

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, Kumasi**

**COLLEGE OF SCIENCE  
THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY**

**INVESTIGATION OF WATER QUALITY USED BY COMMUNITIES IN THE  
SAVELUGU- NANTON DISTRICT OF THE NORTHERN REGION, GHANA**



**BY**

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INVESTIGATION OF WATER QUALITY USED BY COMMUNITIE IN THE SVELUGU  
- NANTON DISTRICT OF THE NORTHERN REGION, GHANA

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BY

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JANUARY 2014

## DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge, it contains no materials previously published by another person or material which has been accepted for the award of any other degree, except where due acknowledgement has been made in the text.

Kapuya Abdulai .....

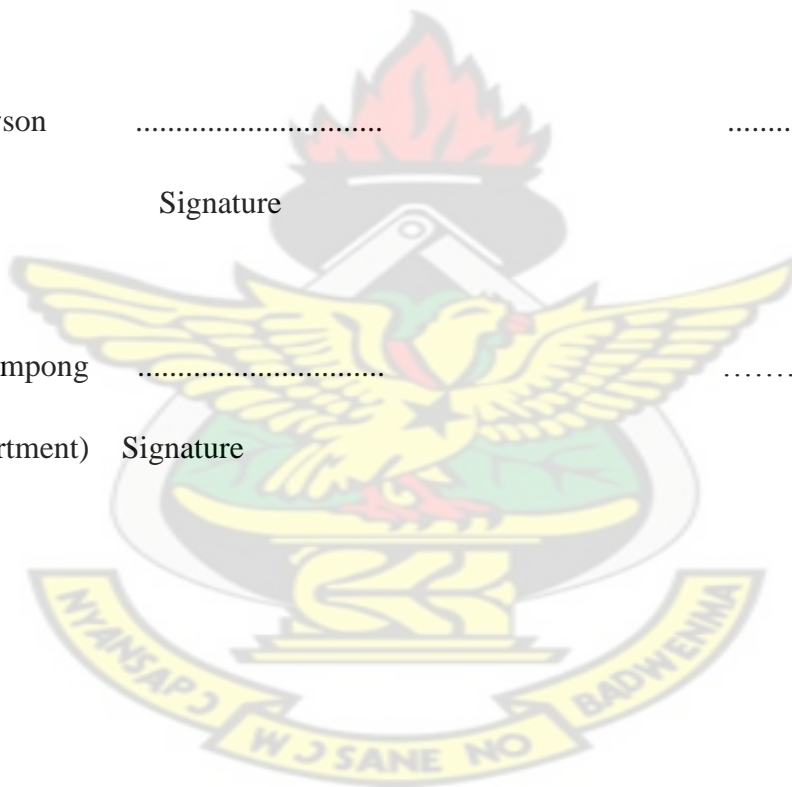
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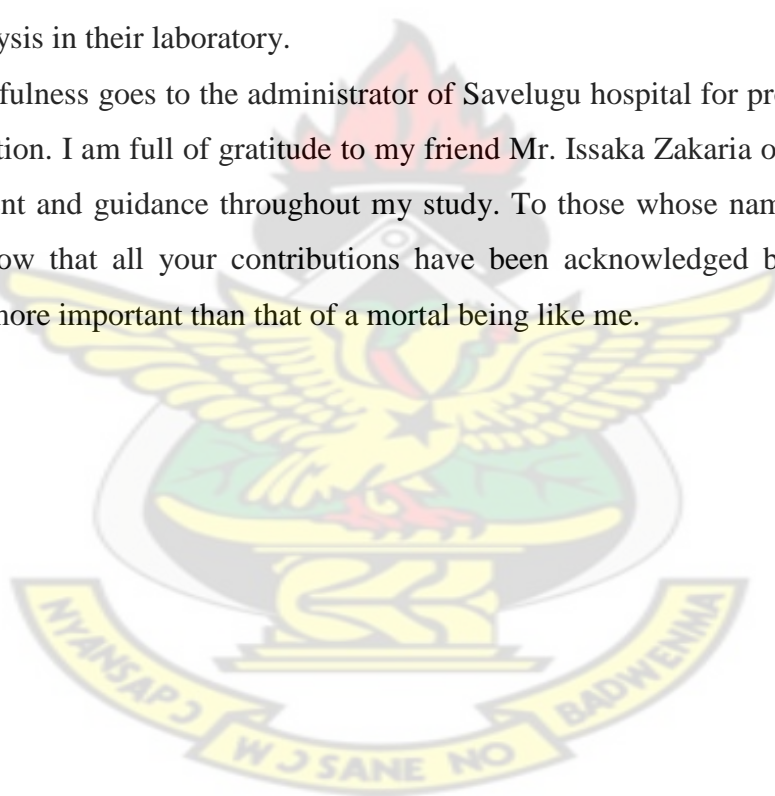
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## ABSTRACT

