KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

KUMASI

WATER QUALITY OF BOREHOLES AND HAND-DUG WELLS AT PAKYI No. 1 IN THE AMANSIE WEST DISTRICT OF ASHANTI REGION OF GHANA.

BY

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DECLARATION

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

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ABSTRACT

The study looked at the water quality of selected boreholes and hand-dug wells which serve as the main sources of drinking water to the inhabitants of Pakyi No1 township in terms of microbial and physicochemical parameters. Water samples were collected and analysed monthly for four months from November, 2012 to February, 2013. The results were compared to World Health Organisation standards. The physicochemical parameters were within WHO standards except PH of some hand-dug wells which were slightly acidic but still within the WHO limit. The nutrients such as NO^{-}_{3} and NO^{-}_{2} were higher in hand-dug wells than the boreholes. Faecal coliforms, *E.coli* and *Salmonella* were also recorded at some points which were higher above recommended level for drinking water by WHO. It was recommended among others that frequent checks should be carried on the borehole areas to identify early incidence of contamination to take action and the surroundings of boreholes should be kept clean by educating the inhabitants.

DEDICATION

I, Osei Peter, dedicate this project work to my lovely wife Doris Nyarko, my two sons Newton Osei and Listowel Osei, my only daughter Osei Addai Benedicta and my late mother Abena Addai.

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INTRODUCTION

1.1 BACKGROUND

Water is one of the essential things needed for the well being of individuals. The quality of sources of drinking water cannot therefore, be left out. To ensure good quality of drinking water, its microbiological and physicochemical analysis should be done. This analysis will help to identify micro-organisms that results in water- borne diseases and its subsequent effects on the health of people especially the rural folks.

Quality drinking water is essential for life. Unfortunately, in many countries around the world, including Ghana, water has become a scarce commodity as only a small proportion of the populace has access to treated water (IDLO, 2006). Alternative sources of water such as rainwater and ground water have become major sources of drinking water for people living in new settlements and some residents who do not have access to treated water in Ghana. The need to assess the quality of water from some of these alternative sources has become imperative because they have a direct effect on the health of individuals (WHO, 2002).

Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources (Singh and Mosley 2003). Even if no sources of anthropogenic contamination exist there is potential for natural levels of metals and other chemicals to be harmful to human health. This was highlighted in Bangladesh where natural levels of arsenic in groundwater were found to be causing harmful effects on the population (Anawara *et al.*, 2002). Unfortunately, this problem arose because the groundwater was extracted for drinking without a detailed chemical investigation. The natural water analyses for physical and chemical properties including trace element contents are very important for public health studies (Baranowski *et al*., 2000). These studies are also a main part of pollution studies in the environment.

Bacterial pathogens enter water supplies from the direct disposal of waste into streams or lakes or from runoff from wooded areas, pastures, feedlots, septic tanks, and sewage plants into streams or groundwater. Coliform can also enter an individual house via backflow of water from a contaminated source, carbon filters, or leaking well caps that allow dirt and dead organisms to fall into the water (NGA, 2008). The presence of *Escherichia coli* in drinking water denotes that the water has been faecally contaminated and therefore presents a potential health risk to households that use them untreated (WHO, 2003).

Research conducted in Ghana by Kwakye-Nuako *et al*., (2007) indicated that 77% of filtered underground water samples sold as sachet water that were analyzed contained infective stages of pathogenic parasitic organisms. Common pathogens and indicators identified in the Kwakye-Nuako *et al*., study include, *Microsporidia spp*. (51.2%), *Cryptosporidium parvum* (63.0%), *Cyclospora cayetenens* (59.3%), *Sarcocystis* sp. (66.7%), Rotifers (18.5%), and Charcoat Leyden crystals (evidence of allergies or parasitic infection) (44.4%). Ninety-three percent of the samples contained unidentified impurities/artifacts. A total of 29.6% of the samples contained at least one type of parasite, 14.8% contained at least 2 types of parasites, 25.9% contained at least three types of parasites, and 29.6% contained four types of parasites. This has grim public health implications as the organisms identified can cause water related diseases that have serious complications in children and adults particularly immune-compromised individuals.

These factors have led to the growing rate of water borne diseases such as typhoid fever and cholera experienced in this part of the world (Edwards, 1993). The current status as described by the WHO/UNICEF Joint Monitoring Programme indicates that 2.6 billion people are without improved sanitation and nearly 900 million people lack access to improved source of potable water and this situation is unacceptable (WHO/UNICEF,2010).

With families living in poverty and local communities often left to look after themselves with none or very little assistance from overstretched or underfunded governments and local communities, a poverty trap is created that simply does not allow for investment in clean water sources and the cycle just continues.

1.2 JUSTIFICATION

Despite the many benefits of improved sources of potable water for human development, many developing countries including Ghana seem to allocate insufficient resources to meet the millennium development goal (MDG) target for sanitation and potable water. There are also great inequalities in access to clean water and sanitation (UNEP, 2009). As a result of insufficient supply of water, most households depend on hand dug wells and bole hole (ground water) for drinking water and for other purposes. It is therefore very important to analyze the quality of ground water to ascertain whether they are safe for drinking.Not much has been done on the quality of water used within Pakyi No. 1 community, it is therefore necessary to ascertain the safeness or otherwise of the water.

1.3 OBJECTIVES OF THE STUDY

Main objective: To assess the microbiological and physicochemical qualities of selected boreholes and hand- dug wells in the Pakyi No.1 township.

Specific objectives:

1. To determine the total and faecal coliforms in boreholes at Pakyi No. 1.

2. To determine the total and feacal coliforms in water from hand dug wells at Pakyi No. 1
3. To determine the physico-chemical parameters of the ground water such as pH, DO, BOD, TDS, TSS and conductivity.
4. To determine the levels of nutrients like, nitrates, phosphates and sulphates in the hand dug wells and boreholes at Pakyi No. 1.

CHAPTER TWO

LITERATUREREVIEW

2. 1 Water as the basis of life.

Most biological phenomena take place in a water medium and therefore wherever water exists in nature it always holds life. It plays an essential role in circulation of body fluids in plants and animals, and it stands as the key substance for the existence and continuity of life through reproduction and different cyclic processes in nature (Krishnan 2008).

Water has an in-built mechanism to maintain its purity after every use, but due to an increase in anthropogenic activities it is unable to do keep up with the rate. Humans are bound therefore to monitor the impact of this activity on natural freshwater continuously (Krishnan, 2008)

2.2 Global Accessibility of Drinking Water

Potable water or drinking water is water of sufficiently high quality that can be consumed or used with low risk of immediate or long term harm (http/www.bbc.co.uk/health living). Access to drinking water and improved sanitation is a fundamental need and a human right which is vital for the dignity and health of all people. The Millennium Development Goal (MDG) target -7 calls for reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015. Reaching this target implies, tackling both the quantity (access, scarcity) and quality (safety) dimensions of drinking water provision (WHO guidelines for drinking water, 2010). The health and economic benefits of improved water supply to households and individuals (especially children) are both indicators used to monitor progress towards the Millennium Development Goals (MDGs) (WHO/UNICEF, 2004).

The most frequently used definition of safe water accessibility is that of the United Nations Development Program (UNDP) which states that, those with access comprise the proportion of the population using any piped water, public tap, borehole with a pump, protected well and springs or rainwater (UNDP, 2002).

The World Bank also provides various definitions dependent on the type of residential area being assessed. In urban areas, such a source (of safe drinking water) may be a public fountain or standpoint located not more than 200 meters away and in rural areas access implies that; members of the household do not have to spend a disproportionate part of the day fetching water(World Bank,1997).

The use of improved sources of drinking water is high globally, with 87% of the world population and 84% of the people in developing regions getting their drinking water from such sources (WHO/UNICEF, 2010). Even so, 884 million people in the world today still do not get their drinking water from improved sources; almost all of them are in developing regions. Sub-Saharan Africa accounts for over a third of that number and is lagging behind in the progress towards the Millennium Development Goal target with only 60% of the population using improved sources of drinking water despite an increase of 11% percentage points since 1990 (WHO/UNICEF 2010).

The rural population without access to an improved drinking water resource is over five times greater than that in urban areas. Of almost 1.8 billion gaining access to improved water in the period 1990-2008, 59% live in urban areas. In urban areas however the increase in coverage is barely keeping pace with population growth (WHO/UNICEF, 2010). In Ghana for instance, it is estimated that approximately 10.3 million people (51%) have access to improved water supplies and for the 8.4 million residents in the country‘s urban areas this increases slightly to 61% with two thirds of these or 40% of the total urban population covered by the Ghana Water Company Limited (GWCL) networks. The estimated rural water supply coverage is much lower at 44% (Water Aid Report, 2008).

2.3 Groundwater as an alternative.

Groundwater is increasingly becoming the source of drinking water for inhabitants of both rural and urban settlements due to constant water shortage which has been hitting most parts of the country. The United Nations declared 1981-1990 a water-and-sanitation decade (WHO, 2002). It has been estimated that lack of clean drinking water and sanitation services leads to water-related diseases globally and between five to ten million deaths occur annually, primarily of small children (Snyder and Merson, 1982).

In Kumasi, the Ghana Water Company Limited (GWCL), which is mandated to provide potable water for the inhabitants of city and urban areas, is unable to supply adequate quantities due to the ever-increasing population and the inability of the government to expand the infrastructure to cater for the requirement of potable water.

Most places do not have pipelines and those who have do not have water flowing through their taps for years. This has led to the people resorting to alternative means of getting water, such as drilling wells and boreholes.

2.4 How water gets into the ground.

Whenever it rains, some of the water flows on the land surface into rivers, lakes and streams some evaporates into the atmosphere whiles a majority seeps into the ground like a glass of water poured on a pile of sand (Clark *et al.,* 1995). The water that eventually get into the soil is utilized by plant and soil organism whiles the water not used moves deeper into spaces in the ground. This water then moves downwards through cracks in the soil and fractures in rocks until it is intercepted by an impermeable layer of clay or rock. The water then accumulates on this layer filling up all available spaces until saturation. The top of the impermeable layer become the water table whiles the accumulated water becomes the ground water.

2.5 Aquifers and bore holes

Ground water users would find life easier if the water level in the aquifers that supplied their wells always stayed the same. Seasonal variations in rainfall and occasional drought affect the volume of the ground water. If a well is pumped at a faster rate than the aquifer is recharged, then the level of the groundwater can be lowered (Davis and De Weist, 1966). The water level in a bore hole can also be lowered if other bore holes near it draw more water than the aquifer is recharged. This makes drawdown fall below the pumps.

Ground water may contain some natural impurities or contaminants, even without human activity or disturbance. Natural contaminants can come from many conditions 9 in the watershed or in the ground. Water moving through underground rocks and soils may pick up magnesium, calcium and chlorides. Some ground water naturally contains dissolved elements such as arsenic, boron, selenium or radon a gas formed by the natural breakdown of radioactive uranium in soil. These natural contaminants become a health hazard when they are present in high doses. In addition to natural contaminants, ground water is often polluted by human activities such as improper use of fertilizers, animal manure, herbicides, insecticides and pesticides. Poorly built septic tanks and sewage systems for household wastewater, leaking or abandoned underground storage tanks, piping storm-waters drains that discharge chemicals to ground water and improper disposal or storage of waste chemical spills at local industrial sites all contribute to the pollution of ground water.

2.6 Ground water construction in Ghana

Groundwater development in Ghana can be traced from the 19th Century where communities solely depended on hand dug wells for their potable source of water supply. The colonial

governments from 1920-1945 initiated a national hand dug well program under the patronage of Rural Water Division a wing of the Gold Coast Survey Department (Osiakwan, 2002).
The construction of boreholes in Ghana began in the 1940's. This was to increase the water supply to rural and urban communities. Since then it is believed that thousands of hand-dug wells and boreholes have been constructed both by local and external donors.

The Ghana Water Company Limited by the year 2000 had constructed 25,000 boreholes all over the country. Through the help of the German government, another 3,000 boreholes have been drilled in southern Ghana between 1978 and 1983 (Issah, 2002). The World Vision International (WVI) between 1985 to June 2000 had drilled 1,523 boreholes throughout the country (WVI, 2000).

The governments of Ghana through collaboration with bodies like Community Water and Sanitation Agency, Catholic Relief Agency, World Vision International and many other non-governmental organizations currently, drill hundreds of boreholes annually throughout the country. This has made boreholes water indispensable in most Ghanaian communities.

2.7 Ground water quality

Water quality is a measure of the condition of water relative to the requirements of one or more biotic species and to any human need or purpose and it is most frequently used by reference to a set of standards against which compliance can be assessed. (Diersing, 2009). Water quality parameters include the physical, chemical and biological characteristics of water.

