QUALITY EVALUATION OF DOMESTIC WATER SOURCES WITHIN ZIOPE COMMUNITY OF THE VOLTA REGION

By

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CERTIFICATION

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

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DEDICATION

Glory, Honour, Blessing, Prosperity, Power and Boundlessness truly belongs to you JEHOVAH! This work is specially dedicated to The Holy Ghost and my loving family.“But as it is written, Eye hath not seen, nor ear heard, neither have entered into the heart of man, the things which God hath prepared for them that love Him.” 1Corinthians 2:9 (KJV)

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ABSTRACT

Water of good quality is of a basic importance to human survival on earth. The provision of potable water to the rural and urban populations is necessary to prevent health hazards. The aim of this project is to assess physicochemical, microbiological and trace metals of samples of domestic raw water sources (Borehole, Hand Dug Well and Pond) within the Ziope community in the Volta Region using WHO standard guidelines. Data on parameters were collected four times from September, 2010 to February, 2011. Most of the parameters analysed were within the WHO guideline limits for potable water. However, microbiological, some physicochemical and heavy metal parameters such as total hardness, total dissolved solid, calcium hardness, chloride, turbidity, total coliform, faecal coliform and lead values determined exceeded WHO standard for drinking water. Those that could be of health concern were turbidity, total coliform and faecal coliform. Thus, microbiologically, the water samples were of poor quality and unfit for human consumption without prior treatment. It is recommended that sediment in the wells should be removed regularly and also be disinfected regularly with chlorine.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
APHA	American Public Health Association
CaH	Calcium Hardness
CIDA	Canadian International Development Agency
CWSA	Community Water and Sanitation Agency
DA	District Assembly
EC	Electrical Conductivity
EDTA	Ethylenediaminetetraaceticacid
EEA	European Environment Agency
FC	Faecal Coliform
GSS	Ghana Statistical Service
HDW	Hand Dug Well
MgH	Magnesium Hardness
NGO	Non Governmental Organization
TC	Total Coliform
TDS	Total Dissolved Solids
TH	Total Hardness
TI	Total Iron
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

Water is one of the essential natural resources that support all forms of plant and animal life (Abida and Harikrishna, 2008). Water has unique chemical properties due to its polarity and hydrogen bonds which means it is able to dissolve, absorb, adsorb or suspend many different compounds (WHO, 2004). Thus, in nature, water is not pure as it acquires contaminants from its surroundings and those arising from humans and animals as well as other biological activities (Abida and Harikrishna, 2008).

Water of good drinking quality is of basic importance to human physiology and man's existence on earth depends on its availability (Lamikanra, 1999; FAO, 1997). The provision of potable water to the rural and urban population is necessary to prevent health hazards (Nikoladze and Akastal, 1989; Lomniezi *et al.*, 2007). Before water can be described as potable, it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is palatable and safe for drinking (Abida and Harikrishna, 2008). Potable water is defined as water that is free from disease producing microorganisms and chemical substances deleterious to health (Tchobanogous *et al.*, 2003). Fresh water can be obtained from a number of sources, among which are streams, lakes, rivers, ponds, rain, springs and wells. Unfortunately, clean, pure and safe water only exists briefly in nature and is immediately polluted by prevailing environmental factors and human activities. Water from most sources is therefore, unfit for immediate consumption without some sort of treatment (Agbaire and Obi, 2009).

Consequent to the realization of the potential health hazards that may result from contaminated drinking water, contamination of drinking water from any source is, therefore, of primary importance because of the danger and risk of waterborne diseases (Agbaire and Obi 2009; Fapetu, 2000).

The government of the Republic of Ghana has launched projects to ensure the provision of improved water supplies to communities in rural areas but due to financial and human resource constraints, it is unlikely that high quality water will be provided to the majority of such people in the immediate future (Gyau–Boakye and Dapaah, 2002). Another limiting factor is that in other areas where such water supplies have been provided, the supplies are not always reliable or sufficient and residents may often have to revert to traditional unprotected sources until the supply is restored. These water sources should, therefore, be examined for indicators of pollution and when the inspection shows that they are subjected to contamination, remedial action should then be taken. This would result in the decline in infections and other communicable diseases and ultimately improve the health standards of rural communities (Gyau–Boakye and Dapaah, 2002).

In Ghana, little data on quality of water sources and associated health problems are available since limited surveys have been conducted. The risk of population exposure to water related diseases is often underestimated because most studies normally approach this problem on a macro scale which all too often excludes most rural communities (Gyau-Boakye and Dapaah, 2002).

Most of the people in the Ziope community do not have direct access to sanitation facilities. Pit latrines provided by the district assembly are at various stages of disrepair and, therefore, unsafe to use and pose serious environment threats. Most of the people living in this community have resorted to defaecation in open places and bushes in and around the

towns. This open defaecation is contributing greatly to environmental and human health problems since pathogen and nutrient contents of the faeces can contaminate surface water and soil and threaten human health. Solid waste management is also a serious problem in the Ziope community since waste disposal facilities are not adequate in all the towns within the community. This also poses a high risk of contamination of domestic water sources.

Despite progress made in human development, the people in the Ziope community currently face an increasing potable water scarcity. The Ziope community water supply depends on direct withdrawal of water from both surface water including rainwater harvesting and groundwater (that is boreholes and hand dug wells) as a source of water for their domestic activities. Hand dug wells serve as the major fresh water source for domestic purposes especially during the rainy season. Most of the hand dug wells are shallow and during the dry season most of them dry out. The people depend mostly on the two ponds. They have only three boreholes and one is abandoned because it tastes too salty and it is brownish in colour. The people in the community do not have access to treated water.

In addition, the two ponds that serve as source of drinking water are not fenced; therefore, both wild and domestic animals searching for drinking water could contaminate the water. Birds and some animals for example, frogs, inhabiting the water can also contaminate the water through direct defaecation and urination. Overgrazing and other poor farming practices, common in the community may result in large quantity of topsoil eroding into the ponds after heavy rains and thereby contributing to high turbidity and also possible contamination with agrochemicals.

In terms of rain water harvesting, traditional methods of rooftop rain water harvesting with roofing and plastic sheets are common. The constraint of this method of rainwater

harvesting is the small storage capacity. This constraint can make it impossible to store enough water during the rainy season.

The quality of the water resources are being affected by both anthropogenic and natural processes. Activities such as runoff from human settlements lacking appropriate sanitary infrastructure, runoff from untreated household wastewater, leachates from refuse dumps, eroded soils and from land use activities such as agricultural chemicals are the major sources of water pollution in the community. Natural processes influencing water quality include: precipitation rate, weathering processes and sediment transport. These activities often result in the degradation of water quality, physical habitation and biological integrity of biotic system (Carpenter *et al.,* 1998; Qadir *et al.,* 2007).

Major types of pollutants introduced through the wastewater are nutrients, synthetic chemicals, trace elements and pathogenic microbes. The indiscriminate use of heavy metals which are ingredients of fertilizers and pesticides was in agriculture may result in deterioration of water quality rendering serious environmental problems posing as a threat to human beings (Fatoki *et al.*, 2001).

The water supply for human consumption is directly sourced without biochemical treatment and the level of pollution has become a cause for major concern. Thus, it can involve serious health problems due to the potential presence of pollutants and pathogenic bacteria. Unhygienic domestic sanitation and unsafe environments lead to incidents of waterborne illness (Ezzati *et al.*, 2002; Guilbert, 2003). Where there is no clean water and proper sanitation, millions of people suffer devastating diseases and millions of children die (Qadir *et al.,* 2007). Water used for drinking purposes, therefore, should be free from toxic elements, living and non-living organisms and excessive amount of minerals that may be harmful to health.

Pollution status of water bodies is usually expressed as biological and physicochemical parameters. Water pollution is of grave consequence because both terrestrial and aquatic life may be affected; it may cause disease due to the presence of some hazardous substances, may distort the water quality, impose physiological stress on biotic community, add odours and significantly hinder economic activities.

1.1 STATEMENT OF PROBLEM

Fresh water resource (rain, river, sea and groundwater) is one of the major components of environmental resources that are under threat either from over exploitation or pollution, exacerbated by human activities on the earth's surface (Efe, 2001). Many developing regions suffer from either chronic shortages of fresh water or the pollution of readily accessible water resources (Lehloesa and Muyima, 2000). According to UNICEF report, about 800 million people in Asia and Africa are living without access to safe drinking water. Consequently, this has caused many people to suffer from various water related diseases (Tanwir *et al.,* 2003). The situation is not different in Ghana particularly in the rural areas. The majority of Ghana's population (58 %) lives in rural areas. Many of these people live without the national infrastructure such as electricity grid and water services (Mohammed, 2006) and 66 % of these people rely on untreated surface water as a drinking water source, exposing them to water borne diseases such as dirrhoea, guinea worm and schistosomiasis (Mohammed, 2006). Unsafe water is a major cause of illness in the country where one in ten children dies before the age of five (Mohammed, 2006). The quality of drinking water is of vital concern to mankind, since it is directly associated with human lives (Fatoki *et al.,* 2001).

Drinking water supplies have a long history of being effected by a wide spectrum of microbes (Grabow *et al.,* 2000). Therefore, the primary goal of water quality management from health perspective is to ensure that consumers are not exposed to pathogens that cause diseases. Protection of water sources and treatment of water supplies have greatly reduced the incidents of these diseases in developed countries (Craun, 1986; Grabow *et al*., 2000). The provision of clean and safe drinking water is one of the major problems in the Ziope community in the Volta Region. Therefore, examining the quality of the source of water in this community is necessary since water from these sources is used for domestic purpose in their raw state. Physicochemical and bacteriological characteristics are very vital water quality monitoring parameters due to their instability once water is extracted from its source. This study is aimed at assessing physicochemical, heavy metal and bacteriological qualities of water sources available in the Ziope community in the Volta Region.

1.2 MAIN OBJECTIVE:

To assess the quality of various domestic (Rainwater, Pond, Hand Dug Wells and Boreholes) water sources within Ziope community in the Volta Region.

1.2.1 SPECIFIC OBJECTIVES

a. To analyze the physicochemical parameters (temperature, turbidity, pH, conductivity, TDS, Ca^{2+}, Cl^{-}, NO_3^{-}, NO_2^{-}, SO_4^{2-} etc.) of the various domestic water sources.

b. To analyze the bacteriological parameters (total and faecal coliforms) of the various domestic water sources.

c. To determine the levels of some heavy metals (Mn, Fe, Pb, and Cu) in the various domestic water sources.

d. To compare the water quality indicators obtained with their respective World Health Organization guidelines and discuss the importance to public health.

1.3 JUSTIFICATION

The maintenance of healthy aquatic ecosystem is dependent on the heavy metal, physicochemical properties and biological diversities (Tchobanogous *et al*., 2003). A regular monitoring of domestic water sources with required number of parameters with reference to the quality of water not only prevents the outbreak of diseases but checks the water from further deterioration (Tchobanogous *et al.,* 2003). Bacteriological assessment, particularly for coliforms (the indicators of contaminations by faecal matters) is routinely carried out to ascertain the quality and potability of water to ensure prevention of further dissemination of pathogens through agency of water under investigation. In addition, the evaluation of potable water supplies for coliform bacteria is important in determining the sanitary quality of drinking water. High level of coliform count indicates a contaminated source, inadequate treatment or post treatment deficiencies (Mathew *et al.,* 1984).

Though some of the heavy metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for life processes in plants, humans and microorganisms, others like Cd, Cr, and Pb have no known physiological activities in humans but are known to be detrimental to health beyond a certain limit (Bruins *et al.,* 2000). Thus heavy metals receive particular concern considering their high toxicity even at low concentrations (Marchorecchio *et al*., 2007). They are nondegradable in nature, carcinogenic and bioaccumulative (Johnson, 1998). The deadlier diseases like edema of eyelids tumor, congestion of nasal mucous membranes and pharynx, muscular, reproductive, and genetic malfunctioning caused by some of these heavy metals have been documented (Johnson, 1998; Tsuji and Karagatzides, 2001). Therefore, monitoring these metals is important for safety assessment of the environment and human health in particular.

Physicochemical characteristics are very vital water quality monitoring parameters due to their instability once water is extracted from its source. Significant variation in physicochemical parameters affect the quality of the water resource hence it is necessary to obtain information on the variations of seasonal physicochemical characteristics of water resources. Water quality data are thus, essential for the implementation of responsible water quality regulation, for characterizing and remediating contamination and for the protection of the health of humans and ecosystem.

CHAPTER TWO

2.0 LITERATURE REVIEW

Much of the current concern with regards to environmental quality is focused on water because of its importance in maintaining human health and health of the ecosystem. Fresh water is finite resource, essential for agriculture, industry and even human existence, without fresh water of adequate quantity and quality, sustainable development will not be possible (Adeyeye and Abulude, 2004).

There is an extensive literature, which stresses deterioration of water quality (Tiwari and Mishra, 1986; Lehloesa and Muyima, 2000). The addition of various kinds of pollutants and nutrients through sewage, industrial effluents, agricultural runoff etc. into the water bodies brings about a series of changes in the physicochemical and biological characteristics of water, which have been the subject of several investigations (Lannik and Zubenko, 2000; Campbell, 2001; Lwanga *et al.,* 2003 and Lomniazi *et al.,* 2007). The reckless disposal of toxic chemicals, over pumping of aquifer and contamination of water bodies with substance that promote algae growth are some of the major cause of water quality degradation. Direct contamination of surface water with metals in discharges from agriculture, mining, smelting and industrial manufacturing, is a longstanding phenomenon. Today there is trace contamination not only of surface water but also of groundwater bodies, which are susceptible to leaching from waste dumps, mine tailings and industrial production sites (Vodela *et al.,* 1997; Ikem *et al.,* 2002). Heavy metals from corrosion products in soil may reach the groundwater via colloid assisted and soil water transport. Organic manure, municipal waste and some fungicides often contain fairly high concentration of heavy metals. Soils receiving repeated applications of inorganic manures, and pesticides have exhibited high concentration of extractable heavy metals and that

thereby increase their concentration in runoff (Lehloesa and Muyima, 2000). While falling as rain, water picks up small amounts of gases, ions, dust and particulate matter from the atmosphere (Grabow *et al.*, 2000). These added substances may be arbitrarily classified as biological, chemical, physical and radiological impurities. They include industrial and commercial solvents, metal and acid salts, sediment, pesticides, plant nutrients, radioactive materials, decaying animal and vegetable matter and living microorganisms, such as algae, bacteria and viruses (Ikem *et al*., 2002; Tuzen and Soylak, 2006). These impurities may give water a bad taste, color, odour or turbidity and cause hardness, corrosiveness, staining or frothing (Lehloesa and Muyima, 2000). Water quality reflects the composition of water as affected by natural cause and man's cultural activities expressed in terms of measurable quantities and related to intended water use (Grabow *et al*., 2000).