Communities in Savelugu-Nanton district depend on boreholes, hand-dug wells pipe borne water and dams. The objective of this study was to investigate the drinking water quality of these sources between January 2013 to June 2013. Three hundred and thirty six (336) water samples were collected from boreholes, hand-dug wells, dams and tabs for laboratory analysis. Total coliform and faecal coliform were enumerated using the membrane filtration method. Physico-chemical parameters such as total hardness, phosphate, chloride, total alkalinity, fluoride, nitrate, iron, manganese, magnesium, calcium, sodium, dissolved oxygen, total dissolved solids and conductivity were determined in the laboratory. Temperature, turbidity, pH were also determined in the field. The result showed that higher coliform counts were recorded for dams and hand-dug wells but very low counts in the boreholes and zero counts for pipe borne water. Values recorded for all physico-chemical properties were within world health organisation (WHO) guideline values except turbidity values for the dams and iron concentration for hand-dug wells and dams in the district. The ranking in terms of quality from the research are in the order; pipe borne water > bore hole water > hand-dug well water > dam water. Water from shallow hand dug wells and dams upon which the communities depend is of poor quality as these are sited close to refuse pits, latrines and areas accessible to domestic animals. Generally, some water samples had values of the physico-chemical properties lower than world health organisation (WHO) guideline values indicating the acceptability of the water for domestic use, but for the biological properties, turbidity and iron in dams need further treatment before they will be safe for domestic use.

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## **DEDICATION**

This thesis is dedicated to my lovely mother Mma Abiba Shaibu who has been my backbone in my achievements and the loving memory of my late Uncle Mr. Alhassan Iddi.

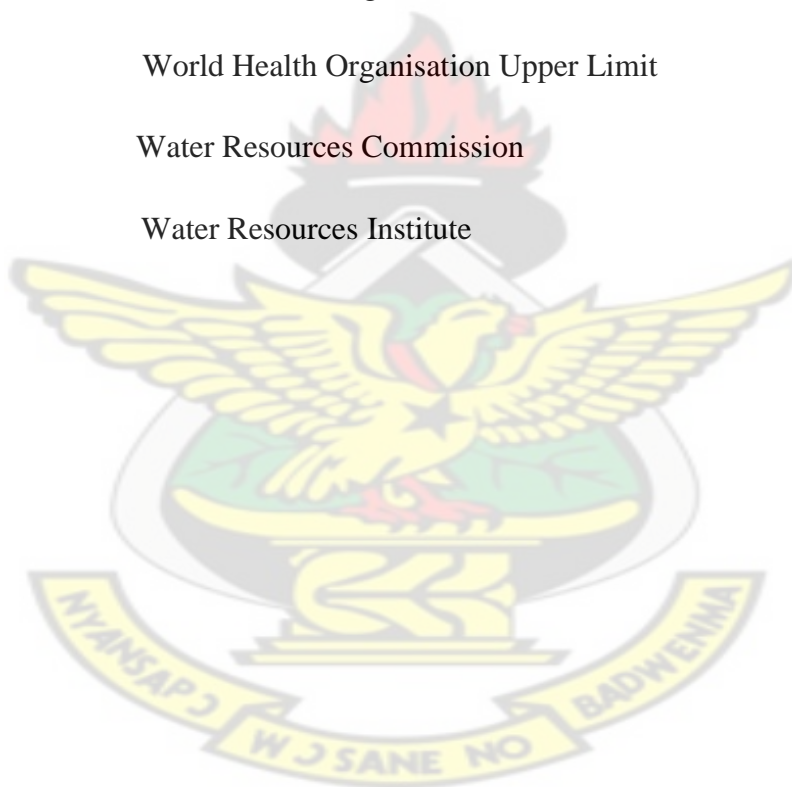
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## ACRONYMS