Groundwater is actually a complex, generally dilute, chemical solution. The chemical composition is derived mainly from the dissolution of minerals in the soil and rocks with which it is or has been in contact. The type and extent of chemical contamination of the groundwater is largely dependent on the geochemistry of the soil through which the water flows prior to reaching the Aquifers (Zuane, 1990). The chemical alteration of the groundwater depends on several factors, such as interaction with solid phases, residence time of groundwater, seepage of polluted runoff water, mixing of groundwater with pockets of saline water and anthropogenic impacts(Umar and Absar, 2003; Umar *et al*., 2006).

Groundwater in its natural state is generally of good quality. This is because rocks and their derivatives such as soils act as filters. However, not all soils are equally effective in this respect and therefore pathogens contained in human excreta such as bacteria and viruses are likely to be small enough to be transmitted through the soil and aquifer matrix to groundwater bodies (Lewis *et al.*, 1982).

Rainfall is a dilute chemical solution and contributes significant proportions to some constituents in groundwater, especially in regions with little soil cover where hard compact rocks occur at or near the surface. As water flows through the ground the dissolution of minerals continues and the concentration of dissolved constituents tends to increase with the length of the flow path. At great depths, where the rate of flow is extremely slow, groundwater is saline, with concentrations ranging up to ten times the salinity of the sea. Groundwater can become unpotable if it becomes polluted and is no longer safe to drink. In areas where the material above the aquifer is permeable, pollutants can seep into groundwater. This is particularly so in a fractured aquifer.

2.8 Water pollution

Water pollution may be defined as any physical, biological or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses (Fei- Baffoe, 2008). Another definition indicates that, water is polluted when it contains enough foreign material to render it unfit for a specific beneficial use such as for drinking, recreation or fish propagation (Fei- Baffoe, 2008).

Water pollution usually occurs when pollutants are discharged directly into water bodies without adequate treatment to remove harmful compounds which affects plants and other organisms living in these bodies of water and in almost all cases the effect is damaging not only to individual species and population, but also to the natural biological communities (http//environment.about.com/environmental events/waterdayqa.htm)

Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells) and has been suggested as the leading worldwide cause of deaths of more than 14,000 people daily. (http/environment.about.com/environmental events/waterdayqa.htm).

Water pollutants can be classified according to the nature of origin or into groups of substances based primarily on their environmental or heath effects. According to the nature of its origin, water pollutants could be classified as Point Source Pollutants (PS) or Non-point Source Pollutants (NPS). A point source is one that reaches the water from a pipe, channel or any other confined and localized source such as discharges from a sewage treatment plant, a factory or a city storm drain.

A non-point or dispersed source is broad, unconfined area from which pollutants enter a body of water; e.g. Surface run-off from agricultural areas carries silt, fertilizers pesticides and animal waste into streams but not at one particular point (Fei Baffoe, 2008)

Other classes of water pollutants are based on their environmental or health effects and may include inorganic chemicals, organic chemicals, oxygen depleting wastes, radioactive materials and thermal pollution.

2.9: Domestic sources of ground water contamination

A major cause of ground water contamination is effluent (outflow) from septic tanks and cesspools. Misuse of these systems for disposal of anything other than domestic or sanitary waste can pose a substantial threat to ground water. Residential wastewater systems can be a source of many categories of contaminants including bacteria, viruses and nitrates from human waste and organic compounds.

Injection wells used for domestic wastewater disposal (septic systems, cesspool drainage wells for storm water runoff, ground water recharge wells) are of particular concern to ground water quality if located close to and up gradient of drinking water wells. Improper storing or disposal of household chemicals such as paints, synthetic detergents, solvents, oils, medicines, disinfectants, pool chemicals, pesticides, batteries, gasoline and diesel fuel can lead to ground water contamination. When stored in garages or basements with floor drains, spills and flooding may introduce such contaminants into the ground water because community landfills are not equipped to handle hazardous materials. Similarly, waste dumped or buried in the ground can contaminate the soil and leach into the ground water.

As urban areas grow, there is an increase in rain water runoff caused by the additions of paved surfaces. Some municipalities use storm water drainage wells to dispose off this additional runoff particularly if the area is not served by storm sewers nor has a limited sewer system. These low-cost low-tech wells and landscaped areas Storm water drainage wells that communities use to control water during storm events pose a threat to ground water particularly in kart area or areas with a high water table. Fertilizers, herbicides, insecticides, fungicides and pesticides applied to the lawn and garden contain hazardous chemicals that can travel through the soil and contaminate the ground water.

In the garage, items that are improperly used, stored or disposed off may potentially contaminate ground water especially if there is a drain to the ground in the floor of the garage. Sources include batteries that contain lead, cadmium or mercury. Paints containing lead and barium, gasoline and oils containing compounds, barium from diesel fuel combustion.

Water used in the home and entering a septic system or sewer system may contain detergents from dishwashing and laundry, organic compounds from garbage, disposal bacteria, nitrates, and sulphates from sewage, greases and oils. Cleaning agents, aerosol sprays coolants and solvents which all contain carbon tetrachloride household pesticides. Water percolating through landfills is known as Leachate. From landfills that contain household and other waste may pick up dissolved solids and volatile organic compounds. Lawns with over applied or misapplied fertilizers, herbicides and fungicides might introduce these contaminants tetrachloride and heavy metals such as manganese into ground (USEPA, 1997).

2.10 Natural sources of groundwater contamination

Ground water contains some impurities even if it is unaffected by human activities. The types and concentrations of natural impurities depends on the nature of the geological materials through which the groundwater moves and the quality of the recharge water.

Ground water moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium and chlorides. Some aquifers have high natural concentration of dissolved constituents such as arsenic, boron and selenium. The effect of these natural sources of contamination on ground water quality depends on the type of contaminants and its concentration.

Some of the contaminants that occur naturally are: Aluminum, arsenic, barium, chloride, chromium, coliform bacteria, copper, fluoride, hardness, iron, lead. Manganese, mercury, nitrate, selenium, silver, sodium, sulfate, zinc (USEPA, 1997).

2.11 Physicochemical assessment of water quality.

Physicochemical parameters are the physical and chemical parameters associated with water which have an influence on its quality and also affect the biological constituents of the water (Oluyemi *et al.*, 2010). The physical factors such as temperature, colour, turbidity and conductivity can affect the aesthetics and taste of the water and may also complicate the removal of microbial pathogens during water treatment. The chemical parameters include pH, alkalinity, hardness, anions such as sulphates, phosphates, nitrates, nitrites, fluoride etc, as well as heavy metals which often tend to pose more chronic health risks through the buildup of the metals, even though some other components like nitrates, nitrites and arsenic can have a more immediate impact on consumers (http/en.wikipedia.org/wiki/drinking water).

2.11.1 Colour

Colour of water is one of the most important and conveniently observed indicators of its quality. The highest quality drinking water should be colourless (WHO, 2008*)*.Potential inorganic, organic or bacteriological contributions of colour to natural water are;

(a) Inorganic constituents such as dissolved iron

(b) Dissolved organic substances like humic or fulvic acids, from anthropogenic sources such as dyes and

(c) Suspended particulate matter such as plant debris, phytoplankton and zooplanktons.

Some of these contributors may be harmless but others are definitely harmful. Suspended organic matter may itself be harmless but may harbour bacterial and viral contaminants which may be harmful to health.

Traditionally, the colours of liquids including drinking water are classified according to the Alpha/Hazen/Pt-Co colour scale (Abid and Jamil, 2005). WHO suggest that, water of colour below 15 Colour Units (CU) is acceptable to consumers although no health based guideline value is proposed for colour in drinking water (WHO, 2008)

2.11.2 pH

pH is a measure of the acidity or alkalinity of a solution. Pure water is said to be of neutral pH which is approximately 7.0 at 25 degree Celsius. Although pH usually has no direct impact on consumers, it is one of the most operational water quality parameters (WHO, 2008). Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8, however lower pH water is likely to be corrosive. Failure to minimize corrosion can result in the contamination of drinking water and have an adverse effect on its taste and appearance. WHO guidelines suggest that the optimum pH required in drinking water should be in the range 6.5-8.5 (WHO, 2008).

2.11.3 Conductivity

Conductivity is a measure of the ability of water to pass on or transmit an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chlorides, nitrates, sulphates, phosphate anions or sodium, magnesium, calcium, iron and aluminum cations (US EPA, 1994). Organic compounds like oil, phenol, alcohol and sugar do not conduct electrical current very well and therefore have low conductivity when in water.

Conductivity is a function of temperature, types of ions present and the concentrations of the ions. The total dissolved solids, (TDS) an index of conductivity, has a direct relationship to salinity and high total dissolved solids limits the suitability of water for potable use (Davis and DeWiest, 1966). Groundwater inflows can have the same effects depending on the bedrock they flow through (Kortatsi, 2006). Conductivity is useful as a general measure of ground water quality because the water tends to have a relatively constant range of conductivity, thus once established can be used as a baseline for comparison with regular conductivity measurements (Kortatsi, 2006). Significant changes in conductivity could then be an indication that a discharge or some other sources of pollution has entered a water body.

2.11.4 Nitrates (NO^-_3) and Nitrites (NO^-_2)

Nitrates and nitrites are naturally occurring ions that are part of the nitrogen cycle. Nitrates are normally present in natural, drinking and waste waters. Nitrates enter water supplies from the breakdown of natural vegetation, the use of chemical fertilizers in modern agriculture and from the oxidation of nitrogen compounds in sewage effluents and industrial wastes. The nitrate concentration in groundwater and surface water is normally low but can reach higher levels as a result of leaching or run-off from agricultural land or contamination from human or animal waste as a consequence of the oxidation of ammonia and similar sources (WHO, 2003).

Anaerobic conditions may result in the formation and persistence of nitrite. The formation of nitrite is as a consequence of microbial activity and may be intermittent. The primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, so called ―blue baby syndrome‖. In this condition nitrate is reduced to nitrite in the stomach of infants and nitrite is able to oxidize haemoglobin (Hb) to methaemoglobin (met Hb) which is unable to transport oxygen around the body. Studies with nitrite in laboratory rats have reported hypertrophy of the adrenal zona glomenulosa (WHO, 2003). N- Nitrosodimethylamine (NDMA) which may be produced as a by- product of industrial processes that use nitrates and/or nitrites and amines under a range of pH has also been found as a potent carcinogen in drinking water (WHO, 2002). The WHO suggests a guideline value of 50mg/l of nitrate in drinking water to protect against methaemoglobinaemia in bottle fed infants and 0.2mg/l as a provisional guideline value for nitrite (WHO, 2008).

2.11.5 Sulphates

Sulphates occur naturally in numerous minerals and are used commercially, especially in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however the highest levels usually occur in groundwater and are from natural sources (WHO, 2008). The existing data do not identity a level of sulphate in drinking water that is likely to cause adverse human health effects. A study from a liquid diet piglet and from tap water studies with human volunteers revealed a laxative effect at concentrations of 1000-1200mg/l with no increase in diarrhoea, dehydration or weight loss (WHO, 2008).

No health based permissible limit is proposed for sulphate, however because of the gastrointestinal effects resulting from ingestion of drinking water containing high sulphate levels, it is recommended that health authorities be notified of sources of drinking water that contain sulphate concentrations in excess of 500mg/liter (WHO, 2008). The presence of sulphate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems (WHO, 2008).

2.11.6 Phosphates

Phosphate exists in three forms in water; orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorus in a different chemical state. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. Phosphates enter water ways from human and animal wastes, phosphorus rich bedrock, industrial effluents and fertilizer runoff from agriculture. Phosphate are not toxic to people or animals unless they are present in very high levels, which could cause digestive problems (http//www. water research.net /watershed/phosphates.htm).

2.12. Bacteriological hazards associated with drinking water.

The greatest risk from microbes in water is associated with consumption of drinking water that is contaminated with human excreta, although other sources and routes of exposure may also be significant (WHO, 2008).

Infectious diseases caused by pathogenic bacteria, viruses and parasites (e.g. protozoa and helminthes) are the most common and widespread health risks associated with drinking water. Some of these pathogens that are known to be transmitted through contaminated drinking water .

Lead to severe and sometimes life threatening diseases like typhoid, cholera, infectious hepatitis (caused by A virus [HAV or HEV], and diseases caused by *Shigella spp and E- coli* Others are typically associated with less severe outcomes such as self limiting diarrheal disease e.g.; Norovirus and *Cryptosporidium*.

The number of known pathogens for which water is a transmission route continue to increase as new or previously unrecognized pathogens continue to be discovered (WHO, 2003).