The composition of surface and groundwater is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal difference in runoff volumes, weather conditions and water levels (Adeyeye and Abulude, 2004). Groundwater is an increasingly important resource all over the world. It supports drinking water supply; livestock needs, irrigation, industrial and many commercial activities (Adeyeye and Abulude, 2004). Groundwater is particularly important as it account for about 88 % safe drinking water in rural areas where population is widely dispersed and infrastructures needed for treatment and transportation of surface water does not exist (Adeyeye and Abulude, 2004). Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies and this is due to restricted movement of pollutants in soil profile (Adeyeye and Abulude, 2004).

However, shallow and permeable water table aquifers are most susceptible to contamination (Marchorecchio *et al.,* 2002). Also the natural impurities in rainwater, which replenishes groundwater systems, get removed while infiltrating through soil strata (Marchorecchio *et al*., 2007). Importantly, groundwater can also be contaminated by naturally occurring sources. Soil and geological formation containing high levels of heavy metals can leach those metals into groundwater. This can be aggravated by over-pumping wells, particularly for agriculture (Marchorecchio *et al.,* 2007).

Owing to the human activities, some ponds have become dumping ground of domestic wastes and other refuge of the society (Grabow *et al.,* 1992). So, the knowledge of extent of pollution and the status of water become essential in order to preserve the valuable sources of water for future generation.

2.1 RURAL WATER SUPPLY IN GHANA

The availability of safe and clean water seems not to be a problem in towns and cities where consumers generally receive a constant supply of water of high quality. In contrast, however, the inaccessibility of water which is fit for use is a serious problem in rural areas. Most rural inhabitants use water directly from contaminated sources without any treatment and therefore, are exposed to many water related diseases.

In Ghana, about 58 % of the population lives in rural areas (Mohammed, 2006). About 66 % of these people rely on untreated surface water as a source of drinking water exposing them to waterborne diseases such as dirrhoea, guinea worm and schistosomiasis (Mohammed, 2006). Unsafe water is a major cause of illness in the country where one in ten children dies before the age of five (Mohammed, 2006). The supply of clean water is limited by lack of infrastructure, capacity and financial resources (CIDA, 2004). Other areas where such water

supplies have been provided, the supplies are not always reliable or sufficient and residents may often have to revert to traditional unprotected sources until the supply is restored.

In an effort to provide cheap, safe and potable drinking water for rural communities, the government of Ghana in collaboration with some Non-Governmental Organizations (NGOs) has constructed boreholes and hand dug wells in some parts of the country. These untreated water sources are being increasingly used as drinking water yet, testing to see whether the water is of good quality is not done. It is generally perceived that wells, springs and boreholes are "clean" sources of water. Although it is true that soils generally function to attenuate microorganisms by a simple filtration mechanism, pollution of ground water by microorganisms, including those of public health significance do occur (Smedley, 1996). Again, elevated concentrations above the WHO drinking water guidelines have been found of Fe, Mn, As, F^-, Pb, Cr in water sources in some communities in Ghana (Smedley, 1996).

Rural communities rely mainly on the direct withdrawal from rivers, streams, ponds, springs, rain water and lakes for their water supply. Most of the sources are unprotected and polluted. The effects of water from unprotected and polluted sources on health are much more acute among the rural residence than among the urban dwellers though 16 % of the urban households depend on wells for domestic water supplies (Gyau-Boakye, 2001).

The unprotected sources such as rivers, streams, lakes, and hand dug wells are usually heavily polluted and are mostly responsible for waterborne and water related diseases such as diarrhoea, cholera, guinea worm, bilharzias and typhoid are reported to be among the rural communities. Malaria, diarrhoea and typhoid are reported to be among the ten top causes of morbidity in the country (Ghana Statistical Service, 2005).

2.2 WATER QUALITY INDICATORS

WHO (2004) suggests guideline values for biologically and chemically derived contaminants in addition to physical parameters in drinking water. The primary purpose of the guidelines is to protect public health by improving drinking water sources and making them safe. Water quality can be determined quantitatively by sampling water with respect to indicator parameters. In this study, the indicating drinking water parameters is divided into three groups; heavy metals, bacteriological and physicochemical parameters.

2.2.1 Bacteriological Parameters

The greatest risk from microbes in water is associated with consumption of drinking water that is contaminated with human and animal excreta, although other sources and roots of exposure may also be significant. Detection of each pathogenic microbe organism in water is technically difficult, time consuming and expensive and therefore, not used for routine water testing procedures (Grabow, 1996). Instead, indicator organisms are routinely used to access the microbiological quality of water and provide an easy, rapid and reliable indication of the microbiological quality of water supplies (Grabow, 1996; WHO, 1993). The intestinal tract of man contains countless rod shaped bacteria known as coliform organisms. Each person discharges from hundred to four hundred billion coliform organisms per day in addition to other kinds of bacteria. Thus, the presence of coliform organisms is taken as an indication that pathogenic organisms may also be present. The most commonly used coliform organisms are total coliform and faecal coliform.

2.2.2 Physicochemical Parameters

2.2.2.1 Temperature

Temperature is one of the most important parameters in natural surface water system. The temperature of surface water governs to a large extent the biological species present and their rate of activities. Temperature has an effect on most chemical reaction that occurs in natural water system. Cooler waters usually have a wider diversity of biological species. At lower temperature, the rate of biological activities that is the utilization of food supplies, growth, reproduction etc. is slower. Higher water temperatures promote the growth of microorganisms in the water, which may increase the taste, odour, turbidity and cause corrosion problems (Gupta, 1999).

2.2.2.2 Chloride (Cl^-)

Most chlorine occurs as chloride (Cl^-) in solution. Chlorides enter surface and groundwater from both anthropogenic and natural sources such as run-off from human habitations, discharges of wastewaters into water bodies, sea water intrusion into groundwater tables, the use of inorganic fertilizers, landfill leachates, septic tank effluents etc (Gupta, 1999). Chloride toxicity has not being observed in human except in the special case of impaired sodium chloride metabolism as reported in congestive heart failure (Gupta, 1999). Healthy individual can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolong intake of large amounts of chloride in the diet. The presence of chlorides in high concentration makes water hard and brackish. Chloride – rich waters have a metallic taste. Chloride increases the electrical conductivity of water and thus its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts, thus increasing levels of metals in drinking water. In lead pipes a protective oxide layer is build up but chloride enhances galvanic corrosion. It can

also increase the rate of pitting corrosion of metal pipes. High concentration of chloride can make waters unpalatable and, therefore, unfit for drinking or livestock watering (APHA, 1992).

2.2.2.3 Specific Conductance (SC) / Conductivity (C)

The ability of conducting a current through a medium is measured by the SC. SC is an indirect measure of the salt content or total dissolved solids (TDS) in water. This property is related to the total concentration of the ionized substances in water, the temperature at which the measurement is made, the nature of the various dissolved substances, their actual and relative concentrations and the ionic strength of the water sample vitally affect the specific conductance. Salts can either originate from natural conditions, i.e. mineralization in the soil, or human activity. This parameter is relatively easily measured in situ and used as an indicator of drinking water contamination (Gupta, 1999).

2.2.2.4 Total Hardness (TH)

Hardness of water is caused by the presence of multivalent cations and is largely due to calcium and magnesium ions. Hardness is the measure of capacity of water to react with soap (Gupta, 1999). There is no health risk linked to hardness, but certain concentrations of hardness may have negative impact on water distribution systems. If water is hard, with concentrations of calcium carbonate above 200 mg/l, it can result in scale deposits in boilers and pipe systems. Soft water, with calcium carbonate concentrations less than 100 mg/l, can lead to pipe corrosion due to the low buffering capacity in the water. Furthermore, hard water leads to excessive use of soap and detergents in households (WHO, 2004), which neither is environmentally friendly nor sustainable. Absolutely, soft water is corrosive and dissolves metals. More cases of cardiovascular diseases are reported in soft water areas. Hard water is useful to growth of children due to presence of calcium.

2.2.2.5 Calcium (Ca)

Calcium is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in calcium mineral, particularly as carbonates and sulphates, especially limestone and gypsum. The cation is abundant in surface and groundwaters. The salts of calcium, together with those of magnesium, are responsible for the hardness of water. Industrial as well as water and wastewater treatment processes also contribute calcium to surface waters. Acidic rainwater can increase the leaching of calcium from soils. Calcium compounds are stable in water when carbon dioxide is present, but calcium level can fall when calcium carbonate precipitates due to increased water temperature, photosynthesis activity or loss of carbon dioxide due to increase in pressure. Calcium is an essential element for all organisms and is incorporated into the shells of many aquatic invertebrates, as well as the bone of vertebrates.

2.2.2.6 Magnesium

Magnesium is common in natural waters as Mg^{2+}, and along with calcium, is a main contributor to water hardness. Magnesium arises principally from the weathering of rocks containing ferro-magnesium minerals and from some carbonate rocks. Magnesium occurs in many organo-metallic compounds and in organic matter, since it is an essential element for living organisms. Natural levels of magnesium in fresh waters may range from 1 to > 100 mgl^{-1}, depending on the rock types within the catchment. Although magnesium is used in many industrial processes, these contribute relatively little to the total magnesium in surface waters.

2.2.2.7 Ammonia (NH_3)

Ammonia occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water by microorganisms. It is also discharged into

water bodies from based pulp and paper production and also as a component of municipal waste. At certain pH levels, high concentration of ammonia is toxic to aquatic life and, therefore, detrimental to the ecological balance of water bodies (APHA, 1992).

Unpolluted water contain small amount of ammonia and ammonia compounds usually less than 0.1 mg/l as nitrogen. Higher concentrations could be an indication of organic pollution such as from domestic sewage, industrial waste and fertilizer runoff. Ammonia is, therefore, a useful indicator of organic pollution. Natural seasonal fluctuations also occur as a result of the death and decay of aquatic organisms, particularly phytoplankton and bacteria in nutritionally rich waters (APHA, 1992).

2.2.2.8 Nitrite and Nitrate (NO_2^- and NO_3^-)

Nitrates are naturally occurring ions that are part of nitrogen cycle. Natural sources of nitrates to surface waters include igneous rocks, land drainage and decay plant and animal. Natural levels which seldom exceed 0.1 mg/l may be enhanced by municipal and industrial wastewaters including leachates from waste disposal site and sanitary landfills. The use of inorganic nitrate fertilizers can also be a significant source (Gupta, 1992). Seasonal fluctuations in nitrate occur with aquatic plant growth and decay, as they are essential nutrients for aquatic plants. A level in excess of 5 mg/l usually indicates pollution by humans or animal waste or fertilizer runoff. Nitrate occurs naturally in groundwater as a result of soil leaching but in areas of high nitrogen fertilizer application, it may reach high levels (500 mg/l) (APHA, 1992). On clearing and ploughing for cultivation, the increased soil aeration that occurs enhances the action of nitrifying bacteria and the production of soil nitrate. Nitrate poisoning in infant animals, including humans, can cause serious problems and even death. Apparently, the lower acidity in an infant's intestinal tract permits growth of nitrate reducing bacteria that convert the nitrate to nitrite which is then absorbed into the

bloodstream. Nitrite has a greater affinity for hemoglobin than oxygen and thus nitrite combines with hemoglobin in the blood to form methemoglobin. Methemoglobin does not have the ability to carry oxygen and the organs and tissues of the body are deprived of this life sustaining elements resulting in the blue colouration of the body (cyanosis). Because oxygen starvation results in a bluish discoloration of the body, nitrate poisoning has been referred to as "blue baby" syndrome, although the correct term is methemoglobinemia (Gupta, 1992).

Nitrite in water is either due to oxidation of ammonium compounds or due to reduction of nitrate. The presence of nitrite indicates that the organic matter present in water is not fully oxidized. The amount of nitrite in potable water should be nil. The presence of nitrates indicates that the organic matter present in water is fully oxidized and the water is no longer harmful (APHA, 1992).

2.2.2.9 Sulphate (SO_4^{2-})

Sulphate is naturally present in surface waters as SO_4^{2-}. Sulphates enter water bodies from the natural mineral pool, the discharge of industrial wastewaters and atmospheric decomposition. Consumption of sulphate bearing waters (that is hard waters) does not cause any health problems (APHA, 1992). However, the major physiological effects resulting from the ingestion of large quantities of sulphates are catharsis, dehydration and gastrointestinal irritation. Water containing magnesium sulphate at levels above 600 mg/l acts as a purgative in humans. The presence of sulphate in drinking water can also result in a noticeable taste; the lowest taste threshold concentration for sulphate is approximately 250 mg/l as the sodium salt. Sulphate may also contribute to the corrosion of distribution systems.

2.2.2.10 Fluoride (F^-)

Fluoride originates from the weathering of fluoride containing minerals and enters surface waters through runoff and groundwater through direct contact. Liquid and gas emissions from certain industrial processes (for example metal and chemical based manufacturing) can also contribute fluoride ions to water bodies. Fluoride mobility in water depends to a large extent on the Ca^{2+} ion content since fluoride forms low solubility compounds with divalent cations (APHA, 1992).

Measurement of fluoride content is especially important when a water body is used for drinking water supply. At high concentrations fluoride is toxic to humans and animals and can cause bone diseases. However, a slight increase in natural levels can help prevent dental caries. Although at higher concentrations above (1.5 – 2.0) mg/l, mottling of teeth and skeletal fluorosis can occur and inadequate amounts with dental caries, (< 1 ml/ l) (WHO, 2004).