AAS	Atomic Absorption Spectrophotometer
APHA	American Public Health Association
CDC	Centre for Disease Control
CFU	Coliform Faecal Unit
CWQRB	California Water Quality Research Board
CSIR	Centre for Scientific and Industrial Research-
DES	Department of Environmental Services
DTU	Development Technology Unit
EC	Electrical Conductivity
EPA	Environmental Protection Agency
EDTA	Ethylene Diamine Tetraacetic Acid
FC	Faecal Coliform
IFM	International Fact-Finding Mission
NBH	Nanton Borehole
NDM	Nanton Dam
NGOs	Non Governmental Organisations
NHDW	Nanton Hand-dug well
NTU	Nephelometric Turbidity Unit
PBH	Pong-Tamale Borehole
PDM	Pong-Tamale Dam
PHDW	Pong-Tamale Hand-dug Well
PPB	Pong-Tamale Pipe Borne
PVC	Poly Vinyl Chloride
SBH	Savelugu Boreholes
SPB	Savelugu pipe borne
SDM	Savelugu Dam
SHDM	Savelugu Hand-dug well
TA	Total Alkalinity
TH	Total Hardness
TDS	Total Dissolved Solids
TSS	Total Suspended Solids

TWDB	Texas Water Development Board
UN	United Nations
UNICEF	United Nations International Children's Education Fund
UNEP	United Nations Environment Programme
UNJMP	United Nations Joint Monitoring Programme
USEPA	United States Environmental Protection Agency
WRI	Water Research Institute WHO World Health Organisation
WHOLL	World Health Organisation Lower Limit
WHOUL	World Health Organisation Upper Limit
WRC	Water Resources Commission
WRI	Water Resources Institute





## CHAPTER 1

### 1.0 INTRODUCTION

Quality drinking water is essential for life, however, limited access to clean and safe water at household level can widen the prevalence of water borne diseases. A primary concern of people living in developing countries is that of obtaining clean drinking water. In Ghana most people in rural areas depend on ground and surface water for sustenance. It has been demonstrated that water of good quality is crucial to sustainable socio-economic development (Bartram and Balance, 2001; Spellman and Drinan, 2000). Indeed, improvement in hygiene and sanitation are contingent upon the availability of good quality water. Quality water is that which makes it suitable for the needs of the consumer without the risk from microbiological or chemical content (Osei and Marfo, 1995).

Water resources such as streams, rivers, lakes, dams, waterfalls, underground and rain water abound in Ghana (Allotey, 1991). However, the major challenge has been how to make these sources safe for human consumption as these sources are affected by natural and anthropogenic activities. Several parameters are employed to ascertain and determine the suitability of water and the impact of the contaminants on human health, which may be found in untreated and treated water. Microbiological, physical, chemical and microscopic examinations are of paramount importance in investigating the quality of water. Water quality can best be assured by maintaining water clarity, chlorine residual in distribution system and low bacterial population in the distributed water (Srinivvasan, 2011). The need to investigate the quality of water from these sources has become imperative because they have a direct effect on the health of individuals. Indeed, improvement in hygiene and sanitation are contingent upon the availability of good water quality.

Direct contamination of surface waters with metals in discharges from mining, smelting and industrial manufacturing processes is a long standing phenomenon (Pearse, 1996). Contamination of water by synthetic micro pollutants results either from direct discharge into surface waters or after transport through the atmosphere. There is trace contamination not only of surface waters but also of ground water bodies, which are susceptible to leaching from waste dumps, mine tailings and industrial production sites (Pearse, 1996).

The residents of the district rely on boreholes, unprotected streams, dams, rivers, hand-dug wells and pipe-borne water for their domestic water needs. Some of these water sources serve as drinking places for animals as well, and the health risks posed by this situation are endless

and far reaching. Contaminated water caused by poor sanitation can lead to both water-borne and water contact diseases. The water-borne diseases are those acquired by ingestion of pathogen not only in drinking water but also from the water that makes it into a person's mouth from washing food, utensils and hands. However, few communities in the district have access to pipe-borne water in their houses.

