

**ASSESSMENT OF DRINKING WATER QUALITY IN EHI  
COMMUNITY IN THE KETU- NORTH DISTRICT OF THE  
VOLTA REGION OF GHANA.**

**BY**

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# DECLARATION

It is hereby declared that this thesis is the outcome of research work undertaken by the author, any assistance obtained has been duly acknowledge. It is neither in part nor whole been presented for another degree elsewhere.

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## **DEDICATION**

This research work is dedicated to God almighty, my late father, Mr. D.B.K. Mensah, my mother Mad.. Juliana Kpedegbo and my two lovely daughters, Selinam and Seyram Ekpe- Mawuli all of young scholars Academy, Ofankor, Accra.

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## ABSTRACT

Ehi community depends on bore holes, surface water and shallow hand dug wells. The aim of this study was to assess the drinking water quality of these sources, between November, 2010 and March 2011. Total coliform, *E. coli* and total heterotrophic bacteria were enumerated using membrane filtration method. Comprehensive physicochemical parameters were determined. Overall, higher bacterial counts were recorded for all sources, except for Bore hole. Values recorded for both physicochemical and bacteriological were within WHO guideline values. Most of chemical ions concentrations were well within WHO guideline values for all the six samples except that higher level of sodium was recorded at Biasevudo well and higher level of Iron at Dzago stream. The ranking in terms of potability are in the order; bore hole water > shallow well water > surface water.

Water from shallow hand dug wells, and surface waters upon which the community depends is of poor quality as these are sited close to refuse pits, latrines and areas accessible to domestic animals. The data are being used to advise the district assembly. An integrated approach is therefore required to minimize faecal pollution of wells and surface water bodies within the community.

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## **CHAPTER ONE**

### **1.0 INTRODUCTION**

#### **1.1 BACKGROUND**

A primary concern of people living in developing countries is that of obtaining clean drinking water. In Africa and Asia, most people in rural areas depend on ground and surface water for sustenance . The situation is not different in Ghana, particularly in the rural areas.

The Ketu- North District, had a projected population of 98,512 as at 2009, based on estimate from the 2000 population census, experienced a population growth rate of 1.9%. (Ghana Statistical Service, 2000).

The provision of clean and safe drinking water is one of the major infrastructural problems for the District. Majority of the people in the District do not have access to reliable potable water sources ( Ketu- North District Assembly, 2010). At Weta Area Council where Ehi community is situated, water availability coverage is as low as 38.1%. The low coverage of water within Weta area council, affect productivity, in that man working hours are spent in search of water.

Out of 281 communities in the District, only 88 of them have boreholes. This leaves the rest of the communities to rather patronize other sources of water such as streams, rivers, underground tank and hand- dug wells. These other sources are not always hygienically good for domestic use, making them more vulnerable to water related diseases. (Ketu- north District Assembly, 2010).

The use of groundwater as the only source of potable water supply is increasing worldwide. In the United States, 90- 95% (Howell, 1995) of rural and suburban water comes from this sources and in Ghana, it is 62- 71% (GEMS/Water Project, 1997).

Most water sources in the District dry up in the dry season, compelling people in those communities to revert to drinking from unwholesome sources which make them vulnerable to water related diseases. The boreholes break down constantly as a result of excessive pressure coupled with the inability of communities to raise enough money for replacement and general maintenance.

In an effort to improve access to potable water, the Assembly has collaborated with a number of development partners, such as Community Water and Sanitation Agency (CWSA), Ghana-German Technical Co-operation (GTZ) and DANIDA, etc., in the provision of potable water in the District. These water sources are mainly boreholes and hand- dug wells. These non- treated water sources are increasingly being used as drinking water yet, testing to see whether the water is of good quality is almost non- existent (Obiri- Danso, *et al.*, 2008).

Ketu- North District is relatively low-lying with altitudes around 66 metres. Communities which are unable to attract donor support have sunk numerous shallow wells of doubtful water quality. It is generally perceived that wells, springs and boreholes are “clean” sources of water. Although it is true that soil generally function to attenuate microorganisms by simple filtration mechanism, especially larger bacteria and protozoa, pollution of groundwater by microorganisms, including those of public health significance do occur (Ashbolt and Veal, 1994; Stanley *et al.*, 1998).

This project sought to assess the drinking water quality of some wells, boreholes, stream and river in Ehi community in Ketu- North District and the extent of their contamination with total coliforms, *Escherichia coli* and Total Heterotrophic Bacteria as well as the concentration of physicochemical parameters were determined.

## **1.2 PROBLEM STATEMENT**

In Ghana, there are lot of information on water qualities of packaged waters sold in the market, some popular surface waters and drinking water quality in general, in some urban and peri-urban areas of the nation.

However, drinking water quality of most water sources in the rural areas have little or no data on their microbial safety. In the case of Ketu-North District, Tay (2004) of Council for Scientific and Industrial Research (CSIR), Water Research Institute (WRI) studied physicochemical qualities of water of some selected Boreholes in Ketu and Akatsi Districts. The microbial quality aspect was missing from the report.

Ehi is a small community with a population of about 5000. This community has no treated pipe-borne water. The inhabitants rely on few bore holes with majority relying on numerous shallow hand dug wells, Dzago stream and river Kplikpa. Locations and management of some of these wells raise suspicion of possible contamination. Ehi is a low lying area. However there is no data on quality of water from these sources to ascertain their suitability for drinking. The inhabitants are vulnerable to water related diseases ( Ketu-North District Assembly, 2010). In view of this, there is the need to assess drinking water quality of these sources.

### **1.3 OBJECTIVE OF THE STUDY.**

The main objective of this study is to assess the quality of water from the various sources of drinking water in Ehi community.

Specifically, the present study seeks to :

- determine the microbiological and physicochemical quality of water.
- Identify the possible sources of contamination.
- Evaluate the spatial similarities or differences between sampling sites.
- Compare the various parameters with World Health Organization's (WHO) guideline values

### **1.4 HYPOTHESIS**

1. The mean levels of bacteriological components in the sources of water in Ehi are significantly different from one another.
2. The average levels of physicochemical component in the sources of water in Ehi are significantly different from one another.

## **CHAPTER TWO**

### **3.0 LITERATURE REVIEW**

#### **2.1 DRINKING WATER**

Drinking water or potable water is defined as that having acceptable quality in terms of its physical, chemical, bacteriological and acceptability parameters so that it can be safely used for drinking and cooking ( WHO, 2004 ). World Health Organization (WHO) defines drinking water to be safe as long as it does not cause the population any significant health risks over a life time of consumption and effort should be made to maintain drinking water quality at the highest possible level. The Covenant on Economic, Social and Cultural Rights (C.E.S.C.R) explicitly recognized water as a fundamental human right in November, 2002 and the countries which ratified the international C.E.S.C.R are compelled to ensure everyone has access to adequate and safe supply of drinking water. Any group of people that do not have access to a potable source of drinking water, are being exposed to high levels of possible contamination and subsequently could result in disease conditions of various magnitudes.

#### **2.2 DRINKING WATER POLLUTION**

Polluted waters contain significant levels of pollutants, usually at levels above WHO certified drinking water quality standards and these are able to cause significant problems when ingested by humans (Cunningham, 1999).

Due to the open accessibility of surface water and hand-dug well, they easily receive foreign materials from various sources which negatively impact on the quality of the water.

Pollution of surface water occurs when the quantity of wastes entering a body of water overwhelms its capacity to assimilate the pollutants these wastes contain. Thus, the natural cleansing ability of oxygen contained in the water is compromised and the water can no longer breakdown organic pollutants (Buchholz,1993). There can be two sources of water pollution, point and non-point source pollution.

According to Buchholz (1993), point sources are those that come from industrial facilities and municipal sewage systems. Thus, they can be said to be pollution that can be traced to a particular source. However, non-point source pollution is diffuse and cannot be traced. Some main causes of non-point pollution are; agricultural, urban runoff, construction sites and waste disposal.

Cairncross and Cliff (1987) have shown that soakage pits and pit latrines can extend their influence on ground-water quality up to 10m or more as groundwater flow is either lateral or vertical. Additionally, filtration does not occur during lateral flow and could carry fecal pollution for much longer distances (Cairncross, 1987) possibly resulting in contamination of well water with pathogens (Zoeteman, 1980); Crain , 1984). Pye and Patric (1983) have shown that land disposal of sewage sludge, illegal dumping of septic tank pumpage, improper toxic waste disposal and run off from agricultural operations all contributed to surface and ground water contamination with chemicals and microorganisms.

Cunningham(1999) further suggested that, often the best way to control non-point pollution is through improved land use practices.

## **2.3 DRINKING WATER QUALITY**

The importance of drinking water quality has been enhanced in the last few years by the increased awareness and attendant publicity afforded to the pollution of water courses, estuaries and coastal areas (Shaw,1998). Globally, the UN declared an International Drinking water supply and Sanitation Decade between 1981 and 1991. Thus, Ghana was provided the impetus to identify and provide solutions to the problems of existing water supply and sanitation systems and also expand coverage so that more people would enjoy the benefits of good drinking water and adequate sanitation (Water Resource Institute, 1998). In the USA, the quality of drinking water is regulated by the safe Drinking Water Act of 1974, as amended in 1977 and 1986; It gives the EPA authority to set national standards to protect drinking water. These standards represent maximum contaminant levels (MCL) allowable and consist of numerical criteria for specified contaminants (Buchholz, 1993). Water supplies, especially in developing countries, have been focused on quantity at the expense of quality and there are calls for marked improvement in quality-better management of chemicals and microorganism content (Barrow, 2005). It is important to note, however, that issues of water quality cannot be considered separate from water quantity. In assessing the quality of drinking water, most consumers usually rely completely upon their senses. Water constituents may affect the appearance, smell or taste of water, thus, the consumer evaluates the quality and acceptability essentially on these criteria. However, we can no longer rely entirely upon our senses in the matter of quality judgement. The absence of any adverse sensory effects therefore does not guarantee the safety of drinking water.

In the submission on the drinking water quality control in small community supplies, WHO explains that although in the rural areas of developing countries, it is expected that a great majority



of water quality problems are related to bacteriological contamination, a significant number of very serious problems may occur as a result of chemical contamination of water sources from agricultural practices and malpractices.

The traditional emphasis on chemical indicators of water quality must be supplemented by more comprehensive indicators based on the total properties of water body including: chemical, physical, biological and ecological parameters. It must also be recognized that fresh water quality is impacted directly by natural and human activities outside the water sphere such as land use practices, erosion and deforestation. Some are also tied to acid deposition or natural contamination. Such problems often require monitoring and protection at the local level, while some have significant transboundary components which are addressed at national and International levels (International Conference on Water and the Environment Report, 1992).

## **2.4 WATER TREATMENT**

In the past, primary emphasis of disinfection was to control water borne diseases through the control of associated bacteriological indicator organisms such as coliforms. According to Bryant *et al.*, (1992), two findings in the 1970's have, however, resulted in significant evaluation of this long established disinfection practice. These are:

Disinfection by-products, formed in the reaction of disinfectants and certain water organic matter may be harmful to human health.

The discovery of newly recognized water-borne diseases causing organisms that could be effectively controlled by the then accepted disinfection procedure. The latter invention proven that the use of discrete indicator organisms was not sufficient to provide prove of inactivation of a broad range of pathogenic microbes. Modern water treatment methods, however, look beyond just

preventing water born diseases but goes on to consider all other constituents whether, biological or physicochemical.

## **2.5 DRINKING WATER SUPPLY**

According to a report by the water resource management submitted by the then Ministry of Works and Housing, the Environmental Protection Agency has initiated regular monitoring programs since 1995 to major rivers to obtain a national water quality database as part of Ghana Environmental Resource Management Project (GERMP). However, very little has been done to monitor the rivers and streams that usually serve as a source of drinking water for many rural folks around the country side. The principal purpose of improving water supply is to help overcome the scourge of killing disease that afflict developing countries and to improve their well being and productivity. Various studies and estimates indicate that in these countries disease typically takes up about a tenth of average person's potentially productive time and in addition, affects risk taking and initiative adversely, disrupts the education and nurture of children, stunt physical development and causes vast suffering and hardship (World Bank-Executed UNDP Project INT/82/002).

The provision of potable water must be paramount in the provision of social amenities in areas that are yet to receive such supplies. This can go a long way to cut the expenditure that governments and donor organizations spend in providing health care for these communities. It is very obvious that with the near eradication of water borne disease in most advanced countries, the monies which otherwise would have been used in treating these diseases, have been channeled into other areas of the economy where they are yielding much fruits. Such monies could even be put into research projects that could help improve the current treatment and supply methods available. The necessity

of water cannot be over emphasized and the entire society must make it a point to help increase potable water supply in all areas.

## **2.6 DRINKING WATER QUALITY PARAMETERS**

Physicochemical and biological quality of raw water is important not only in the assessment of the degree of pollution but also in the choice of the best source and the treatment needed (WHO, 1984). Agricultural activity along a river or water body is a potential source of total solids. The parameters that were considered as part of this study are discussed below.

### **2.6.1 pH**

The pH of a water is a measure of how acidic or alkaline (basic) the water is on a scale of 0 to 14. Pure distilled water is neutral with a pH of 7. pH measurement below 7 indicate that the solution is acidic containing more  $H^+$  ions than  $OH^-$  ions. Measurement above 7 indicates that the reverse situation exists making the water alkaline. It is important to note that for every one unit change on the pH scale, there is approximately a ten –fold in how acidic or alkaline the sample is. The usual pH for fresh water aquatic system is 6 to 9 with most water ways around pH is an indicator of existence of biological life as most of them thrive in a quite narrow and critical pH range. However, (WHO,1984) stipulated that drinking water should have pH range of 6.5 to 8.5. Darko-Mantey *et al.*,(2005), did a study on drinking water from different sources and observed a pH range of 6.1 to 7.2. pH is related in several different ways to almost every other water quality parameter, as aqueous chemical equilibria invariably involve hydrogen ions,  $H^+$  (WHO,1984)

Water sample with low pH attributed to discharge of acidic water into these sources by agricultural and domestic activities. . In fact 98% of all world groundwater are dominated by  $Ca^{2+}$

and  $\text{HCO}_3^-$  due to lime stone weathering in the catchments and under groundwater beds (Meybeck, 1997). Though pH has no direct effect on the human health, all the biochemical reactions are sensitive to variation of pH. For most reactions as well as for human beings, pH value 7.0 is considered as the best and ideal

### **2.6.2 Total Solids**

It refers to matter suspended or dissolved in water or wastewater, the greater the amount of total suspended solids (TSS), the murkier it appears and the higher the measured turbidity. Total solids include both TSS, the portion of total solids retained by a filter and total dissolved solids (TDS), the portion that passes through a filter. TSS is an indication of the amount of erosion that took place.

The TDS in water consist of organic salts and dissolved materials. In natural waters, salts are chemical compounds comprise of anions such as carbonates, chlorides, sulphates and nitrates (primarily in ground water), and cations such as potassium, magnesium, calcium and sodium. In ambient conditions, these compounds are present in portions that create a balanced solution (<http://www.duluthstreams.org>). According to WHO (1984), there has not been any deleterious physiological reactions occurring in persons consuming drinking water that have TDS values in excess of 1000mg/l. WHO, however, recommends the low level of the latter as a guideline value for TDS. Kempster *et al.*, (1997) reported a critical TDS value of 2450mg/l above which some long term health problems might be anticipated due to excessive concentrations of dissolved particles in drinking water.

### **2.6.3 Electrical conductivity**

Conductivity is a measure of the ability of water to conduct an electrical current and is directly related to the total dissolved salt content of the water. Ions come from the breakdown of compounds and conduct electricity because they are negatively or positively charged when dissolved in water. Some ions also occur naturally as water flows over certain types of rocks or soil. Calcium and carbonate ions dissolve into water when calcite containing rocks such as, lime stone and shale, are present.