2.2.2.11 pH

The pH value of water is a measure of the hydrogen ion concentration in water and is used to express the intensity of acids or alkaline conditions. In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such carbon dioxide, hydrogen sulphide and ammonia also affects the pH of water. Water with a pH of 7 is considered neutral, whereas water with a pH less than 7 is` acidic and that with a pH greater than 7 is alkaline in nature. The pH as a parameter does not hold any health significance. The acidic water causes tuberculation and the alkaline water causes incrustation (APHA, 1992). For potable water, the pH value should be between 6.50 and 8.50. If pH value of water is below 4, it will produce a sour taste and if it is more than 8.50 it will impart a bitter taste. A higher value of pH induces the

formation of trihalomethanes which are responsible for causing cancer in human beings. Also, it hastens the scale formation in water heating apparatus and reduces the germicidal potential of chlorine. The lower value of pH starts corrosion pipes and thereby toxic metals like Zn, Pb, Cu, etc are released (APHA, 1992).

2.2.2.12 Total Dissolved Solids (TDS)

TDS is the term applied to the residue remaining in a weighed dish after the sample has been passed through a standard fiber glass filter and dried to constant mass at (103 – 105) ^{0}C or (179 – 181) ^{0}C. TDS in water are composed of inorganic salts mainly chemical, sulphates and bicarbonates of Ca, Mg, K and Na. If small amount of organic matter are present, they also contribute to TDS. TDS in water originates from natural sources and the entry of wastewater discharges (APHA, 1992). Concentrations of TDS are a major feature to be considered when ground water sources are tapped. High concentrations of TDS make the water brackish or saline and impart a disagreeable metallic taste to drinking water. Other problem includes hardening of water and scale formation in conduits, boilers and solar water heaters. Dissolved minerals, gases and organic constituents may produce aesthetically displeasing colour, taste and odour. Significant health effects associated with ingestion of TDS have not been recorded. Some chemicals may be toxic and some of the dissolve organic constituents have been shown to be carcinogenic (APHA, 1992).

2.2.2.13 Turbidity

It is the measure of the extent to which light is emitted, absorbed or scattered by suspended material in water. The turbidity in water is the reduction of transparency due to the presence of particulate matter such as clay or silt, finely divided organic matter, plankton or other microscopic organisms. These cause light to be scattered and absorbed rather than transmitting in straight lines through the samples. Most turbidity in surface water results

from erosion of colloidal materials such as clayed algae, microorganism, silt, rock, fragments and metal oxide from the soil. Vegetable tubers and microorganisms may also contribute to turbidity. Household and industrial waste waters may contain a wide variety of turbid producing materials. Soaps, detergents and emulsifying agents produce stable colloids that results in turbidity. The colloidal material associated with turbidity provides adsorption site for chemical that may be harmful or cause undesirable taste and odour and for biological organisms that may be harmful. Disinfection of turbid water is difficult because of the adsorptive characteristic of some colloids and because the solids may partly shield organisms from the disinfectant. In natural water bodies, turbidity may impart a brown or other colour to water, depending on the light absorbing properties of the solids and may interfere with light penetrations and photosynthetic reactions in streams and lakes (APHA, 1992).

2.2.3 HEAVY METALS

Heavy metals are elements that have specific gravity greater than 4.0 that is at least five times that of water which is 1.0 at 4^{0} C. They exist in water in colloidal, particulate and dissolved phases (Adepoju–Bello *et al.,* 2009). Their occurrence in water bodies being either of natural origin (for example eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of anthropogenic origin (that is solid waste disposal, industrial or domestic effluents, harbour channel dredging) (Marcovecchio *et al.,* 2007). Even though some of the metals are essential to sustain life for example cobalt, copper, iron, manganese and zinc are needed at low levels as catalyst for enzyme activities (Adepoju–Bello *et al.,* 2009). Excess exposure to heavy metals can result in toxicity. Some metals that were analysed in this work are Cu, Pb, Mn and Fe.

2.2.3.1 Copper (Cu)

Copper is found mainly as a sulphide, oxide or carbonate in the minerals. Copper is essential as micro nutrient for aquatic life widely used as a very effective algaecide and molluscicide (Saeed, 1999; Shaker *et al.,* 2000). Since copper from anthropogenic sources eventually contaminate water bodies, toxicity of these metal to aquatic organisms has been intensely studied over the past two decades (WHO, 1998; Adepoju–Bello and Alabi, 2005).

Copper may occur in simple ionic form or in one of many complexes with groups such as cyanides, chlorides, ammonia or organic ligands. A test for copper is essential because of dissolved copper salts even in low concentrations are poisonous to some biota. Copper doses in excess of nutritional requirements are excreted. However, at high doses, copper can cause acute effect such as damage to the liver and renal systems and anaemia (Adepoju-Bello and Alabi, 2005).

2.2.3.2 Lead (Pb)

Soil and household dust are significant sources of lead exposure for small children, but the levels are highly variable, ranging from < 5 mg/l to tens of milligrams per litre in contaminated areas. As lead is immobile, levels and contaminated soils will remain essentially unchanged unless action is taken to decontaminate them. The highest lead concentrations usually occur in surface soil at depths of (1 – 5) cm (Adepoju–Bello and Alabi, 2005).

Lead is present in tap water to some extent as a result of its dissolution from natural sources but primarily from household plumbing systems in which the pipe, solder, fitting or service connections to homes contain lead. PVC pipes also contain lead compounds which can dissolve in drinking water. The amount of lead dissolve from the plumbing system depends

on several factors including the presence of chloride and dissolve oxygen, pH, temperature, water hardness, and standing time of the water (APHA, 1992).

Lead is a cumulative general metabolic poison in infants, the fetus and pregnant women are the most susceptible to adverse health effects due to Pb poisoning. Its effects on the central nervous system can be particularly serious (Adepoju–Bello and Alabi, 2005).

2.2.3.3 Manganese (Mn)

Manganese is an essential element for many living organisms including humans. Elemental and inorganic forms of manganese may be present in the atmosphere as suspended particulates. In surface waters, manganese occurs in both dissolved and suspended forms. Anaerobic groundwater often contains elevated levels of dissolved manganese. The divalent form predominates in most water at pH 4 – 7, but more highly oxidized forms may occur at higher pH values or result from microbial oxidation. Manganese can be adsorbed onto soil to an extent depending on the organic content and its cation exchange capacity. It may bioaccumulate in lower but not higher organisms so that biomagnifications in food chains is not significant (Adepoju–Bello and Alabi, 2005).

Manganese concentrations in lakes and rivers around the world range from 0.001 to about 0.6 mg/l. Higher levels in aerobic waters are usually associated with industrial pollutions. Reducing conditions in groundwater and some lakes and reservoirs are conducive to high levels; up to 1.3 mg/l in neutral water and 9.6 mg/l in acidic water (Adepoju–Bello and Alabi, 2005).

In an epidemiological study in Japan, adverse effects were seen in humans consuming manganese dissolved in drinking water. The manganese was derived from 400 dry cell batteries buried near a drinking water well. A total of sixteen cases of poisoning were

reported, the symptoms including lethargy, increased muscle tone, tremor and neural disturbances. The most severe effects were seen in elderly people, but only minor ones in children (APHA, 1992).

2.2.3.4 Iron (Fe)

Aeration of iron – containing layers in the soil can affect the quality of both groundwater and surface water if the groundwater table is lowered or nitrate leaching takes place. Dissolution of iron can occur as results of oxidation and decrease in pH (APHA, 1992).

In drinking water supply, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide which settles out as a rust coloured silt. Anaerobic groundwater may contain iron (II) at concentrations of up to several milligrams per litre without discoloration or turbidity in the water when pumped directly from a well, although turbidity and color may developed in piped systems at iron levels above (0.05 – 0.1) mg/l. Staining of laundry and plumbing may occur at concentrations above 0.3 mg/l (Adepoju–Bello and Alabi, 2005).

Although iron has got little concern as a health hazard, it is still considered as a nuisance in excessive quantities. Long time consumption of drinking water with a high concentration of Fe can lead to liver diseases such as cirrhosis. Iron also promotes a growth of iron bacteria. This gives a rusty appearance to the water.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 DESCRIPTION OF THE STUDY AREA

The Ziope community where this research was carried out is located within the Adaklu-Anyigbe District in the Volta Region of Ghana. The District shares boundaries with Ho Municipal and South-Dayi District at north; North Tongu and Akatsi Districts at the south; Eastern Region at West and Republic of Togo at the east. The Adaklu-Anyigbe District is located between 6.0 N–$6^0$207 N and 005 ^{0} E–0045^0 E.

The population of Ziope community is about 5000 and many are mainly engaged in farming and petty trading. All the inhabitants rely solely on the Hand Dug Wells, Boreholes and Ponds as there is no treated pipe borne water supply to this community.

3.2 SAMPLING SITE

A map showing Volta Region, Adaklu-Anyigbe District and Ziope community with the sample collection points are shown in Fig. 1.

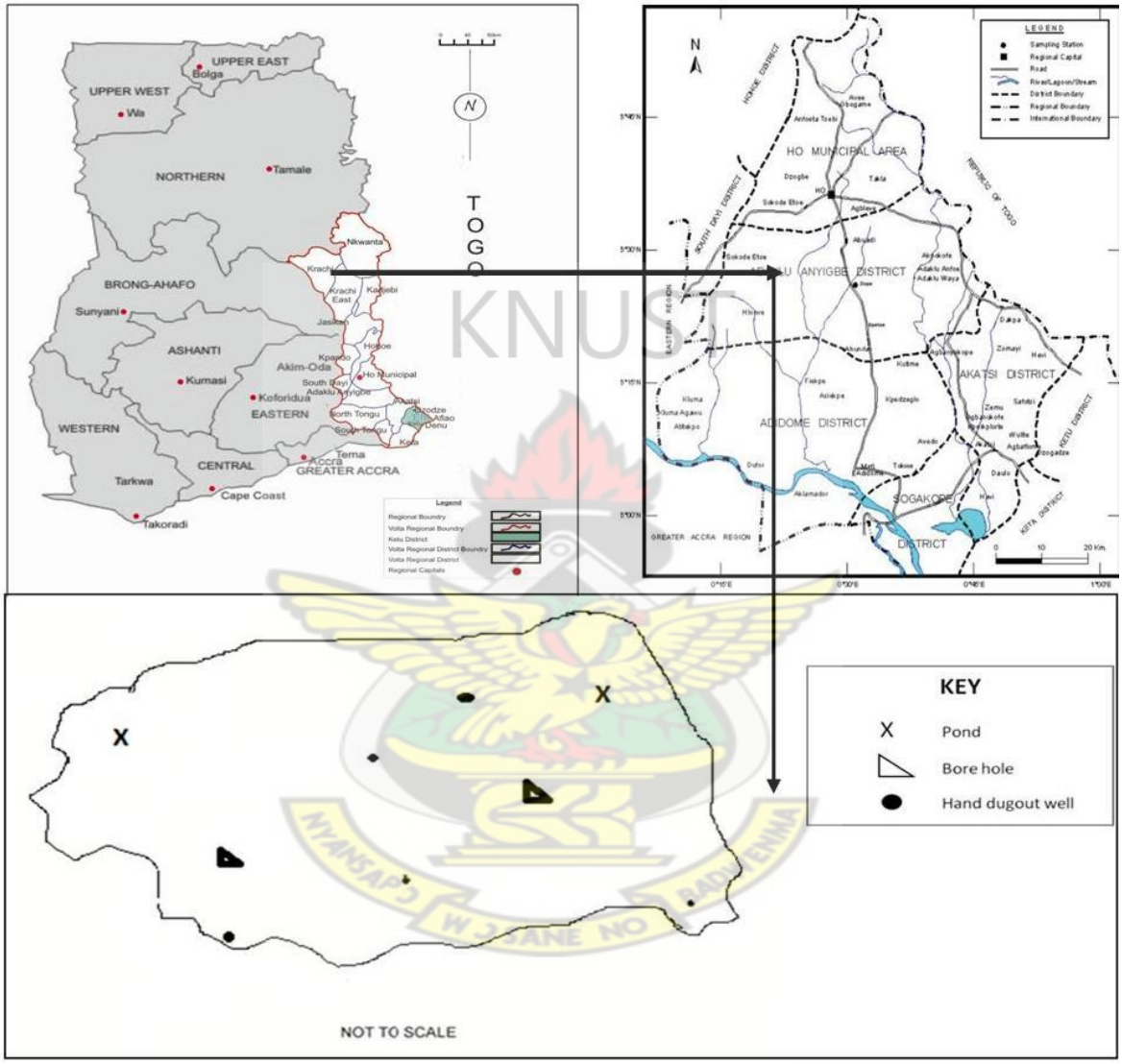

Fig. 1. Maps of Volta Region, Adaklu-Anyigbe District and Ziope Community showing sample collection points.

Nine sampling sites located in the Ziope community were selected for this study. Pictures showing conditions of all the sampling points are presented in Plates 1-9.

Plate 1. Photograph of Hand Dug Well 1

Plate 2. Photograph of close up of the top of Hand Dug Well 2 showing the improvised 'bucket' made from plastic oil gallon used in fetching water from the well.

Plate 3. Photograph of Hand Dug Well 3 showing a plastic gallon container and attached rope used for fetching water from the well.

Plate 4. Photograph of the interior portion of Hand Dug Well 4 showing the brick wall with resident algae on the faces of the blocks.

Plate 5. Photograph of the interior portion of Hand Dug Well 5

Plate 6. Photograph of Borehole 1

Plate 7. Photograph of Borehole 2

Plate 8. Photograph of Pond 1 showing children fetching water from the shallow water. Note the weeds growing at the periphery of the Pond.

Plate 9. Photograph of Pond 2 showing agricultural activities and weeds growing at the periphery of the Pond.