### **1.1 Problem Statement**

Water is essential to sustain life, and a good quality drinking water must be available to all. Water is used for irrigation, in the industries, for recreation, cooking, washing, bathing and drinking (Bartram and Balance, 2001). Therefore effort should be made to achieve drinking-water that is as safe as practicable. In Ghana, there are a 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 has little or no data on their microbial safety. The situation is not different in Savelugu-Nanton district. The present study is focused on identifying the best water sources, analyzed water from the sources to ascertain the levels of biological and physicochemical properties in the water and suggest strategies to improving the quality of drinking water from the various sources to reduce waterborne diseases.

Ground and surface water supply for drinking are often directly sourced from the ground without biochemical treatment, and the level of pollution has become a cause for major concern. Water hardness is caused by dissolved polyvalent metallic ions, predominantly  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  cations. High concentration of these cations in water may be due to dissolution of polyvalent metallic ions from sedimentary rocks, seepage and run-off from soil (Gupta and Saharanb, 2009). In the rainy season, run-offs from the surroundings containing pesticides and fertilizers from farmlands are washed into the surface water bodies and underground water sources. As a result of flooding, faecal waste can mix with river water or other protected water sources (Corwin, 1996). These could affect the quality of water and can cause water-related diseases in the Savelugu- Nanton District.

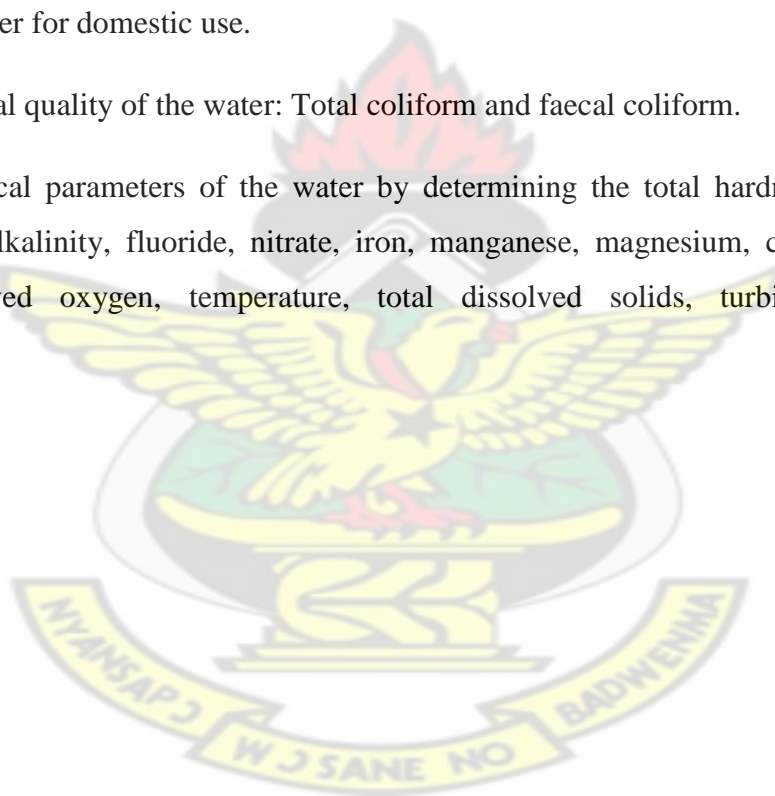
## 1.2 Objectives of the study

The overall objective of the present study was to determine the quality of domestic water and compare the various parameters with World Health Organisation (WHO) guideline values. The parameters to determine are total hardness, chloride, fluoride, sulphate, phosphate, total alkalinity, fluoride, nitrate, iron, calcium, manganese, magnesium, calcium, sodium, potassium, magnesium, dissolved oxygen, turbidity, pH, electrical conductivity, smell, total dissolved solids, total coliform and faecal coliform present.

## 1.3 Specific Objectives

The specific objectives were to determine the:

1. sources of water for domestic use.
2. microbiological quality of the water: Total coliform and faecal coliform.
3. physico-chemical parameters of the water by determining the total hardness, phosphate, chloride, total alkalinity, fluoride, nitrate, iron, manganese, magnesium, calcium, copper, sodium, dissolved oxygen, temperature, total dissolved solids, turbidity, pH, and conductivity.