Conductivity is an indirect measure of the presence of dissolved solids and can be used as an indicator of water pollution. Electrical conductivity is widely used to indicate the total ionized constituents of water. It is widely related to the sum of cations or anions as determined chemically and is closely correlated, in general, with the total salt concentration

(<http://www.duluthstreams.org>)

Human activities also influence conductivity. Acid mine drainage can add iron, sulphate, copper, cadmium and other ions if minerals containing them are exposed to air and water. Sewage and farm runoff can raise conductivity due to the presence of nitrate and phosphate. Runoff roads can also carry salt and other materials that contribute ions to water. `WHO (1984) recommended 1000 $\mu$ S/cm maximum contaminant limit for drinking water. Asare-Bediako (2008) did assessment of drinking water quality on river Ofin and reported a mean value of 228  $\mu$ S/cm. In a similar work done by Tay (2004) on ground water in Ketu District, he reported conductivity range of 420 to 5180  $\mu$ S/cm with a mean of 1737.1  $\mu$ S/cm.

#### **2.6.4 Turbidity**

For water to be aesthetically accepted, its clarity must be ensured. Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in a straight lines through the sample. Turbidity may be due to organic and / or inorganic constituents. Organic particulates may harbour microorganisms. Thus, turbid conditions may increase the possibility for waterborne diseases. Nonetheless, inorganic constituents have no notable health effects. If turbidity is largely due to organic particles, dissolved oxygen depletion may occur in the water body. The excess nutrients may results in algal growth.

Although it does not adversely affect human health, turbidity is an important parameter in that it can protect microorganisms from disinfection effects, can stimulate bacteria growth and indicates problems with treatment processes (WHO, 2004). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5NTU is usually acceptable to consumers (WHO, 2004). Ashietey *et al.* (2005) recorded turbidity value range between 12.46 and 30NTU in Lake Owabi. Tay (2004) also recorded turbidity range of 0.4 to 23.5NTU in ground water in Ketu District.

#### **2.6.5 Nitrate**

Nitrate ( $\text{NO}_3^-$ ) is a water-soluble and is made up of nitrogen and oxygen. It is formed when nitrogen from ammonia or other sources combines with oxygenated water. Nitrate is a natural constituent of plants and is found in vegetables at varying levels depending on the amount of fertilizer applied and on other growing conditions.

Water naturally, contains less than 1 mg nitrate-nitrogen per liter and is not a major source of exposure. Higher levels indicate that the water has been contaminated. Common source of  $\text{NO}_3^-$  contamination include fertilizer, animal waste, septic tanks, municipal sewage treatment systems, feedlots and decaying plant debris.

Nitrate is the most stable oxidized form of combined nitrogen in most environmental media. Most nitrogenous materials in natural waters tend to be converted to nitrates and therefore, all sources of combined nitrogen (particularly organic nitrogen and ammonia) should be considered as potential nitrate sources. Nitrates occur naturally in mineral deposits (generally sodium or potassium nitrates), in soils, seawater, freshwater systems, the atmosphere, and in biota.

The toxicity of nitrates in human is due to the body's reduction of nitrate to nitrites. This reaction takes place in the saliva of humans at all ages and gastrointestinal tract of infants during the first, three months of life. The toxicity of nitrate is demonstrated by vasodilatory / cardiovascular effects at high dose levels. Methaemoglobinemia, "Blue-Baby Disease", is an effect in which haemoglobin is oxidized to methaemoglobin, resulting in asphyxia. It is a serious condition that can cause brain damage or death.

Infants up to three months of age are the most susceptible subpopulation with regard to nitrate. Nitrate compounds have demonstrated adverse toxic effects in infants. Due to potential toxicity and widespread occurrence in water, it is regulated and should not exceed 10mg/l in drinking water (WHO, 1984).

Tay (2004) recorded  $\text{NO}_3^-$  concentration ranging from 0.01 to 324mg/l in ground water studied in the Ketu District.

### **2.6.6 Total Phosphorous and Phosphate, $\text{PO}_4^{3-}$**

Phosphates enter the water ways through both non-point sources and point sources. Nonpoint source (NPS) pollution refers to water pollution from diffuse sources. Nonpoint source pollution can be contrasted with point source pollution, where discharges occur to a body of water at a single location. The non-point sources of phosphates include: natural decomposition of rocks and minerals, storm water runoff, agricultural runoff, erosion and sedimentation, atmospheric deposition, and direct input by animals/wildlife; whereas: point sources may include: wastewater treatment plants and permitted industrial discharges. In general, the non-point source pollution typically is significantly higher than the point sources of pollution. Therefore, the key to sound management is to limit the input from both point and non-point sources of phosphate. High concentration of phosphate in water bodies is an indication of pollution and largely responsible for eutrophication (MacCutheon et al., 1983)

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate.

The following criteria for total phosphorus were recommended by US EPA (1984):

1. no more than 0.1 mg/L for streams which do not empty into reservoirs,
2. no more than 0.05 mg/L for streams discharging into reservoirs, and
3. no more than 0.025 mg/L for reservoirs.

(<http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/index.html>)

WHO (1984), set maximum contaminant level at 0.3mg/l.



Appreciably low concentration of phosphate were observed in earlier study done by Tay (2004) on ground water in the Ketu District which varied from 0.001 to 0.6 mg/l. Ansa-Asare et al., (2006) also recorded concentration ranging from <0.001 to 0.921mg/l in surface water in South Western Ghana.

Phosphorus is normally low (< 1 mg/l) in clean portable water sources and usually not regulated (Nduka *et al.*, 2008).

### **2.6.7 Sulphate, $\text{SO}_4^{2-}$ , And Hydrogen sulphide, $\text{H}_2\text{S}$**

Sulphate is combination of sulphur and oxygen and is part of naturally occurring minerals in some soil and rock formations that contain groundwater. The mineral dissolves over time and is released into groundwater, as water moves through soil and rock formations that contain sulphate minerals.

Sulphates are discharged into the aquatic environment in wastes from industries that use sulphates and sulphuric acid, such as mining and smelting operations, kraft pulp and paper mills, textile mills and tanneries (Delisle *et al.*, 1977).

Atmospheric sulphur dioxide ( $\text{SO}_2$ ), formed by the combustion of fossil fuels and by the metallurgical roasting process, may also contribute to the sulphate content of surface waters. It has frequently been observed that the levels of sulphate in surface water correlate with the levels of sulphur dioxide in emissions from anthropogenic sources (Keller *et al.*, 1986).

Sulphur trioxide ( $\text{SO}_3$ ), produced by the photolytic or catalytic oxidation of sulphur dioxide, combines with water vapour to form dilute sulphuric acid, which falls as "acid" rain or snow (Delisle *et al.*, 1977). These "acid" rains or snows flow in to water bodies and increase the sulphate contents.

Dissolved sulphate may be reduced to sulphide, volatilized to the air as hydrogen sulphide, precipitated as an insoluble salt or incorporated in living organisms (Delisle *et al.*, 1977). Sulphur-reducing bacteria, which use sulphur as an energy source, are the primary producers of large quantities of hydrogen sulphide. These bacteria chemically change natural sulphates in water to hydrogen sulphide. Sulphur-reducing bacteria live in oxygen-deficient environments such as deep wells, plumbing systems, water softeners and water heaters.

Hydrogen sulphide gas also occurs naturally in some groundwater. It is formed from decomposing underground deposits of organic matter such as decaying plant material. It is found in deep or shallow wells and also can enter surface water through springs, although it quickly escapes to the atmosphere. Hydrogen sulphide often is present in wells drilled in shale or sandstone, or near coal or peat deposits or oil fields.

Sulphates have a detoxifying effect on the liver and stimulate the function of the gall bladder and thus the digestive function as well.

USEPA as well as WHO set the Maximum contaminant level of sulphate in drinking water at 250 mg/L

Dehydration has been reported as a common side effect following the ingestion of large amounts of magnesium or sodium sulphate. Sulphates can interfere with disinfection efficiency by scavenging residual chlorine in the distribution system. The presence of sulphate salts in drinking water could increase corrosion of mild steel in the delivery system. Sulphate-reducing bacteria may be involved in the tuberculation of metal pipes. The hydrogen sulphide produced by these bacteria may lower the aesthetic quality of the water by imparting an unpleasant taste and odour

and may increase corrosion in both metal and concrete pipes. (<http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sulphate-sulfates/index-eng.php> )

### **2.6.8 Total Hardness /Carbonate, $\text{CO}_3^{2-}$ and Bicarbonate, $\text{HCO}_3^{2-}$**

Water hardness is a traditional measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to produce a lather, and it also leads to scaling of hot water pipes, boilers and other household appliances. Water hardness is caused by dissolved polyvalent metallic ions. In fresh waters, the principal hardness-causing ions are calcium and magnesium; strontium, iron, barium and manganese ions also contribute.

The degree of hardness of drinking water may be classified in terms of its calcium carbonate concentration as follows: soft, 0 to <60 mg/L; medium hard, 60 to <120 mg/L; hard, 120 to <180 mg/L; and very hard, 180 mg/L and above (Thomas 1953). Although hardness is caused by cations, it is often discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness. Carbonate hardness refers to the amount of carbonates and bicarbonates that can be removed or precipitated from solution by boiling. This type of hardness is responsible for the deposition of scale in hot water pipes and tea kettles. Non-carbonate hardness is caused by the association of the hardness-causing cations with sulphates, chlorides and nitrates. It is also referred to as "permanent hardness" because it cannot be removed by boiling.

The principal natural sources of hardness in water are sedimentary rocks and seepage and runoff from soils. In general, hard waters originate in areas with thick topsoil and limestone formations. Groundwater is generally harder than surface water. Groundwater rich in carbonic acid and dissolved oxygen usually has a high solvating power; in contacting soil or rocks containing

appreciable amounts of minerals, such as calcite, gypsum and dolomite, hardness levels up to several thousand milligrams per litre can result. The two main industrial sources of hardness are the inorganic chemical and mining industries. The cations that are the major contributors to hardness -- calcium and magnesium -- are not of direct public health concern.

Soft water can lead to corrosion of pipes and, consequently, certain heavy metals such as copper, zinc, lead and cadmium may be present in the distributed water. The degree to which this occurs is also a function of pH, alkalinity and dissolved oxygen concentration (see also review of pH). In some communities, corrosion is so severe that the water must be treated (<http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/hardness-dureted/index-eng.php>)

In areas with hard water, household pipes can become clogged with scale; hard waters also cause incrustations on kitchen utensils and increase soap consumption. Hard water is thus both a nuisance and an economic burden to the consumer. Public acceptance of hardness varies among communities; it is often related to the hardness to which the consumer has become accustomed, and in many communities hardness greater than 200 mg/L is tolerated. It has been suggested that a hardness level of 80 to 100 mg/L (as  $\text{CaCO}_3$ ) provides an acceptable balance between corrosion and incrustation (Bean, 1968). However, waters with hardness in excess of 500 mg/L are unacceptable for most domestic purposes.

### **2.6.9 Total Alkalinity**

Alkalinity or  $A_T$  is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate. Alkalinity can also be defined as a measure of the presence of bicarbonate, carbonate or hydroxide constituents. The alkalinity is equal to the stoichiometric sum

of the bases in solution. In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Other common natural components that can contribute to alkalinity include borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulphide. Alkalinity is usually given in the unit mEq/L (milliequivalent per liter), ppm (part per million), or mg/L (milligram per liter).

(<http://www.advacedaquarist.com/issues/feb2002/chemistry.htm>)

Alkalinity in water comes from a high concentration of carbon-based mineral molecules suspended in the solution. Water with high alkalinity is said to be "hard." The most prevalent mineral compound causing alkalinity is calcium carbonate, which can come from rocks such as limestone or can be leached from dolomite and calcite in the soil.

([http://www.ehow.com/about\\_5098791\\_causes-high-alkalinity-water.html#ixzz1Hfw7KCsE](http://www.ehow.com/about_5098791_causes-high-alkalinity-water.html#ixzz1Hfw7KCsE)).

Fresh drinking water should have an alkalinity level of 20 to 200 milligrams of calcium carbonate per liter of water. Concentrations less than 100 ppm are desirable for domestic water supplies. The recommended range for drinking water is 30 to 400 ppm. A minimum level of alkalinity is desirable because it is considered a "buffer" that prevents large variations in pH.

Alkalinity is not detrimental to humans. Moderately alkaline water (less than 350 mg/l), in combination with hardness, forms a layer of calcium or magnesium carbonate that tends to inhibit corrosion of metal piping. Many public water utilities employ this practice to reduce pipe corrosion and to increase the useful life of the water distribution system. High alkalinity (above 500 mg/l) is usually associated with high pH values, hardness and high dissolved solids and has adverse effects on plumbing systems, especially on hot water systems (water heaters, boilers, heat exchangers,

etc.) where excessive scale reduces the transfer of heat to the water, thereby resulting in greater power consumption and increased costs. Water with low alkalinity (less than 75 mg/l), especially some surface waters and rainfall, is subject to changes in pH due to dissolved gasses that may be corrosive to metallic fittings.

### **2.6.10 Chloride, Cl<sup>-</sup>**

Chlorides in groundwater and surface water can be naturally occurring in deep aquifers or caused by pollution from sea water, brine, or industrial or domestic wastes. Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium (CaCl<sub>2</sub>) [Department of National Health and Welfare (Canada), 1992]. Chloride in water may be considerably increased by treatment processes in which chlorine or chloride is used.

Chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can, however, become accustomed to concentrations in excess of 250 mg/litre.

Chloride increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts (WHO Regional Office for Europe, 1979), thus increasing levels of metals in drinking-water. In lead pipes, a protective oxide layer is built up, but chloride enhances galvanic corrosion (Gregory, 1990). It can also increase the rate of pitting corrosion of metal pipes. Tay (2004) observed that, ground water in Ketu and Akatsi Districts had chloride concentration ranging from 42.1mg/l to 1260mg/l. Ansa-Asare et al. (2006) also observed concentration range of 2.0 to 64.5mg/l in surface waters of south-Western and Coastal river basins of Ghana..

### **2.6.11 Fluoride, F<sup>-</sup>**

Fluorine is a common element that does not occur in the elemental state in nature because of its high reactivity. Traces of fluorides are present in many waters; higher concentrations are often associated with underground sources. In seawater, a total fluoride concentration of 1.3 mg/litre has been reported (Slooff, 1988). In areas rich in fluoride-containing minerals, well water may contain up to about 10 mg of fluoride per litre. The highest natural level reported is 2800 mg/litre. Fluorides may also enter a river as a result of industrial discharges (Slooff, 1988). In groundwater, fluoride concentrations vary with the type of rock the water flows through but do not usually exceed 10mg/litre (US EPA, 1984).

Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking-water have been carried out. These studies clearly establish that fluoride primarily produces effects on skeletal tissues (bones and teeth). Low concentrations provide protection against dental caries, especially in children. The pre- and post-eruptive protective effects of fluoride (involving the incorporation of fluoride into the matrix of the tooth during its formation, the development of shallower tooth grooves, which are consequently less prone to decay, and surface contact with enamel) increase with concentration up to about 2 mg of fluoride per litre of drinking-water; the minimum concentration of fluoride in drinking-water required to produce it is approximately 0.5 mg/litre.

However, fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental fluorosis (prevalence: 12–33%) at drinking-water concentrations between 0.9 and 1.2 mg/litre (Dean, 1942); the period of greatest susceptibility is at the time of mineralization of the secondary upper central incisor teeth at about 22–26 months of age.. This has been confirmed in numerous subsequent studies, including a recent large-scale survey carried out in China (Chen,

1988), which showed that, with drinking-water containing 1 mg of fluoride per litre, dental fluorosis was detectable in 46% of the population examined.

Elevated fluoride intakes can also have more serious effects on skeletal tissues. Skeletal fluorosis (with adverse changes in bone structure) may be observed when drinking-water contains 3–6 mg of fluoride per litre. Crippling skeletal fluorosis usually develops only where drinking-water contains over 10 mg of fluoride per litre (IPCS, 1984).

WHO set maximum contaminant concentration at 1.5mg/L in 1984 and reaffirmed it in 1993. Concentrations above this value carry an increasing risk of dental fluorosis, and much higher concentrations lead to skeletal fluorosis. Tay (2004) however, reported fluoride concentration varying from 0.001 to 1.5 mg/l, in ground water in Ketu District.