3.3 WATER SAMPLE COLLECTION

Triplicate monthly water samples were collected from Hand Dug Well (HDW) 1, HDW 2, HDW 3, HDW 4, HDW 5, Borehole 1, Borehole 2, Pond 1 and Pond 2 for four months that is from September, October and December 2010 to January 2011. Sampling covered both the rainy (September - October) and the dry or Hamattan (December – January) seasons. Photographs of water sources are shown in Plates 1-9. Water samples were collected with plastic containers previously cleaned by washing with nonionic detergents then rinsed with tap water and later soaked in 10 % HNO_3 for 24 hrs and finally rinsed with de-ionized water prior to usage they were then air dried in a dust free environment. Sample containers at the point of sampling were rinsed with sample water three times before filling. The samples were labelled and transported to the laboratory and stored in the refrigerator at about 4 ^{o}C prior to analysis. Bacteriological samples were put into stopper pre-sterilized 500 ml glass bottles to protect the samples from contamination. Test on samples for bacteria was conducted within six hours after sampling. Water samples for physicochemical analyses were collected into plastic bottles. All samples were kept in a nice chest (8–10) ^{0}C immediately after collection and transported to the laboratory on the same day.

Heavy metal samples were filtered using 0.45 μm pore diameter membrane filters. The filtered samples were acidified with 1 ml of concentrated HNO_3 in 500 ml of sample for preservation. Removal of the particulate matter by filtration prevents dissolution or desorption of trace metal from the particulate phase to the dissolved phased within the samples.

3.3.1 Sampling of Surface Water

The cap of the bottle was carefully removed to prevent contamination of the inner surface. The sample was taken by holding the bottle at the bottom and plunging it about 15 cm below the water surface. The bottle was filled leaving about 25 cm of empty space to allow mixing during laboratory analysis. It was then immediately closed and kept in an ice chest.

3.3.2 Sampling from Groundwater

From a Borehole, the water was left to run from the tap for about 5 min to get representative sample. The bottles were then filled and immediately closed. From Hand Dug Wells, samples were collected below (0.5 – 0.6) m of water level with the help of metallic stick tied at the neck of sterile plastic bag with a 10 m rope. The water fetched was poured into the bottles and immediately closed.

3.4. DETERMINATION OF PHYSICOCHEMICAL PARAMETERS

The pH, temperature and electrical conductivity were determined on site.

3.4.1 pH

The electrode of the pH meter (Model 3150 JENWAY) with a temperature sensor was immersed into the water sample contained in the plastic container and the stable value read. The pH meter was calibrated by immersing the electrode in two buffer solutions of pH 4.01 and 7.00 prepared from capsules of BDH buffer. The pH meter was adjusted to correspond to the standard buffers (4.01 and 7.00). The water sample was placed in a beaker and the electrode was rinsed with distilled water and lowered into the sample. The pH meter was allowed to stabilize and the pH of the sample taken.

3.4.2 Electrical Conductivity (EC) and Total Dissolved Solid (TDS)

These were measured with a digital conductivity meter with cell constant of 1.0. The instrument was kept clean and standardized with KCl solution before use. The electrode was rinsed with distilled water and lowered into the water sample contained in the plastic container. The conductivity in μScm^{-1} of the sample was recorded. TDS was also measured by selecting the TDS key while the electrode remained in the water sample used to measure conductivity and the TDS value and mgl^{-1} was recorded.

3.4.3 Turbidity

Values were recorded using Hanna Instrument, LP 2000 turbidimeter. The turbidimeter was calibrated with the 1000, 100, 10 and 0.02 NTU standards. The cuvette was rinsed three times with the samples to be tested. The light shield cap was replaced and all outside surfaces cleaned and made dry. The cuvette was pushed firmly into the optical well and index to the lowest reading. The NTU values were measured by pressing and releasing the arrow button and the value recorded.

3.4.4 Total Hardness:

EDTA Titrimetric Method was used to determine the total water hardness in the samples. Determination of total hardness was carried out by measuring 50 ml of the water sample into a 250 ml conical flask. About 4 ml of ammonium chloride in concentrated ammonia, the buffer solution and 6 drops of eriochrome black T indicator solution were added prior to titration. The content in the conical flask was titrated against 0.01 M EDTA to the end point indicated by a distinct colour change from violet to blue coloration. Titration was repeated for consistent titre values from which an average titre was calculated (APHA, 1992).

Total hardness was then calculated using the formula:

$$\text{Total hardness in } \frac{\text{mg}}{\text{l}}\ CaCO_3 = \frac{\text{ml of EDTA x M x 1000}}{\text{ml of sample}}$$

where M = Molarity of EDTA used.

3.4.5 Calcium (Ca)

EDTA Titration Method was used to determine calcium hardness in the sample. Two milliliters (2.0 ml) of 1 M NaOH was added to 50 ml of the sample. The mixture was stirred and 0.1 g of the murexide (ammonium purpurate) indicator was added to it. 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(APHA, 1992.

The value was calculated using the formula:

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

where A = ml of EDTA titrant used

$$B = \frac{\text{ml of standard calcium solution}}{\text{ml of EDTA titrant}}$$

3.4.6 Magnesium (Mg)

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

3.4.7 Alkalinity

This was determined by measuring 50 ml sample into a conical flask. About 2 drops of phenolphthalein indicator was added and the resulting mixture titrated against a standard 0.10 M H_2SO_4 solution until the pink color disappeared. The burette reading was recorded and five drops of methyl orange indicator was added to the solution and titrated against the standard 0.10 M H_2SO_4 solution to the first permanent pink color at pH 4.5 (APHA, 1992).

Alkalinity was then calculated using the formula:

$$\text{Alkalinity mg/l} = \frac{\text{V x M x 1000}}{\text{ml of sample used}}$$

where V = Volume of acid used

3.4.8 Nitrate (NO_3^-)

Hydrazine reduction method was used to determine the concentration of nitrate in the samples. The sample was filtered in the field through a 0.45 μm membrane filter and stored at 4 ^oC. Nitrates, from the sample aliquot were reduced to nitrites with hydrazine sulphate. The resulting nitrites, together with the original nitrites, were then reacted with sulphanilamide to form a diazo compound. This compound was then reacted with N (1-naphthyl) ethylenediaminedihydrochloride to form an azo dye. The azo dye colour intensity, proportional to the nitrate and nitrite concentration, was determined colourimetrically at 520 nm and compared to identically-prepared standard and blank

solutions. The nitrate concentration was obtained by subtracting the original nitrite concentration, determined from a duplicate sample (APHA, 1992). The method detection limit was 0.005 mg/l.

3.4.9 Nitrite (NO_2^-)

Diazotization method was employed in determining nitrite concentration in the samples. The sample was filtered in the field through a 0.45 μm membrane filter and preserved at 4 ^oC. The sample aliquot was reacted with sulphanilamide to form a diazo compound. This compound was then reacted with N-(1-naphthyl) ethylenediaminedihydrochloride to form an azo dye. The azo dye intensity, proportional to the nitrite concentration, was determined colourimetrically at 540 nm with the aid of an Ultra Violet Spectrophotometer (APHA, 1992) and compared to identically-prepared 0.001 mg/l standard and blank solutions (APHA, 1992). The method detection limit was 0.001 mg/l.

3.4.10 Sulphate (SO_4^{2-})

One hundred milliliters (100 ml) of water sample was measured into a 250 ml Erlenmeyer flask. Five milliliters (5 ml) of conditioning reagent was added and mixed by stirring. One gramme (1 g) of barium chloride crystals was added while stirring and timed for 60 seconds. The absorbance was then determined at 420 nm on the spectrophotometer within 5 minutes. The concentration was then read directly from the calibration curve on the computer screen.

3.4.11 Chloride ion (Cl^-)

Argentometric method was used to determine chloride concentration in the sample. Exactly 50 ml of filtered water sample was pipette into a 250 ml conical flask. The pH of the diluted water sample was determined. About 1ml of 0.25 M potassium chromate was added to the conical flask. Water sample was titrated against the standard $AgNO_3$ solution slowly while stirring the sample using a magnetic bar and stir plate. The end point was indicated by the persistence of a reddish brown color through the yellow solution for about 30 seconds. Blank (distilled water) was titrated using the same procedure. Volume of $AgNO_3$ for the blank was subtracted from the average used for the sample. This volume was used to determine the concentration of chloride ion in the water sample.

The value was calculated using the following formula

$$Cl^-(mg/l) = \frac{(A-B) \times M \times 35.450}{\text{ml of sample used}}$$

Where A = ml of titration of sample

B = ml of titration of blank

M = molarity of $AgNO_3$

3.4.12 Fluoride (F^-).

SPADNS (sodium 2-(parasulphophenylazo) -1, 8-dihydroxy-3, 6-naphthalene disulphonate) was mixed with zirconylsacid reagent and added to the sample. The absorbance was read spectrometrically at 570 nm and compared to identically-prepared standard and blank solutions (APHA, 1992). Detection limit was 0.001 mg/l.

3.5 HEAVY METAL ANALYSIS

Perkin Elmer (5100) Atomic Absorption Spectrophotometer (AAS) with deuterium background corrector was used in the determination of heavy metals. Determinations were carried out in air/acetylene flame using hollow cathode lamps of each metal used as radiation source. Prior to analysis the AAS was calibrated according to the manufacturer's manual. Calibration curves were established using internal and external standards. Recovery values were merely quantitative (> 95% for all the metals). Limits of detection of the analyzed metals were determined as trice standard deviation of the lowest detectable concentrations by the AAS for the mean of three replicate analyses. Procedural blanks and duplicates were run alongside as part of the quality assurance program.

The sample aliquot was digested in nitric acid, diluted appropriately with distilled water, then aspirated and the absorbance measured spectrometrically using UNICAM 969 SOLAAR 32 Atomic Absorption Spectrophotometer at 248.3 nm for Fe, at 283.3 nm, for Pb, at 279.8 nm for Mn and at 324.7 nm for Cu. The detection limits are 0.05 mg/l for Pb, 0.005 mg/l for Mn, 0.01 nm for Cu and 0.02 nm for Fe.

3.6 Measurement of Bacteriological Parameters

The membrane filtration method was used in the determination of two parameters, which were Total Coliform (TC) and Faecal Coliform (FC).

3.6.1 Total Coliform Determination

A one hundred milliliter (100 ml) portion of each of the raw water samples were filtered through 47 mm diameter membrane filters of 0.45 μm pore size. The membrane filter was incubated on M-Endo agar and alternatively on Mac Conkey Agar at 37 ^{o}C for 24 hours (APHA, 1992). Total coliform was detected as dark-red colonies with a metallic (golden)

sheen on the M-Endo agar; and also as all bacteria colonies with yellow ring around them on the MacConkey Agar. The total number of colonies appearing was counted for each plate.

3.6.2 Faecal Coliform Determination

100 ml portion of each of the water samples were filtered through 47 mm membrane filters of 0.45 μm pore size. The membrane filter was incubated on M-FC agar at 44 ^{o}C for 24 hours. Faecal coliform was detected as blue colonies on the M-FC agar. The total number of colonies appearing was counted for each plate (APHA, 1992).

3.6.3 Experimental Precautions for bacteriological analyses

The samples were removed from storage and allowed to warm to room temperature. The incubation chamber for the analyses was cleaned with ethanol to prevent contamination. The porous plate of the membrane filtration unit and the membrane filter forceps were sterilized by being applied with 98 % alcohol which was burnt off in a Bunsen flame. The sterile forceps were then used to transfer the sterile membrane filter onto the porous plate of the membrane filtration unit with the grid side up. A sterile meshed funnel is secured to the base of the membrane filtration unit by means of screw threads. 100 ml of the sample was added to the membrane filtration unit using the funnel measure. The flame from the Bunsen burner was kept on throughout the whole analyses and the forceps were flamed intermittently to keep it sterile.

The sample was filtered through the membrane filter under partial pressure created by a syringe fitted to the filtration unit. The filtrate was discarded and the funnel unlocked and removed. The sterile forceps were then used to transfer the membrane filter onto a sterile labelled Petri dish containing the appropriate growth medium (M. F.C agar for faecal

coliform and M. Endo agar for total coliform). The membrane filter was placed on the medium by rolling action to prevent air bubbles from forming at the membrane-medium interface. The Petri dishes were incubated upside down at the appropriate temperatures (37 ^{o}C for total coliforms and 44 ^{o}C for faecal coliforms) for 24 hours. After incubation, typical colonies were identified and counted. The colonies were counted three times with the aid of a colony counter and the mean was recorded.

3.7 STATISTICAL ANALYSIS

Data were analysed using one way analysis of variance (ANOVA). The statistical tool used to examine the water quality in the community in comparison with the WHO standard was one sample t-test inference about the mean. The test involves testing whether significant differences, below or above, exist between the community values and the WHO standards**.**

CHAPTER FOUR

4.1 RESULTS

The range, average and standard deviation of the physical properties of the drinking water samples in the Ziope community in the Volta Region are summarized in Table 1.

Table 1: The range, mean and standard deviation of the physical parameters of the water samples from Ziope.