2.12.1 Indicator Organisms

Indicator organisms are used to measure potential fecal contamination in water. In water quality analysis it may be possible to isolate microbial pathogens from contaminated water especially when it is heavily polluted, however large volumes (several litres) of the water may be required, selective media are required for isolation and the subsequent identification of the organisms involves biochemical, serological and other tests on pure cultures.

Reliance is therefore placed on relatively simple and more rapid bacteriological tests for the detection of certain commensal intestinal bacteria (especially *E . coli* and other coliform bacteria) as indicator organisms. This is because they are easier to isolate and characterize and also present always in faeces of man and warm blooded animals and hence in sewage in large numbers. The presence of such faecal indicator organisms in a sample of drinking water thus denotes that intestinal pathogens could be present, and that the supply is therefore potentially dangerous to health (Berg, 1978)

2.12.2 Faecal coliforms

A faecal coliform is a facultatively anaerobic rod shaped gram negative, non sporulating bacterium. Faecal coliforms are capable of growth in the presence of bile salts or similar agents, are oxidase negative and produce acid and gas from lactose within 48hrs at 44+ 0.50^{o}C (Doyle, 2006). The presence of faecal coliform bacteria in aquatic environments indicate that the water has been contaminated with a faecal material of man or animals. Faecal coliform bacteria can enter drinking waters through direct discharge of waste from mammals and birds, from agricultural and storm runoff and from untreated human sewage. Individual home septic tanks can become overloaded during the rainy season and allow untreated human waste to flow into drainage ditches and into groundwater.

Agricultural practices such as allowing animal wastes to wash into nearby streams during the rainy season, spreading manure and fertilizer on fields during rainy periods and allowing livestock watering in streams can all contribute to faecal coliform contamination. Faecal coliform bacteria do not directly cause diseases, but high quantities suggest the presence of disease causing agents. Faecal coliforms like other bacteria can usually be killed by boiling water or treating with chlorine. Washing thoroughly with soap after contact with contaminated water can also help prevent infections.

2.12.3 *E- coli*

Escherichia coli (commonly abbreviated *E. coli*) is a gram negative rod shaped bacterium that is commonly found in the lower intestines of warm blooded organisms. *E- coli* and related bacteria constitute about 0.1% of gut flora (Eckburb *et al.*, 2005) and fecal oral transmission is the major route through which pathogenic strains of the bacterium cause diseases. Cells are able to survive outside the body for a limited amount of time which makes them ideal organisms to test environmental samples for faecal contamination. *E. coli* can be differentiated from other thermotorelant coliforms by the ability to produce indole from typtophan or by the production of the enzyme β-glucuronidase.

E. coli is present in very high numbers in human and animal faeces and is rarely found in the absence of faecal pollution. It is considered the most suitable index of faecal contamination and as such it is the first organism of choice in monitoring programmes for verification, including surveillance of drinking water quality (Asbolt *et al.*, 2001). Water temperatures and nutrient conditions present in potable water distribution systems are highly unlikely to support the growth of these organisms (Grabow, 2000)

2.12.4 Salmonella

Salmonella spp. belongs to the family of enterobacteriaceae. They are motile gram negative bacilli that do not ferment lactose but most produce hydrogen gas from carbohydrate fermentation (Clarke and Barnet, 1987). Common species include *Salmonella enterica* or *Salmonella cholaesius*, *Salmonella bongori* and *Salmonella typhi*. All of the enteric pathogens except *S. typhi* are members of the species of *Salmonella enterica*.

Salmonella infections typically are zoonotic and can be transferred between humans and non human animals. The pathogens typically gain entry into water systems through feacal contamination from sewage discharges, livestock and wild animals. *Salmonella* can survive for weeks outside a living body and are not destroyed by freezing. However UV-radiation and heat accelerate their demise (Sorrells *et al.*, 1970).

Salmonella infections cause four clinical manifestations: gastroenteritis (ranging from mild to fulminant diarrhoea, nausea and vomiting) bacteraemia or septicaemia (high spiking fever with positive blood cultures), typhoid fever/ enteric fever sustained fever with or without diarrhoea) and a carrier state in persons with previous infections (Angulo *et al.*, 1997). Typhoid fever is a more severe illness and can be fatal. Over 16 million people worldwide are infected with typhoid fever each year with 500,000 to 600,000 fatal cases (WHO, 2003).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The Amansie West District was carved out of the former Amansie District in 1988. The district shares common boundaries with eight districts namely: Atwima Nwabiagya and Atwima Mponuah to the west, Bekwai Municipality, Amansie Central and Obuasi Municipality to the east, Atwima Kwanwoma to the north and Upper Denkyira and Bibiani districts to the south, as shown in Figure 1. The district serves as a regional boundary between Ashanti region on one side and Central and Western regions on the other side. The district is located within latitude 6.05° West; 6.35° North ; 1.40° South and 2.05° East (Fig. 1).

The Amansie West district spans on an area of about 1,364 square kilometers and it is one of the longest districts in Ashanti region forming about 5.4% of the total land area of the Ashanti region. Manso Nkwanta is the district capital and it is about 65km from Kumasi. Other bigger settlements include Abore, Agroyesum, Ahwerewa, Pakyi No. I and Pakyi No. 2. The location of the district makes it a gate way to Ashanti region from Western to Central regions.

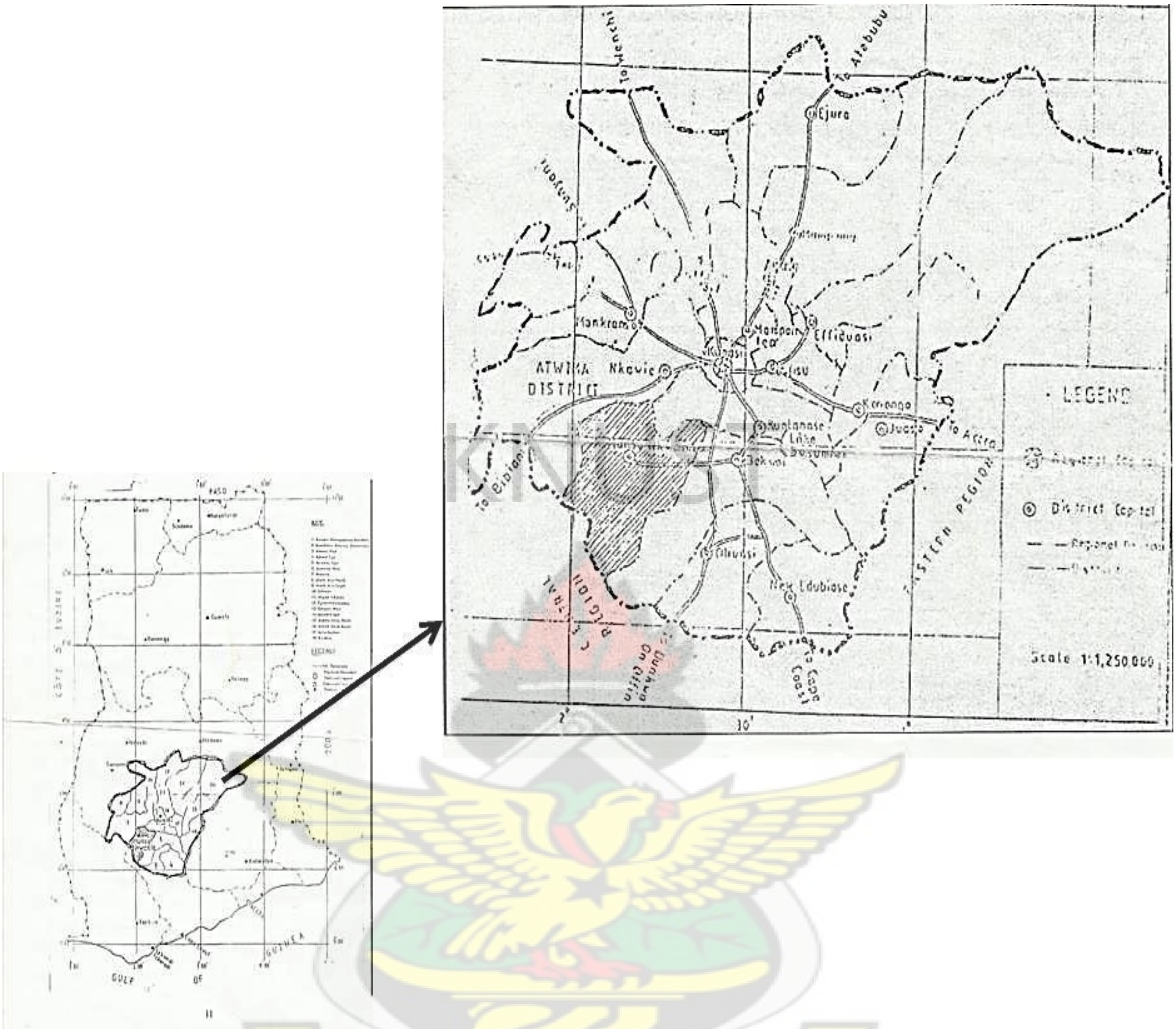

Figure 1: Map of Ghana showing the study area

3.2 Relief and drainage

The topography of the district is generally undulating with an elevation of 210 m above sea level. The most prominent feature is the range of hills, which stretches across the north-western part of the district, especially around Manso Nkwanta and Abore. These have an elevation of between 560 m and 630 m. The district is drained in the north by the Offin and Oda Rivers and their tributaries such as Jeni, Pumpin and Emuna. The drainage pattern of the district can be harnessed for irrigational cultivation of rice, vegetable farming and aqua culture.

3.3 Climate

The climate of the district is wet semi-equitorial climatic, it has a double rainfall maxima region with the major rainy season occurring between March and July. The minor rainfall season occurs between September and November. Mean annual rainfall ranges between 855 mm and 1500 mm. the average number of rainy days for the year is between 110 and 120 days. The months December to March are usually dry and characterized by high temperatures and early morning moist/fog and cold weather conditions. Temperature are generally high throughout the year with mean monthly temperature of about 21°C . Humidity is high during the rainy season. Average humidity is about 84.16%.

This climatic condition is suitable for the cultivation of cash and food crops such as cocoa, oranges, plantain and vegetables to feed agro based industries in the district and beyond. It must be stressed however that current trends in the climatic conditions of the district is becoming unpredictable as a result of climatic change. This has however affected agricultural activity. The situation calls for measures to reduce the overreliance on climate for agricultural production (Amansie west District profile, 2013).

3.4 Vegetation

The vegetation of the district is mainly of the rain forest type and exhibits semi-deciduous characteristics. This makes the land fertile and suitable for agricultural investments. Food and cash crops such as cassava, rice, maize, cocoa, citrus, oil palm, citronella grass and others are widely grown in the area. As a result of the bad practice such as shifting cultivation, slash and burn method of farming, illegal mining and illegal logging, has gradually destroyed and replaced by secondary forest.

3.5 Conditions of the natural environment

The natural environment of the district is gradually losing its purity and importance. This can be attributed to the increase in population and its attendant problems and effects on the environment. The district can boast of natural environment ranging from forest resources with rich species of flora and fauna to vast arable land that can support the production of both food and cash crops. Chainsaw operators and some timber merchants are encroaching on the reserves so rapidly that it is feared that the reserves will lose their value in the next few years. Furthermore the activities of both small scale mining and "galamsey" operators are having serious effect on the natural environment.

3.6 Population size and growth

In 1984 the district population was 85,619. The 2000 national population and housing census put the district population at 108,273 people. This is about 3% of the regional population. Currently, the population of the district has been projected to 144,104. This is made up of 3.8% urban and 96.27% rural (Amansie west District profile, 2013)

3.7 Spatial distribution

As already stated, the 2000 population and housing census puts the total population of the district at 108, 273 people. This population is found in the over three hundred towns, villages and hamlets in the district. The most populous town in the district is Mpatuam with a population of 5,425 inhabitants. Population distribution of the district is skewed positively towards the north eastern part of the district. These areas include Pakyi No. 1 and Pakyi No. 2, Antoakrom and Esuowin. The growth in population in these areas can be attributed to the very good road network, for instance the Kumasi-Obuasi Highway passes through Pakyi No. 1 and Pakyi No. 2. These two communities have become dormitory towns for the labour force in Kumasi (Amansie west District profile, 2013).

3.8 Sample collection

Monthly water samples were collected from selected boreholes and hand- dug wells in Pakyi No. 1 from November, 2012 to February, 2013. A sample each was taken from five different hand-dug wells and boreholes in various households in the Pakyi No.1 over a period of three months. The water samples were collected into 1 litre pre-washed and screw-capped bottles that have been sterilized with water at 100 °C to avoid contamination by any physical, chemical or microbial means. The boreholes were labeled BH1 to BH5 in the order of collection and hand-dug wells were assigned HD1 to HD5 according to how they were collected.

