	.0608847
	AAH	-.04571429	.01828401	.185	-.1023133	.0108847
MAH2	FH	.04428571	.01828401	.215	-.0123133	.1008847
	MAH	-.00142857	.01828401	1.000	-.0580276	.0551704
	SL	.03000000	.01828401	.657	-.0265990	.0865990
	MAH3	-.04000000	.01828401	.324	-.0965990	.0165990
	MBH	.03428571	.01828401	.507	-.0223133	.0908847
	AAH	-.01571429	.01828401	.977	-.0723133	.0408847
MAH3	FH	.08428571*	.01828401	.001	.0276867	
	MAH	.03857143	.01828401	.366	-.0180276	
	SL	.07000000*	.01828401	.007	.0134010	.1408847
	MAH2	.04000000	.01828401	.324	-.0165990	.0951704
	MBH	.07428571*	.01828401	.004	.0176867	.1265990
	AAH	.02428571	.01828401	.835	-.0323133	.0965990
MBH	FH	.01000000	.01828401	.998	-.0465990	.1308847
						.0808847
						.0665990

Multiple Comparisons

	MAH	-.03571429	.01828401	.458	-.0923133	.0208847
	SL	-.00428571	.01828401	1.000	-.0608847	.0523133
	MAH2	-.03428571	.01828401	.507	-.0908847	.0223133
	MAH3	-.07428571*	.01828401	.004	-.1308847	-.0176867
	AAH	-.05000000	.01828401	.115	-.1065990	.0065990
AAH	FH	.06000000*	.01828401	.031	.0034010	
	MAH	.01428571	.01828401	.986	-.0423133	
	SL	.04571429	.01828401	.185	-.0108847	.1165990
	MAH2	.01571429	.01828401	.977	-.0408847	.0708847
	MAH3	-.02428571	.01828401	.835	-.0808847	.1023133
	MBH	.05000000	.01828401	.115	-.0065990	.0723133
						.0323133
						.1065990

*. The mean difference is significant at the 0.05 level.

Zinc

Turkey HSD

	Subset for alpha = 0.)5		
Sample	1	2	3
FH	.0128571		
MBH	.0228571	.0228571	
SL	.0271429	.0271429	
MAH2	.0571429	.0571429	.0571429
MAH	.0585714	.0585714	.0585714

AAH		.0728571	.0728571
MAH3			.0971429
Sig.	.185	.115	.324

Salinity

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
FH	MAH	-4.20571429E2*	7.24404249E1	.000	-6.4481406E2	-1.9632879E2
	SL	-14.42857143	7.24404249E1	1.000	-2.3867121E2	209.8140624
	MAH2	-1.59142857E2	7.24404249E1	.319	-3.8338549E2	65.0997767
	MAH3	-2.92142857E2*	7.24404249E1	.004	-5.1638549E2	-67.9002233
	MBH	-6.06000000E2*	7.24404249E1	.000	-8.3024263E2	-3.8175737E2
	AAH	1.84142857E2	7.24404249E1	.171	-40.0997767	408.3854910
MAH	FH	4.20571429E2*	7.24404249E1	.000	196.3287948	644.8140624
	SL	4.06142857E2*	7.24404249E1	.000	181.9002233	630.3854910
	MAH2	2.61428571E2*	7.24404249E1	.013	37.1859376	485.6712052
	MAH3	1.28428571E2	7.24404249E1	.573	-95.8140624	352.6712052
	MBH	-1.85428571E2	7.24404249E1	.165	-4.0967121E2	38.8140624
	AAH	6.04714286E2*	7.24404249E1	.000	380.4716519	828.9569195
SL	FH	14.42857143	7.24404249E1	1.000	-2.0981406E2	238.6712052
	MAH	-4.06142857E2*	7.24404249E1	.000	-6.3038549E2	-1.8190022E2
	MAH2	-1.44714286E2	7.24404249E1	.431	-3.6895692E2	79.5283481
	MAH3	-2.77714286E2*	7.24404249E1	.007	-5.0195692E2	-53.4716519

Multiple Comparisons

	MBH	-5.91571429E2*	7.24404249E1	.000	-8.1581406E2	-3.6732879E2
	AAH	1.98571429E2	7.24404249E1	.113	-25.6712052	422.8140624
MAH2	FH	1.59142857E2	7.24404249E1	.319	-65.0997767	383.3854910
	MAH	-2.61428571E2*	7.24404249E1	.013	-4.8567121E2	-37.1859376
	SL	1.44714286E2	7.24404249E1	.431	-79.5283481	368.9569195
	MAH3	-1.33000000E2	7.24404249E1	.532	-3.5724263E2	91.2426338
	MBH	-4.46857143E2*	7.24404249E1	.000	-6.7109978E2	-2.2261451E2
	AAH	3.43285714E2*	7.24404249E1	.000	119.0430805	567.5283481
MAH3	FH	2.92142857E2*	7.24404249E1	.004	67.9002233	516.3854910
	MAH	-1.28428571E2	7.24404249E1	.573	-3.5267121E2	95.8140624
	SL	2.77714286E2*	7.24404249E1	.007	53.4716519	501.9569195
	MAH2	1.33000000E2	7.24404249E1	.532	-91.2426338	357.2426338
	MBH	-3.13857143E2*	7.24404249E1	.002	-5.3809978E2	-89.6145090
	AAH	4.76285714E2*	7.24404249E1	.000	252.0430805	700.5283481
MBH	FH	6.06000000E2*	7.24404249E1	.000	381.7573662	830.2426338
	MAH	1.85428571E2	7.24404249E1	.165	-38.8140624	409.6712052
	SL	5.91571429E2*	7.24404249E1	.000	367.3287948	815.8140624
	MAH2	4.46857143E2*	7.24404249E1	.000	222.6145090	671.0997767
	MAH3	3.13857143E2*	7.24404249E1	.002	89.6145090	538.0997767
	AAH	7.90142857E2*	7.24404249E1	.000	565.9002233	1.0143855E3
AAH	FH	-1.84142857E2	7.24404249E1	.171	-4.0838549E2	40.0997767

	MAH	-6.04714286E2*	7.24404249E1	.000	-8.2895692E2	-3.8047165E2
	SL	-1.98571429E2	7.24404249E1	.113	-4.2281406E2	25.6712052
	MAH2	-3.43285714E2*	7.24404249E1	.000	-5.6752835E2	-1.1904308E2
	MAH3	-4.76285714E2*	7.24404249E1	.000	-7.0052835E2	-2.5204308E2
	MBH	-7.90142857E2*	7.24404249E1	.000	-1.0143855E3	-5.6590022E2

*. The mean difference is significant at the 0.05 level.

Salinity

Turkey HSD

	Subset for alpha = 0.05				
Sample	1	2	3	4	5
AAH	1.4714286E2				
FH	3.3128571E2	3.3128571E2			
SL	3.4571429E2	3.4571429E2			
MAH2		4.9042857E2	4.9042857E2		
MAH3			6.2342857E2	6.2342857E2	7.5185714E2
MAH				7.5185714E2	9.3728571E2
MBH					.165
Sig.	.113	.319	.532	.573	

NB: The numbers shown (1, 2... n) shows significant differences between sampling sites as against sampling parameter under consideration. i.e. 1>2>3>…>n