Parameter /Site	Turbidity (NTU)	TDS (mg/l)	Conductivity (µS/cm)	Alkalinity (mg/l)	TH (mg/l)	CaH (mg/l)	MgH (mg/l)
Range HDW1	5.4 – 5.9	553-565	950-970	130-140	350-370	52-56	42-45
Mean ± SD	5.6±0.25	552.8±10.21	960± 11.55	134.5±5.26	361±8.41	54.3±1.71	43.5±1.73
Range HDW2	5.4 – 5.8	538-564	946-962	130-134	345-355	50-54	41-44
Mean ± SD	5.6 ± 0.23	552±10.68	953.5±8.70	131.8±2.06	351.7±4.72	51.8±2.06	42.5±1.3
Range HDW3	5.5 – 5.8	558-570	955-980	132-141	360-378	53-58	38-40
Mean ± SD	5.7 ± 0.17	563.8±4.92	967.5±11.90	136.2±4..92	370.8±7.89	55.8±2.22	39±1.15
Range HDW 4	5.5 – 5.7	540-560	950-965	128-130	350-380	50-57	40-43
Mean ± SD	5.6 ± 0.10	552.5±8.66	960±7.07	129±1.15	360±13.54	53.8±2.99	41.3±1.5
Range HDW 5	5.4 – 5.8	565 - 573	960-980	140-145	371-385	54-59	40-42
Mean ± SD	5.6 ± 0.19	569±3.37	970±11.55	142.3±2.63	378.7±6.85	57±2.45	41±1.15
Range Pond 1	8.2 – 9.0	294-295	198-215	151-161	160-168	18-28	12-16
Mean ± SD	8.6 ± 0.41	294.5±0.58	203.8±7.68	155.8±5.50	164±4.62	21.5±4.43	13.8±2.06
Range Pond 2	8.2 – 9.0	297-298	200-218	150-154	163-165	20-29	14-19
Mean ± SD	8.6 ± 0.39	297.8 ± 0.50	207±7.70	152±2.31	164±1.15	22.3±4.5	16±2.45
Range Borehole 1	2.1 – 2.8	508-518	730-738	130-142	215-220	51-54	32-34
Mean ± SD	2.5 ± 0.40	514±4.24	733.8±3.30	135.5±6.40	217.5±2.89	52.8±1.5	33±1.15
Range Borehole 2	2.2 – 2.9	514-524	741-748	130-135	220-225	53-54	32-36
Mean ± SD	2.5 ± 0.38	520±4.32	745±3.56	132.5±2.89	223±2.45	53.5±0.58	33.8±2.06

The turbidity values for the Hand Dug Well (HDW) ranged from (5.4 – 5.9) NTU, that of the Ponds was (8.2 – 9.0) NTU and the Borehole had a range of (2.1 – 2.9) NTU. The turbidity values for HDW and Pond were above the WHO safety guideline value of 5 NTU for drinking water, whereas the Borehole samples had their values below the WHO guideline. The total dissolved solids (TDS) values for the HDW ranged from (538 – 558) mg/l, whiles the Ponds recorded a range of (294 – 298) mg/l and the Borehole had a range of (508 – 524) mg/l. All the HDW and the Borehole samples had TDS values above the WHO safety guideline value of 500 mg/for drinking water. The conductivity values for the HDW, Pond and the Boreholes ranged from (946 – 980, 198 – 218 and 508 – 524) μS/cm respectively. The conductivity values for HDW and Borehole were above the WHO safety guideline values of 250 μS/cm whereas that of the Pond was below it. The alkalinity values for the HDW, Pond and the Borehole ranged from (128-145, 150 – 161 and 130 – 142) mg/l respectively. All the values were below the WHO safety guideline value of 200 mg/l.

The total hardness (TH) values for the HDW and the Borehole ranged from (345 – 385 and 215 – 225) mg/l respectively. The levels are above the WHO safety guideline value of 200 mg/l for drinking water. The Pond water had TH values ranging from (160 – 168) mg/l. The CaH value range for the HDW ranged from (50 – 59) mg/l, (18 – 29) mg/l for Pond and (51 – 54 mg/l) for Borehole. The CaH values for HDW and Borehole were above the WHO safety guideline value of 50 mg/l whereas that of Pond was below. The MgH values for the HDW ranged from (40 – 45) mg/l, the Pond had a range of (12 – 19) mg/l and the Borehole had (32 – 36) mg/L. All the values were below the WHO safety guideline value of 50 mg/l**.**

The range, average and standard deviation of the chemical properties of water samples collected from the Ziope community in the Volta Region are summarized in Table 2.

Table 2: The range, mean and standard deviation of the indicated parameters of the water samples from Ziope

Parameter/ site	pH	Cl^- (mg/l)	F^- (mg/l)	SO_4^{2-} (mg/l)	NH_3 (mg/l)	NO_2^- (mg/l)	NO_3^- (mg/l)
Range HDW1	7.2-7.3	253-263	0.13-0.14	30.1-30.4	0.11- 0.13	0.12- 0.15	8.11-8.14
Mean ± SD	7.2±0.05	257.5±4.8	0.13±0.01	30.25±0.17	0.12± 0.01	0.14±0.01	8.13+0.02
Range HDW2	7.1-7.2	251-260	0.17-0.17	30.0-30.5	0.11- 0.11	0.12-0.14	8.12-8.14
Mean ± SD	7.1±0.05	254.8±3.86	0.17±0.00	30.23±0.26	0.11± 0.00	0.13±0.01	8.13±0.01
Range HDW3	7.1-7.3	256-264	0.16-0.16	30.1-30.5	0.11–0.11	0.11- 0.15	8.12-8.15
Mean ± SD	7.2±0.12	260.8±3.59	0.16±0.00	30.3±0.21	0.11±0.00	0.13±0.01	8.14±0.12
Range HDW4	7.1-7.2	255-260	0.18-0.18	30.1-30.3	0.12- 0.25	0.11-0.16	8.11-8.15
Mean ± SD	7.1±0.05	256.5±2.38	0.18±0.00	30.2±0.12	0.18±0.07	0.13±0.03	8.13±0.02
Range HDW5	7.1-7.2	259-265	0.17-0.18	30.0-30.4	0.12- 0.18	0.12-0.15	8.11-8.14
Mean ± SD	7.1±0.05	263±2.83	0.18±0.01	30.20±0.23	0.15±0.03	0.13±0.01	8.13±0.02
Range Pond 1	7.3-7.4	150-155	0.12-0.14	39.0-39.0	0.20 - 0.21	0.30-0.31	10.14-10.20
Mean ± SD	7.4±0.058	152.5±2.89	0.14±0.01	39.0±0.00	0.20±0.01	0.30±0.01	10.16±0.03
Range Pond 2	7.3-7.5	153-158	0.11-0.13	39.0-39.8	0.25-0.27	0.30-0.32	10.15-10.20
Mean ± SD	7.4±0.10	156±2.45	0.13±0.01	39.406±0.46	0.255± 0.01	0.31±0.01	10.18±0.03
Range Borehole 1	7.1-7.3	251-252	0.34-0.38	27.1-27.3	0.14-0.14	0.10-0.12	4.10-4.12
Mean ± SD	7.2±0.10	251.5±0.58	0.35±0.02	27.20±0.12	0.14±0.00	0.11±0.01	4.11±0.01
Range Borehole 2	7.0-7.2	252-253	0.38-0.38	27.1-27.1	0.14-0.14	0.10-0.11	4.10-4.12
Mean ± SD	7.1±0.10	252.3±0.5	0.38±0.00	27.10±0.00	0.14±0.00	0.11±0.01	4.11±0.01

The pH values for the HDW ranged from 7.1 – 7.4; that of the Ponds ranged from 7.3 – 7.5 and the Borehole samples had a range of pH 7.0 – 7.3. All the water samples recorded pH values that were within the WHO safety guideline values of 6.5 – 8.5. The water samples from the various sources can be classified as slightly alkaline. Concentration of Cl^- for the HDW, Pond and Borehole samples ranged from 251 – 265, 150 – 158 and 251 – 253 mg/l respectively. The Cl^- values for HDW and Borehole were above the WHO safety guideline values of 250 mg/l whereas that of the Pond was below. Fluoride recorded concentrations ranging from (0.13 – 0.18, 0.11 – 0.14 and 0.34 – 0.38) mg/l for the HDW, Pond and Borehole respectively. All the values were below the WHO safety guideline value of 1.5 mg/l.

Concentration of SO_4^{2-} for the HDW ranged from (30.0 – 30.5) mg/l that of the Pond was (39.0 – 39.8) mg/l whiles that recorded by the Borehole was (27.1 – 27.3) mg/l. The concentrations of NH_3 in all the water samples were generally low when compared with the WHO guideline for drinking water. The values ranged from (0.11 – 0.25) mg/l in the samples obtained from the HDW; they ranged from (0.20 – 0.27) mg/l for Pond and 0.14 mg/l for Borehole water samples. Nitrite concentrations in all the water samples were generally low. They ranged from (0.11 – 0.16) mg/l for the HDW, (0.30 – 0.32) mg/l for Pond and (0.10 – 0.12) mg/l for borehole. The NO_3^- concentrations were relatively higher in all the samples in Table 2. The samples from the HDW recorded the highest concentrations ranging from (8.11 – 8.15) mg/l; the Pond samples had concentrations ranging from (10.14 – 10.20) mg/l and the Borehole samples has a concentration range of (4.10 – 4.12) mg/l.

The range, mean and standard deviation of the heavy metal and bacteriological properties of the water samples from the Ziope community in the Volta Region are summarized in Table 3.

Table 3: The range, mean and standard deviation of heavy metal and bacteriological parameters of the water samples.

Parameter / Site	Mn (mg/l)	Fe (mg/l)	Pb (mg/l)	Cu (mg/l)	TC ($MPN100ml^{-1}$)	FC ($MPN100ml^{-1}$)
Range	0.06-0.06	0.27-0.27	0.01-0.03	0.14-0.14	215-243	90-115
HDW1 Mean ± SD	0.06±0.00	0.27±0.00	0.02±0.01	0.14±0.00	228.25±15.35	108.25±19.72
Range	0.05-0.10	0.05-0.10	0.04-0.04	0.16-0.16	210-235	90-113
HDW 2 Mean ± SD	0.08±0.03	0.08±0.03	0.04±0.00	0.16±0.00	219.25±11.35	101.25±11.93
Range	0.04-0.04	0.04-0.04	0.01-0.03	0.18-0.18	215-251	92-100
HDW 3 Mean ± SD	0.04±0.00	0.04±0.00	0.02±0.01	0.18±0.00	233.00±20.78	95.25±4.10
Range	0.06-0.08	0.06-0.08	0.03-0.03	0.15-0.15	218-240	92-100
HDW 4 Mean ± SD	0.07±0.01	0.07±0.01	0.03±0.00	0.15±0.00	229.00±11.60	96.00±4.62
Range	0.04-0.04	0.04-0.04	0.02-0.02	0.15-0.15	220-248	90-90
HDW 5 Mean ± SD	0.04±0.00	0.04±0.00	0.02±0.00	0.15±0.00	233.50±15.61	90.00±0.00
Range	0.02-0.002	0.02-0.02	0.00-0.02	0.14-0.14	820-865	120-150
Pond 1 Mean ± SD	0.02±0.00	0.02±0.00	0.01±0.01	0.14±.00	841.75±24.06	134.50±16.76
Range	0.01-0.01	0.01-0.01	0.00-0.02	0.14-0.14	820-850	120-137
Pond 2 Mean ± SD	0.01±0.00	0.01±0.00	0.01±0.01	0.14±.00	833.75±15.02	127.50±8.81
Range	0.04-0.08	0.08-0.08	0.01-0.02	0.20-0.20	44-52	3-4
Borehole 1 Mean ± SD	0.08±0.00	0.08±0.00	0.02±0.01	0.20±0.00	47.50±4.12	3.50±0.58
Range	0.08-0.08	0.08-0.08	0.01-0.02	0.20-0.20	44-53	3-6
Borehole 2 Mean ± SD	0.08±0.00	0.08±0.00	0.02±0.01	0.20±0.00	48.50±5.20	4.5±1.73

The concentrations of Mn in the HDW ranged from (0.04 – 0.10) mg/l; the Pond had a concentration range of (0.01 – 0.02) mg/l while the Borehole recorded a range of (0.4 - 0.08) mg/l. Concentrations of Fe in the HDW, Pond and Borehole ranged from (0.24 – 0.28, 0.15 – 0.18 and 0.22 – 0.25) mg/l respectively. All the values were below the WHO safety guideline values of 0.3 mg/l**.** Concentrations of Pb in all the samples were high above the WHO safety guideline values of 0.01 mg/l for drinking water. Concentrations of Pb were in the ranges of (0.01 – 0.04, below detection – 0.02 and 0.01- 0.02) mg/l for HDW, Pond and Borehole. Cu concentration for the HDW ranged from 0.14 – 0.18 mg/l, those of the samples from the three Ponds ranged from 0.14 mg/l and the Borehole samples had below detection limit - 0.20 mg/l.

The TC levels in the water samples from the HDW ranged from (210–251) MPN100ml^{-1}, the Pond samples had a range of (820–865) MPN100ml^{-1} while the Borehole recorded a range of (44 – 53) MPN100ml^{-1}. FC levels in all the samples were also far above the WHO safety guideline of 0 MPN100ml^{-1}. The samples from the Ponds recorded the highest value in the range of (120 – 150) MPN100ml^{-1}, the HDW recorded FC concentration in the range of (90 –133) MPN100ml^{-1}. The Borehole samples recorded the least concentration of (3 – 6) MPN100ml^{-1}.

The raw data (Appendix 1) were statistically analysed using the Microsoft Excel and SPSS software applications. The analysis was done in three parts: part one seeks to established if the data taken for different times from the same sampling points in the year are significantly different in all the parameters measured; part two performs significant tests to establish whether significant differences exist between the WHO standard values for drinking water and those found in the samples from the Ziope Community. Part three has to do with inter correlations between the parameters that measure the quality of water. The

statistical tool used for part one is the one way analysis of variance for nine different sources of water in the community. In part two, one sample t-estimate test for the mean measure was done for 20 WHO parameters with respect to quality water to check if significant differences exist below or above the WHO values.

The nine sources of water in the community are made up of five Hand Dug Wells (HDW), two Ponds and two Boreholes. The 20 WHO parameters for drinking water considered for this research were:

Turbidity, pH, Electrical Conductivity, Total Dissolved Solid, Alkalinity, Total Hardness, Calcium Hardness, Magnesium Hardness, Chloride, Fluoride, Sulphate, Free Ammonia, Nitrate Ammonia, Nitrite Ammonia, Manganese, Total Iron, Lead, Copper, Total Coliform, Faecal Coliform. For the purposes of inference, a significance value of 0.05 was set.

4.2 Testing the differences in data collected

Data were analysed using the one way analysis of variance (ANOVA). This is a technique that allows the statistics practitioners to compare two or more independent populations of interval data. The procedure works by analyzing the variances of the populations in question, hence the name. Thus the technique analyze the variance of the data to determine whether we can infer that the population means differ.