All the water samples collected were stored in ice and transported to the laboratories of microbiological and natural resource and environment for analysis. The samples were taken to Faculty of Natural Resources Chemical laboratory at KNUST for physicochemical assessment and microbial analysis done at the Department of Theoretical and Applied Biology, KNUST and analysis was completed within 14 days. p^H of the water samples were measured on-site with a Suntex® SP-707 portable pH meter. The determinations of the other physicochemical properties of the water samples was performed on the same day of sampling. Test on samples for bacteria was conducted within 6 hours of sampling while that for anions was done within 14 days.

3.9 Chemical analysis

A photometric method was used for the determination of Fe, Mn, NO_3^-, NO_2^-, SO_4^{2-}, PO_4^{2-}, SiO_2 and F^-. Analytical water test tablets prescribed for Palintest® Photometer 5000 (Wagtech, Thatcham. Berkshire, UK) series was used. Each sample was analyzed for Fe, NO_3^-, SO_4^{2-} and PO_4^{2-} using procedures outlined in the Palintest Photometer Method for the examination of water. Other analyses such as the determination of total hardness, Mg and Ca concentrations, were done by complexometric titration using EDTA. The method of chemical analysis was adopted from earlier work by Baronowski and Stables (2000) and Kwakye Nuako *et al*., (2007).

3.9. l. Sulphate determination

Solutions of concentration 1µg/ml were prepared. To each of these was added 10ml of conditioning reagent and 0.3 g of barium chloride. The standards were allowed to stand for 45 minutes. The respective absorbance of the solution at 420 nm was determined. From this data a graph of absorbance versus concentration was plotted. A 10 ml volume of conditioning reagent was added to 25 ml of sample. It was followed by the addition of 0.3 g of $BaCl_{2,}$ the mixture was then diluted to 100 ml with double distilled water. Prepared samples were allowed to stand for 45 minutes. The concentrations were determined using the UV-Visible spectrophotometer at 420 nm. A blank without $BaCl_2$ was prepared and run at the same wavelength.

3.9.2. Phosphate determination

Ascorbic acid Method (orthophosphate-Phosphorus)

Standard solutions of 1, 2, 3 and 4 µg/ml were prepared. To these were added 2 ml of combined reagent. The absorbance of the solutions after 10 minutes was taken at 655 nm against a blank solution. A curve of absorbance versus concentration was plotted. To 50 ml of the sample was added 2 ml of combined reagent. The mixture was allowed to stand for 10 minutes after which the absorbance of the sample was taken with calibrated curve. A blank analysis was performed with all the reagents without sample for all the analysis.

3.9.3 Nitrate determination

Aliquots of 0.1, 0.2, 0.3 and 0.4 ml of the stock solution were measured into different 100ml volumetric flasks. To these, 2 ml of 0.1M NaOH was added followed by the addition of 1, 2, 3 and 4 ml of colour developing reagent respectively. The mixtures were diluted to 100ml mark forming 0.25 µg/ml, 0.50 µg/ml, 0.75 µg/ml and 1.00 µg/ml respectively. A straight line graph of absorbance at 543 nm versus concentration passing through the origin was obtained for the prepared standard solutions. An aliquot of 2 ml of 0.1M NaOH solution and 1ml of colour developing reagent was added to a 50 ml sample.

The mixture was allowed to stand for 15 to 20 minutes. The nitrite concentration was determined at wavelength 543 nm of absorbance. A blank analysis was performed with all the reagents without samples for all the analysis.

3.10. Microbial analysis

Test on samples for microorganisms was conducted within 6 hours of sampling**.** Standard methods for the determination of faecal coliform and *E. coli* (Brenner *et al*., 1993 and APHA, 1995) employed.

3.10.1. Faecal coliforms

The Most Probable Number (MPN) method was used to determine faecal coliforms in the samples. Serial dilutions of 10^{-1} to 10^{-4} were prepared by picking 1ml of the sample into 9 ml of sterile distilled water. One milliliter aliquots from each of the dilutions were inoculated into 5 ml of MacConkey Broth and incubated at 44^0C for 18-24hrs. Tubes showing colour change from purple to yellow and gas collected in the Durham tubes after 24 hours were identified as positive for faecal coliforms. Counts per 100 ml were calculated from MPN tables.

3.10.2. *E. coli*

From each of the positive tubes identified a drop was transferred into a 5ml test tube of trypton water and incubated at 44^0C for 24 hours. A drop of Kovacs' reagent was then added to the test tube of trypton water. All tubes showing a red ring colour development after agitation denoted the presence of indole and recorded as presumptive for thermotolerant coliforms (*E. coli*). Counts per 100 ml were calculated from MPN tables.

3.10.3. *Salmonella*

Prepared 10 ml of manufactured formula of Buffered Peptone Water (BPW) was in a universal bottle and serial dilution samples added to it. It was incubated at 37^0C for 24 hours. Then 0.1ml of the sample from the BPW was placed in 10 ml of Selenite broth in universal bottle and incubated at 44^0C for 48 hours. Swaps from the bottle were made onto Salmonella Shigella Agar (SSA) and incubated for 48 hours at 37^0C. Black colonies with an outer cream margin on the SSA indicate the presence of *Salmonella*.

3.11 STATISTICAL ANALYSIS

The work was subjected to mean analysis and ANOVA under 0.05 level of confidence.

CHAPER FOUR

4.0 RESULTS

4.1. Physicochemical parameters measured for the borehole water (BH) samples.

The mean dissolved oxygen (DO) levels in the samples ranged from 2.46-3.56 mg/L, with the highest DO recorded at Point 5 and the least recorded at Point 4 for the borehole water samples. There was no statistical difference the DO values recorded across the study area for bore hole and hand dug wells (p value= 0.234).

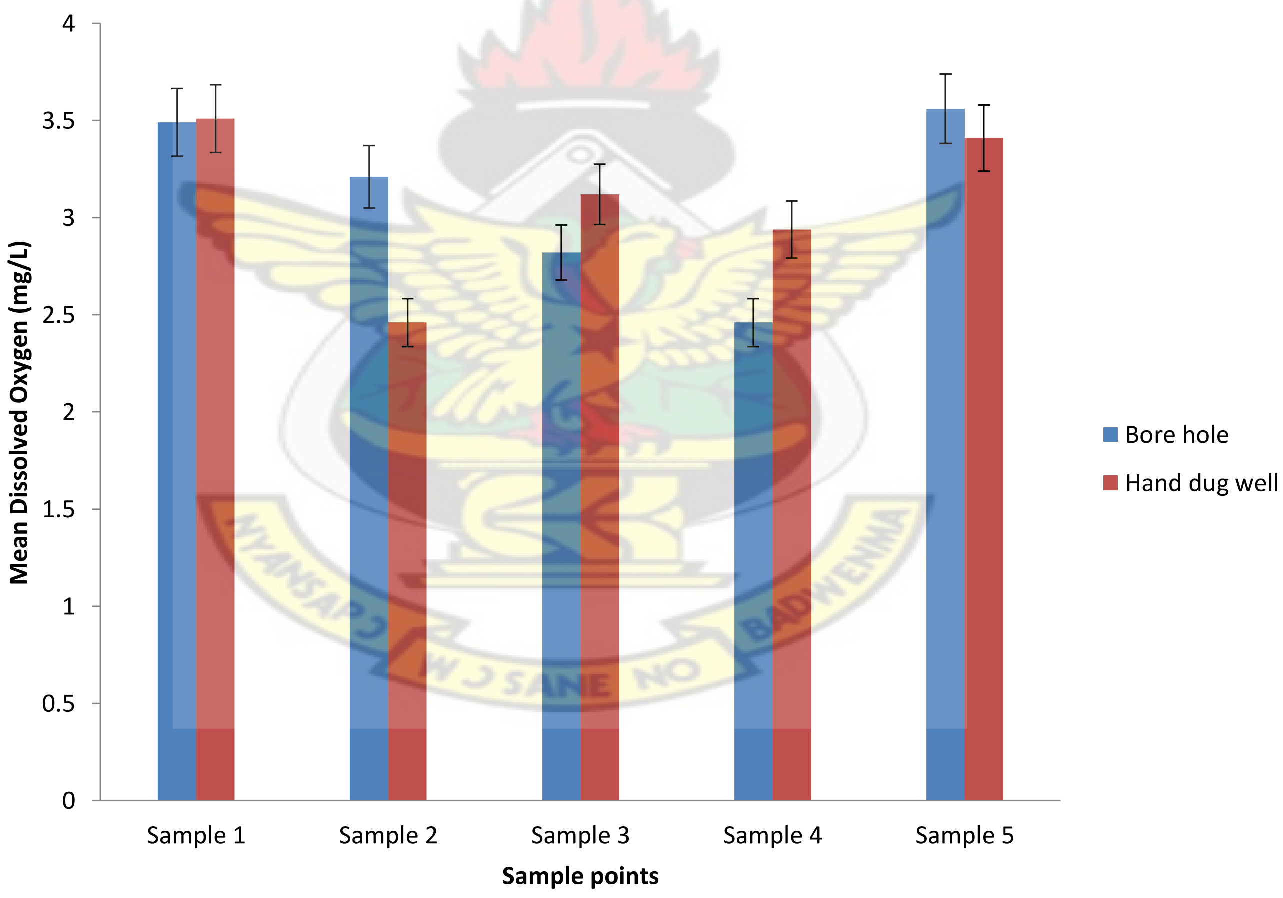

Fig 2: Mean concentrations of DO for both borehole water and hand dug well water.

The pH was found to be slightly acidic although still within the recommended WHO standards except (Point 3), with values ranging from 6.26-7.04 for borehole water. pH of the hand dug wells was found to be slightly acidic but still within the WHO recommended standards (6.5-8.5), with mean values ranging from 6.24-7.21 (Fig 3). Statistically there was no difference (p value= 0.345).

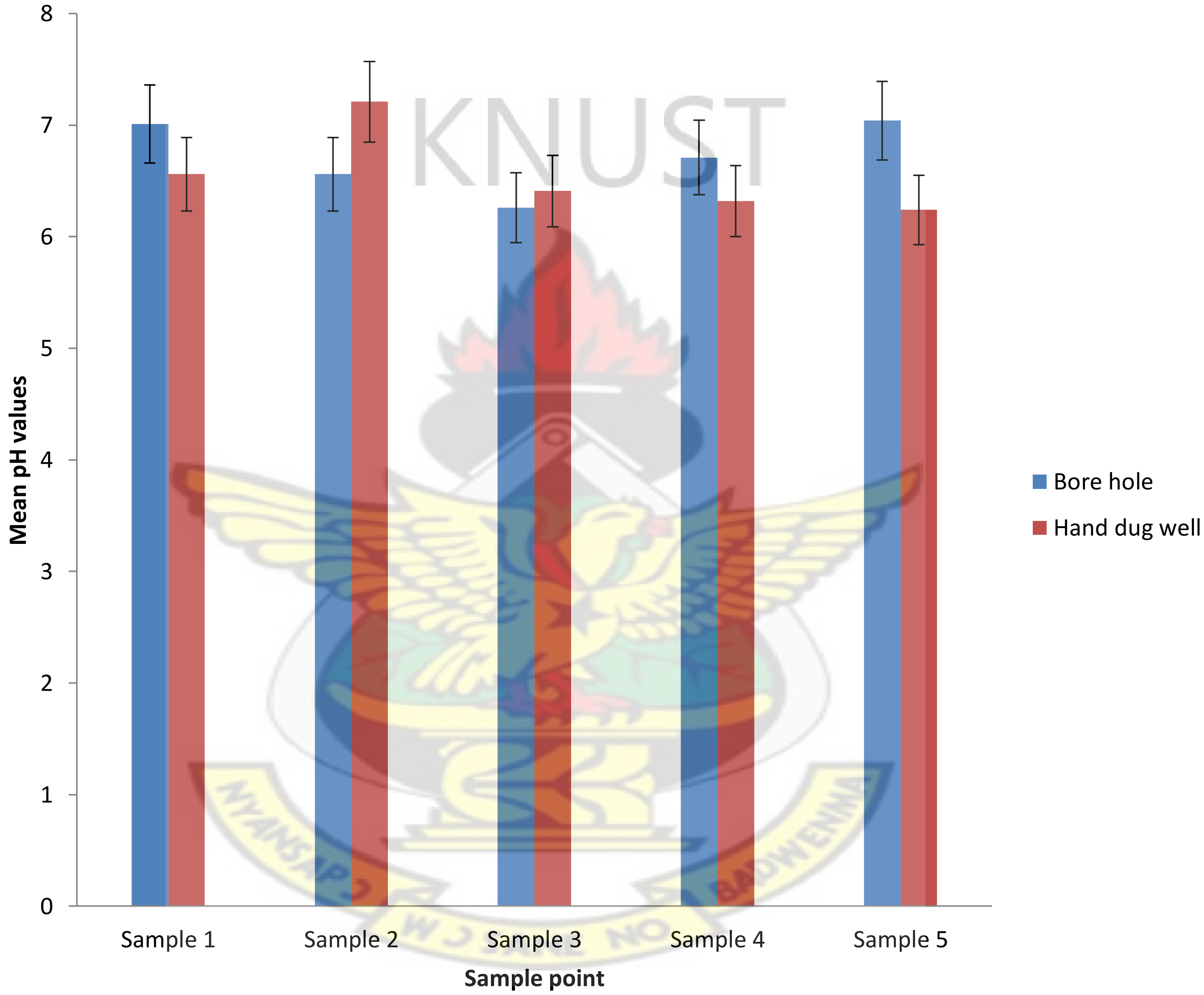

Figure 3: Mean pH values for borehole and hand dug well water samples

The WHO has a recommended value of 1000.00µm hos/cm for electrical conductivity (EC) of drinking water, the mean values however were below this recommended figure. The highest of 476 µm hos/cm was and 471 µm hos/cm recorded at Point 4 for both boreholes and hand dug wells. Meanwhile the lowest of 245 µm hos/cm was recorded at Point 1 for boreholes and the Point 2 with 189 µm hos/cm for hand dug wells. (Fig 4). The difference in the values recorded for both bore hole and hand dug wells was not statistically significant.