#### **2.6.12 Sodium ion, Na<sup>+</sup>**

Sodium is a soft, silvery-white, highly reactive metal that is never found in nature in the uncombined state. Sodium, an alkali-metal element, has a strong tendency to exist in the ionic form. In biological systems and even in solids such as sodium chloride, sodium remains distinctly separate as the sodium ion.

The sodium ion is ubiquitous in water. Most water supplies contain less than 20 mg of sodium per litre, but in some countries levels can exceed 250 mg/litre. Saline intrusion, mineral deposits, seawater spray, sewage effluents, and salt used in road de-icing can all contribute significant quantities of sodium to water. In addition, water-treatment chemicals, such as sodium fluoride, sodium bicarbonate, and sodium hypochlorite, can together result in sodium levels as high as 30



mg/litre. Domestic water softeners can give levels of over 300 mg/litre, but much lower ones are usually found [WHO Regional Office for Europe, 1979 (EURO Reports and Studies No. 2)].

Sodium is the most abundant cation in the extracellular fluid. It is largely associated with chloride and bicarbonate in regulation of acid-base equilibrium. Maintenance of the osmotic pressure of body fluid, and thus prevention of excess fluid loss, is another important function of sodium. Sodium also acts in preserving the normal irritability of muscle and permeability of cells. (WHO, 1984).

In general, sodium salts are not acutely toxic because of the efficiency with which mature kidneys excrete sodium. However, acute effects and death have been reported following accidental overdoses of sodium chloride [WHO Regional Office for Europe, 1979 (EURO Reports and Studies No. 2) ] . Acute effects may include nausea, vomiting, convulsions, muscular twitching and rigidity, and cerebral and pulmonary oedema [Department of National Health and Welfare (Canada), 1992]. Excessive salt intake seriously aggravates chronic, congestive heart failure, and ill effects due to high levels of sodium in drinking-water have been documented [ WHO Regional Office for Europe, 1979 (EURO Reports and Studies No. 2) ]. The effects on infants are different from those in adults because of the immaturity of infant kidneys. Infants with severe gastrointestinal infections can suffer from fluid loss, leading to dehydration and raised sodium levels in the plasma (hypernatraemia); permanent neurological damage is common under such conditions.

An excessive level of sodium is easily detected by taste. In solutions at room temperature, taste thresholds for sodium present in salts such as sodium chloride and sodium sulphate are approximately 130 to 140 mg/L. Generally, the taste is offensive at a concentration of >200 mg/L

sodium (whether chloride or sulphate) [WHO Regional Office for Europe, 1979 (EURO Reports and Studies No. 2)]. Tay 2004 reported a concentration range of 24.1 to 668mg/l with mean value of 140.75 in ground water of Ketu District.

### **2.6.13 Potassium ion, K<sup>+</sup>**

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. It occurs widely in the environment, including all natural waters. It can also occur in drinking-water as a consequence of the use of potassium permanganate as an oxidant in water treatment. In some countries, potassium chloride is being used in ion exchange for household water softening in place of, or mixed with, sodium chloride, so potassium ions would exchange with calcium and magnesium ions (WHO, 2009).

Although concentrations of potassium normally found in drinking-water are generally low and do not pose health concerns, the high solubility of potassium chloride and its use in treatment devices such as water softeners can lead to significantly increased exposure.

Potassium and sodium maintain the normal osmotic pressure in cells. Potassium is a cofactor for many enzymes and is required for the secretion of insulin, creatinine phosphorylation, carbohydrate metabolism and protein synthesis.

Excessive loss of salts, such as through severe diarrhoea or intense and prolonged sweating, can result in a loss of potassium, which can result in hypokalaemia if the loss is sufficient. This can cause a range of effects, including cardiac arrhythmia, muscle weakness, nausea and vomiting, and low muscle tone in the gut. Longer-term hypokalaemia is believed to cause a predisposition to hypertension (UKEVM, 2003).

Adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals. Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting (Gosselin, Smith & Hodge, 1984).

Case-studies of toxicity resulting from high doses of salt substitutes have described chest tightness, nausea and vomiting, diarrhoea, hyperkalaemia, shortness of breath and heart failure (WHO, 2009). WHO set maximum contaminant level at 30mg/l. Tay (2004), reported concentration range of 1.0 to 40.2mg/l in drinking water in the district.

#### **2.6.14 Iron ions, $\text{Fe}^{2+}$ and $\text{Fe}^{3+}$**

Iron is the second most abundant metal in the earth's crust, and it accounts for about 5% of the metal. Iron is most commonly found in nature in the form of its oxides ( Elinder,1986).

The median iron concentration in rivers has been reported to be 0.7 mg/litre. In anaerobic groundwater where iron is in the form of iron(II), concentrations will usually be 0.5–10 mg/litre, but concentrations up to 50 mg/litre can sometimes be found (National Research Council , 1979). Concentrations of iron in drinking-water are normally less than 0.3 mg/litre but may be higher in countries where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution.

Aeration of iron-containing layers in the soil can affect the quality of both groundwater and surface water if the groundwater table is lowered.

Dissolution of iron can occur as a result of oxidation and decrease in pH.

In drinking-water supplies, iron(II) salts are unstable and are precipitated as insoluble iron(III) hydroxide, which settles out as a rust-coloured silt. Staining of laundry and plumbing may occur at

concentrations above 0.3 mg/litre . 0.3 mg/litre is however, set to be maximum contaminant level. Iron also promotes undesirable bacterial growth ("iron bacteria") within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping [Department of National Health and Welfare (Canada), 1990]. Iron in water can cause yellow, red, or brown stains on laundry, dishes, and plumbing fixtures such as sinks. In addition, iron can clog wells, pumps, sprinklers, and other devices such as dishwashers, which can lead to costly repairs. Iron gives a metallic taste to water, and can affect foods and beverages - turning tea, coffee, and potatoes black (<http://www.health.state.mn.us/divs/eh/wells/waterquality/iron.pdf>.)

Iron is an essential element in human nutrition. Iron gives the haemoglobin of blood it's red colour and allows the blood to carry oxygen ([http://www.int/water\\_sanitation health/dwq/chemicals/iron.pdf](http://www.int/water_sanitation_health/dwq/chemicals/iron.pdf))

### **2.6.15 Calcium ions $\text{Ca}^{2+}$**

Calcium occurs in water naturally. One of the main reasons for the abundance of calcium in water is its natural occurrence in the earth's crust. Calcium is also a constituent of coral. Rivers generally contain 1-2 ppm calcium, but in lime areas rivers may contain calcium concentrations as high as 100 ppm. Calcium is essential to human health (<http://www.lenntech.com/Periodic-chart-elements/Ca-en.htm>).

In a watery solution calcium is mainly present as  $\text{Ca}^{2+}$  (aq), but it may also occur as  $\text{CaOH}^+$  (aq) or  $\text{Ca}(\text{OH})_2$  (aq), or as  $\text{CaSO}_4$  in seawater.

Calcium is an important determinant of water hardness, and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste.

Hard water may assist in strengthening bones and teeth because of its high calcium concentration.

Calcium carbonate has a positive effect on lead water pipes, because it forms a protective lead(II)carbonate coating. This prevents lead from dissolving in drinking water, and thereby prevents it from entering the human body.

Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Most of these disorders have treatments but no cures. Calcium is unique among nutrients, in that the body's reserve is also functional: increasing bone mass is linearly related to reduction in fracture risk (WHO, 2004).

The WHO Guideline maximum contaminant level of calcium in drinking water is 200mg/l. When one takes up large amounts of calcium this may negatively influence human health.

(<http://www.lenntech/elements-and-water/overview.hmt>). Tay (2004) recorded  $\text{Ca}^{2+}$  concentration range of 19.2mg/l to 361mg/l with the mean of 107.5mg/l in ground waters of the District.

#### **2.6.16 Magnesium ion, $\text{Mg}^{2+}$**

Rivers contain approximately 4 ppm of magnesium, marine algae 6000-20,000 ppm, and oysters 1200 ppm. Magnesium and other alkali earth metals are responsible for water hardness. Water containing large amounts of alkali earth ions is called hard water, and water containing low amounts of these ions is called soft water (<http://www.lenntech.com/element-and-water/magnesium-and-water.htm>).

Large number of minerals contains magnesium, for example dolomite (calcium magnesium carbonate;  $\text{CaMg}(\text{CO}_3)_2$ ) and magnesite (magnesium carbonate;  $\text{MgCO}_3$ ). Magnesium is washed from rocks and subsequently ends up in water.

It also ends up in the environment from fertilizer application and from cattle feed. Magnesium sulphate is applied in beer breweries, and magnesium hydroxide is applied as a flocculant in wastewater treatment plants.

It is unusual to introduce legal limits for magnesium in drinking water, because there is no scientific evidence of magnesium toxicity. However, due to the role magnesium plays in water hardness, WHO drinking water guideline has maximum contaminant level to be 150mg/l ( WHO, 2006).

Scientists have observed that people in areas with higher levels of magnesium in their drinking water exhibit rates of sudden cardiac death that are three to four times lower than those of people living in municipalities with the lowest magnesium levels in drinking water (Eisenberg, 1992).

This has drawn the attention of national and international public health officials. For example, a recent World Health Organization (WHO) report on the quality of drinking water cited 80 studies that have examined the relationship between cardiovascular death and water “hardness” (measured principally by magnesium and calcium content). The WHO concluded that the magnesium content of water is indeed a cardiovascular risk factor and that supplementing drinking water with magnesium should be a priority, much as fluoride became one ([http://www.nsf.org/international/press\\_release.asp?p\\_id=12041](http://www.nsf.org/international/press_release.asp?p_id=12041)).

### **2.6.17 Manganese**

The element manganese is present in over 100 common salts and mineral complexes that are widely distributed in rocks, in soils and on the floors of lakes and oceans. Manganese is most often present as the dioxide, carbonate or silicate. It may exist in oxidation states ranging from -3 to +7; the manganous ( $\text{Mn}^{2+}$ ) and manganic ( $\text{Mn}^{4+}$ ) oxidation states are the most important for aquatic

systems [Canadian Council of Resource and Environment Ministers (CCREM), 1987]. Manganese occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. In surface waters, manganese occurs in both dissolved and suspended forms, depending on such factors as pH, anions present and oxidation–reduction potential (ATSDR, 2000). Anaerobic groundwater often contains elevated levels of dissolved manganese. The divalent form ( $\text{Mn}^{2+}$ ) predominates in most water at pH 4–7, but more highly oxidized forms may occur at higher pH values or result from microbial oxidation (ATSDR, 2000). However, human activities are also responsible for much of the manganese contamination in water in some areas.

Ambient manganese concentrations in seawater have been reported to range from 0.4 to 10  $\mu\text{g/litre}$  (ATSDR, 2000), with an average of about 2  $\mu\text{g/litre}$  (Barceloux, 1999).

Levels in fresh water typically range from 1 to 200  $\mu\text{g/litre}$  (Barceloux, 1999). Higher levels in aerobic waters are usually associated with industrial pollution.

Manganese is an essential element for many living organisms, including humans. For example, some enzymes require manganese (e.g., manganese superoxide dismutase), and some are activated by the element (e.g., kinases, decarboxylases). Adverse health effects can be caused by inadequate intake or overexposure. Manganese deficiency in humans appears to be rare, because manganese is present in many common foods, at concentrations exceeding 0.1 mg/litre, the manganese ion imparts an undesirable taste to beverages and stains plumbing fixtures and laundry (Griffin, 1960). When manganese(II) compounds in solution undergo oxidation, manganese is precipitated, resulting in encrustation problems. At concentrations as low as 0.02 mg/litre, manganese can form coatings on water pipes that may later slough off as a black precipitate (Bean, 1974). A number of countries have set standards for manganese of 0.05 mg/litre, above which problems with discolouration may occur.

However, WHO set, a health-based guideline value of 0.4 mg/litre which should be adequate to protect public health. This guideline value is derived from human dietary studies. Concentrations below 0.05 mg/litre are usually acceptable to consumers, although this may vary with local circumstances (WHO, 2004).

## **2.7.0 MICROBIOLOGICAL QUALITY OF WATER**

### **2.7.1 Coliform Bacteria and *E. coli***

The microbial quality of water is determined by the presence of bacteria indicative of faecal (sewage ) contamination, namely, total coliforms and faecal coliforms such as *Escherichia coli*. Coliforms occur naturally in soil and in the gut of humans and animals. Thus, their presence in water may indicate contamination. *E. coli* and certain species of *Enterobacter aerogenes* are present only in the gut of humans and animals. Their presence therefore indicates definite faecal pollution. The presence of coliform bacteria in well water may be as a result of surface water infiltration or seepage from a septic system (Obiri-Danso *et al* 2008).

Total coliforms are a group of bacteria commonly found in the environment, for example in soil or vegetation, as well as the intestines of mammals, including humans. Total coliform bacteria are not likely to cause illness, but their presence indicates that your water supply may be vulnerable to contamination by more harmful microorganisms.

*E. coli* is the only member of the total coliform group of bacteria that is found only in the intestines of mammals, including humans. The presence of *E. coli* in water indicates recent faecal contamination and may indicate the possible presence of disease-causing pathogens, such as bacteria, viruses, and parasites. Although most strains of *E. coli* bacteria are harmless, certain strains, such as *E. coli* O157:H7, may cause illness, such as hemorrhagic diarrhea and hemolytic uremic syndrome (HUS) which causes kidney failure, especially in young children



and elderly persons (Karch *et al*, 2005). Total coliforms and *E. coli* are used as indicators to measure the degree of pollution and sanitary quality of well water, because testing for all known pathogens is a complicated and expensive process. The main source of pathogens in drinking water is through recent contamination from human or animal waste, from

- improperly treated septic and sewage discharges
- leaching of animal manure
- storm water runoff
- domestic animals or wildlife

During and after precipitation, bacteria and other harmful microorganisms from any of these sources may be washed into rivers, lakes, or groundwater. Poor well construction or poor maintenance can increase the risk of groundwater contamination.

In water, coliform bacteria have no taste, smell, or colour. They can only be detected through a laboratory test. The Canadian drinking water quality guideline for total coliforms is none detectable per 100 mL. The Canadian drinking water quality guideline for *Escherichia coli* is none detectable per 100 mL. This means that in order to conform to the guideline: For every 100 mL of drinking water tested, no total coliforms or *E. coli* should be detected [0 colony forming units per 100 millilitres (0 CFU/100 mL)]. *E. coli* in drinking water indicates the water has been contaminated with fecal material that may contain disease-causing microorganisms, such as certain bacteria, viruses, or parasites.

The health effects of exposure to disease-causing bacteria, viruses, and parasites in drinking water are varied. The most common symptoms of waterborne illness include nausea, vomiting, and diarrhea. Infants, the elderly, and those with compromised immune systems may suffer more severe effects. In extreme cases some pathogens may infect the lungs, skin, eyes, nervous system,

kidneys, or liver and the effects may be more severe, chronic, or even fatal. One should not assume that one's water is safe to drink just because it has not made him / her sick in the past. If bacteria are present in one's water, there is a risk that it could make him / her ill. (<http://www.gov.ns.ca/nse/water/privatewells.asp> ).

Bacteria cannot be removed from water with pitcher-type carbon filters. Bacteria can be removed by keeping water at a rolling boil for at least one minute. Effective treatment methods for microbial contamination include:

- permanent point-of-entry disinfection units, which can use
- chlorine
- ozone
- ultraviolet light (UV light)
- distillation

### **2.7.2 Total Heterotrophic Bacteria, THB / Heterotrophic Plate Count, HPC**

*Heterotrophic bacteria* are non-coliform species of bacteria that utilize an organic substance for its development. Heterotrophic bacteria can be widespread throughout a water system. The presence of heterotrophic bacteria in drinking water is not an indication that the water presents a health risk. Rather, no specific significance or health standards are associated with these non-pathogenic non-coliform bacteria.

Heterotrophic plate count (HPC) is a microbial method that uses colony formation on culture media to approximate the levels of heterotrophic flora.

The current Guidelines for Canadian Drinking Water Quality do not specify a maximum allowable concentration for HPC bacteria but recommend that HPC levels in municipal drinking-waters should be less than 500 cfu/ml ( Health Canada, 1996). In the USA, acceptable HPC levels in municipal drinking-water have been set at less than 500 cfu/ml (US EPA 2001).