The tool works by testing the hypothesis;

H_o: $\mu_1 = \mu_2 = \mu_3 = ... = \mu_n$ against

H_1: At least two means differ

So in this case, the following hypotheses were to be tested;

Hypothesis 1, 2, 3, 4, 5, 6, 7, 8 and 9

The mean measurement for the four times is the same for HDW 1, HDW 2, HDW 3, HDW 4, and HDW 5. Pond 1 and Pond 2, Borehole 1 and Borehole 2

We reject H_o if the p – value in the test is less than the significant level of 0.05. Below is the table on inference for comparing similar parameters for HDW 1.

From the summary statistics at the first part of Appendix 2A, it could be observed that the mean for measurements done for HDW 1 appears not significantly different from the four measurements. Moreover, the p – value in the second part of the table also records, 1.00, which is far greater than 0.05. These imply that hypothesis one cannot be rejected hence the measurements taken for the four times for HDW 1 are not significantly different.

The same arguments were true for hypothesis 2, 3, 4, 5, 6, 7, 8 and 9. The tables for the summary and ANOVA can be found in Appendix 2B-J.

On the whole, all the four measurements for the nine different sources of water are not significantly different. This implies that whatever the standard of water is in the community was captured very well in all four measurements taken for the period. What this means is that nothing was done about the water condition used by the people of Ziope community from September, 2010 to February, 2011. Hence the rest of the analysis would be done using figures that were obtained recently from the community; these figures depict the true state of water quality in the community at the moment.

4.3 Testing Parameters with WHO Standards

This section provides statistical tests that seek to examine the present water quality in the community in comparison with the WHO standards. The WHO international standards of water quality should not be above the following levels:

The statistical tool used to perform such tests is the one sampled t-test inference about the mean. The test involves testing whether significant differences, below or above, exist between the community values and the WHO standards. Appendix 4A-S is SPSS outputs for the data collected.

The upper part of the Appendix 4A gives the mean turbidity of 5.32 NTU, which is marginally higher than the WHO standard value of 5 NTU. The lower part shows that there is not much significant (significant value of 0.66 is greater than 0.05) difference between the community value and the WHO value and that, the mean difference is 0.32 NTU above the required standard. The electrical conductivity of the water sources in the community appears to have mean value of 748.44 mg/l above the WHO standard. There is, therefore, a high significant difference above the required standard. The total dissolved solid of the water sources in the community had mean value of 514.89 mg/l above the WHO standard of 500 mg/l with a mean difference of 14.89 mg/l. Appendix 4E shows that alkalinity in water sources in the community is also below the required standard by a significant value of 64.33 mg/l. The water sources in the community appear to be significantly hard, above the required standard by mean difference of 89.44 mg/l, with a mean total hardness of 289.44 mg/l. The calcium hardness of the water sources in the community had mean value of 53.11 mg/l above the WHO standard of 50 mg/l with a mean difference of 3.11 mg/l. The magnesium hardness is however significantly lower than the WHO standard with mean of 35 mg/l and a mean difference from the standard 50 mg/l of -15.00 mg/l.

The chloride concentration in the water bodies in the community had a mean value of 253.53 mg/l above the WHO standard value of 250 mg/l. There is a significant difference between the community water pH and the WHO standard of 8.5. This difference is below (this is why the negative sign) the standard with a mean difference of 1.34. This shows that the pH of water sources in the community is acceptably within the WHO standards. For the

fluoride concentration, there is a significant difference between that of the community and the required standard, below the standard value of 1.5 mg/l by a mean of 1.30 mg/l. The sulphate concentration of the water sources in the community had a mean of 31.40 mg/l below the WHO standard value of 400 mg/l with a mean difference of -368.60 mg/l. Ammonia has a mean value of 0.14 mg/l below the WHO standard value of 0.5 mg/l and a mean difference of -0.36 mg/l.

The nitrate concentration of the water sources in the community had a mean of 7.67 mg/l below the WHO standard value of 10 mg/l with a mean difference of -2.33 mg/l. The nitrite concentration of the water sources in the community had a mean of 0.15 mg/l below the WHO standard value of 0.2 mg/l with a mean difference of - 0.05 mg/l.

The manganese concentration with mean value of 0.06 mg/l is significantly below the WHO standard value of 0.4 mg/l total iron concentration with mean value of 0.23 mg/l is also significantly below the WHO standard value of 0.3 mg/l. The mean value, the significant value and the mean difference value are all suggesting that the amount of lead in the water sources is higher than the required value. Copper with a mean value of 0.16 mg/l, 1.84 mg/l mean difference below the WHO standard value of 2. The total coliform in the water bodies in the community had a mean value of 312.22 $MPN100ml^{-1}$ above the WHO standard value of 0 $MPN100ml^{-1}$. The faecal coliform in the water bodies in the community had a mean value of 78.33 $MPN100ml^{-1}$ above the WHO standard of 0 $MPN100ml^{-1}$.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Physical characteristics

The range, mean and standard deviation of the physical properties of drinking water samples in the Ziope community in the Volta Region are summarized in Table 1 in chapter four. Mean turbidity for HDW ranged from 5.6 ± 0.10 NTU to 5.7 ± 0.17 NTU, 8.6 ± 0.39 – 8.6 ± 0.41 NTU for Pond and 2.5 ± 0.38 – 2.5 ± 0.40 NTU for Borehole. Significant difference exist between the community value 5.32, NTU and the WHO value 5.0 NTU, with a mean difference of 0.32 NTU above the WHO standard. The lowest value of 5.6 ± 0.10 NTU, 8.6 ± 0.39 NTU and 2.5 ± 0.38 NTU were recorded in HDW 4, Pond 2 and Borehole 2 respectively. The highest value of 5.7 ± 0.17 NTU, 8.6 ± 0.41 NTU and 2.5 ± 0.4 NTU were recorded in HDW 3, Pond 1 and Borehole 1 respectively. The high turbidity values above the WHO standard for drinking water may be due to suspended matter such as clay, salt, finely divided organic and inorganic matters, planktons, and microscopic organisms. Detergents and emulsifying agents produce stable colloids that could result in turbidity (APHA, 1992). The use of turbid water for domestic properties may constitute a health risk because this could stimulate the growth of bacteria and pathogenic microorganisms (Qadir *et al.*, 2007).

Mean TDS for HDW ranged from 552.5 ± 8.66 – 569 ± 3.37 mg/l, 294.5 ± 297.8 mg/l for the Pond and 514 ± 4.24 mg/l – 520± 4.32 mg/l for the Borehole. Significant difference exists between the community value (514.89 mg/l) and the WHO value (500 mg/l) with a mean difference of 14.89 mg/l above WHO standard for drinking water. The high TDS values above the WHO guideline for drinking water may be due to decomposition and

mineralization of inorganic materials (Abida, and Harikrishna, 2008). TDS is positively correlated with calcium hardness and chloride with a value of 1 as shown in the correlation for water parenthesis in Table 4. Water with high TDS values, usually have no health threats to humans until the value exceed 10,000 mg/l. However, high TDS may produce aesthetically displeasing colour, taste and odour as well as hardening of water (Gupta and Gupta, 1999).

Mean conductivity for HDW ranged from 953.5 ± 8.70 – 970 ± 11.55 µS/cm, 203.8 ± 7.68 – 207 ± 7.70 µS/cm for Pond and 733.8 ± 3.30 – 745 ± 356 µS/cm for Borehole. Significant difference exists between the community value (748.44 µS/cm) and the WHO value (250 µS/cm) with a mean difference of 498.44 mg/l above WHO standard for domestic water. The highest values of 953.5 ± 8.70 µS/cm, 203.8 ± 7.68 µS/cm and 733.8 ± 3.30 µS/cm were recorded in HDW 2, Pond 1 and Borehole 1 respectively. The high conductivity values could be due to decomposition and mineralization of organic materials (Abida, and Harikrishna, 2008). Conductivity had a significant positive correlation with calcium hardness, chloride and TDS as presented in Table 4.

(Verma *et al*., 2000), demonstrated that for a complete quantification of fresh water acidity, the measurement of alkalinity is recommended. In view of this alkalinity was determined for the samples. The highest alkalinity values of 142.3 ± 2.63 mg/l, 155.8 ± 5.5 mg/l and 135.5 ± 6.40 mg/l were recorded in HDW 5, Pond 1 and Borehole 1 respectively. The alkalinity values were below the WHO standard. No significant difference exists between the community value (135.67 mg/l) and the WHO standard value (200 mg/l).

Mean total hardness ranged from 51.7 ± 4.72 – 370.8 ± 7.89 mg/l for HDW 14 ± 1.15 – 164 ± 4.62 mg/l for Pond and 217.5 ± 2.89 – 223 ± 2.45 mg/l for Borehole. Significant

difference exists between the summary value (289.4 mg/l) and the WHO value (200 mg/l) with a mean difference of 89.44 mg/l. The lowest values of 351.7 ± 4.72 mg/l, 164 ± 1.15 mg/l and 217.5 ± 2.80 mg/l were recorded in HDW 2, Pond 1 and Borehole 1 respectively. The highest values of 370.8 ± 7.89 mg/l, 164 ± 4.62 mg/l and 233 ± 2.45 mg/l were recorded in HDW 3, Pond 2 and Borehole 2 respectively. The increase in total hardness above WHO standard may be due to decomposition and mineralization of organic materials (Abida, and Harikrishna, 2008). Total hardness also corrected positively with TDS, calcium hardness and chloride with a value of 1 as shown in Table 4. The use of hard water for domestic purpose leads to excessive use of soaps and detergents and finally leaves spots on glasses, dingy film on laundry and on bathroom fixtures. However hard water provides calcium salts needed by children to make strong bones and teeth (WHO, 2004).

The highest calcium hardness value were 57 ± 2.45 mg/l for HDW, 22.3 ± 4.5 mg/l for Pond and 53.5 ± 0.58 mg/l for Borehole. Significant difference exists between the community value (53.11 mg/l) and the WHO value (50 mg/l) with a mean difference of 3.11 mg/l. The high values of calcium hardness above WHO standard may be due to discharge from agricultural and domestic waste waters (Rajkumar, 2004). The salts of calcium are responsible for the hardness of water. Mean magnesium hardness for the various water samples were 39 ± 1.15 mg/l, 13.8 ± 2.06 mg/l and 33 ± 1.15 mg/l for HDW, Bond and Borehole respectively. No significant difference exist between the community value (35 mg/l) and WHO standard value (50 mg/l).

5.2 Chemical characteristics

The mean pH of the samples collected from the various sampling sites within the study area ranged from pH 7.1 ± 0.05 – 7.2 ± 0.12, 7.4 ± 0.06 – 7.4 ± 0.01 and 7.1 ± 0.10 – 7.2 ±

0.10 for HDW, Pond and Borehole respectively. This clearly indicates that all the samples fall within the WHO and EPA – Ghana standard of pH 6.5 – 8.5. The recorded pH range was however higher than the natural background of pH 7.0 for surface water. No significant difference was noted in the observed pH ranges at each site at $p < 0.05$ confidence level. The increase in pH of the water samples above the normal background levels may be due to the presence of dissolved carbonate and bicarbonate present in the water, which is known to affect pH of almost all surface waters (Abida and Harikrishna, 2008). Based on these guidelines, the pH of the stream waters would not adversely affect its use for domestic and recreational purposes and the aquatic ecosystem.

Water samples in the HDW and the Ponds had mean Cl^- concentrations above the WHO and EPA-Ghana acceptable limits for drinking and domestic water that is 250 mg/l. The highest mean concentration was recorded from HDW 5 with a value of 263 $\pm$ 2.83 mg/l and the lowest concentration was from Borehole 2 with a value of, 152.5 $\pm$ 2.89 mg/l. Significant difference exists between community value (253.53 mg/l) and the WHO value (250.00 mg/l) with a mean difference of 3.53 mg/l above the WHO standard. The high level of Cl^- could be due to discharge from agricultural and domestic wastewaters. Chloride toxicity has not been observed in human except in special cases of impaired sodium chloride metabolism as reported in congestive heart failure (Gupta and Gupta, 1999). Little is known about the effect of prolonged intake of large amount of chloride in the diet. The presence of chlorides in high concentrations makes water hard and increases the electrical conductivity. High concentration of chloride can make waters unpalatable and therefore, unfit for drinking (APHA, 1992).

All the domestic water sources in the study area were characterized by low fluoride ion concentrations and fell within the WHO and EPA-Ghana acceptable limits for drinking and

domestic water that is 1.5 mg/l. The highest concentration was recorded from Borehole 2 with a value of 0.73 ± 0.02 mg/l and the lowest concentration was from Pond 2 with a value of 0.11 ± 0.13 mg/l. No significant difference exists between the community value (0.2 mg/l) and WHO standard value (1.5 mg/l).

The mean SO_4^{2-} levels which were recorded in all the water samples during the sampling period were lower compared with the WHO recommend levels of 400 mg/l. The highest concentration was recorded in Pond 2 with a mean concentration of 39.41 ± 0.46 mg/l whiles the lowest mean concentration of 27.10 ± 0.02 mg/l was recorded in Borehole 2. No significant difference exists between the community value (31.40 mg/l) and WHO standard value (400 mg/l).

The mean ammonia levels recorded in all the samples at the time of this work were far below the WHO and EPA – Ghana recommend levels of 0.5 mg/l. The highest concentration was recorded in Pond 2 with a mean concentration of 0.26 ± 0.01 mg/l while the lowest mean concentration of 0.11 ± 0.002 mg/l was recorded HDW 2. No significant difference exists between the community values (0.14 mg/l) WHO standard value (0.5 mg/l). Ammonia is naturally present in surface water and groundwater and can also be produced by the deamination of organic nitrogen containing compounds. It can also be produced from the hydrolysis of urea. The problem of waste and odour may, however, arise when the NH_3-N level is greater than 2 mg/l (WHO, 2004).