## **CHAPTER 2**

### **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. The changes in physical characteristics like temperature, transparency, suspended solids and chemical characteristics of water such as dissolved oxygen, nitrate and phosphate provide valuable information on the quality of the water (Mustapha, 2008). The existence of elevated levels of elements and organisms in drinking water constitutes poor water quality, which is a recipe for disease outbreaks (Ntengwe, 2003).

#### **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 faecal 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 judgment. 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 proves 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 diseases in most advanced countries, the monies which otherwise would have been used in treating these diseases, have been channelled 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 Natural Processes Affecting Water Quality**

Although degradation of water quality is almost invariably the result of human activities, certain natural phenomena can result in water quality falling below that required for particular purposes. Natural events such as torrential rainfall and hurricanes lead to excessive erosion and landslides in affected rivers and lakes (Balek, 1977).

Seasonal overturn of the water in some lakes can bring water with little or no dissolved oxygen to the surface. Such natural events may be frequent or occasional. Permanent natural conditions in some areas may make water unfit for drinking or for specific uses such as irrigation (Peavy et al., 1986). The nature and concentration of chemical elements and compounds in a fresh water system are subject to change by various types of natural processes, that is, physical, chemical, hydrological and biological (Balek, 1977). Some chemical elements have a strong affinity for particulate matter and, as a result of precipitation/dissolution and adsorption /desorption reactions, they may be found in only



trace amounts in solution. Other elements, however, are highly soluble and rarely, if ever, present in water in particulate form. The tendency for a chemical to be present in the soluble form rather than associated with particulate is expressed as the Soluble Transport Index. Groundwater can be contaminated naturally or through human activity. Residential, municipal, commercial, industrial and agricultural activities can all affect groundwater quality (US EPA, 1993).

## **2.7 Water consumption and health**

Water is essential for life and is a basic human need. Water borne diseases are a result of consuming water contaminated by human, animal or chemical waste. These diseases cause an estimated 12 million deaths worldwide each year (Buor, 2004). About 1.9 million children die, 20 % from diarrheal disease per year in India. Globally, one person dies from water-related disease every minute (UNICEF, 2005). Polluted water is the source of viral hepatitis, cholera, leptospirosis, typhoid fever, amoebiasis, schistosomiasis, dracunculiasis, malaria and onchocerciasis. In Ghana, prominent diseases directly linked to water pollution include diarrheal, intestinal worms and typhoid infections (Buor, 2004). The quality of rainwater in tanks has been the subject of much controversy. Good quality drinking water is “free from disease-causing organisms, harmful chemical substances and radioactive matter, is aesthetically appealing and is free from objectionable color or odor” (Life Water Canada, 2007). Common health concerns for rainwater quality in developing countries are related to bacteria, particularly *E. Coli* and to aesthetic properties, such as colour, taste, smell and hardness (Zhu, 2004). According to Moe *et al.* (1991) the incidence of diarrhea in children was significantly related to drinking water containing high levels of bacterial contamination (>1000 *E. coli* per 100 ml) but little difference was observed between illness rates of children using either good quality drinking water (<1 *E. coli*/100 ml) or moderately contaminated drinking water (2 - 100 *E. coli* per 100 ml). The quality of rainwater collected depends on when it is collected, how it is stored as well as method of use (Ariyananda, 2003).

## **2.8 Water quality parameters**

Water from different sources is tested to ensure its quality for drinking. However, water contains many elements and any one of them can be a reason for its rejection for human consumption. The following are water quality parameters that are usually determined: pH, total alkalinity, smell, taste, turbidity, nitrite, fluoride, iron, faecal coliform and Total coliform.