The heterotrophic population in potable water may include a broad range of genera, including some opportunistic bacterial pathogens. In numerous studies, heterotrophic bacteria isolated from water have been shown to possess very few virulence factors (Lye and Dufour, 1991; Payment *et al.*, 1994; Edberg *et al.*, 1996, 1997) and are therefore of no human health consequence. At a recent expert meeting dealing with HPC in drinking water management, it was also concluded that HPC in drinking water are not a health concern to the general public (WHO, 2002).

Under some circumstances, however, opportunistic pathogens within the heterotrophic flora can constitute a health risk for immunocompromised individuals, including the very young. For example, some species of *Pseudomonas* can become serious secondary pathogenic invaders in post-operative infections, in burn cases, and in the very young (Wilson *et al.*, 1983).

## **CHAPTER THREE**

### **3.0 MATERIALS AND METHODS**

#### **3.1 STUDY SITE**

Ehi community is located in the Ketu – North District in the Volta Region of Ghana with Dzodze as the capital (Fig. 1). The District was known as the Ketu District until the year 2008 when the Ketu North District was carved out of it.

The District covers a land area of 754km<sup>2</sup> with an estimated population of 83,161 as at the year 2000. This has been projected to be 98,571 in 2010. The District's population is currently growing at a rate of 1.9% which is lower than the national rate of 2.6%. The population of Ehi is estimated to be 5000 (Ghana Statistical Service, 2000).

The District is located between latitudes 6° 03'N and 6° 20'N and longitudes 0° 49'E and 1° 05'E. It shares boundaries with the Akatsi District to the North and the Republic of Togo to the East. To the South, it is bounded by Ketu South district. The district capital (Dzodze) is about 80km from Ho the regional capital.

Ketu North District is relatively low lying with altitudes around 66 metres. The plain nature of the terrain makes movement within the district easy. The Drainage of the district is towards the South and is dominated by several seasonal streams that flow in wide valleys between Ohawu and Ehi to end in the swamplands of Afife. The major rivers include Kplikpa and Tsiyi. There are about six large fresh water reservoirs (dams) -Ohawu, Kporkuve, Dzodze, Tadzewu, Dekpor-Adzotsi (Ehi) and Larve as well as a few small community dugouts in the district.

The District experiences the dry Equatorial type of climate. The average monthly temperatures vary between 24°C and 30°C, which are generally high for plant growth throughout the year. The mean annual rainfall for the District is around 1,270mm. The rainfall is of double maxima type occurring from April to July and September to November. The dry season, which is mainly dominated by the dry harmattan winds, extends from December to February in the district. Generally rainfall in the District is considered low and erratic particularly during the minor season.

The original vegetation of the District is Savannah woodland made up of short grassland with small clumps of bush and trees as well as Mangrove forests in the marshlands are found in the District. However, the extensive farming activities in the district have, over the years, reduced the natural vegetation. Amid these are cultivated holdings of cassava, maize, coconut, oil palm, and black berry trees and the occasional baobab and fan palm. The decimation of the vegetation by population pressure may have adversely affected rainfall in the district.

One major source of water in the District is borehole. Analysis of water situation in the District shows that out of 281 communities in the District, only 88 of them have boreholes. This makes the rest of the communities rather patronized unwholesome sources of water such as streams, underground tank and hand-dug well making them vulnerable to water related diseases. These other sources are not sometimes hygienically good for domestic use.( Ketu- North District Assembly, 2010)



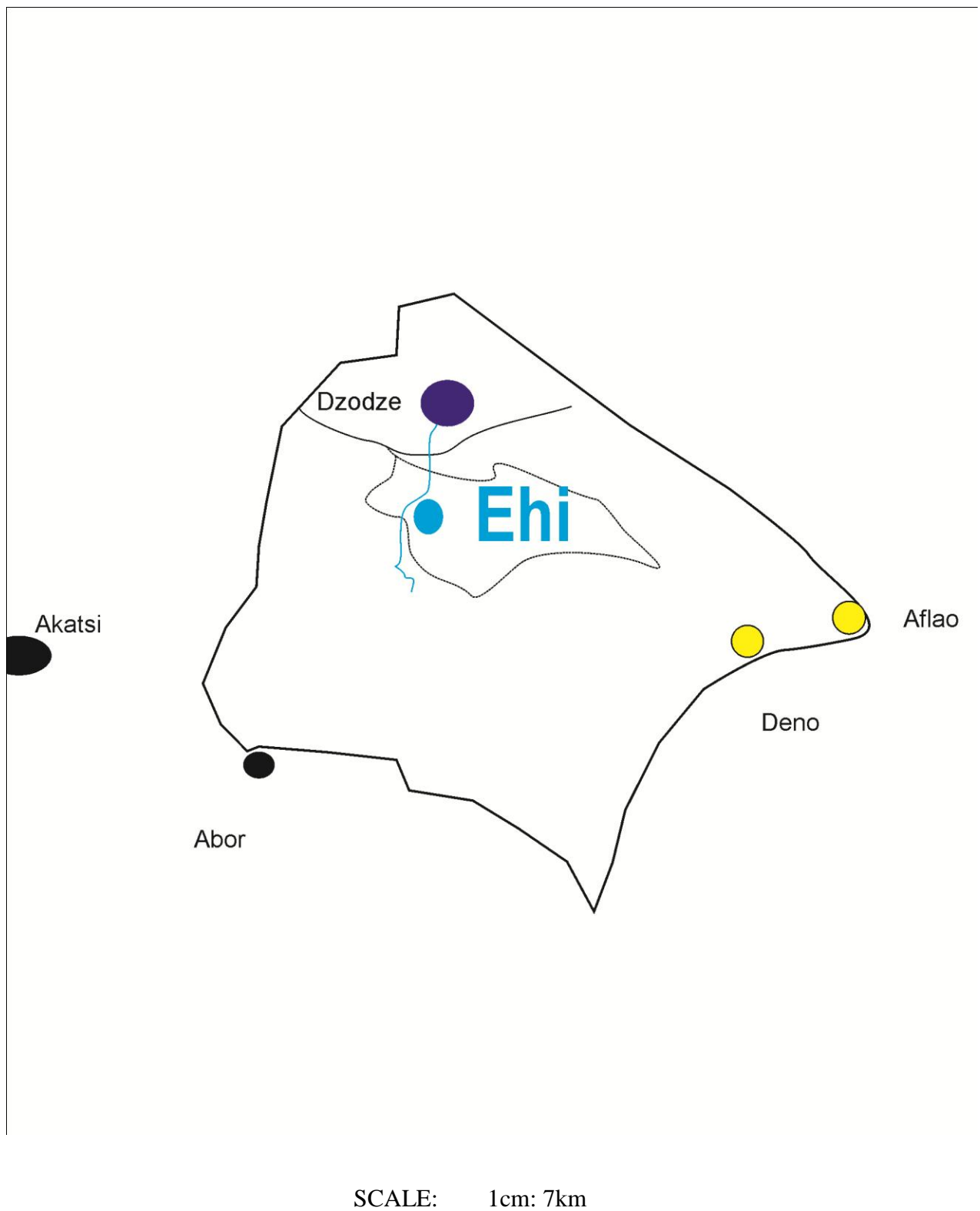


Fig. 2; Map of Ketu District showing Ehi Community.

The study area has about five bore holes several hand dug wells with no pipe borne water. Due to salty taste of water from these bore holes, many inhabitants prefer water from the hand dug wells. Occasionally, especially during the dry season, some of the boreholes and the wells dry up and the inhabitants resort to the available stream and river for their water needs, including drinking.

### **3.2 SAMPLING**

Water samples were collected from six different sources, namely , three hand-dug wells (Xosevudo , Biasevudo, and Dzagotovudo wells); a Bore hole, a stream (Dzago) and a river (Kplikpa). The samples were collected between November, 2010 and March, 2011. Samples were collected once every two months from all designated sampling points (Fig. 3 and Plate 1). At each sampling site, two samples were collected into 500 ml sterilized bottles. These were stored in an ice chest containing ice cubes and transported to the laboratory for analysis within 24 hours.



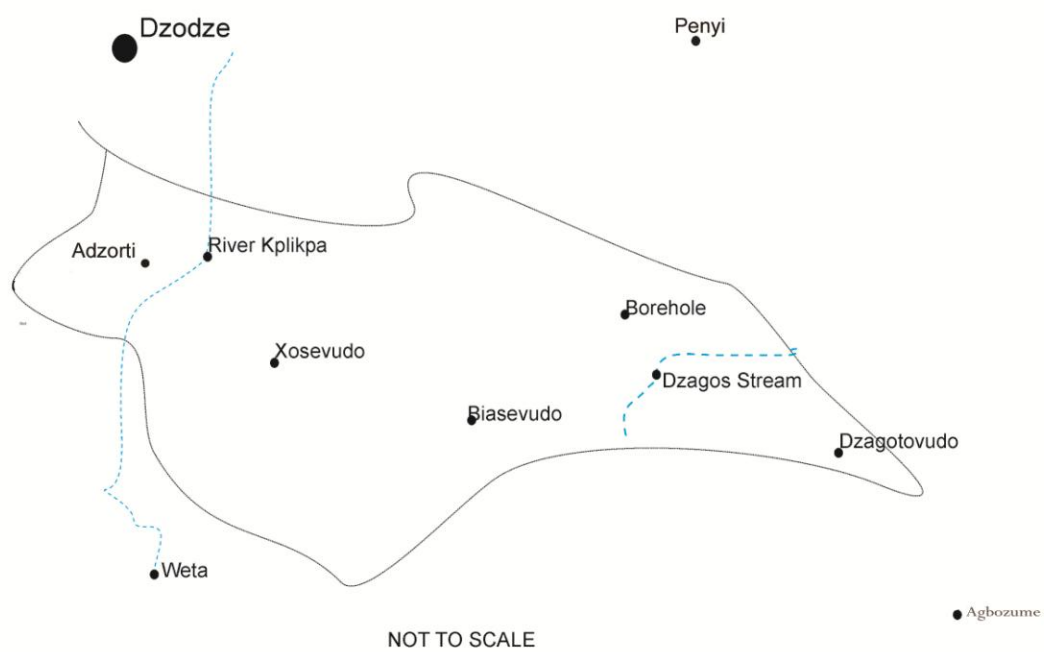


Fig. 3; A map of Ehi showing the sampling points.

### **3.3 DETERMINATION OF PHYSICOCHEMICAL AND MICROBIOLOGICAL PARAMETERS**

#### **3.3.1 The pH values**

The pH values were determined using the calibrated WTW 323 pH meter, at the laboratory. The probe was rinsed with distilled water and immersed in the samples. Readings were recorded after stabilization.

#### **3.3.2 Total Suspended Solid (TSS)**

Marked evaporating crucibles (eg; A1, B1, C1, etc ) were heated in an oven and cooled in a desiccator. The clean crucibles were weighed with an analytical balance. 20ml of each of the samples was measured with a measuring cylinder, poured into each crucible and placed on the water bath to evaporate to dryness. Upon drying, the crucibles were removed and placed in an oven at 105°C for one hour after which they were cooled in a desiccator for 20 minutes and reweighed using an analytical balance. The weights were recorded as A2, B2, C2, etc. The differences in the weights ie A2-A1, B2-B1, C2-C1, etc., were calculated as total solids.

$$Ts \text{ (mg/l)} = \frac{\text{Weight of Sample in Dish} - \text{Weight of empty Dish}}{\text{Volume of Sample}}$$

#### **3.3.3 Total Dissolved Solids (TDS)**

TDS was determined using Gravimetric method (APHA, 1998) in which the sample is vigorously shaken and a measured volume transferred into a 100ml graduated cylinder by means of a funnel. The sample was filtered through a glass fibre filter and a vacuum applied for about

three minutes to ensure that water was removed as much as possible. The sample was washed with deionised water and suction continues for at least three minutes. The total filtrate was transferred (with washings) to a weighed evaporating dish and evaporated to dryness on a water bath. The evaporated sample was dried for at least one hour at 180°C. The dried sample was cooled in a desiccator and weighed. Drying and weighing process was repeated until a constant weight was obtained.

### **3.3.4 Turbidity**

Turbidity was measured using the HACH 2100 AN turbidimeter. The cuvette was rinsed with distilled water and filled with the sample. The procedure was repeated for each and the blank. The cuvette was placed into the instrument's light cabinet and covered with the light shield. After stabilization, turbidity value was read and recorded.

### **3.3.5 Determination of Colour**

Apparent and true colours were determined with HACH DR/2010 Portable Data logging Spectrophotometer. The water samples were filtered and their pH adjusted to 7.6. Water samples which had their pH value less than 7.6 were adjusted with 1 or 2 drops of 1.0N NaOH(aq) depending on the pH. The wavelength used for the colour determination was 465nm. The stored program was calibrated in colour units based on APHA recommended standard of one colour unit equal to 1mg/l platinum as the chloroplatinate ion. True colour of the samples were measured after filtering out suspended particles, but for apparent colour measurement, the samples were not filtered (APHA, 1998).

### 3.3.6 Ammonia- Nitrogen ( $\text{NH}_4^+$ - N)

Direct Nesslerization Method was used to determine  $\text{NH}_4^+$  - N. The water sample was allowed to settle and 50 ml pipetted into conical flask. For turbid samples, the samples were filtered and the filtrate used for analysis. Two drops of Rochelle salt solution was added to the diluted sample or five drops in the case of undiluted samples. Samples were mixed well and 2 ml of Nessler's reagent added. A blank (50ml ammonia-free water plus five drops Rochelle salt and 2ml Nessler's reagent) was prepared. Samples were allowed to stand for 10 minutes for colour development and its absorbance was determined using a UV/VIS spectrophotometer at a wavelength of 410 nm (400 to 425 nm ) using a 1 cm light path cuvette. The spectrometer was zeroed with the blank solution. The prepared calibration curve was used to determine the concentration of ammonia- nitrogen in the unknown water sample. The results were expressed in mg/l of sample to 3 significant figures. ( APHA1998 )

### 3.3.7 Nitrite- Nitrogen ( $\text{NO}_2^-$ – N)

#### Diazotization Method

50 ml of sample was placed in a Nessler tube; set aside until preparation of standards are completed.

2 ml of buffer- colour reagent was added to each standard sample, mixed and allowed colour to develop for at least 15 minutes. The pH of the solutions at this stage were between 1.5 and 2.0. The absorbance in the spectrophotometer was measured at 540 nm against the blank and concentration of nitrite- nitrogen plotted against absorbance.

The concentration of nitrite- nitrogen was directly read from the calibration curve. If less than 50 ml of sample was taken, calculation of the concentration is as follow:

$$\text{NO}_2^- \text{ - N in mg/l} = \left( \frac{\text{mg/l from standard curve} \times 50}{\text{ml sample}} \right)$$

The results were expressed in mg/l to three significant figures.

### **3.3.8 Nitrate- Nitrogen ( $\text{NO}_3^-$ - N)**

#### **Hydrazine Reduction Method**

An amount of 10.0 ml of the sample was pipetted into a test-tube. 1.0 ml of 1.3 M NaOH (aq) was added and mixed gently. 1.0 ml of reducing mixture was added and mixed gently. It was then heated at 60 °C for 10 minutes in a water bath, and allowed to cool to room temperature and 1.0 ml of colour developing reagent added. It was shaken to mix and the absorbance read.

#### **Calculations**

The sample concentrations were directly computed from calibration curve. Sample concentration was equal to the sum of  $\text{NO}_3^-$  - N and  $\text{NO}_2^-$  - N. The concentration of  $\text{NO}_3^-$  - N was obtained by determining the concentration of  $\text{NO}_2^-$  - N separately and subtracted. The result was expressed as  $\text{NO}_3^-$  - N in mg/l to 3 significant figures.

### 3.3.9 Phosphate ( $\text{PO}_4^{3-} - \text{P}$ )

#### Stannous Chloride Method

0.05 ml (1 drop) phenolphthalein indicator was added to a 100ml water sample free from colour and turbidity. Strong acid solution was added drop wise to discharge the colour, if sample turns pink.