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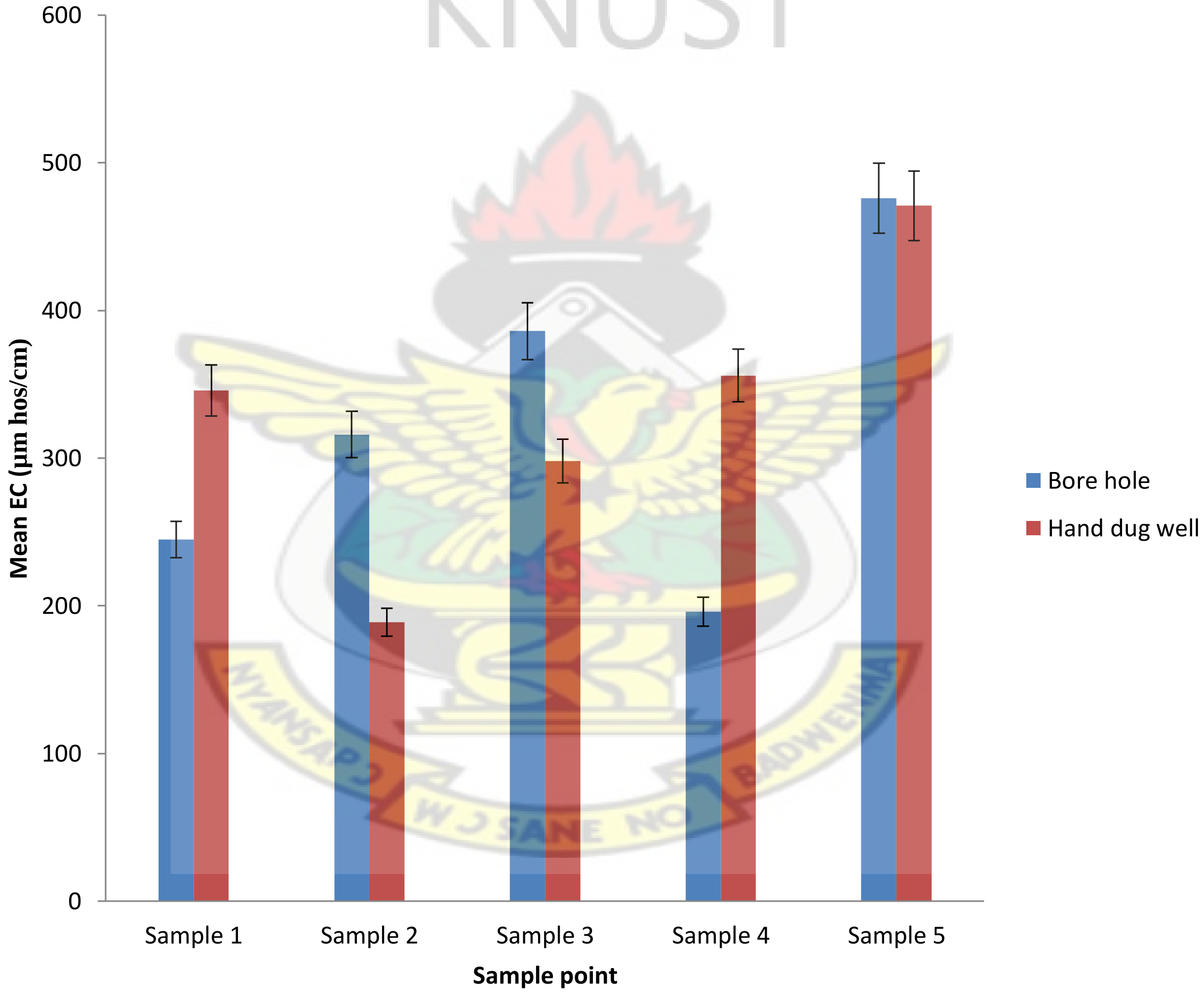

Fig 4: Mean values of electrical conductivity values for the water samples.

Total dissolved solids had mean values ranging between 179-396 and 118-516 mg/L for borehole and hand dug well water respectively, indicating a higher mean concentration in the hand dug well than the borehole water (Fig 5). However this difference was not significant at 95% confidence interval (p value= 0.543).

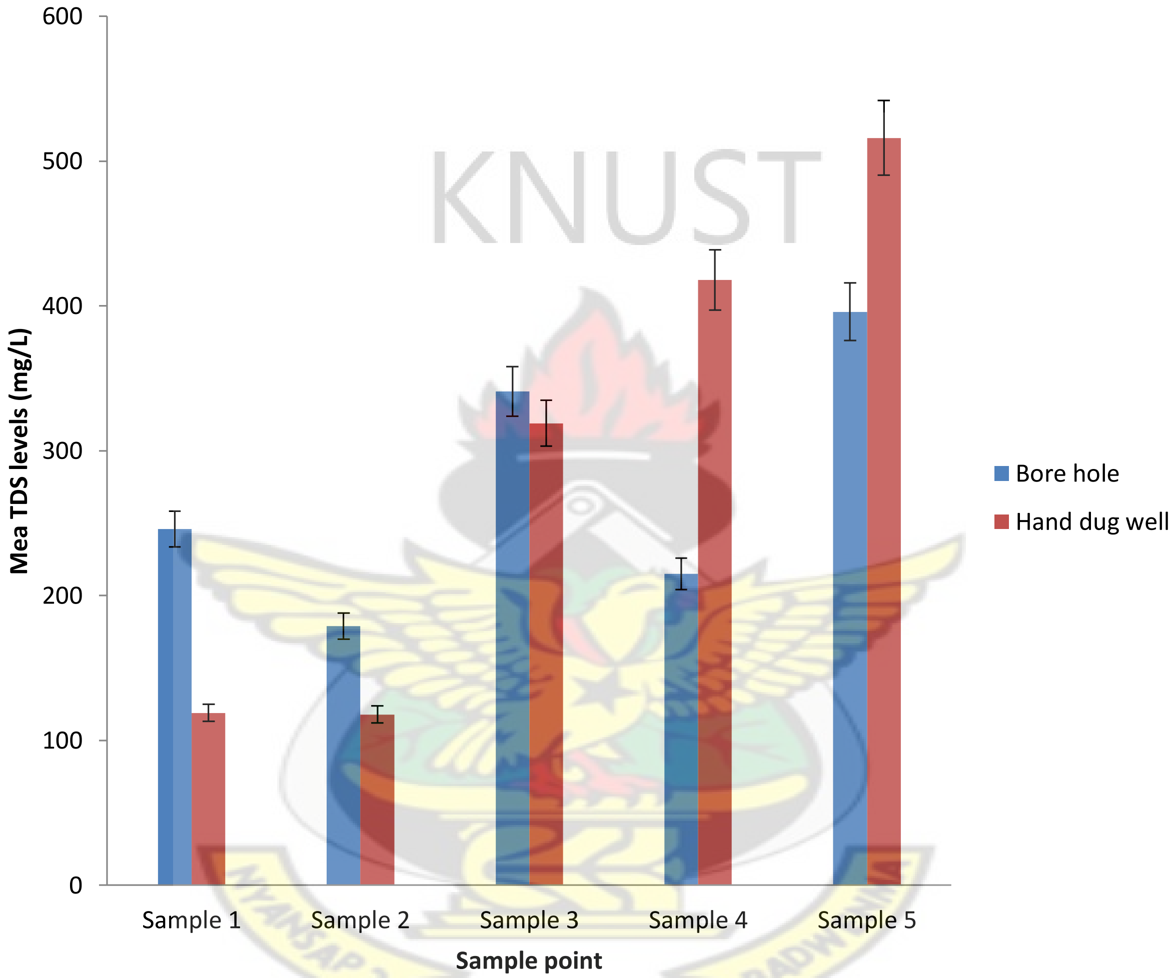

Figure 5: Mean Total Dissolved Solid concentrations.

The salinity of the water was determined with the highest mean value for borehole (0.19 PSU) recorded at Point 5 and the lowest of 0.06 PSU at Point 4 (Fig 6). In the hand dug wells the highest was recorded at Point 2 with 0.16 PSU and the lowest of 0.06 PSU at Point 5. There was no statistical difference in the values recorded (p value = 0.410).