### 2.8.1 Water pH

The term “pH” is a mathematical transformation of the hydrogen ion ( $H^+$ ) concentration; it conveniently expresses the acidity or basicity of water. Pure distilled water is neutral with a pH of 7. Acid rain has a pH level of less than 5.6 (Radojevic and Harrison, 1992). Industrial pollutants such as sulfur dioxide emissions from power plants are the main causes of acid rain (Eby, 2004). Human activities are responsible for the production of these atmospheric pollutants. The chemical reactions that lead to acid rain begin as energy from sunlight in the form of photons which hits ozone molecules to form free oxygen and single reactive oxygen atoms in the atmosphere. These oxygen atoms react with water molecules to produce electrically charged, negative hydroxyl radicals which are responsible for oxidizing  $SO_2$  and  $NO_2$  to sulfuric and nitric acids respectively (Radojevic and Harrison, 1992). The balance hydrogen ions ( $H^+$ ) and hydroxide ions ( $OH^-$ ) in water determines the acidity or basicity of water. Therefore, when analysts measure pH, they are determining the balance between these ions (USEPA, 2006). A pH of 6.5 - 8.5 is the ideal range with the maximum environmental and aesthetic benefits (Environmental Protection Agency, 2008). Eighty-one (81) boreholes were sampled for quality assessment in the Savelugu - nanton district and the results showed that, the pH of the boreholes are slightly acidic to basic ranging from 6.1-8.3 pH units Tay (2012). 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. Mensah (2011) also recorded a pH range of 5.75 – 7.53 in his work on the assessment of drinking water quality in the EHI community of the Keta north district.

### 2.8.2 Total alkalinity

There is no health guideline value for total alkalinity. Alkalinity is the total measure of the substances in water that have "acid-neutralizing" ability (USEPA, 2006). Alkalinity indicates a solutions power to react with acid and neutralize it. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity (CWQRB, 2005). Bathing or washing in water of excessive alkalinity can cause change in the value of PH of lacrimal fluid around the eye, causing eye irritation (Srinivasan 2011)

### 2.8.3 Turbidity

Turbidity does not have a health guideline, but the recommended value is below 5.0 NTU for effective disinfection (WHO, 2006). Turbidity measures the fine suspended matter and its

ability to impede light passing through water, mostly caused by colloidal matter (Shelton, 2000). It is measured in Nephelometric Turbidity Unit (NTU). Excessive turbidity in water causes problems with water purification processes such as flocculation and filtration, which may increase treatment cost (DWAF, 1998). 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 5.0NTU is usually acceptable to consumers (WHO, 2004). Mensah (2011) recorded 2NTU for boreholes and 34NTU for well. Tay (2004) also recorded turbidity range of 0.4 to 23.5NTU in ground water in Ketu District.

#### **2.8.4 Electrical conductivity**

A conductivity of 300  $\mu\text{S}/\text{cm}$  is the ideal for consumption (WHO, 2006). Conductivity is a measure of the ability of water to pass current (CWQRB, 2005). Conductivity in water is affected by the presence of chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 °C in  $\mu\text{S}/\text{cm}$ . Pushard (2005) indicates that distilled water has conductivity in the range of 0.5 - 3  $\mu\text{S}/\text{cm}$  and industrial water is as high as 10,000  $\mu\text{S}/\text{cm}$ .

#### **2.8.5 Total hardness**

Total hardness of water refers to the total concentration of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions in the water. Temporary hardness of water refers to the amount of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions that can be removed as insoluble carbonates by boiling the water (Suffredini, 1994). Hard water is caused by dissolved calcium and magnesium as it passes through soil and rock formations. Other minerals, such as iron, may also contribute to water hardness.

Hardness of minerals in water has a wide impact on households. Soap scum is composed of  $\text{CaCO}_3$ ,  $\text{Mg}(\text{OH})_2$ , and  $\text{CaSO}_4$ . The presence of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions in water can lead to galvanic corrosion (Hermann, 2007). Hard water interferes with cleaning task, laundering, dishwashing, bathing and personal grooming. Clothes laundered in hard water may look dingy and feel harsh and scratchy. Dishes and glasses may be spotted when dry. Bathing with soap in hard water leaves a sticky film of soap curd on the skin. The soap curd causes skin irritations and can leave the hair looking dull, lifeless and difficult to manage. McNally *et al.* (1998) in his study correlated domestic hard water usage with increased eczema in children.