When more than 0.25 ml (5 drops ) was required, a smaller volume of sample was taken and diluted to 100 ml with de-ionised water and then a drop of phenolphthalein indicator added and discharged if sample turned pink colour with the acid. 4.0 ml molybdate reagent and 0.5 ml ( 10 drop ) stannous chloride reagent were added with thorough mixing after each addition.

Between 10 and 12 minutes, the absorbance was measured at wavelength of 690 nm on a spectrophotometer, the spectrophotometer was zeroed with blank solution .

#### Calculation

From the calibration curve, the concentrations of the samples were determined using measured absorbances. The results were expressed in mg/l to 3 significant figures ( APHA,1998).

### 3.3.10 Sulphate ( $\text{SO}_4^{2-}$ )

#### Turbidimetric Method

Sulphate ion is precipitated in an acidic medium with barium chloride to form a barium sulphate crystal with uniform size. The absorbance of the  $\text{BaSO}_4$  suspension is measured by a photometer at 420 nm and the sulphate concentration is determined by comparison of the reading with a standard curve.

## **Determination**

100ml sample was measured and diluted to 100 ml into a 250 ml Erlenmeyer flask. Exactly 5 ml conditioning reagent was added and mixed by stirring. A spoonful of barium chloride crystals was added while still stirring and commenced timing for 60 seconds at a constant speed. After stirring, the absorbance was measured at 420 nm on the spectrophotometer-Ultraspec model II within 5 minutes. The result were read directly from the calibration curve, and expressed in mg/l, to three significant figures ( APHA, 1998).

### **3.3.11 Fluoride (F<sup>-</sup>)**

#### **SPADNS method**

The SPADNS [( Sulphophenylazo)dihydroxynaphthalenedi-sulphonate] colorimetric method is based on the reaction between fluoride and a zirconium-dye lake. Fluoride reacts with the dye lake, dissociating a portion of it into a colourless complex anion ( $\text{ZrF}_6^{2-}$ ) and the dye. As the amount of the fluoride increases the colour produced becomes progressively lighter. The reaction rate between fluoride and the Zirconium ions is influenced greatly by the acidity of the reaction mixture. ( APHA, 1998)

## **Determination**

50ml of water sample was measured into a conical flask. 5.0 ml each of SPADNS solution and Zirconyl-acid reagent were added. They were mixed well and the absorbance read, by first setting the spectrometer to zero. If the absorbance fell beyond the range of the standard curve, the procedure was repeated using diluted samples.

## Calculation

The calibration curves were used to determine the concentration of fluoride in the sample. The results were expressed in mg/l F<sup>-</sup> and recorded to three significant figures.

( APHA,*et al.*, 1995 ).

### 3.3.12 Total Alkalinity

A 50ml sample was measured into a conical flask. Two drops of methyl orange indicator was added. The resulting mixture titrated against a standard 0.1M HCl(aq) to the first permanent pink colour at pH 4.5 (APHA, 1998). The following equation was used in calculation.

$$\text{Alkalinity as CaCO}_3 \text{ (mg/l)} = \frac{A \times N \times 50,000}{T}$$

T

Where

A = volume of acid used (ml)

T = volume of water sample (ml)

N = normality of standard acid used.



### **3.3.13 Total Hardness**

#### **EDTA Titrimetric Method**

A 100ml of the water sample was put into a 250ml conical flask. Two drops of Erichrome black T indicator was added. The content in the conical flask was titrated against a standard EDTA solution (0.01M) until the contents of the flask changed from wine-red to blue at the end point. Titration was repeated until a consistent titre was obtained. The value of the average titre was recorded (APHA, 1998)

#### **Calculations**

Total Hardness as  $\text{CaCO}_3$  (mg/l) = titre value x 20.

### **3.3.14 Calcium Hardness**

A 100ml of the water sample was put into a 250ml conical flask. 4ml aqueous NaOH was added to the contents of the flask, followed by the addition of about 0.2g murexide indicator. The content in the conical flask was titrated against 0.02M EDTA to the end point which is indicated by pink colouration. Titration was repeated until a consistent titre was obtained (APHA, 1998).

#### **Calculation**

Calcium Hardness as  $\text{CaCO}_3$  (mg/l) = Average titre value x 20.

### **3.3.15 Magnesium hardness**

The magnesium hardness of a sample is calculated as the difference between the total hardness and calcium hardness values obtained from analysis of the sample.

### 3.3.16 Calcium

#### EDTA Titrimetric Method

When EDTA is added to water containing both calcium and magnesium, it combines first with the calcium that is present. Calcium can be determined directly using EDTA when the pH is made sufficiently high so that the magnesium is largely precipitated as the hydroxide and an indicator is used which combines with calcium only.

#### Determination

50ml of sample was pipetted, and 2.0 ml of NaOH solution was added. It was stirred and 0.1 - 0.2g of the murexide indicator added. It was then titrated immediately after the addition of the indicator. EDTA titrant was added slowly, with continuous stirring until the colour changes from salmon to orchid purple. The end point was checked by adding 1 or 2 drops of titrant in excess to make sure that no further colour change took place. It was ensured that not more than 15 ml EDTA was required for the titration.

#### Calculations

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

Where A = ml of EDTA titrant used

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

The results were expressed as mg/l Ca to 3 significant figures (APHA *et al.*,1995).

### 3.3.17 Magnesium Ions

#### Calculation Method

Calcium and Total hardness were determined by EDTA titrimetric method. Magnesium hardness is calculated from the differences between the total hardness and the calcium hardness when these are expressed in the same units.

#### Determination

Follow Total hardness and Calcium determinations.

#### Calculations

From the calcium titration, calcium hardness was calculated.

$$\text{Calcium hardness as mg CaCO}_3/\text{l} = \frac{A \times B \times 1000}{\text{ml sample}}$$

Where;

A= ml titrant for sample

A = mg CaCO<sub>3</sub> equivalent to 1.00ml EDTA titrant at the calcium indicator endpoint.

$$\text{Then calcium hardness as mg CaCO}_3/\text{l} = \frac{\text{concentration of Ca}}{0.4}$$

Where ;

$$0.4 = \frac{\text{Atomic weight of Ca}}{\text{Molecular weight of CaCO}_3}$$

The total hardness concentration was recorded as mg/l  $\text{CaCO}_3$ .

Magnesium hardness as mg/l  $\text{CaCO}_3$  = total hardness – calcium hardness.

Mg/l Mg = (total hardness – calcium hardness ) x 0.243

Where 0.243 = atomic weight of Mg / molecular weight of  $\text{CaCO}_3$ .

The magnesium concentration was expressed as mg Mg/l to one decimal place.

(APHA et al, 1995).

### **3.3.18 CHLORIDE ( $\text{Cl}^-$ )**

A 100ml of the water sample was measured into a 250ml conical flask and 3 drops of potassium dichromate indicator was added to the contents of the flask. The content in the conical flask was titrated against standardized silver nitrate solution, stirring constantly, to the end point which is indicated by a permanent red colour. The volume of the titre was recorded (APHA, 1998).

#### **Calculation**

Chloride, mg/l = titre value x 10

### **3.3.19 Total Iron (Fe) And Manganese (Mn)**

An aliquot of 5ml of concentrated Nitric acid was added to 50ml of sample of water in a 100ml beaker. This was heated to boil until its volume got to about 20ml. Another 5ml of concentrated nitric acid was added and the beaker was covered with a watch glass and the heating continued for 10minutes. A final 5ml of concentrated nitric acid was used to rinse the sides of the beaker. The

solution was poured into a 50ml volumetric flask and topped with distilled water to the mark. A blank solution was similarly prepared. The ion analyses were performed on an Atomic Absorption Spectrophotometer (Unicam 969), using acetylene gas as a fuel and air as oxidizer. Calibration curves were prepared separately for all the metals by running suitable concentrations of the standard solutions. The digested samples were aspirated into the fuel rich air-acetylene flame and the concentrations of the metal ions were determined from the calibration curves. Average values of three replicates were taken for each determination. The absorbance of the blank was taken before analysis of the samples (APHA, 1998).

### **3.4.1 Determination of Coliform Bacteria and Total Heterotrophic Bacteria.**

Water samples from each of the six sampling site were analysed for the presence of coliform bacteria using the membrane filtration method. 100ml of each of the water samples were separately filtered through 0.45µm pore size membrane filter (millipore).

Determination of total coliform (TC) was done by incubating the membrane filter on Hichrome media at 37°C for 24 hours and determined as colony forming unit per 100ml.

*Escherichia coli* counts were made by incubating the membrane filter on Hichrome media at 44°C for 24 hours. The colonies were blue.

Total heterotrophic bacteria (THB) count for each of the water samples were determined using nutrient agar (NA).

One milliliter (1ml) each of the samples were separately used as inocula on NA plates and incubated at 37°C for 48 hours.

The colonies were counted with the aid of microscope. Where they were more, they were counted per square on the membrane filter and multiplied by the number of squares on the filter membrane.

The colonies were however calculated as;

Coliform colonies/100mL = (coliform colonies counted x 100) / (mL sample filtered)

THB colonies/ ml = (THB colonies counted x 1)/ (ml sample filtered) (APHA, 1998).

### **3.5.1 Quality Assurance Of Physicochemical Parameter Data**

Samples were taken in triplicates and the average of each result was taken for the analysis. All instruments used in this study were calibrated with standard and known concentrations. Calibration curves were prepared separately for all ions by running suitable concentrations of the standard solutions. Concentrations of the analyte samples were determined from the calibration curves. Average values of three replicates were taken for each determination. Suitable blanks were also prepared and analysed in the same manner.

### **3.6.1 Sanitation Survey**

The following guideline questions were used to survey the various sampling points.

Site location of well;

- Is the well located at least 15m from a septic tank or any non watertight sewer line?
- Is the well located at least 30m from any drainfield, seepage pit or other wastewater subsurface disposal system?

- Is the well located at least 30m away from any feedlot, manure pit, manure or sewage lagoon, or livestock lot?
- Is the well located uphill from potential sources of bacterial contamination?
- Is the well casing depth at least 1m below the static water level or at least 3m deep in sand and gravel, 5m in sandstone, or 10m in bedrock, whichever is deeper?

Well construction;

- Does the well have a watertight casing, preferably of heavy-gauge metal or NSF (formerly National Sanitation Foundation) approved plastic?
- Are all joints in the well casing screwed, welded or otherwise properly sealed?
- Does the well casing extend at least 30cm above the grade of the land surface?
- Is a sanitary well cap used on the casing?
- Is pitless installation used, or if pit installation of pumping and storage equipment is used, is the pit at least 3m away from the well?
- Does the ground surface slope/drain away from the well?

(Sharon *et al*, 2008 )

Activities around river and stream;

- Do people farm around the river and the stream?
- Do they dump their sewage and solid wastes into the water body ?
- Do livestock drink from these water bodies ?

### 3.7.1 Statistical Analysis

The data was analysed using GENSTAT and Excel. Data was analysed using completely randomized design. The mean content of the different bacteriological and physicochemical parameters in each source of water was computed with corresponding ANOVA and least significant differences (LSD) value at 5% degree of confidence using GENSTAT. Results were mainly presented in cross – tabulations.

To establish whether the mean content of a parameter was the same or not in all the sources of water, the corresponding value of Fpr in the ANOVA table was compared with an  $\alpha = 0.05$  ( the probability of saying the mean content of a parameter was the same in all the source of water when in actual fact it was not ). Also, to be able to establish which sources of water had their mean bacteriological and physicochemical components being significantly different from one another, pair wise mean differences were compared with the corresponding LSD value. Conclusion was drawn after on the following basis.

When  $F_{pr} < 0.05$ , it was concluded that the mean content of a bacteriological or physicochemical component was not the same in all the different sources of water.

When the absolute difference of two means was greater than the corresponding LSD value, it was concluded that the mean content of the bacteriological or physicochemical parameter in the corresponding two sources of water was significantly different from each other.



## CHAPTER FOUR

### 4.0 RESULTS

#### *Introduction*

The mean values of all the various parameters were computed from the raw data obtained from the field. These mean values were presented in a tabular and ANOVA table forms.

#### 4.1 MICROBIOLOGICAL QUALITY OF WATER SAMPLES

##### *Escherichia coli (E.coli)*

Result from Table 1, shows that only the Bore hole recorded zero level of *E. coli* in conformity with the WHO guideline. This was followed by Xosevudo with 4cfu/100ml. The highest was however recorded at Dzago stream with 806 cfu/100ml.

##### **Total coliform (T.C)**

The data presented in Table 1 show no coliform in the Bore hole. However, different level were recorded from the other sources. The highest (1767cfu/100ml) occurred at Dzago stream and was followed by Dzagotovudo with 1060cfu/100ml.

##### **Total Heterotrophic Bacteria (THB)**

The THB concentrations obtained for the six sampling points is represented by Table 1. With the exception of the Borehole, all THB concentrations were above the WHO guideline value of 500cfu/ml. The Borehole showed the least THB concentration of 491 cfu/ml whiles the Dzago stream (4800 cfu/ml ) showed the highest concentration.

Table 1; Concentration of *Escherichia coli*, Total coliform, Total Heterotrophic Bacteria of the various sources of water in Ehi community and their respective WHO guidelines for drinking water.

<b>Sources</b>	<b>Bacteriological parameters</b>		
	<i>Escherichia coli</i> (cfu/100ml)	Total Coliform (cfu/100ml)	Total Heterotrophic Bateria (cfu/ml)
Xosevudo (well)	4	409	1879
Dzagotovudo (well)	138	1060	2881
Biasevudo (well)	17	837	768
Kplikpa (river)	274	934	2003
Dzago (stream)	806	1767	4800
Bore Hole	0	0	491
WHO Standards	0	0	500
LSD	321.6	894.4	2929.4

## 4.2 SANITATION SURVEY

The sanitation survey revealed that wells did not have cover slabs (Plate 1 and 2). Well water was drawn normally using various receptacles (plastic or aluminium buckets) with varying degrees of hygiene. These receptacles had no windlass on these wells and all users had to use one rope for drawing water which was often left in water that had been spilt around the well above the surrounding ground level to divert runoff water but this was not the case with any of the wells included in this study. The construction and depth of the wells could further explain

contamination levels. All the three wells studied were shallow, approximately 1.2 to 3.4m in depth. The lining of all wells was defective as they were fissured. Ideally, wells should be constructed with concrete ring pipes but only the upper 2m were cemented thus allowing easy seepage. Lastly, all the wells and surface water were sited within a 10m or less radius from pit latrines, refuse pits and other social amenities. There were serious agricultural activities around the banks of the surface water studied. Livestock drank directly from these water bodies.



Biasevudo well

Plate 1: The Various sampling points.



Xosevudo well



Dzagotovudo well

Plate 2: The Various sampling points.



Borehole



Kplikpa river



Dzago stream

Plate 3: The Various sampling points.

### **4.3PHYSICOCHEMICAL PARAMETERS**

#### **4.3.1 Chloride, Total Iron, Sodium And Sulphate Ions Concentrations In Water Samples.**

##### **Chloride Ions, $\text{Cl}^-$**

Result in Table 2 show that, the  $\text{Cl}^-$  concentration in all the six sources of drinking tested were within the WHO guideline acceptable value of 250mg/l. The  $\text{Cl}^-$  concentration for all the six sources varied between 1.7 and 187.3mg/l. The lowest concentration was recorded in Dzago stream (1.7mg/l) followed by Kplikpa river (10.2mg/l), Xosevudo (40mg/l), Dzagotovudo (90.6mg/l), Bore hole (94.3mg/l) and the highest chloride ion level was found in Biasevudo (187.3mg/l).

##### **Total Iron Ions**

The level of total iron concentration in the six sampling points ranged from 0.2 to 11.9mg/l (Table 2). The lowest concentration level was obtained in Biasevudo , followed by Borehole(0.24mg/l), Xosevudo(1.1mg/l), Dzagotovudo (1.2mg/l), Kplikpa (2.9mg/l) and the highest being Dzago stream (11.9mg/l). It was only Biasevudo and Borehole whose concentration level were within the WHO guideline level of 0.3mg/l.