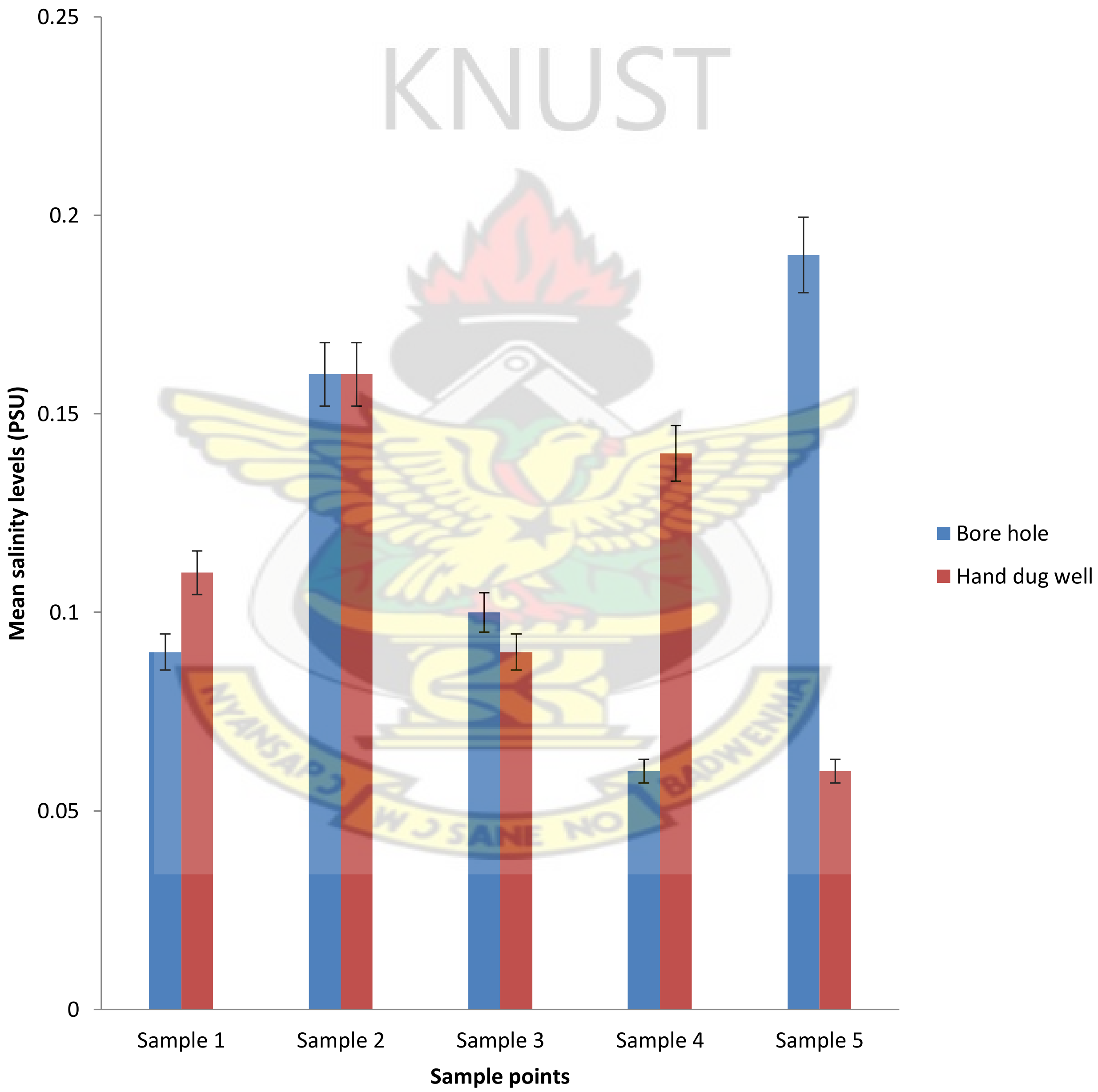

Figure 6: Mean salinity concentrations for water samples

4.3. Mean nutrient levels in the water sampled.

The WHO (2008) has a standard of 50.0 µg/L for nitrates, however mean values ranging from 0.09-0.78 µg/L were recorded. In addition to nitrates the values for both phosphates and sulphates were also determined with their mean values ranging from 1.37-2.01 mg/L and 1.17-1.74 mg/L respectively (Appendix I Table 4.3). The mean nitrate values ranged from 0.49-0.91µg/L for the hand dug well water samples taken. In addition to nitrates the values for both phosphates and sulphates were also determined as in the case of the boreholes, with their values ranging from 1.56-1.98 mg/L and 1.19-1.84 mg/L respectively (Appendix I Table 4.4). The mean levels of nitrate and phosphate was higher in the hand- dug wells as compared to the boreholes, but in the case of sulphate it was the reverse (Fig. 7). Statistically there was no difference between the results obtained for both borehole and hand dug wells (p value= 0.243).

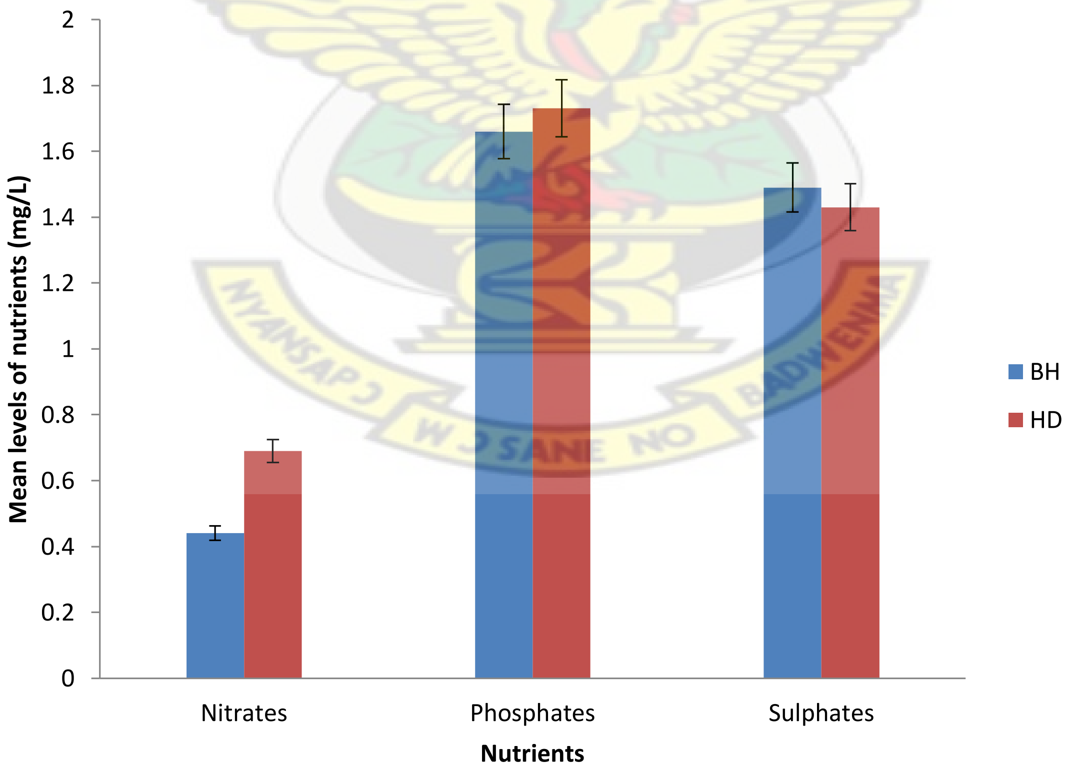

Fig. 7 : Comparison of nutrient levels in Boreholes and Hand- dug wells.

4.4. Microbial quality of the water samples.

The microbial quality of the water was also determined with mean values of faecal coliforms ranging between 3.42×10^4 and 3.91×10^4 cfu/100ml. The faecal coliform for hand dug wells ranged between $3.61\times10^4$and $4.94\ \times10^4$cfu/100ml, all above the recommended WHO standard of 0 cfu/100ml of water (Fig 8).Fecal coliform contamination was however not statistically significant across the sampling points for both borehole and hand dug wells (p value = 0.453).

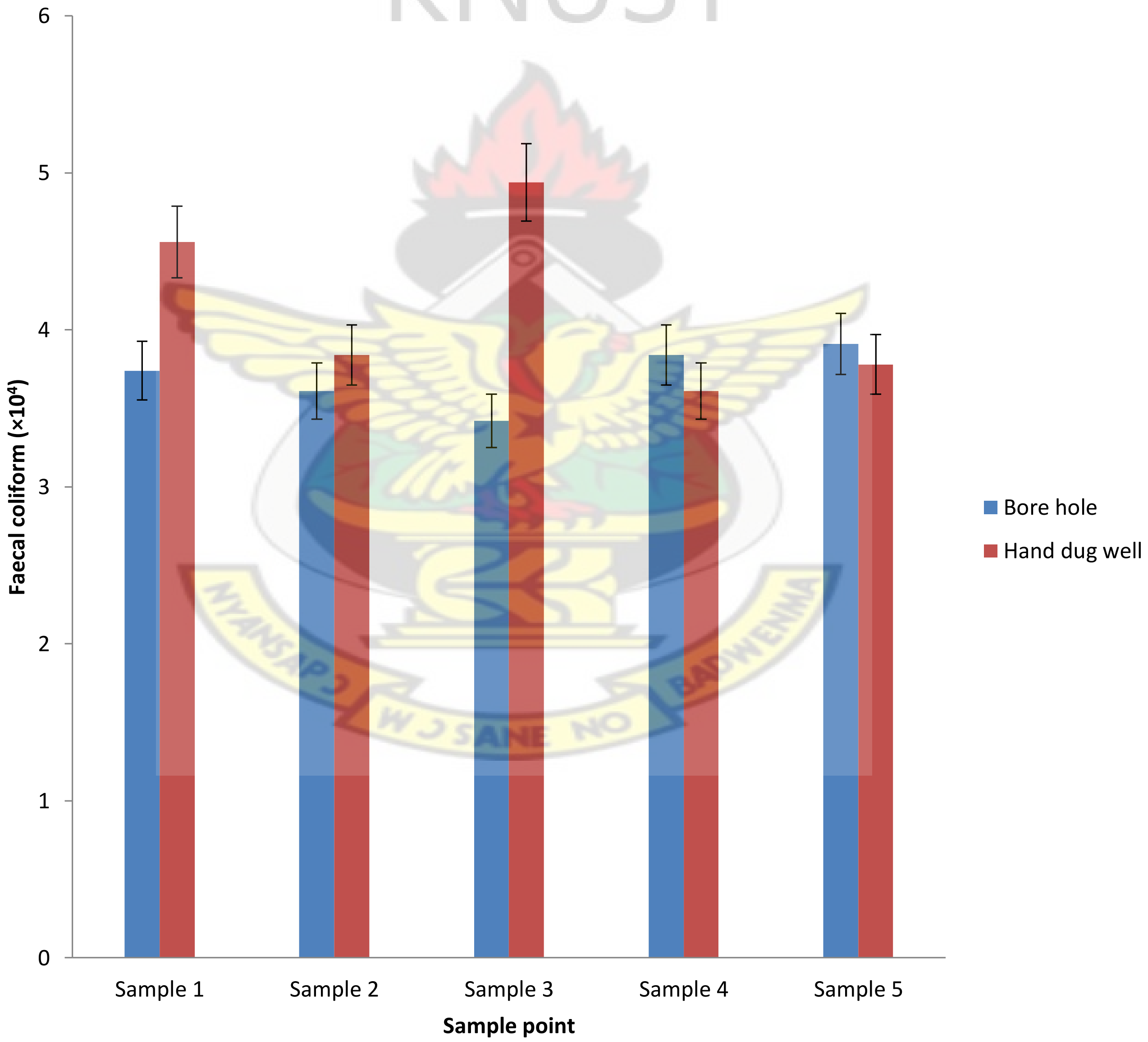

Fig 8: Mean faecal coliform in the water samples.

E. coli was also measured, giving mean values ranging between $0.91\times10^2 - 2.04\times10^2$ and $0.27\times10^2 - 2.39\times10^2$ for the borehole and hand dug well water respectively (Fig 9). Statistically there was no difference in the *E. coli* contamination levels in the water from both borehole and hand dug wells (p value = 0.063).

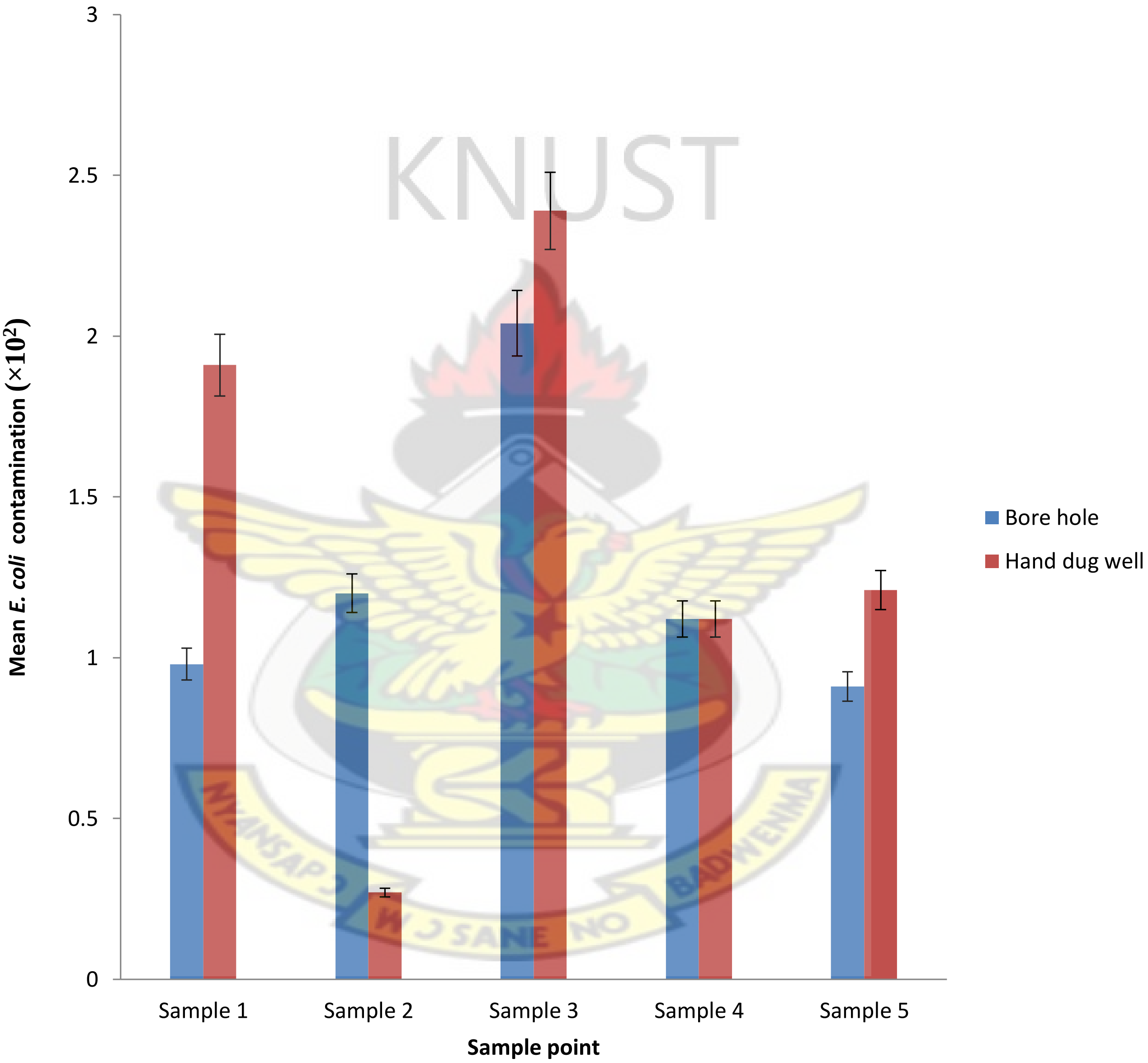

Fig 9:Mean *E.coli* concentrations in both borehole and hand dug well water samples.