All the samples showed nitrite values below the WHO limit of 3.0 mg/l. The highest mean value of 0.31 ± 0.01 mg/l was recorded from Pond 2 whiles the lowest mean value of 0.11 ± 0.01 mg/l was recorded from Borehole 2). Again all the water samples showed nitrate values below the WHO limit of 10 mg/l except for the samples from the Ponds. The highest

mean value of 10.18 ± 0.03 mg/l was recorded from Pond 2 while the lowest mean value of 4.11 ± 0.01 mg/l was recorded in the samples from Borehole 2. No significant difference exists between the community value (7.67 mg/l) and WHO standard value (10 mg/l).

5.3 Heavy Metal and Bacteriological quality.

The mean concentrations that were recorded for manganese were all below the WHO guidelines for domestic and drinking water that is 0.4 mg/l. Therefore, this will not pose any health threat for humans and the survival of aquatic organism. HDW 2 showed the highest mean concentration of 0.08 ± 0.02 mg/l while Pond 2 showed the least mean concentration of 0.01 ± 0.00 mg/l. No significant difference existed between the community values (0.06 mg/l) and the WHO standard value (0.04 mg/l).

The mean concentrations of Fe in the water samples ranged from 0.01 mg/l in Pond 2 to 0.27 ± 0.00 mg/l in HDW 1. All the water samples did not exceed the background level of 0.67 mg/l and the WHO limit of 1.0 mg/l. The presence of iron in drinking water may increase the growth of pathogenic organisms, since most of these organisms need iron to grow. The major effect of the presence of iron in domestic water is aesthetic because of the colour (Lamikanra, 1999). Therefore, Fe concentration does not currently present any aesthetic problems in all the water sources in this community.

The mean concentration of Cu in the water samples were all above the normal background level of 0.005 mg/l. They were however, far below both the WHO and EPA-Ghana guidelines for domestic and drinking water of 1.0 mg/l and 2.0 mg/l respectively. The highest mean value of 0.28 ± 0.01 mg/l was in Borehole 2 and the lowest of 0.14 ± 0.03 mg/l was also recorded in HDW 2. No health threats to aquatic and human health by Cuin the water is anticipated at this point in time.

The water samples within the study area were characterized by mean lead concentrations which were above the normal background level of 0.005 mg/l; an indication of pollution. The highest value was recorded in HDW 2 (0.04 ± 0.00 mg/l) and the lowest value was also recorded in Pond 1, with mean concentrations of 0.01 ± 0.01 mg/l. Significant difference exists between the community value (0.02 mg/l) and the WHO value (0.01 mg/l) with a mean difference of 0.01 mg/l above the WHO standard. These concentrations as recorded from the samples were slightly above the WHO recommended level of 0.01 mg/l. At levels higher than 0.01 mg/l, possible neurological damage in foetus and young children may occur (WHO, 2004). This level was exceeded in the samples; therefore, direct or indirect use of water from the streams for domestic use without treatment could be detrimental to pregnant women and young children in the communities within the study area. The ponds water would not also be suitable for the maintenance of aquatic ecosystem, livestock, watering and irrigation. Lead is used in paints (as pigments), polyvinylchloride (PVC), plastics, pencils, batteries, pesticides etc. Human activities may introduce lead into the environment. Since the community is a farming community, it appears that the use of pesticides and paints are likely to be the cause of the high levels of lead in the water. Other possible sources of lead pollution in the study area could be from the geology of the catchment, from sewage effluent discharge, from rural and urban runoff and from seepage from waste sites.

For water to be considered no risk to human health, the faecal coliform count in the water sample should be zero (WHO, 1987, 2004). Pond 1 recorded the highest faecal coliform concentration with a logarithmic mean of 841.75 ± 24.06 MPN100ml^{-1} and the lowest concentration was recorded in Borehole1 with 47.50 ± 4.12 MPN100ml^{-1}. This is shown in Table 3. Significant difference exists between the community value (312.22 MPN100ml^{-1}) and the WHO value (0 MPN100ml^{-1}) with a mean difference of 312.22 MPN100 ml^{-1} above

the WHO standard. The presence of high faecal coliform counts is a sign of the extent of contamination of the water bodies in the study area by potential pathogens or disease-causing organism. The faecal coliform levels observed in the samples make them unsuitable for both primary contacts (such as swimming) and secondary contact, i.e. for boating and fishing (WHO, 2004). It is presumed that there may be health risks to humans and other aquatic animals. In Ghana for instance, incidence of enteric diseases are second to malaria in terms of the number of cases reported in the national hospitals. About 40,000 cases of enteric diseases are reported annually in the country due to poor water quality.

Total coliform and faecal coliform are bacteria whose presence indicators that the water may be contaminated by human or animal wastes. The possible sources of contamination could be due to runoffs from settlements lacking appropriate sanitation infrastructure, runoff from untreated household wastewater and leachates from refuse dumps (Carpenter *et al.*, 1998 and Qadir *et al.,* 2007). Domestic consumption of water contaminated with total coliform and faecal coliform may lead to the incidence of diarrhoea, nausea and headaches. These pathogens may pose a special health risks for infants, young children and people with severely compromised immune system (Qadir *et al.*, 2007).

5.4 Correlation Matrix for Water Parameters

Table 4 shows the general inter correlations between the parameters for Hand Dug Wells, Ponds and the Boreholes. The purpose of this matrix is to find out if increasing values for one parameter necessarily results in corresponding increase or decrease in the other, or vice versa. The correlation Table would also reveal parameters between which there is no correlation. A high correlation was deemed to be one that is within the range of 0.7 to 1.0; a moderate high correlation is one from 0.4 to 0.6; a weak correlation is one ranging from 0.1

to 0.3. No correlation recorded zero. A positive correlation would show direct relationship while, negative correlation values reveals inverse relationship.

Twenty parameters were thus defined as follows;

V_1 = *Turbidity*

V_2 = *pH*

V_3 = *Electrical Conductivity*

V_4 = *Total Dissolved Solid*

V_5 = *Methyl Orange Alkalinity*

V_6 = *Total Hardness*

V_7 = *Calcium Hardness*

V_8 = *Magnesium Hardness*

V_9 = *Chloride*

V_{10} = *Fluoride*

V_{11} = *Sulphate*

V_{12} = *Free Ammonia*

V_{13} = *Nitrate Ammonia*

V_{14} = *Nitrite Ammonia*

V_{15} = *Manganese*

V_{16} = *Total Iron*

V_{17} = *Lead*

V_{18} = *Copper*

V_{19} = *Total Coliform*

V_{20} = *Faecal Coliform*

Table 4: Correlation Matrix for Water Quality Parameters of samples taken from different locations within the Ziope community of the Volta Region.

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	V_{16}	V_{17}	V_{18}	V_{19}	V_{20}
V_1	1.0																			
V_2	0.7	1.0																		
V_3	-0.6	-0.7	1.0																	
V_4	-0.6	-0.7	1.0	1.0																
V_5	0.7	0.8	-0.8	-0.8	1.0															
V_6	-0.2	-0.6	0.9	0.9	-0.6	1.0														
V_7	-0.5	-0.7	1.0	1.0	-0.8	0.9	1.0													
V_8	-0.6	-0.7	1.0	1.0	-0.8	0.9	1.0	1.0												
V_9	-0.6	-0.7	1.0	1.0	-0.8	0.9	1.0	1.0	1.0											
V_{10}	-0.6	-0.2	0.3	0.3	-0.3	**0.0**	0.2	0.2	0.2	1.0										
V_{11}	0.9	0.7	-0.8	-0.9	0.8	-0.5	-0.8	-0.8	-0.8	-0.6	1.0									
V_{12}	0.6	0.6	-0.7	-0.7	0.6	-0.6	-0.8	-0.7	-0.7	-0.3	0.7	1.0								
V_{13}	**1.0**	0.5	-0.4	-0.5	0.6	0.0	-0.3	-0.4	-0.4	-0.7	0.8	0.4	1.0							
V_{14}	0.9	0.8	**-0.9**	-0.9	0.9	-0.7	-0.9	-0.9	-0.9	-0.5	1.0	0.8	0.7	1.0						
V_{15}	-0.8	-0.7	0.6	0.7	-0.8	0.3	0.6	0.7	0.6	0.5	-0.8	-0.6	-0.8	-0.8	1.0					
V_{16}	-0.6	-0.6	0.9	0.9	-0.7	0.9	0.9	0.9	0.9	0.2	-0.8	-0.8	-0.4	-0.8	0.6	1.0				
V_{17}	-0.1	-0.3	0.6	0.6	-0.4	0.6	0.5	0.6	0.6	0.0	-0.3	-0.4	0.0	-0.4	0.4	0.5	1.0			
V_{18}	-0.8	-0.4	0.3	0.3	-0.4	-0.1	0.2	0.2	0.2	0.6	-0.7	-0.4	-0.9	-0.6	0.6	0.2	0.0	1.0		
V_{19}	0.9	0.8	-0.8	-0.9	0.8	-0.6	-0.8	-0.8	-0.8	-0.6	1.0	0.7	0.8	1.0	-0.8	-0.8	-0.4	-0.7	1.0	
V_{20}	0.9	0.5	-0.3	-0.3	0.5	0.1	-0.2	-0.3	-0.2	-0.7	0.8	0.4	1.0	0.6	-0.7	-0.3	0.1	-0.9	**0.7**	1.0

On a whole there were very high correlations existing between the parameters. However, very low correlations, as low as zero, also existed between some parameters. There were a number of negative correlations also between the parameters. There was high correlation between total hardness and total dissolved solid, calcium hardness and chloride as well as between turbidity, total coliform and faecal coliform all with correlation value of 1 as shown in Table 4. A correlation value of -0.9 recorded for conductivity and nitrite indicated that the high level of conductivity value did not depend on the concentration of nitrite in the water sources. Also total hardness and Fluoride contents were not related at all, an increase in one, does not cause corresponding increase or decrease in the other as the correlation value between them is 0.0.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

In this study, some microbiological and physicochemical properties, heavy metal for example total coliform and faecal coliform, turbidity, total hardness, TDS, CaH, Cl^- and Pb values of the water were above the WHO safety guidelines for drinking water. Those that were of health concern include turbidity total coliform and faecal coliform. TC and FC were enumerated in all the samples of the water sources. The high number of indicator microorganism counts observed reflected the poor quality of water being used by the Ziope community. The possible sources of contamination could be due to runoff from human settlements lacking appropriate sanitation infrastructure, runoff from untreated household wastewater and leaches from refuse dumps. Thus, microbiologically, the water samples were found to be unfit for human consumption without prior treatment. The Boreholes were better source of potable water followed by the Hand Dug Wells while the Ponds were of poor quality.

6.2 RECOMMENDATIONS

Activities such as car washing, watering livestock and doing laundry should be prohibited on a radius of about 20 m from the water sources. Access to the water sources by domestic and grazing animals should be restricted by fencing. The sediment in the wells should be removed regularly and also the wells should be disinfected regularly with chlorine. A clean environment should be established through provision of adequate infrastructure for solid waste disposal, facing out open dumpsites to safeguard public health from water borne diseases. Public Health Authorities should educate the public about the potential danger of the public water supply.

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APPENDICES

APPENDIX 1A

PHYSICOCHMICAL PARAMETERS SEPTEMBER, 2010

Parameter	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
Temperature	^{0}C	27.3	27.3	27.0	27.3	27.2	27.7	27.8	26.8	27.0
Turbidity	NTU	5.7	5.8	5.8	5.6	5.8	8.8	8.9	2.8	2.9
pH		7.3	7.1	7.3	7.2	7.1	7.4	7.5	7.3	7.2
Conductivity	µS/cm	950.0	946.0	955.0	950.0	960.0	200.0	205.0	730.0	741.0
TDS	mg/l	553	564	564	555	570	295	298	508	508
TH	mg/l	350	345	360	350	375	160	163	215	220
Alkalinity	Mg/l	140	134	140	130	145	160	154	140	135
CaH	mg/l	55	54	57	55	59	28	29	57	53
MgH	mg/l	42	41	38	40	40	12	14	32	32
Chloride	mg/l	254	251	260	255	263	150	155	251	252
Fluoride	mg/l	0.14	0.17	0.16	0.18	0.17	0.14	0.13	0.34	0.38
Sulphate	mg/l	30.4	30.5	30.5	30.3	30.4	39.0	39.8	27.3	27.1
Ammonia	mg/l	0.13	0.11	0.11	0.25	0.18	0.21	0.27	0.14	0.14
Nitrate	mg/l	8.14	8.14	8.15	8.15	8.14	10.17	10.2	4.12	4.12
Nitrite	mg/l	0.15	0.14	0.15	0.16	0.15	0.31	0.32	0.12	0.11

APPENDIX 1B

TRACE METAL PARAMETERS SEPTEMBER, 2010

Parameter	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
Manganese	mg/l	0.06	0.05	0.04	0.06	0.04	0.02	0.01	0.08	0.08
Total Iron	mg/l	0.27	0.26	0.26	0.24	0.28	0.18	0.15	0.25	0.22
Lead	mg/l	0.03	0.04	0.03	0.03	0.02	0.01	0.01	0.02	0.02
Copper	mg/l	0.14	0.16	0.18	0.15	0.15	0.14	0.14	0.20	0.20

APPENDIX 1C

MICROBIOLOGICAL PARAMETERS SEPTEMBER, 2010

Parameter	Unit	HDW 1	HDW 2	HDW 3	HDW 4	HDW 5	Pond1	Pond2	B.hole1	B.hole2
TC	$MPN100ml^{-1}$	240	220	251	238	248	860	843	50	53
FC	$MPN100ml^{-1}$	133	110	99	100	90	148	133	4	6