##### **Sodium Ion, $\text{Na}^+$**

Table 2, shows that all the six sources of drinking water except Biasevudo had levels of sodium ion which were within the acceptable WHO guideline value of 200mg/l. Dzago stream had the least level of sodium ion content of 14.5mg/l, followed by Kplikpa river (26.8mg/l) which was

not significantly different from that of Dzago stream (LSD = 13.02). The highest level of  $\text{Na}^+$  content was found in Biasevudo (224.7mg/l). The second highest level was found in the Bore hole (73.1mg/l).

#### **Sulphate ion ( $\text{SO}_4^{2-}$ )**

$\text{SO}_4^{2-}$  content value recorded range between 15 to 150.3mg/l. All the six sources of drinking water in Ehi had acceptable levels of  $\text{SO}_4^{2-}$  as prescribed by the WHO guideline (value of 250 mg/l). The lowest level was found in Xosevudo with a concentration of 15 mg/l followed by Dzago stream (23.3 mg/l), Dzagotovudo (30.4 mg/l), Kplikpa river (34.1 mg/l), Bore hole (49.9mg/l). The highest level was found in Biasevudo (150.3 mg/l) (Table 2).

Table 2; mineral contents of water in Ehi community compared to their respective WHO guidelines for safety water.

Sources	Mineral (ionic) content of various water sources			
	Cl <sup>-</sup> (mg/l)	Fe <sup>2+</sup> & Fe <sup>3+</sup> (mg/l)	Na <sup>+</sup> (mg/l)	SO <sub>4</sub> <sup>2-</sup> (mg/l)
Xosevudo (well)	40	1.1	29.7	15
Dzagotovudo (well)	90.6	1.2	36.3	30.4
Biasevudo (well)	187.3	0.2	224.7	150.3
Kplikpa (river)	10.2	2.9	26.8	34.1
Dzago (stream)	1.7	11.9	14.5	23.3
Bore Hole	94.3	0.24	73.1	49.9
WHO Guideline	250	0.3	200	250
LSD	15.44	8.96	13.02	15.63

#### 4.3.2 Bicarbonate, Total Alkalinity, Calcium And Magnesium Hardness Content In Sample Waters

##### Total Alkalinity

Table 3, shows that the lowest value for total alkalinity was found in Xosevudo (10.7 mg/l), followed by Dzagotovudo (18.7 mg/l), Dzago stream (52 mg/l), Kplikpa river (72 mg/l ) and the Borehole (310mg/l). The highest level was found in Biasevudo (325.3). Total Alkalinity, however, ranged from 10.7 to 325.3mg/l.



Table 3; Physicochemical quality of the indicated parameters of different sources of water in Ehi community.

Water Sources	Physico-chemical parameters			
	Bicarbonate (mg/l)	Calcium Hardness (mg/l)	Total Alkalinity (mg/l)	Magnessium Hardness (mg/l)
Xosevudo (well)	22	10.7	10.7	11.3
Dzagotovudo (well)	23	64.8	18.7	45.9
Biasevudo (well)	263	138	325.3	152.7
Kplikpa (river)	88	32.1	72	19.3
Dzago (stream)	58	33.4	52	27.3
Bore Hole	378	241	310	112
LSD	141.1	17.17	33.31	25.23

### 4.3.3 Total Hardness and Total Dissolved Solids, Conductivity and pH

#### Total Hardness

All the sources of water had levels of Total Hardness within the WHO acceptable limit of 500mg/l (Table 4). The least level was found in Xosevudo (22 mg/l), followed by Kplikpa river (51.4 mg/l), Dzago stream (62 mg/l), Dzagotovudo (110.7mg/l) and Biasevudo (290.7mg/l). The highest level was found in the Bore hole (352 mg/l).

### **Total Dissolved Solids, TDS.**

From Table 4, all the six sources of water had levels of TDS content which met the WHO guideline standard value of 1000 mg/l. The mean TDS content values ranged from 89.3 to 968.7 mg/l. Dzago stream had the lowest TDS value of 89.3 mg/l; followed by Kplikpa river (95.3 mg/l), Xosevudo (111.3 mg/l), Dzagotovudo (290 mg/l) and the Bore hole (652.7 mg/l). The highest level was observed in Biasevudo (968.7 mg/l).

### **The pH**

Data in Table 4 shows that the pH of water obtained from these six sources, varied from pH 5.75 to 7.53. Xosevudo had the lowest pH value, followed by Dzagotovudo (pH 5.96), Dzago stream, (pH 6.36), Biasevudo (pH 7.38), borehole (pH 7.5) and kplikpa river (pH 7.53) being the highest.

### **Conductivity**

The conductivity of water samples from the various sources ranged from 162.7 to 1761 $\mu$ s/cm (Table 4). The least level of conductivity was observed in Dzago stream (162.7), followed by Kplikpa river (173.3  $\mu$ s/cm), Xosevudo (202.3  $\mu$ s/cm), Dzagotovudo (527.7  $\mu$ s/cm), and Borehole (1179  $\mu$ s/cm). Biasevudo had the highest conductivity of 1761 $\mu$ s/cm.

Table 4; Total Hardness, Total Dissolved Solids, Conductivity and pH of the various sources of water in Ehi community and their respective acceptable WHO limits.

Water Sources	Physicochemical parameters			
	TDS (mg/l)	Total Hardness (mg/l)	Conductivity( $\mu$ S/Cm)	pH
Xosevudo (well)	111.3	22	202.3	5.75
Dzagotovudo (well)	290	110.7	527.7	5.96
Biasevudo (well)	968.7	290.7	1761	7.38
Kplikpa (river)	95.3	51.4	173.3	7.53
Dzago (stream)	89.3	62	162.7	6.36
Bore Hole	652.7	352	1179	7.5
WHO Standards	1000	500	1000	6.5-8.5
LSD	36.87	18.73	73.69	1.027

#### 4.3.4 The Turbidity, Colour and Total Suspended Solids Of the Various Water Sources

##### Turbidity

From Table 5, only two out of the six sources, namely Biasevudo (4NTU) and Borehole (2NTU) had their levels of turbidity within the limit of acceptable standard of drinking water of 5NTU according to WHO (2004). The level ranged from 2 to 129NTU. The highest level was obtained in Dzago stream.

### **Total Suspended Solids ( TSS)**

TSS content levels ranged from 1 to 37.3mg/l. The least level was recorded in Biasevudo and Borehole (1mg/l), while the highest level was obtained in Dzago stream (37.3mg/l) (Table5).

### **Apparent Colour (Hz)**

Only the colour levels of water samples from Bore hole (5Hz) and Biasevudo (7Hz) were within WHO guideline value of 15Hz (Table5). The rest were Xosevudo (54.17), Dzagotovudo (62Hz), Dzago stream (175Hz) and the highest colour level was observed in Kplikpa river (200Hz).

Table 5; Turbidity, Total Suspended Solids(TSS) and Colour of the various sources of water in Ehi community compared with their respective WHO safety guidelines values.

<b>Water Sources</b>	<b>Physico-chemical parameters</b>		
	Turbidity (NTU)	Colour (Hz)	TSS (mg/l)
Xosevudo (well)	40	54.17	13.3
Dzagotovudo (well)	34	62	12.7
Biasevudo (well)	4	7	1
Kplikpa (river)	54	200	11.7
Dzago (stream)	129	175	37.3
Bore Hole	2	5	1
WHO Standards	5	15	-
LSD	88.5	109.0	19.84

### 4.3.5 Magnesium, Potassium, Calcium and Manganese Ions

#### **Magnesium ion, $Mg^{2+}$**

Magnesium ion concentration of all the sources of water were within the WHO acceptable guideline value of 150mg/l (Table 6). The concentration ranged from 2.73 to 37.03mg/l. The least concentration was observed in Xosevudo (2.73mg/l), followed by Kplikpa river (4.7mg/l), Dzago stream (6.63mg/l), Dzagotovudo (11.17mg/l) and Borehole (27.1mg/l). The highest level was observed in Biasevudo (37.03mg/l).

#### **Potassium ion, $K^{+}$**

All the six sources had their  $K^{+}$  concentration level meeting the WHO acceptable guideline level of 30mg/l. The level ranged from 1.9 to 32 mg/l. The least level was found in Xosevudo (1.9mg/l), followed by Dzago stream (2.4mg/l), Kplikpa river (3.5mg/l), Borehole (5.5mg/l), the highest level being observed in Biasevudo (32mg/l) (Table 6).

#### **Calcium Ion, $Ca^{2+}$**

The  $Ca^{2+}$  levels of the various sampling points ranged from 4.27 to 94.3mg/l. They were all within the WHO acceptable standard (200mg/l). The least level was found in Xosevudo (4.27 mg/l) followed by Kplikpa (12.8mg/l), Dzago stream (13.33mg/l), Dzagotovudo (25.9mg/l) and Biasevudo (55.3mg/l). The highest level was found in the Bore hole (94.3 mg/l) (Table 6).

#### **Manganese ion, $Mn^{2+}$**

As indicated in Table 6, the level of  $Mn^{2+}$  ranged from 0.17 to 1.38 mg/l, with the exception of Dzago stream(1.38mg/l), all other sources had their levels within the WHO acceptable guideline

value of 0.4 mg/l. The least level was observed in Biasevudo (0.17mg/l), followed by Xosevudo (0.260mg/l),Dzagotovudo (0.3),Borehole (0.28mg/l) and Kplikpa (0.42mg/l).

Table 6; Mineral ion in the composition of the indicated sources of water from the Ehi community compared to their respective acceptable WHO guidelines values.

<b>Water Sources</b>	<b>Physicochemical parameters</b>			
	Magnesium( mg/l)	Potassium (mg/l)	Calcium (mg/l)	Mn <sup>2+</sup> (mg/l)
Xosevudo (well)	2.73	1.9	4.27	0.26
Dzagotovudo (well)	11.17	5.1	25.9	0.3
Biasevudo (well)	37.03	32	55.3	0.17
Kplikpa (river)	4.7	3.5	12.8	0.42
Dzago (stream)	6.63	2.4	13.33	1.38
Bore Hole	27.1	5.5	96.2	0.28
WHO Standard	150	30	200	0.4
LSD	5.576	25.31	6.256	1.353

#### **4.3.6 Nitrate, Nitrite, Ammonium, Phosphate and Fluoride Ions Concentrations In Water Samples**

##### **Nitrate ion, NO<sub>3</sub><sup>-</sup>**

The NO<sub>3</sub><sup>-</sup> concentration in all the six sampling points were within the acceptable WHO guideline value of 10mg/l (Table 7). The level ranged from 0.009 to 0.992mg/l. The lowest level

was observed in Dzago stream , followed by Kplikpa river (0.214mg/l), Dzagotovudo (0.283mg/l), Borehole (0.6mg/l) and Biasevudo (0.693mg/l). The highest level was found in Xosevudo (0.992mg/l).

#### **Nitrite ion, $\text{NO}_2^-$**

The level of  $\text{NO}_2^-$  concentration ranged from 0.018 to 0.485mg/l (Table 7). All the six sampling points had their  $\text{NO}_2^-$  level within WHO acceptable standard of 1mg/l. The least was observed in the Borehole (0.018mg/l), followed by Xosevudo (0.158mg/l), Dzago stream (0.209mg/l), Dzagotovudo (0.212mg/l) and Biasevudo (0.305mg/l). the highest level was found in Kplikpa river (0.485mg/l).

#### **Ammonium ion, $\text{NH}_4^+$**

From Table 7, the  $\text{NH}_4^+$  concentration level of all the six sampling points was below detection limits of <0.001 mg/l.

#### **Phosphate**

The concentration of phosphate in the water sampled from the sampling points ranged from 0.09 to 0.347mg/l (Table 7). The higher levels were observed inDzago stream (0.347mg/l) and Kplikpa river (0.203mg/l).The least level was observed in Borehole.

#### **Fluoride ion, $\text{F}^-$**

The level of concentration of  $\text{F}^-$  of the six sampling points ranged from 0.005 to 0.142 mg/l (Table 7). They were all within the acceptable WHO guideline value of 1.5mmg/l. The least concentration level was observed in Borehole. The highest concentration level was observed in Biasevudo (0.142mg/l).

Table 7; Nitrate, Nitrite, Ammonium, Phosphate and Fluoride ions concentrations in the various sources of water in Ehi community compared to their respective WHO acceptable guidelines

<b>Sources</b>	<b>Physicochemical parameters</b>				
	Nitrate(mg/l)	NO <sub>2</sub> <sup>-</sup> (mg/l)	NH <sub>4</sub> <sup>+</sup> (mg/l)	Phosphate (mg/l)	F <sup>-</sup> (mg/l)
Xosevudo (well)	0.992	0.158	0.001	0.173	0.05
Dzagotovudo (well)	0.283	0.212	0.001	0.2	0.142
Biasevudo (well)	0.693	0.305	0.001	0.189	0.137
Kplikpa (river)	0.214	0.485	0.001	0.203	0.03
Dzago (stream)	0.009	0.209	0.001	0.347	0.005
Bore Hole	0.6	0.018	0.001	0.09	0.005
WHO Standards	10	1	0.75	0.3	1.5
L.S.D	0.4067	0.3789	0.4964	0.2780	0.1896



## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 Microbiological Quality of Water Samples

For water to be considered no risk to human health, the total coliform bacteria and *E.coli* in water sample should be zero and THB count should not exceed 500cfu/ml (WHO, 2004). With the exception of the from Bore hole, the rest recoded high number of THB, coliform bacteria and *E.coli*. Total coliform bacteria count ranged from 0 to 1767 cfu/100ml and that of *E.coli* ranged from 0 to 806cfu/100ml. *E.coli* varied significantly in all the six sources of water in Ehi community (Fpr.<0.001) (ANOVA Table 1). Total coliform count was significantly different in the six sources of water (Fpr.<0.009) (ANOVA Table 2). However, THB did not vary significantly (Fpr.= 0.065) (ANOVA Table3).

Bore hole recorded zero level of Total coliform and *E.coli* count, and also, the level of THB was within WHO acceptable limit. This might attributed to the fact that, Bore hole had aprons that carried waste water away from the immediate vicinity into a seepage area downhill. The Bore hole was fitted with hand pumps, thus preventing any human and animal contact with the water body (Plate 1).

The high levels of microbial indicators in the wells (Dzagotovudo, Biasevudo and Xosevudo) might be due to soakage pits and latrines in the vicinity that had extended their influence on water qualities. Ground water flow is either lateral or vertical. During lateral flow, filtration does not occur and could carry feecal pollution for much longer distance (Cairncross, 1987). Musa *et al* (1999), working on peri-urban and rural well in Sudan, observed that *E. coli* counts in peri-

urban water supplies were less than in rural water sources. They explained that this might be because these wells were better protected from surface contamination. High microbial counts for potable water have been found in several earlier studies in the tropics.

Presumably, the extreme high values of these microbial indicators recorded in the two surface waters, might be due to anthropogenic activities like defecation ( by both humans and animals), swimming, washing and disposal of household waste along the banks of these water bodies. Thielman and Geurrant (1996), Feachem (1980), Cairncross and Cliff (1987) have all reported *E.coli* counts greater than  $10^4$  from rivers, ponds and wells in tropical countries. The proximity of domestic and grazing animals to water sources have been shown to play a role in the severity of faecal contamination of water sources (Tiedemann *et al.*, 1988; Doran and Linn, 1979). The Ehi community raise their domestic animals ( sheep, goat, cattle and poultry) by the free feeding range system. These animals roam the community in search of food and water and in the process indiscriminately contaminate water bodies with their faeces.

The microbial indicator levels observed at these sampling sites with exception of Bore hole, make water unsuitable for drinking (WHO, 2004), predisposing significant health risks to humans. In Ghana, for instance, enteric diseases are second to malaria in 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 (Ministry of Health, 1996).

## **5.2 Sanitation**

Ehi is a low lying area and one needs not to dig deep to hit the water table. Hence filtration, adsorption and trapping of bacteria by fine sandy materials, clays and organic matter is not effective (Wilson *et al.*, 1983)

In comparison, boreholes had aprons that carried waste water away from their immediate vicinity into a seepage area downhill (Plate 1). The boreholes were fitted with hand pumps, thus preventing any human and animal contact with the water body. However, due to lack of regular maintenance of the hand pumps on these boreholes, they were not tightly mounted or fitted on their concrete platforms and the walls had cracks, which could allow dirty water back into them.