Hard water requires extra detergent use, unnecessary rinse cycles, hot water use, fabrics lose their usefulness, and wearing out of washing machines. When doing laundry in hard water, soap get lodge in the fabric and create a stiff and rough surface on the clothes. A sour odour may develop in clothes, and the continuous laundering can cause a shorter life span for the clothing. A Purdue University study in Indiana observed that, "fabrics washed in hard water tend to wear out as much as 15 % faster than fabrics washed in soft water (Hairston and LaPrade, 1995). Also hard water has negative effect on colours and laundry washed in hard water resoiled with greater ease. Cooking with hard water can also cause problems. Hard water can produce scale on pots. Some vegetables cooked in hard water lose colour and flavour. Home economists have reported that beans and peas may become tough and shriveled when cooked in excessively hard water (Hairston and LaPrade, 1995). Hard water may affect the performance of household appliances. When hard water is heated, a hard scale is formed that can plug pipes and coat heating elements. With increased deposits of scale on the heating unit, heat is not transmitted to the water fast enough and overheating of the metal causes failure. Build-up of deposits will also reduce the efficiency of the heating unit, increasing the cost of fuel (Hairston and LaPrade, 1995).

The concentration of total hardness in drinking water sources ranges between 75 - 1110 mg/l (Gupta *et al.*, 2009). A partial solution to this hardness problem is the addition of builders such as complex phosphates and silicates which can be added to counteract the hardness. Hard water also has a great effect on herbicides and their effectiveness, particularly, diquat, glyphosphate and paraquat. According to WHO (2006) domestic water of total hardness above 500 mg/l is not recommended due to potential scale formation. At 500 mg/l level, soap consumption is very high and pipe and water heater scaling is severe. Treatment is not recommended unless hardness exceeds at least 51 mg/l (Hairston and LaPrade, 1995).

#### **2.8.6 Sodium ion ( $\text{Na}^+$ )**

Sodium is a soft, silvery –white, highly reactive metal that is never found in nature in uncombined state. Sodium an alkali-metal element has 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 more than 20mg of sodium per litre, but in some countries levels can exceed 250ml/litre . Saline intrusion, mineral deposits, sea water 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 300mg/litre, but much lower ones are usually found [ WHO Regional office for Europe, 1979 (Euro reports and studies no.4) ].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.

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

Total dissolved solids are correlated fairly well to the total mineral content of the water (deposits left after evaporation of a water sample), primarily salts, carbonates and metals. Organic compounds may also be dissolved solids. A high concentration of TDS is an indicator of possibly high volume contamination and further investigation may be recommended.

### 2.8.8 Nitrate ( $\text{NO}_3^-$ )

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.

High concentration of nitrate above 50 mg/l in drinking water is deleterious especially to babies due to the formation of methaemoglobinemia (WHO, 2006). Nitrate is the more stable oxidized form of combined nitrogen in most environmental media (USEPA, 2006). Nitrates occur naturally in mineral deposits, in soils, seawater, freshwater systems, the atmosphere, and in biota. Lakes and other static water bodies usually have less than 1.0  $\mu\text{g/l}$  of nitrate. Groundwater levels of nitrates may range up to 20  $\mu\text{g/l}$  or more, with higher levels occurring in shallow aquifers beneath areas of extensive development (USEPA, 2006).

The toxicity of nitrite is demonstrated by cardiovascular effects at high dose levels and methemoglobinemia at lower dose levels. Methemoglobinemia, "Blue-Baby Disease" is an effect in which haemoglobin is oxidized to methemoglobin, resulting in asphyxia (Knepp and Arkin 1973). Three months old infants are the most susceptible subpopulation with regard to nitrate. In adults and children, about 10 % of ingested nitrate is transformed to nitrite, while 100 % of ingested nitrate can be transformed to nitrite in infants (Knepp and Arkin, 1973).

### 2.8.9 Fluoride

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). The fluoride content of drinking water is a very important factor from the health point of view. There are many sources of fluoride in the diet. Dentists apply fluoride to teeth; some municipal water systems add fluoride to their water supplies; many tooth pastes have fluoride as an additive; and some foods also have elevated fluoride such as fish and tea. At higher concentration, there are health concerns. Waldbott (1998) indicates that excessive fluoride intake causes fluorosis, cancer, arthritis, and other diseases. The optimal concentration recommended by the Centre for Disease Control for New Hampshire is 1.1 mg/l. Below 0.5 mg/l, there is little tooth decay protection whilst above 1.5 mg/l, prevents little tooth decay. In the range of 2.0 - 4.0 mg/l of fluoride, staining of tooth enamel is possible. Studies have shown that above 4.0 mg/l, skeletal fluorosis as well as the

staining of teeth is possible (DES, 2007). In groundwater, fluoride concentrations vary with the type of rock the water flows through but do not usually exceed 10mg/litre (US EPA, 1984). Tay (2004) however, reported fluoride concentration varying from 0.001 to 1.5 mg/l, in ground water in Ketu District