APPENDIX 1D

PHYSICOCHMICAL PARAMETERS OCTOBER, 2010

Parameter	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
Temperature	0C	27.3	27.3	27.2	27.3	27.2	27.9	27.8	27.0	27.0
Turbidity	NTU	5.9	5.8	5.8	5.7	5.6	9.0	9.0	2.8	2.8
pH		7.2	7.2	7.3	7.1	7.2	7.4	7.4	7.2	7.2
Conductivity	µS/cm	950	946	960	960	960	202	205	734	748
TDS	mg/l	268.0	260.0	240.0	253.0	240.0	94.3	98.0	215.0	222.0
TH	mg/l	138	133	141	130	144	161	154	142	135
CaH	mg/l	364	352	353	342	385	160	163	215	222
MgH	mg/l	49	48	46	47	40	18	20	39	37
Chloride	mg/l	42	42	38	40	40	12	14	32	32
Fluoride	mg/l	150	145	148	140	155	55	58	115	120
Manganese	mg/l	0.13	0.17	0.16	0.18	0.18	0.14	0.13	0.34	0.38
Sulphate	mg/l	30.4	30.4	30.4	30.3	30.4	39.0	39.8	27.3	27.1
Ammonia	mg/l	0.13	0.10	0.11	0.24	0.18	0.20	0.25	0.14	0.14
Nitrate	mg/l	8.14	8.14	8.15	8.15	8.14	10.17	10.20	4.12	4.12
Nitrite	mg/l	0.15	0.13	0.15	0.15	0.13	0.30	0.30	0.12	0.11

APPENDIX 1G

PHYSICOCHMICAL PARAMETERS JANUARY, 2011

Parameter	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
Temperature	0C	27.0	27.1	26.9	27.0	27.1	27.3	27.5	26.6	26.8
Turbidity	NTU	5.4	5.4	5.5	5.5	5.4	8.2	8.4	2.1	2.2
pH		7.2	7.1	7.1	7.1	7.1	7.3	7.3	7.1	7.0
Conductivity	µS/cm	970	960	975	965	980	215	218	733	748
TDS	mg/l	553	538	558	540	565	294	297	515	520
TH	mg/l	370	355	375	355	384	168	165	220	225
CaH	mg/l	52	52	53	50	54	20	20	54	54
MgH	mg/l	45	44	40	42	42	116	119	34	35
Chloride	mg/l	256	260	263	260	265	155	158	262	253
Fluoride	mg/l	0.13	0.17	0.16	0.18	0.18	0.12	0.11	0.18	0.18
Ammonia	mg/l	0.11	0.11	0.11	0.12	0.12	0.20	0.25	0.14	0.14
Nitrate	mg/l	8.11	8.12	8.12	8.11	8.11	10.14	10.15	4.10	4.10
Nitrite	mg/l	0.12	0.12	0.11	0.11	0.12	0.30	0.30	0.10	0.10

APPENDIX 1H

TRACE METAL PARAMETERS JANUARY, 2011

Parameters	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
Manganese	mg/l	0.06	0.10	0.04	0.08	0.04	0.02	0.01	0.08	0.08
Total Iron	mg/l	0.27	0.26	0.26	0.24	0.28	0.18	0.15	0.25	0.22
Lead	mg/l	0.01	0.04	0.01	0.03	0.02	0.02	0.02	0.01	0.01
Copper	mg/l	0.14	0.16	0.18	0.15	0.15	0.14	0.14	0.20	0.20

APPENDIX 1I

MICROBIOLOGICAL PARAMETERS JANUARY, 2011

Parameters	Unit	HDW 1	HDW 2	HDW 3	HDW 4	HDW5	Pond1	Pond2	B.hole1	B.hole2
TC	$MPN10ml^{-1}$	215	210	215	218	220	822	820	44	44
FC	$MPN\ 100ml^{-1}$	90	90	92	92	90	120	120	3	3

APPENDIX 1J

PHYSICOCHMICAL PARAMETERS FEBRUARY, 2011

Parameter	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
Temperature	^{0}C	27.0	27.1	27.0	27.0	27.1	27.5	27.5	26.6	26.9
Turbidity	NTU	5.4	5.4	5.5	5.5	5.4	8.2	8.2	2.1	2.2
pH		7.2	7.1	7.1	7.1	7.1	7.3	7.3	7.1	7.1
Conductivity	ųS/cm	970	962	980	965	980	198	200	738	743
TDS	mg/l	565	553	570	555	573	295	298	518	524
TH	mg/l	360	355	370	355	371	168	165	220	225
CaH	mg/l	54	53	55	53	56	20	20	54	54
MgH	mg/l	45	43	40	43	42	15	17	34	36
Chloride	mg/l	260	255	261	255	265	150	153	251	252
Fluoride	mg/l	0.13	0.17	0.16	0.18	0.18	0.14	0.13	0.34	0.38
Sulphate	mg/l	30.1	30.0	30.1	30.1	30.0	39.0	39.0	27.1	27.2
Ammonia	mg/l	0.11	0.11	0.11	0.12	0.12	0.20	0.25	0.14	0.14
Nitrate	mg/l	8.11	8.12	8.12	8.11	8.11	10.14	10.15	4.10	4.10
Nitrite	mg/l	0.12	0.12	0.11	0.11	0.12	0.30	0.30	0.10	0.10

APPENDIX 1K

TRACE METAL PARAMETERS OCTOBER, 2011

Parameters	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
Manganese	mg/l	0.06	0.10	0.04	0.08	0.04	0.02	0.01	0.08	0.08
Total Iron	mg/l	0.27	0.26	0.26	0.24	0.28	0.18	0.15	0.25	0.22
Lead	mg/l	0.01	0.04	0.01	0.03	0.02	0.00	0.00	0.01	0.01
Copper	mg/l	0.14	0.16	0.18	0.15	0.15	0.14	0.14	0.20	0.20

APPENDIX 1L

MICROBIOLOGICAL PARAMETERS OCTOBER, 2011

Parameters	Unit	HDW1	HDW2	HDW3	HDW4	HDW5	Pond1	Pond2	B.hole1	B.hole2
TC	MPN $100ml^{-1}$	215	212	215	220	220	820	820	44	44
FC	MPN $100ml^{-1}$	95	92	90	92	90	120	120	3	3

APPENDIX 2A

ANOVA for Hypothesis One

SUMMARY

Group	Count	Sum	Average	Variance
HDW 1	20	2379.46	118.97	49604.62
HDW 1	20	2371.55	118.58	49719.36
HDW 1	20	2338.95	116.95	51243.77
HDW 1	20	2348.65	117.43	51352.11

APPENDIX 2B

ANOVA for Hypothesis Two

Groups	*Count*	*Sum*	*Average*	*Variance*
HDW 2	20	2307.47	115.37	48671.94
HDW 2	20	2326.45	116.32	48823.87
HDW 2	20	2296.98	114.85	49806.47
HDW 2	20	2306.58	115.33	50112.58

APPENDIX **2C**

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.83163	3	7.61	0.00	1.00	2.72
Within Groups	3750882	76	49353.72			
Total	3750905	79				

APPENDIX **2D**

ANOVA for Hypothesis Three

Groups		*Count*	*Sum*	*Average*	*Variance*
HDW3		20	2317.68	115.88	49646.46
HDW3		20	2329.58	116.48	50099.24
HDW3		20	2295.99	114.80	50998.97
HDW3		20	2304.69	115.23	51533.47

APPENDIX **2E**

ANOVA for Hypothesis Four

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
HDW 4	20	2295.32	114.77	48978.43
HDW 4	20	2304.30	115.22	49792.62
HDW 4	20	2316.92	115.85	50787.25
HDW 4	20	2320.72	116.04	50820.55

APPENDIX **2F**

ANOVA for Hypothesis Six

Groups	*Count*	*Sum*	*Average*	*Variance*
POND1	20	1769.38	88.47	37364.13
POND1	20	1783.86	89.19	37794.11
POND1	20	1726.52	86.33	34344.84
POND1	20	1702.62	85.13	33998.83

APPENDIX **2G**

ANOVA for Hypothesis Seven

Groups	*Count*	*Sum*	*Average*	*Variance*
POND 2	20	1751.43	87.57	35909.60
POND 2	20	1766.39	88.32	36471.60
POND 2	20	1733.53	86.68	34165.15
POND 2	20	1708.63	85.43	33968.47

APPENDIX **2H**

ANOVA for Hypothesis Eight

Groups	*Count*	*Sum*	*Average*	*Variance*		
BOREHOLE 1	20	1579.67	78.98	28388.88		
BOREHOLE 1	20	1590.57	79.53	28641.40		
BOREHOLE 1	20	1575.46	78.77	28602.81		
BOREHOLE 1	20	1580.52	79.03	28979.85		
ANOVA						
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.15	3.00	2.05	0.00	1.00	2.72
Within Groups	2177645.82	76.00	28653.23			
Total	2177651.97	79.00				

APPENDIX **2I**

ANOVA for Hypothesis Nine

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BOREHOLE 2	20	1606.47	80.32	29298.6
BOREHOLE 2	20	1617.37	80.87	29786.95
BOREHOLE 2	20	1606.23	80.31	29810.81
BOREHOLE 2	20	1601.73	80.09	29492.17

APPENDIX 3

WHO Quality Water Standard

Parameter	Standard	Unit	Parameter	Standard	Unit	Parameter	Standard	Unit
Turbidity	5	NTU	MgH	50	mg/l	Manganese	0.4	mg/l
pH	6.5 – 8.5		Chloride	250	mg/l	TI	0.3	mg/l
Conductivity	250	mg/l	Fluoride	1.5	mg/l	Lead	0.01	mg/l
TDS	500	mg/l	Sulphate	400	mg/l	Copper	2	mg/l
TA	200	mg/l	Ammonia	0.5	mg/l	TC	0.00	MPN100 ml^{-1}
TH	200	mg/l	Nitrate	10	mg/l	FC	0.00	MPN100 ml^{-1}
CaH	50	Mg/l	Nitrite	0.2	mg/l			

APPENDIX **2J**

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.63	3.00	2.21	0.00	1.00	2.72
Within Groups	2249383.33	76.00	29597.15			
Total	2249389.96	79.00				

APPENDIX 4A

Testing Turbidity with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Turbidity	9	5.32	2.14	0.71

TEST VALUE = 5						
	t	Df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Turbidity	0.45	8	0.66	0.32	-1.3258	1.9703

Appendix 4B

Testing pH with WHO standard

Parameter	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
pH	9	7.16	0.09	0.03

TEST VALUE = 8.5						
	t	df	Sig.(2tailed)	Mean Diff.	95%Confidence Interval of the Difference	
					Lower	Upper
pH	45.734	8	0.00	- 1.344	-1.42	- 1.28

Appendix 4C

Testing Electrical Conductivity with WHO standard

Parameter	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
EC	9	748.44	326.49	108.83

TEST VALUE = 250						
	t	df	Sig.(2tailed)	Mean Diff.	95%Confidence Interval of the Difference	
					Lower	Upper
EC	4.58	8	0.00	498.44	247.49	749.40

Appendix 4D

Testing Total Dissolved Solid with WHO standard

Parameter	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
TDS	9	514.89	68.27	22.76

TEST VALUE = 500						
	t	Df	Sig.(2tailed)	Mean Diff.	95%Confidence Interval of the Difference	
					Lower	Upper
TDS	12.62	8	0.00	14.89	48059	530.00

Appendix 4E

Testing Alkalinity with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Alkalinity	9	135.67	9.08	3.03

TEST VALUE = 200						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Alkalinity	-21.25	8	0.00	-64.33	-71.32	-57.35

Appendix 4F

Testing Total Hardness with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
TH	9	289.44	92.47	30.82

TEST VALUE = 200						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
TH	2.90	8	0.02	89.44	18.40	160.51

Appendix 4G

Testing Calcium Hardness with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
CaH	9	53.11	14.35	4.78

TEST VALUE = 53.11						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
CaH	1.440	8	0.19	3.11	4.14	17.92

Appendix 4H

Testing Magnesium Hardness with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
MgH	9	35.00	11.34	3.78

TEST VALUE = 50						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
MgH	- -0.97	8	0.00	- 15.00	- 23.71	-6.29

Appendix 4I

Testing Chloride with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Chloride	9	253.53	38.24	12.75

TEST VALUE = 250						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Chloride	10	8	0.00	3.53	163.95	270.30

Appendix 4J

Testing Fluoride with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Fluoride	9	0.20	0.09	0.03

TEST VALUE = 1.5						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Fluoride	-42.05	8	0.00	-1.30	-1.37	-1.23

Appendix 4K

Testing Sulphate with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Sulphate	9	31.40	4.48	1.49

TEST VALUE = 400						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Sulphate	-246.77	8	0.00	- 368.60	- 372.04	365.16

Appendix 4L

Testing Ammonia with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Ammonia	9	0.14	0.05	0.02

TEST VALUE = 0.5						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Ammonia	-21.875	8	0.00	- 0.36	-0.39	-0.32

Appendix 4M

Testing Nitrate with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Nitrate	9	7.67	2.20	0.73

TEST VALUE = 10						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Nitrate	-3.17	8	0.01	- 2.23	- 4.02	-0.64

Appendix 4N

Testing Nitrite with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Nitrite	9	0.15	0.08	0.03

TEST VALUE = 0.2						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Nitrite	-1.67	8	0.13	- 0.05	-0.11	-0.02

Appendix 4O

Testing Manganese with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Manganese	9	0.06	0.03	0.01

TEST VALUE = 0.4						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Manganese	-33.42	8	0.00	- 0.34	-0.37	-0.32

Appendix 4P

Testing Total Iron with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
TI	9	0.23	0.04	0.01

TEST VALUE = 0.3						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
TI	-4.51	8	0.00	- 0.07	-0.10	-0.03

Appendix 4Q

Testing Lead with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Lead	8	0.02	0.014	0.01

TEST VALUE = 0.01						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Lead	1.00	7	0.36	- 0.01	-0.00	0.02

Appendix 4R

Testing Copper with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
Copper	9	0.16	0.02	0.01

TEST VALUE = 2						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
Copper	-221.5	8	0.00	- 1.84	-1.86	-1.82

Appendix 4S

Testing Total Coliform and Faecal Coliform with WHO standard

Parameter	N	Mean	Std. Deviation	Std. Error Mean
FC	9	78.33	44.36	14.788
TC	9	312.22	296.97	98.99

TEST VALUE = 0						
	t	df	Sig.(2tailed)	Mean Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
FC	5.30	8	0.00	78.33	44.23	112.44
TC	3.15	8	0.01	312.22	83.95	540.49