Cairncross and Cliff (1987) have shown that soakage pits and pit latrines can extend their influence on ground-water quality up to 10m or more as groundwater flow is either lateral or vertical. Additionally, filtration does not occur during lateral flow and could carry faecal pollution for much longer distances (Cairncross and Cliff, 1987) possibly resulting in contamination of well water with pathogens (Zoeteman, 1980). Crain (1984) and Pye and Patric (1983) have shown that land disposal of sewage sludge, illegal dumping of septic tank pumpage, improper toxic waste disposal and run off from agricultural operations all contributed to surface and ground water contamination with chemicals and microorganisms. The sample sites Biasevudo and Dzagotovudo were all within 5m of the community's open pit latrines and mountainous refuse dumps

## 5.3 Physicochemical Parameters

### 5.3.1 Chloride, Total Irons, Sodium And Sulphate Ions Concentrations In Water Samples.

#### Chloride Ion, $\text{Cl}^-$

$\text{Cl}^-$  level in the water samples were all within the WHO maximum acceptable limit for drinking water (250mg/l).

There was a significant difference between the means of all the six sources of water ( $F_{pr} < 0.001$ ). These differences might be due to different levels of chloride salts in the soil and sediments at these sites, and results of differences in the degree of domestic waste around these sources (Department of National Health and Welfare, 1990). However, pair wise, mean differences comparison with corresponding LSD value (15.44mg/l) of  $\text{Cl}^-$  indicated that, Kplikpa river (10.2mg/l) and Dzago stream (1.7mg/l) (surface water) were significantly the same, as Dzagotovudo (90.6mg/l) and Bore hole (94.3mg/l) (ground water).

Tay (2004), working in the Ketu Districts on ground water, found chloride concentration ranging from 42.1 to 1260mg/l, with the mean of 246.68mg/l. This agrees with the range of 40 to 187.3mg/l obtained in ground water in this study. The  $\text{Cl}^-$  concentration range of surface water (1.7 to 10.2mg/l) was similar to that recorded (2.0 – 64.5 mg/l) by Ansa-Asare *et al.*, (2006) in surface waters.

The  $\text{Cl}^-$  content in the surface water was generally lower than that in the ground water. This result agrees to that of Hauser (2001), which stated that  $\text{Cl}^-$  concentration is usually greater in ground water than surface water. The higher levels of  $\text{Cl}^-$  observed in Biasevudo (187.3 mg/l),

Borehole (94.3mg/l) and Dzagotovudo (90.6mg/l), may be attributed to high chloride salt deposits in the areas where these sources were sited (Gregory,1990).

### **Sodium Ion, Na<sup>+</sup>**

The water sources in the sampling sites had appreciably low Na<sup>+</sup> levels, ranging from 14.5 to 224.7mg/l and fell within WHO maximum acceptable limits for drinking water (200mg/l), although Biasevudo recorded values slightly higher than acceptable limits.

From the ANOVA Table 6, the Fpr. < 0.001 was less than 0.05 confidence level, therefore, the average content of Na<sup>+</sup> was significantly different in all the six source of water. In terms of LSD value (13.02) of Na<sup>+</sup>, the Na<sup>+</sup> concentration in Dzago stream (14.5mg/l) and Kplikpa river (26.8mg/l) were not significantly different.

The higher level observed in Biasevudo may be due to mineral deposits in the sediment and the surrounding soil. The variation in the level also indicated that the study area had different levels of Na deposits. Na<sup>+</sup> has positive correlation with Cl<sup>-</sup>. This shows that factors that may have contributed to Cl<sup>-</sup> may directly affect Na<sup>+</sup> values. Tay (2004) reported a concentration range of 24.1 to 668mg/l with mean value of 140.75mg/l, which agreed with the range observed in this study.

### **Sulphate Ion, SO<sub>4</sub><sup>2-</sup>**

Drinking water from the sampling areas generally had low SO<sub>4</sub><sup>2-</sup> concentration ranging from 15 to 150.3mg/l. They were all within the WHO acceptable maximum contaminant limits (250mg/l).

The average level of  $\text{SO}_4^{2-}$  was significantly different in all the six sources of water in the community when compared with the WHO acceptable guideline level ( $\text{Fpr} < 0.001$ ). Pair wise mean differences comparison with corresponding LSD value of 15.63 of  $\text{SO}_4^{2-}$  indicated that the concentration in water at Xosevudo (15mg/l) is not significantly different from that of Dzagotovudo (30.4 mg/l). Furthermore, Dzagotovudo, Kplikpa river (34.1mg/l), Dzago stream (23.3 mg/l) were significantly not different from each other.

The  $\text{SO}_4^{2-}$  concentrations in the various ground water, may be attributed to natural occurrence of sulphate compounds in the sediments and the surrounding soil.  $\text{SO}_4^{2-}$  may also be leached in the ground water by farming activities in the study area. Atmospheric sulphur dioxide ( $\text{SO}_2$ ), formed by the combustion of fossil fuels and by the metallurgical roasting process, may also contribute to the sulphate content of surface waters as shown by Keller *et al* (1986). It has frequently been observed that the levels of sulphate in surface water correlate with the levels of sulphur dioxide in emissions from anthropogenic sources (Keller and Pitblade, 1986). Excessively high concentration of  $\text{SO}_4^{2-}$  may decrease pH of the water and increase its bacterial load, for example, sulphate reducing bacteria (Delisle *et al.*, 1977).

### **Total Iron**

Sampled water from the study area were characterized by high concentration of total Fe and were above WHO maximum acceptable limits of 0.3mg/l. The exceptions were for Biasevudo and the Borehole water whose concentrations fell within the WHO maximum acceptable limit. However, similar work done by previous researchers in the District, recorded relatively lower concentration. Tay (2004) have reported low concentration of Fe ranging from 0.001 to 1.94mg/l in ground waters. Cobbina (2005) also reported mean Fe concentration of 2.42mg/l in surface waters.

From the Anova Table 20, the concentration levels varied significantly at all the sampling points.

The surface waters (Dzago stream and Kplikpa river) generally recorded extreme high concentration levels of Fe. This may be explained that, the soil layers and sediments of these water bodies were iron-riched. There are a number of reasons that may explain the relatively low concentrations of Fe in ground waters. According to Asklund and Eldvall (2005), sorption processes are probably very important for metal concentrations of ground water. Sorption can considerably lower the metal concentration in ground water (Asklund and Eldvall, 2005). Hence the deeper the well/ borehole the lower the concentration observed.

Iron is not harmful at its acceptable concentration but gives a bitter taste to water when present in large amounts. Unlike most organic and microbiological contaminants, many metals tend to accumulate in the top layer of the soil, which aggravates their effects on the local ecosystem (WHO, 2006).

### **5.3.2 Total Hardness and Total Dissolved Solids, Conductivity and pH**

#### **Total Hardness**

Hardness is a natural feature of water, reflecting calcium and magnesium, as carbonates, bicarbonates and sulphates. Water hardness in this study varied widely with values ranging from 22 to 352mg/l. These values were, however, within WHO maximum contaminant value of 500mg/l.

From ANOVA Table 9, the  $F_{pr} < 0.001$  was less than 0,05 confidence level, therefore the average content level of Total Hardness was significantly different in all the six sources of water

when compared with the WHO acceptable guideline level. Pair wise mean difference comparison with corresponding LSD value (18.73) of Total Hardness indicated that, Kplikpa river and Dzago stream were significantly the same, all other sources had their total hardness significantly different from one another. The relative higher values recorded for the hardness of water from Biasevudo and Borehole may be due to the presence of higher concentrations of dissolved calcium and magnesium in these water sources (Table 2&6). Hardness positively correlated with  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  concentrations. This shows that factors that may have contributed to  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  concentrations may directly affect hardness values. Luxenburg (2001) also, attributed high hardness value to the high values of total dissolved solids.

According to Thomas (1953), the degree of hardness of drinking water may be classified in terms of its calcium carbonate concentration as follows:

Soft; 0 to <60 mg/l; Medium Hard: 60 to < 120 mg/l; and Hard 180 mg/l and above.

Based on the above classification, Xosevudo (22 mg/l) and Kplikpa river (51.4) were soft water sources. Comparing 62 mg/l content in Dzago stream with 60 mg/l, It can be said that there is no significant difference between the two figures, with corresponding LSD value of 18.73. Hence Dzago stream was soft water source. Dzagotovudo (110.7) may be classified as medium hard, whilst Biasevudo and Bore hole were hard water sources. Soft water lathers well with soap whereas hard water does not.

### **Total Dissolved Solid, TDS**

The TDS values ranged from 89.31 to 968.7mg/l (Table 4). This range fell within the results obtained by Darko-Mantey *et al.*, (2005). They reported TDS concentration range between 108 and 442mg/l in drinking water from wells and springs in Ashanti Region of Ghana. The TDS



values obtained in this study were within WHO acceptable maximum contaminant limit of 1000mg/l. The values recorded in this project were well within the critical value of 2450mg/l, above which long term health problems might be anticipated (Kempster *et al.*, 1997).

From the ANOVA Table 10, the  $F_{pr} < 0.001$  was less than 0.05 confidence level, therefore, the average content of TDS is significantly different in the six sources of water.

Pair wise mean differences comparison with corresponding LSD value (36.87) of TDS indicated that the levels of TDS in Dzago stream, Kplikpa river and Xosevudo did not vary significantly, but the rest of the sources, namely Dzagotovudo, Biasevudo and Bore hole varied significantly. Generally, the surface water (Dzago stream and Kplikpa river) recorded lower TDS values than those of groundwater. This might be due to high level of soluble salts comprising of anions such as carbonates, chlorides, sulphates and nitrates and cations such as potassium, magnesium, calcium and sodium in the sediment and soil of these sources (<http://www.duluthstreams.org>).

## **pH**

The pH of water varied between 5.75 and 7.53. This agrees with that obtained by Tay (2004) in the District. He obtained pH range of 5.14 to 7.15. The pH values of Xosevudo, Dzagotovudo, and Dzago stream were below the WHO acceptable guideline value of 6.5-8.5. However, both surface and ground waters generally had pH values within the range of pH 6 to 9 range of natural waters (Stumm and Morgan, 1981) and did not vary significantly, although Xosevudo, Dzagotovudo and Dzago stream were slightly acidic.

From the ANOVA Table 11,  $F_{pr} = 0.004$  which was less than 0.05 confidence level, therefore the mean pH values vary significantly. Pair wise mean differences comparison with corresponding LSD value (1.027) indicated that the pH values of Xosevudo and Dzagotovudo did not vary significantly, that of Biasevudo, Kplikpa and Borehole did not also vary significantly. Water sample with low pH attributed to discharge of acidic water into these sources by agricultural and domestic activities. Sample collected from Biasevudo, Kplikpa and Borehole were slightly basic which can be seen from its pH and alkalinity values. In fact 98% of all world groundwater are dominated by  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  due to lime stone weathering in the catchments and under groundwater beds (Meybeck, 1997). Though pH has no direct effect on the human health, all the biochemical reactions are sensitive to variation of pH. For most reactions as well as for human beings, pH value 7.0 is considered as the best and ideal. In the present study, pH value of water samples varied in a narrow permissible limits in all sources. pH was positively correlated with conductivity and total alkalinity.

### **Conductivity**

Electrical conductivity from literature is dependent on the concentration and mobility of ions. Electrical conductivity ranged between 202.3 to 1179  $\mu\text{S}/\text{cm}$ . (Tay (2004), did a study on drinking water from different sources in the District and observed a conductivity range varying from 420 to 5180  $\mu\text{S}/\text{cm}$  with a mean of 1737 $\mu\text{S}/\text{cm}$ , which is similar to that observed in this study. The mean conductivity varied significantly in all the sampling points. Pair wise mean difference comparison indicated that, river Kplikpa's conductivity was significantly the same with Dzago stream (ANOVA Table 21). Surface waters (Dzago stream and Kplikpa river) recorded relatively low conductivity values which were within WHO guideline value of 1000 $\mu\text{S}/\text{cm}$ . Conductivity recorded in Xosevudo and Dzagotovudo were also within the

guideline value. The bore hole and Biasevudo recorded values greater than the WHO guideline. This might be due to high level of soluble salts such as salts comprising of anions such as carbonates, chlorides, sulphates and nitrates and cations such as potassium, magnesium, calcium and sodium in the sediment and soil of these sources (<http://www.duluthstreams.org>).

It is well known that the conductance of water increases with salt, total dissolved solids and conductivity can be used to delineate each other, conductivity is proportional to the total dissolved solids (Meybeck, 1997).

### **5.3.3 The Turbidity, Colour and Total Suspended Solids Of the Various Water Sources**

#### **Colour**

The colour level of water at the six sampling points varied significantly (ANOVA Table 12). They ranged from 5 to 200 Hz. This fell within colour levels range of 1.25 to 750Hz as obtained by Cobbina (2005) in drinking water from wells and reservoirs in Tamale municipality. Bore hole and Biasevudo met WHO guideline of 15 Hz. The ground water in comparison, recorded lower colour levels. This might be due to the filtration ability of the soil. The high colour value observed in the surface waters (Dzago stream and kplikpa river) might however, be as a result of erosion and runoff into them.

Colour level positively correlated with turbidity and total suspended solids, and therefore it was also affected by the same factors that affected turbidity and TSS. Colour affects the easthetic quality of drinking water and gives an indication of pollution.

## **Turbidity**

Turbidity levels as a result of amount of suspended solids present in the water body was, however, very much higher than WHO guideline value of 5NTU, in exception of the bore hole and Biasevudo. The mean turbidity levels in all the six sources did not vary significantly (ANOVA Table 13).

The high level of turbidity could be attributed to the runoff into the Dzago stream and Kplikpa river. Also, it may be due to anthropogenic inputs, both point and non point sources in the Xosevudo and Dzagotovudo since they were not properly lined.

Turbidity like TSS is higher in surface water samples, followed by shallow well samples and lowest in borehole samples confirming a relationship between turbidity and TSS (Betram and Balance, 1996). The occurrence of turbidity of surface water may be permanent or seasonal. These high turbidity values affected the clarity of the water and reduce the depth to which light could penetrate. Turbidity has also been long known to hinder disinfection by shielding microbes, some of them perhaps pathogens. This is the most important significance of turbidity monitoring and therefore it has been an indication of poor filtration process of water supplies (Hauser, 2001). The high turbidity value seen in this study is an indication of poor filtration process of water supplies in the Ehi community.

## **Total Suspended Solids ( TSS)**

Water samples under the study, recorded high TSS values ranging from 1 to 37.3 (Table 5). From ANOVA Table 23, the TSS levels in all the sampling points varied significantly.

TSS was found to be highest in all the surface water samples. Surface water and shallow wells have been known to be affected by flooding, effluent, discharge and infiltration (Nduka et al., 2008).

The greater the amount of total suspended solids (TSS), the murkier it appears and the higher the measured turbidity. TSS is an indication of the amount of erosion that took place. (<http://www.duluthstreams.org>).

### **5.3.4 Magnesium, Potassium, Calcium And Manganese Ions**

#### **Magnesium Ion, $Mg^{2+}$**

All the six water samples recorded low  $Mg^{2+}$  concentrations, which agree with the observation of Tay (2004), who reported that water sources in Akatsi and Ketu Districts were characterized by low magnesium ion concentrations and fell within WHO maximum acceptable limits for drinking (150mg/l).

The average content of  $Mg^{2+}$  was significantly different in all the six sources of water compared with WHO acceptable guideline value (ANOVA Table 14). Pair wise, mean difference comparison with LSD value of 5.576, indicated that Xosevudo well (2.73mg/l), Kplikpa (4.7mg/l) and Dzago stream (6.63mg/l) did not vary significantly, also, Dzagotovudo (11.17mg/l) and Dzago stream did not vary significantly.

Like  $Ca^{2+}$ , no evidence of adverse health effect specifically attributed to  $Mg^{2+}$  in drinking water has been established (Tay, 2004). However, undesirable effects due to the presence of  $Mg^{2+}$  in drinking water may be its ability to render water hard. Magnesium is washed from rocks and subsequently ends up in water.