Salmonella was detected at only one point from the borehole water (Point 4), however two points (Points 1 and 3) from the hand dug well water samples were contaminated with *Salmonella* (Fig 10). *Salmonella* contamination difference was statistically significant among the two types of underground water studied (p value= 0.045).

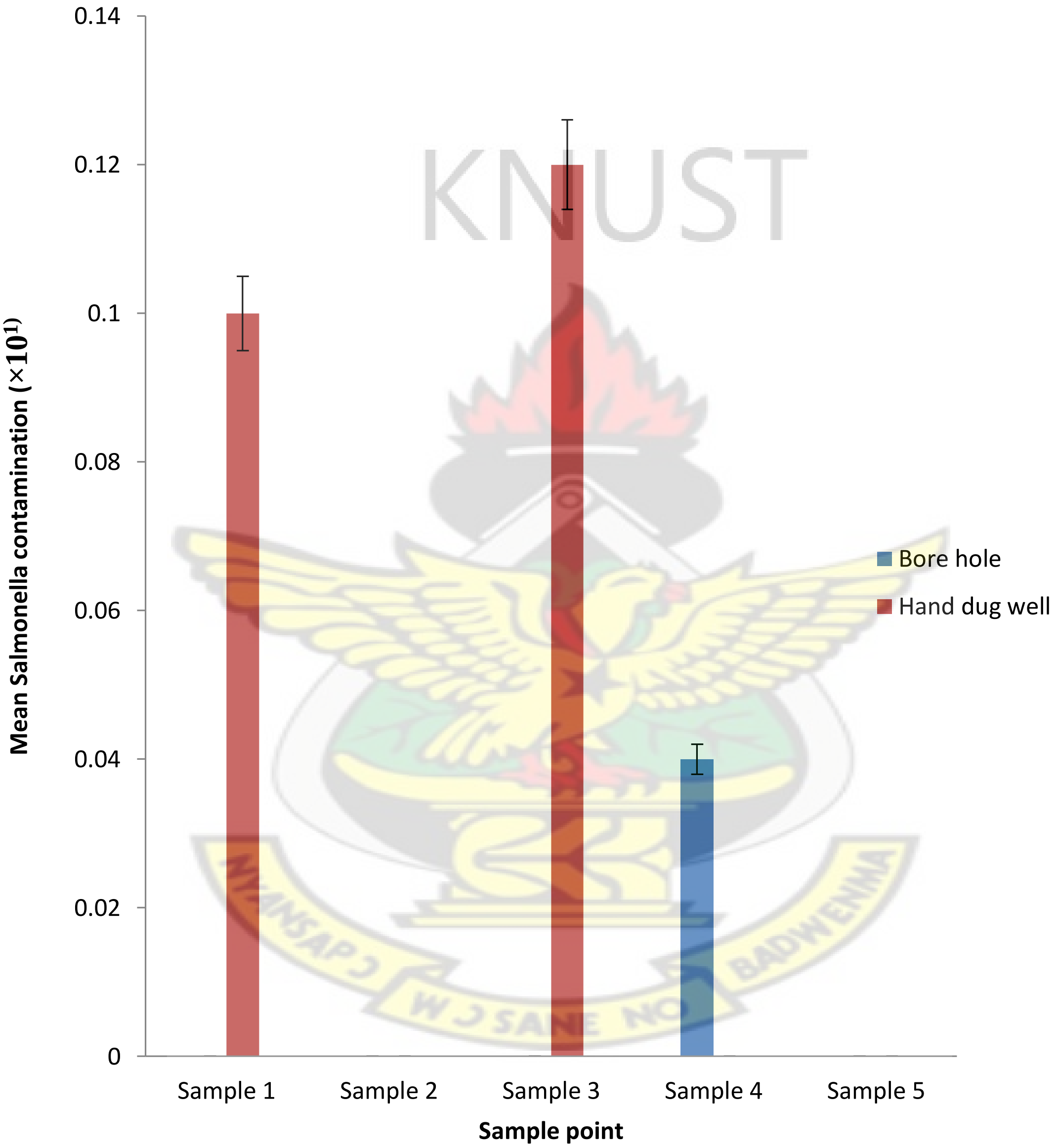

Figure 10: Mean *Salmonella* concentration in the water samples

CHAPTER FIVE

5.0 DISCUSSION

The physical parameters as determined in the study were all within the WHO Standards with the exception of the pH for the hand-dug well (HD3, HD4 and HD5) and the borehole at `BH3. These samples showed the water to be more acidic than that recommended for human consumption. Acidic water results in serious health complications. Acid water may occur naturally as a result of mixture of volcanic gases, or gaseous emanations in geothermal areas. There are some areas in which natural sediments at or near the surface contain enough reduced minerals to lower the pH of the natural run-off. Many natural factors can affect groundwater quality, however, the primary factors include the source and chemical composition of recharge water, the lithological and hydrological properties of the geologic

unit, the various chemical processes occurring within the geologic unit, and the amount of time the water has remained in contact with the geologic unit (residence time) (www. Pubs.usgs.gov/wriwri024045/htms/reports2.htm). In the study, one water sample taken from the borehole (BH3) at the down site of the community had low pH-6.21 and the three samples taken from hand-dug wells (HD3, HD4 and HD5).

According to Diersing-Nancy (2009), water quality should be assessed based on some set standards, the WHO standard for potable water is 6.50-8.50 and the water from borehole (BH3) was below the WHO standard which was not good for human consumption. The low pH in these drinking water may be due to alteration of groundwater as stated by Umar *et al*., (2006). The hand -dug wells lacked adequate cover and therefore exposed them to run-offs. They are easily affected by factors as dissolved solids, contaminations, runoffs, unlike the boreholes that were mostly observed to have been covered and have enough protection from the external environment. Conductivity is a function of temperature, types of ions present and the concentrations of the ions. The total dissolved solids (TDS), an index of conductivity, has a direct relationship with salinity and high total dissolved solids limits the suitability of water for potable use (Davis and DeWiest, 1966), from this current survey values of these interlinked parameters were all within the allowable standards of 1000mg/L for drinking water as set by the WHO (2008).

The human body requires essential nutrients for good nutrition, but not in excess quantities as too much of these nutrients have their own health implications. It is worth noting that during the study, all nutrient levels studied were within the WHO limits set for drinking water at recommended state of sulphate at 500mg/L (WHO, 2008). However the levels for nitrates and phosphates were higher in the hand- dug wells than that in the boreholes. These higher values could be attributed to the fact that the hand dug wells were situated at places near to the toilet facilities in their homes and others have their animal pens close to the wells. Moreover, the higher values obtained may be the result of different containers used to fetch water from the wells. Some of these values can result from these wells near to the agricultural sites and the surface runoffs which have increased nitrate and phosphate levels of the wells. When chemical fertilizers are used on agricultural fields, runoff can wash off some of these fertilizers into rivers and grounds, thus resulting in the groundwater contamination.

It is recommended by the WHO that no microbial organisms should be found in 100ml of drinking water. The greatest risk from microbes in water is associated with consumption of potable water that is contaminated with human excreta, although other sources of exposure is significant (WHO,2008). Faecal coliforms and *E. coli* which indicate contamination with faecal matter were detected in the water from both the hand- dug wells and the boreholes. However, *Salmonella* was recorded in two (2) hand- dug wells (HD1and HD3) out of the five hand-dug well samples taken, compared to only one from the borehole samples (BH4).The faecal coliforms and *Salmonella* observed in this study could be attributed to some of these wells located close to toilet facilities, pens of sheep and goats and runoff from rain into these potable water sources. In some instances, these wells had no covers, in other cases the covers were rusty and therefore particles and other materials could easily contaminate the water. Then also, the receptacles that are used in fetching the water from the wells were mostly left in the open and in some cases on the floor and thus exposing them to contamination with micro-organisms from the environment. As observed in some case, the wells were situated downhill to places of convenience therefore leakages or seepages from these places were able to contaminate the water with bacterial pathogens. The construction and depths of the wells could further explain contamination levels. Ideally, wells should be constructed with culverts but due to financial constraints, only the upper part of the wells were made with concrete thus allowing easy seepage. Treated pipe water received in consumer homes within the Kumasi metropolis was found to contain coliform bacteria that vary from 30 - 78 MPN $100ml^{-1}$ total coliforms and 0 -18 MPN $100ml^{-1}$ faecal coliforms (Quist,1999). In a similar work on wells within urban Kumasi, recorded lower faecal coliform counts of 1.45×10^5, 2.5×10^5 and 4.5×10^2. Working on peri-urban and rural well water supplies in Sudan, Musa *et al*., (1999) found out that faecal coliform counts in peri-urban water supplies were less than in rural water sources. They explained that the observation was so because the wells were better protected from surface contamination. High microbial counts for potable water have been found in other studies in the tropics; Obiri-Danso *et al.,* (2008) reported faecal coliform counts greater than 10^4 from rivers, ponds and lakes in the tropics like Ghana. This was so because land disposal of sewage sludge, illegal dumping of septic tank pumpage, improper toxic waste disposal and runoff from agricultural operations have been contributing to groundwater contamination with micro-organisms.

CHAPTER SIX

CONCLUSSION AND RECOMMENDATIONS

6.1 CONCLUSSION

Water is an indispensable resource necessary for the sustenance of life. Due to rapid urbanization, water supply in developing countries (including Ghana) is inadequate, resulting in the sourcing of water from various avenues. Peri-urban areas like Pakyi No. 1 rely heavily on hand- dug wells and boreholes to supply their water needs due to the inability of the water company to supply them with treated water.

The results obtained from this study showed that in terms of physicochemical parameters the water from both boreholes and hand- dug wells were good for human consumption, but it is worth mentioning that although the nutrient levels were all within the recommended limits, the hand- dug wells recorded higher values than the boreholes therefore raising concern of adequate cover for the wells in order to reduce the amount of runoffs that contaminate it. Low pH levels were also recorded in some instances raising health issues as to the wholesomeness of the water.

Faecal, *E. coli* and *Salmonella* were also recorded in some places, these microbial pathogens are indicators of faecal contamination and therefore renders the water unwholesome according to the WHO Standards.

6.2 RECOMMENDATIONS

Based on the outcome of the study the following is recommended;

1. It is recommended that water quality analysis be carried out on all the boreholes in the area frequently. This will ensure that incidences of contamination are noticed earlier for remedial action to be taken.
2. The inhabitants should be educated on the need to keep their surroundings clean most especially around the boreholes.
3. The community should be educated on the need to keep the receptacles used for the fetching of the water clean always as to prevent contamination.
4. The wells should be raised well above surrounding ground level to divert runoff water when constructing hand- dug wells to avoid unnecessary seepage and contamination.
5. It is also recommended that further studies are conducted in the area to the specific pathways through which contamination occurs so as to make prevention of contamination much easier.

REFERENCES

Abid, M.A. and Jamil, A. (2005). The Assessment of Drinking Water Quality and Availability in NWFP,RWSSP, Peshawar

American Public Health Association (APHA) (1995). Standard methods for the examination of water and wastewater.American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 19th edition, Washington, D.C.

Anawara, H.M., Akaib, J., Mostofac, K.M.G., Safiullahd, S., Tareqd, S.M. (2002). Arsenic poisoning in groundwater-health risk and geochemical sources in Bangladesh. *Environ. Int., 27, 597-604*

Angulo, F.J., Maybeck, M. and Stanley D.W. (1997). A community waterborne outbreak of Salmononellosis and the effectiveness of a boil water order. *American Journal of Public Health 87 : 580-58*

Ashbolt, N. J., Grabow, W. O. K. and Snozzi, M. (2001). In "Water Quality: Guidelines, Standards and Health. Risk assessment and management for water-related infectious disease, Chapter 13" (L. Fewtrell and J. Bartram, eds), pp. 289-315. *IWA Publishing, London*

Baranowski, T. and Stables, G. (2000) Process evaluations of the 5-a-day projects. *Health Education and Behavior, 27, 157–166*

Berg, G. (1978). The Indicator System. In Indicators of Viruses in Water and Food (ed.G.Berg), pp. 1-13*, Ann Arbor Science Publishers, Ann Arbor, MI*.