However, The level of  $Mg^{2+}$  in this study could be attributed to the natural occurrence of its salts in the sediment of these sources.

### **Calcium Ion, $Ca^{2+}$**

Drinking water from the study areas were characterized by low  $Ca^{2+}$  concentrations which fell within the WHO maximum acceptable limits for drinking water (200mg/l). The concentration ranged from 4.27 to 96.2mg/l, similar to finding by Tay (2004) on ground water in the district, recording  $Ca^{2+}$  concentration range of 19.2 to 361mg/l with the mean of 107.5mg/l.

The  $F_{pr} < 0.001$  was less than 0.05 confidence level (ANOVA Table 5), Therefore the average content of  $Ca^{2+}$  was significantly different in all the six sources of water, compared with the WHO standard. In terms of LSD value (6.256) of  $Ca^{2+}$ , indicated that  $Ca^{2+}$  concentration in Dzago stream (13.33mg/l) and kplikpa river (12.8mg/l) were significantly the same. The concentration in the surface water were generally lower than that in the ground water. The level of  $Ca^{2+}$  concentration in the various samples may be attributed to the natural occurrence of calcium compounds in the sediments and surrounding soils. No evidence of adverse health effects specifically attributed to calcium and magnesium in drinking water has been established. However, undesirable effects due to the presence of calcium and magnesium in drinking water may result from their ability to render water hard (Tay, 2004).

### **Potassium Ion, $K^{+}$**

$K^{+}$  concentrations was generally low, though Biasevudo recorded concentration slightly above WHO acceptable guideline value of 30mg/l. Tay (2004), reported  $K^{+}$  concentration range of 1.0

to 40.2mg/l in drinking water in the District. Concentrations of potassium normally found in drinking water are generally low (UKEVM, 2003). The mean content level was significantly the same in all the various sampling points (ANOVA Table 15). The level of  $K^+$  concentration may be due to the natural occurrences of potassium salts in the soil or sediment of these sources. Adverse health effects due to potassium consumption from drinking water are unlikely to occur in healthy individuals. However, individual with pre-existing kidney damage may suffer adverse effects (Gosselin *et al.*, 1984).

### **Mn<sup>2+</sup>**

Mn<sup>2+</sup> concentrations ranged between 0.17 and 1.38mg/l, conforming to that recorded by Tay (2004), who found concentration ranging from 0.005 to 42.6 mg/l in ground waters of Ketu District. Ansa-Asare and Darko (2005) observed concentration range of 0.080 to 0.445 mg/l in surface waters along south-western and coastal river basins of Ghana. The Mn<sup>2+</sup> concentration in all the six sources were significantly the same (ANOVA Table 17).

Levels of Mn<sup>2+</sup> in Kplikpa river and Dzago stream (surface waters) exceeded the WHO guideline value of 0.4 mg/l. Mn<sup>2+</sup> may have entered the water ways through wet and dry deposition from air or through rain (Akabzaa and Dariman, 2001). It may also possible that Mn<sup>2+</sup> could have been washed into the surface waters from agricultural chemicals used by farmers in the study area. The relatively low concentration of Mn<sup>2+</sup> might be that tailings and soils rain-washed into the ground water bodies have low levels or no Mn<sup>2+</sup>. At concentrations exceeding 0.1 mg/litre, the manganese ion imparts an undesirable taste to beverages and stains plumbing fixtures and laundry (Griffin, 1960).

### 5.3.5 Nitrate, Nitrite, Ammonium, Phosphate And Fluoride Ions

#### Concentrations In Water Samples

##### Nitrite $\text{NO}_3^-$

$\text{NO}_3^-$  concentrations were generally low. This was well within the WHO guideline value of 10mg/l. The mean content level of  $\text{NO}_3^-$  was significantly different in all the six sampling points (ANOVA Table16). The concentration of  $\text{NO}_3^-$  in these sources could be attributed to the natural occurrences of  $\text{NO}_3^-$  salts in the sediments of these sources. The 0.009 to 0.992mg/l range observed falls within the reported WHO (2004) values, that water naturally, contains less than 1 mg nitrate-nitrogen per liter. Higher levels would have indicated that the water has been contaminated. Nitrates in this study might have occurred naturally in mineral deposits (generally sodium or potassium nitrates), in freshwater systems ( WHO,1984). High concentration may give rise to potential health risks particularly in pregnant women and bottle-fed infants (Kempster *et al.*,1997). The toxicity of nitrates in human is due to the body's reduction of nitrate to nitrites.  $\text{NO}_2^-$  poisoning causes the blue baby syndrome (methaemoglobinaemia).

##### Nitrite Ion, $\text{NO}_2^-$

The level of  $\text{NO}_2^-$  concentration ranged from 0.018 to 0.485mg/l (Table 7). All the six sampling points had their  $\text{NO}_2^-$  level within WHO acceptable standard of 1mg/l. in a similar study, Ansa- Ansa- Asare et al.,(2006) observed concentration level ranging from <0.001 to 0.184 mg/l in surface water of South-Western and Coastal river basins of Ghana. This is agrees with those obtained in this study.

From the ANOVA Table 18, the mean concentration level of  $\text{NO}_2^-$  vary significantly in all the sampling points even compared with the WHO guideline value.



$\text{NO}_2^-$  poisoning causes the blue baby syndrome (methaemoglobinaemia). Unconfirmed scientific reports also indicated that livestock can be affected by nitrate poisoning (Kilter *et al.*, 1997).

The concentration of  $\text{NO}_2^-$  in these sources could be attributed to the natural occurrences of  $\text{NO}_2^-$  salts in the sediments of these sources.

### **Ammonium Ion, $\text{NH}_4^+$**

The  $\text{NH}_4^+$  recorded in all the water samples were below the detection level of  $<0.001\text{mg/l}$ . Ammonia is naturally present in surface water and ground water and can be produced by deamination of organic nitrogen containing compound. It can also be produced from the hydrolysis of urea. The problem of taste and odour may however, arise when  $\text{NH}_3\text{-N}$  level is greater than  $2\text{mg/l}$ . (Kempster *et al.*, 1997).

### **Phosphate**

Drinking water from the various sampling sites generally had low phosphate concentrations ranging from  $0.09$  to  $0.347\text{ mg/l}$ . Tay (2004) recorded concentrations ranging from  $0.001$  to  $0.6\text{mg/l}$  with a mean value of  $0.11\text{mg/l}$ . Ansa-Asare *et al.*, (2006) also recorded concentration ranging from  $<0.001$  to  $0.921\text{mg/l}$  in surface water in South Western Ghana. These results agreed with those obtained in the present study.

From ANOVA Table 22, the average concentration level in all the water samples in the six sampling points were significantly the same. Pair wise mean difference comparison indicated that the levels in Kplikpa river and Dzago stream were significantly the same. Those in wells ie Xosevudo, Biasevudo and Dzagotovudo were also the same.

The surface water sources had relatively high concentrations. This may be attributed to storm water runoff, agricultural runoff, erosion and sedimentation and direct input by animals/ wildlife. (Ricklef and Shluter, 1993). However, concentrations in the groundwater may be due to natural decomposition of rocks and minerals that contain phosphates.

The introduction of phosphorus in form of phosphates in aquatic environment is a major cause of eutrophication (Wagner, 1974; Lindsay *et al.*, 1960). Phosphorus is a vital nutrient for all living things. Phosphorus occurs naturally, almost solely as phosphate. Most phosphates are dissolved but some are in combination with suspended particles in the water and may contribute to turbidity. Phosphorus is normally low (< 1 mg/l) in clean portable water sources and usually not regulated (Nduka *et al.*, 2008).

### **Fluoride Ion F<sup>-</sup>**

Drinking water from the various sampling points were characterized by low fluoride ion concentrations and fell within WHO acceptable limits of drinking and potable water of 1.5 mg/l. The concentrations ranged from 0.005 to 0.142 mg/l. This was in conformity with a range between .001 and 1.5 mg/l observed in the District's drinking water sources by Tay (2004).

From ANOVA Table 19, the mean concentration level of F<sup>-</sup> vary significantly in all the sampling points, even compared with WHO guideline.

The F<sup>-</sup> concentrations in the surface water were relatively lower than those of the ground water in the study area. Higher concentrations are often associated with underground sources (Sloof, 1988). The F<sup>-</sup> concentrations in these waters however, might be due to fluoride-containing minerals. The relatively low concentrations could be explained that the various sampling points

were not rich in fluoride-containing minerals. This also indicated that there is no evidence of industrial pollutions.

Concentrations above 1.5mg/l carry an increasing risk of dental fluorosis, and much higher concentrations lead to skeletal fluorosis. However, Low concentrations provide protection against dental caries, especially in children (WHO, 1984).

## **CHAPTER SIX**

### **6.0 CONCLUSION AND RECOMMENDATION**

#### **6.1 CONCLUSION**

The Kplikpa river, Dzago stream (surface waters), and Dzagotovudo well, Biasevudo well and Xosevudo well analysed in this study contained high microbial indicator counts which were considered in excess of WHO recommended guidelines for drinking water (WHO, 2006). This implies that, water from these sources are not suitable for drinking without treatment.

Generally, most of the physicochemical parameters were within WHO maximum contaminant levels.

With the exception of Borehole and Biasevudo well, all the water samples had values of total suspended solids, turbidity and colour higher than WHO guideline values. The concentration of sodium and Iron were very high in Biasevudo well and the two surface waters studied respectively. All surface and ground water contaminations often correlate with areas of poor hygienic standards and sanitation. Some of these water sources were also contaminated by their mineral-rich soils and sediments.

#### **6.2 RECOMMENDATIONS**

Minimizing faecal pollution of wells, boreholes and surface waters within the community must be an integrated approach. Developing sound water resource management programmes will be crucial to Ghana's poverty reduction, economic growth, food security and maintenance of natural systems. There is the need for greater community participation in water management.

Receptacles for drawing water from open wells should be kept clean and permanently attached to a windlass when not in use. Well lids must be kept dry and clean and should be constructed as a single unit and not in pieces with openings at the joints to allow water through. The apron run-off and seepage area should be kept clean. Wells must be well lined with concrete rings instead of cementing the upper 1 – 2M as this would prevent the development of fissures within wells. Hand pumps offer a greater degree of protection because they seal off the well/ borehole from external sources of contamination and should thus be maintained. Wells should be sited at higher elevations so as not to serve as a sink during rainfall. Wells should be sited at least 30M away from septic tanks, latrines and rubbish dumps. Wells and boreholes aprons should be well reinforced with steel wire to avoid cracking; and finally, access to surface waters, wells and boreholes by domestic and grazing animals should be restricted by fencing.

Since the two main surface water ( Dzago stream and Kplikpa river), are used for drinking and other domestic purposes without treatment, the following could be done.

- Constant or regular monitoring of the catchment area of these water bodies is required to ensure good water quality standards are achieved.
- The District Assembly should design sanitation programmes and propagate these through environmental education throughout the community to prevent pollution of water bodies and the spread of water related diseases.
- Improved forms of latrines and proper waste disposal facilities should be constructed for the inhabitants living in the Ehi community to avoid defecating and indiscriminate waste disposal in the water bodies.

Above all, except for borehole water, water must be treated before use for drinking.

The Ketu North District Assembly is encouraged to increase boreholes and ensure their regular maintenance in the community.

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## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	1574893.	262482.	7.78	<.001
Residual	14	472240.	33731.		
Total	20	2047133.			

ANOVA Table 1; Analysis Of Variance Of Mean Of E.Coli In Sources Of Water In Ehi Community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	7215281.	1202547.	4.61	0.009
Residual	14	3652081.	260863.		
Total	20	10867362.			

ANOVA table 2; Analysis of variance of mean of Total coliform in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	43835073.	7305846.	2.61	0.065
Residual	14	39175739.	2798267.		
Total	20	83010812.			

ANOVA table 3; Analysis of variance of mean of Total Heterotrophic Bacteria in the six sources of water in Ehi community.

## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	154427.97	25738.00	331.26	<.001
Residual	14	1087.77	77.70		
Total	20	155515.75			

ANOVA Table 4; Analysis Of Variance Of Mean Level Of  $\text{Cl}^-$  In The Six Sources Of Water In Ehi Community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	88757.70	14792.95	1158.98	<.001
Residual	14	178.69	12.76		
Total	20	88936.39			

ANOVA table 5; Analysis of variance of mean level of  $\text{Ca}^{2+}$  in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	139964.86	23327.48	421.90	<.001
Residual	14	774.08	55.29		
Total	20	140738.94			

ANOVA table 6; Analysis of variance of mean level of  $\text{Na}^+$  in the six sources of water in Ehi community.

## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	140253.60	23375.60	293.36	<.001
Residual	14	1115.55	79.68		
Total	20	141369.15			

ANOVA table 7; Analysis of variance of mean level of  $\text{SO}_4^{2-}$  in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	5	319878.4	63975.7	182.44	<.001
Residual	12	4208.0	350.7		
Total	17	324086.4			

ANOVA Table 8; Analysis of variance of mean level of Total Alkalinity in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	606290.1	101048.4	882.91	<.001
Residual	14	1602.3	114.4		
Total	20	607892.4			

ANOVA Table 9; Analysis of variance of mean level of Total Harness in the six sources of water in Ehi community.

## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
sample	6	3025136.2	504189.4	1137.69		<.001
Residual	14	6204.4	443.2			
Total	20	3031340.6				

ANOVA Table 10; Analysis of variance of mean content level of Total Dissolved Solids in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
sample	6	11.4457	1.9076	5.54	0.004	
Residual	14	4.8164	0.3440			
Total	20	16.2621				

ANOVA Table 11; Analysis of variance of mean pH level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
sample	6	118135.	19689	5.09	.006	
Residual	14	54198	3871			
Total	20	172333				

ANOVA Table 12; Analysis of variance of mean colour level in the six sources of water in Ehi community.

## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	36629.	6105.	2.39	0.084
Residual	14	35783.	2556.		
Total	20	72412.			

ANOVA Table 13; Analysis of variance of mean turbidity level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	49856.80	8309.47	819.67	<.001
Residual	14	141.93	10.14		
Total	20	49998.73			

ANOVA Table 14; Analysis of variance of mean  $Mg^{2+}$  level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	3234.3	539.1	2.58	0.068
Residual	14	2925.5	209.0		
Total	20	6159.9			

ANOVA Table 15; Analysis of variance of mean  $K^+$  level in the six sources of water in Ehi community

## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
sample	6	240.44855	40.07476	743.01		<.001
Residual	14	0.75510	0.05394			
Total	20	241.20365				

ANOVA Table 16; Analysis of variance of mean  $\text{NO}_3^-$  level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
sample	6	3.0928	0.5155	0.86		0.544
Residual	14	8.3528	0.5966			
Total	20	11.4456				

ANOVA Table 17; Analysis of variance of mean  $\text{Mn}^{2+}$  level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F	pr.
sample	6	1.88548	0.31425	6.71		0.002
Residual	14	0.65526	0.04680			
Total	20	2.54074				

ANOVA Table 18; Analysis of variance of mean  $\text{NO}_2^-$  level in the six sources of water in Ehi community.

## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	5.38125	0.89687	76.48	<.001
Residual	14	0.16417	0.01173		
Total	20	5.54542			

ANOVA table 19; Analysis of variance of mean F<sup>-</sup> level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	6	1802.75	300.46	11.49	<.001
Residual	14	366.11	26.15		
Total	20	2168.86			

ANOVA table 20; Analysis of variance of mean Total Iron level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	5	6576893.	1315379.	766.72	<.001
Residual	12	20587.	1716.		
Total	17	6597481.			

ANOVA Table 21; Analysis of variance of mean conductivity level in the six sources of water in Ehi community.

## APPENDIX

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	5	0.10334	0.02067	0.85	0.543
Residual	12	0.29312	0.02443		
Total	17	0.39645			

ANOVA Table 22; Analysis of variance of mean phosphate level in the six sources of water in Ehi community.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	5	2645.8	529.2	4.25	0.019
Residual	12	1492.7	124.4		
Total	17	4138.5			

ANOVA Table 23; Analysis of variance of mean TSS level in the six sources of water in Ehi community.