Brenner, K.P., Rankin, C.C., Roybal, Y.R., Stelma, G.N., Jr, Scarpino, P.V. and Dufour, A.P. (1993) New medium for the simultaneous detection of total coliform and *Escherichia coli* in water *Appl. Environ. Microbiol. 59:3534-3544. EPA/600/J-99/225*

Cairncross, S. and Cliff, J.L. (1987). Water use and health in Mireda, Mozambique, *Trans. Royal Soc. Trop.Med. Hyg*. 81:51-54

Clark, M.A. and Barret, E.L. (June 1987). The pHs gene and Hydrogen Sulphide Production of Salmonella typhimurium. *Journal of Bacteriology 169 (6) 2391-2397*

Clark, B., Koning N. and Roos J. C. (1993). The Continued Influence of Organic Pollution on the Water Quality of the Turbid Modder River. Water South Africa. 25(3): 285-292.

Davis, S. and De Weist, R. (1966). Hydrogeology. *John Wiley &Sons, Inc., New York, p463*

Diersing, N. (2009). "Water Quality: Frequently Asked Questions. Florida Brooks National Marine Sanctuary, Key West, FL

Doyle, M.P. and Erickson, M. C. (2006). Closing the door on feacal coliform assay. Microbe1:162-163. ISSN 1558- 746

Eckburb, P.B., Bik, E.M., Bernstein, C.N., Purdom, E. and Dethlefsen, L. (2005). Diversity of the human intestinal microbial flora, Science 308 : 1635-1638

Edwards, D.D. (1993) Troubled water in Milwaukee. ASM News 59, 342–345

Fei- Baffoe, B. (2008). Pollution Control, IDL Course Material for BIOL 505, MSc Environmental Science-KNUST, Kumasi. Pp 50, KNUST Press (2008)

Grabow, W.O.K. (2000). The Safety of Water Disinfection Chem. and Microb. Risks. Radisson Denville Resort, Miami Beach, Florida. USA, 15-17 November.

http//environment.about.com/environmental events/waterdayqa.htm/ Date accessed: 12/7/2013

http/en.wikipedia.org/wiki/drinking water. Date accessed: 24/9/2013

http//www. water research.net /watershed/phosphates.htm. Date accessed: 9/12/1012

http//www. Pubs.usgs.gov/wriwri024045/htms/reports2.htm. Date accessed: 23/03/2013.

http//www.bbc.co.uk/health living/global accessibility to drinking water. Date accessed: 22/03/2013

International Development Law Organization (2006) Voice of Development Jurists Series. IDLO. Water Tenure Reform and Pubic Access to Water as a Basic Need

Issah, A. (2002). Assessment of Underground Water Quality and Levels of Heavy Metals in the Upper East and Northern Regions of Ghana (Published Thesis) Department of Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi. Pp3-4.

Kortatsi, B. K. (2006). Hydrochemical Characterization of groundwater in the Accra Plains of Ghana. *Environmental Geology Journal vol 50 pp 299 – 31*

Kwakye-Nuako, G., Borketey, P.B., Mensah-Attipoe, I., Asmah, R.H., Ayeh-Kumi, P.F. (2007) Sachet Drinking Water in Accra: The Potential Threats of Transmission of Enteric Pathogenic Protozoan Organisms. *Ghana Med J*. 2007;41(2):62–7.

Krishnan, J. R. (2008). Investigation on Hydrobiology and Water Quality Parameters Of Periyar Lake, Thekkady, Kerala (PhD Thesis), Mahatma Ghandi University, Kerala, India

Lewis, W.J., Foster, S.S.D. and Drasar, B.S. (1982) .The Risk of Groundwater Pollution by On-site Sanitation in Developing Countries. *IRCWD Report 01/82, IRCWD, Duebendorf, pp 79*

National Groundwater Association (NGA) (2008). 601 Dempsey Road, Westerville, Ohio. 614-898-7791. http://www.H_2O-ngwa.org/pubaff/bacq_a.html,

Obiri-Danso, K., Adjei, B., Stanley, K.N., Jones, K. (2008). Microbiological quality and metal levels in wells and boreholes water in some peri-urban communities in Kumasi, Ghana. *African Journal of Environmental Science and Technology*, vol. 3(1), pp059-066

Oluyemi, E.A., Adekunle, A.S., Adenuga, A. A. and Makinde, W.O. (2010). Physico-Chemical Properties and Heavy Metal content of water sources in Ife North Local Government Area of Osun State, Nigeria : African Journal of Environmental Science and Technology vol 4 (10) Pp 691-69

Osiakwan, G.M. (2002). 'Baseline Studies into the Groundwater Resources in The Bosomtwi-Atwima-Kwanwoma District of Ashanti Region (Published thesis) Nkrumah University of Science and Technology, Kumasi Ghana, Pp.23-26

Quist, K.A. (1999). Feacal indicators in drinking water in the urban area of Kumasi. Msc. Dissertation, Biological Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Roger, B., Casidey, R., and Frey, R. (1998). Water Hardness: Inorganic reactions Experiments Department of Chemistry, Washington University, St. Louis.

Singh, S. and Mosley, L.M. (2003). Trace metal levels in drinking water on Viti Levu, Fiji Islands. South Pacific *Journal of Natural Science.21 pp 31–34*

Snyder, J. D., and Merson, M. H. (1982). The Magnitude of the Global Problem of Acute Diarrheal Disease: A Review of Active Surveillance Data. *Bulletin of the World Health Organization. 1982;60:605–13*

Sorrels, K. M, Speck, M. L. and Warren, J. A. (1970). Pathogenicity of Salmonella gallinarumAfter Metabolic Injury by Freezing. *Applied and Environmental Microbiology* 19(1) 39-4

Umar, R., and Absar, A. (2003). Chemical characteristics of groundwater in parts of the Gambhir river basin, Bharatpur District, Rajasthan, India. *Environmental Geology*, 44:535–544

Umar, R., Muqtada, M., Khan, A., and Absar, A. (2006). Groundwater hydrochemistry of a sugarcane cultivation belt in parts of Muzaffarnagar district, Uttar Pradesh, India. *Environmental Geology*, 49: 999–1008

United Nations Environment Programme (2009). Clearin the water. A focus on water quality solutions..*UNON, Publishing Services Section*, Nairobi,

United Nations Development Programme (UNDP). (2002). Statement by UNDP Administrator Mr.Mark Malloch Brown.

USEPA (1997). Sources of ground water contamination. Agricultural and Biological Engineering Department. Purdue University Indiana.

USEPA (1994). Sources of ground water contamination, agricultural and Biological Engineering Department, Purdue University, Indiana.

Water Aid Annual Report (2008). Annual Report 2008/09

WHO (2002). Managing Water in the Home: Accelerated Health Gains from Improved Water Supply. Geneva: World Health Organisation, Document No. WHO/SDE/WDE/WSH/02. Available: http://www.who.int/phe.

WHO (2013.). Guidelines for drinking water quality. Second Edition. Volume 1:Recommendations. Geneva: World Health Organisation.

WHO (2003). World Health Report 2003. Shaping our future. World Health Organisation. ISBN 9241562439 (http://www.who.int/whr/en/).

WHO/UNICEF (2010). Joint Monitoring Programme for Water Supply and Sanitation. Progress on Sanitation and Drinking-water: 2010 Update.*Publications of the World Health Organization can be obtained from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland*

World Health Organization (2010). Guidelines for drinking-water quality. http://www.who.int/en/

WHO (2008). Guidelines for Drinking Water Quality, 3rd ed. Vol 1. Incorporating the first and Second Addenda, WHO, Geneva (2008): ISBN 978 92 4 154761

WHO/UNICEF (2004). Joint Monitoring Programme for Water Supply and Sanitation. SANITATION and DrINkINg-wATer Progress on 2004 UPDATE

World Bank (1997). Water and Development: An Evaluation of World Bank Support. The World Bank Group.

World Vision International (WVI) (2000). Rural Water Project Ghana, Quarterly Report Kumasi, Pp 1-3.

Zuane, J. D. (1990). Drinking Water Quality: Standards and Control, Van Nostrand Reinhold, New York.

APPENDICES

APPENDIX I

Table 1: Mean values of physical parameters measured for the borehole water samples.

SAMPLE ID	DO	Ph	EC	TDS	Salinity
WHO STANDARD		**6.50-8.50**	**1500.00μm hos/cm**	**1000.00 mg/L**	
BH1	3.49 (±0.23)	7.01(±1.50)	245(±23.50)	246(±35.40)	0.09(±0.02)
BH2	3.21(±0.45)	6.56(±2.70)	316(±28.10)	179(±56.30)	0.16(±0.04)
BH3	2.82(±0.34)	6.26(±1.30)	386(±32.60)	341(±33.20)	0.10(±0.01)
BH4	2.46(±0.67)	6.71(±1.20)	196(±43.10)	215(±45.30)	0.06(±0.04)
BH5	3.56(±0.75)	7.04(±2.40)	476(±32.40)	396(±23.20)	0.19(±0.04)

Table 2: Mean values of physical parameters measured for the hand dug well water samples.

SAMPLE ID	DO	Ph	EC	TDS	Salinity
WHO STANDARD		**6.50-8.50**	**1500.00μm hos/cm**	**1000.00 mg/L**	
HD1	3.51(±0.56)	6.56(±1.20)	346(±45.30)	119(±43.20)	0.11(±0.04)
HD2	2.46(±0.23)	7.21(±2.30)	189(±65.20)	118(±67.30)	0.16(±0.05)
HD3	3.12(±0.45)	6.41(±1.50)	298(±28.40)	319(±56,90)	0.09(±0.04)
HD4	2.94(±0.89)	6.32(±1.30)	356(±34.50)	418(±67.90)	0.14(±0.03)
HD5	3.41(±0.90)	6.24(±1.80)	471(±56.20)	516(±56.30)	0.06(±0.03)

Table 3: Mean nutrient levels in the borehole water sampled.

SAMPLE ID	NITRATES	PHOSPHATES	SULPHATES
WHO STANDARD	50.0 µg/L		250.00 mg/L
BH1	0.56(±0.05)	1.56(±0.45)	1.17(±0.34)
BH2	0.41(±0.06)	1.48(±0.35)	1.23(±0.56)
BH3	0.78(±0.03)	1.86(±0.36)	1.71(±0.67)
BH4	0.09(±0.03)	1.37(±0.67)	1.59(±0.45)
BH5	0.34(±0.12)	2.01(±1.20)	1.74(±0.34)

Table 4: Nutrient levels in the hand-dug well water sampled.

SAMPLE ID	NITRATES	PHOSPHATES	SULPHATES
WHO STANDARD	50.0 µg/L		250.00 mg/L
HD1	0.49(±0.03)	1.74(±0.56)	1.29(±0.34)
HD2	0.55(±0.12)	1.56(±0.18)	1.22(±0.67)
HD3	0.64(±0.32)	1.88(±0.45)	1.19(±0.45)
HD4	0.86(±0.12)	1.49(±0.32)	1.60(±0.34)
HD5	0.91(±0.03)	1.98(±0.45)	1.84(±0.78)

Table 5: Mean microbial loads of the borehole water sampled.

SAMPLE ID	FAECAL COLIFORMS(×10^4)	*E. coli* (×10^2)	*Salmonella* (×10^1)
WHO STANDARD			
BH1	3.74(±0.43)	0.98(±0.04)	ND
BH2	3.61(±0.56)	1.20(±0.23)	ND
BH3	3.42(±0.90)	2.04(±0.56)	ND
BH4	3.84(±1.5)	1.12(±0.76)	0.04
BH5	3.91(±1.3)	0.91(±0.45)	ND

Table 6: Microbial loads of the hand dug well water samples.

SAMPLE ID	FAECAL COLIFORMS(×10^4)	*E. coli* (×10^2)	*Salmonella* (×10^1)
WHO STANDARD			
HD1	4.56(±2.30)	1.91(±0.45)	0.10
HD2	3.84(±1.30)	0.27(±0.08)	ND
HD3	4.94(±2.10)	2.39(±1.3)	0.12
HD4	3.61(±1.30)	1.12(±0.34)	ND
HD5	3.78(±1.20)	1.21(±0.23)	ND