### **2.8.10 Iron**

Metallic iron occurs in the free-state and is widely distributed and ranked in abundance among the entire element in the earth's crust, next to aluminium (Antovics *et al.*, 1971). Chemically, iron is an active metal, and combines with the halogens (fluorine, chlorine, bromine, iodine and astatine) sulphur, phosphorus, carbon, and silicon. When exposed to moist air, iron forms a reddish-brown, flaky, hydrated ferric oxide commonly known as rust. There are two kinds of iron with respect to the mechanism of absorption in diet. These are heme-iron and non-heme iron (Halberg, 1982). Before iron can be absorbed, two conditions must exist, first, the iron is separated from its organic complex, and second, the ferric iron is reduced to ferrous iron. Although the body can absorb both the ferrous ( $\text{Fe}^{+2}$ ) and ferric ( $\text{Fe}^{+3}$ ) iron, absorption is greater when iron is available in the ferrous form (Fifield and Haines, 1996).

The basic biochemical role of iron in humans is to permit the transfer of oxygen and carbon dioxide from one tissue to another. It accomplishes this primarily as part of both haemoglobin and myoglobin which are iron containing proteins in the blood and muscle (Cook *et al.*, 1972). It is also important in blood formation. Iron also functions as a catalyst in the conversion of beta-carotene to vitamin A. Iron is also necessary for the growth of microorganisms, and it is an essential part of enzymes and immune substances needed to destroy invading infection organisms (Cook *et al.*, 1972). Acute iron toxicity is nearly always due to accidental ingestion of iron containing medicines and most often occurs in children. Severe toxicity occurs after ingestion of more than 0.5 g of iron or 2.5 g of  $\text{FeSO}_4$  (Fifield and Haines, 1996). Toxicity manifest with vomits being bloody owing to ulceration of the gastrointestinal tract; stools become black. These are followed by signs of shocks and metabolic acidosis, liver damage and hepatic cirrhosis.

### **2.8.11 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 contains 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 high concentration of calcium. Inadequate intake of calcium have been associated with the risk 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>).

#### **2.8.12 Magnesium ion ( $\text{Mg}^{2+}$ )**

Rivers contain approximately 4ppm of magnesium, marine algae 6000-20,000ppm, and oysters 1200ppm. 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. 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).

### **2.8.13 Manganese ( $Mn^{2+}$ )**

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 ( $Mn^{2+}$ ) and manganic ( $Mn^{4+}$ ) 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 ( $Mn^{2+}$ ) 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).

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#### **2.8.14 Sulphate ( $\text{SO}_4^{3-}$ )**

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). 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>)

#### **2.8.15 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. High concentration of phosphate in water bodies is an indication of pollution and largely responsible for eutrophication (MacCutcheon 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. Phosphorus is normally low (< 1 mg/l) in clean portable water sources and usually not regulated (Nduka *et al.*, 2008).



### 2.8.16 Chloride ions (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.

## 2.9 MICROBIOLOGICAL QUALITY OF WATER

The microbial quality of water is determined by the presence of bacteria indicative of faecal (sewage ) contamination, namely, total coliforms and faecal coliforms. Coliform bacteria are common in the environment and are generally not harmful (Environmental Protection Agency-EPA, 2008). *Escherichia coli* indicate the presence of disease-producing organisms that normally live in the intestinal tracts of human or warm-blooded animals (EPA, 2008). The major pathogenic organisms that affect the safety of drinking water are bacteria, viruses, protozoa and worm infections. Typhoid, cholera and dysentery are caused by bacteria and protozoa (WHO, 2003). High level of turbidity can protect micro-organisms from the effect of disinfection, stimulate the growth of bacteria and give rise to significant chlorine demand (Lundgren and Akerberg, 2006). The WHO recommends zero *Escherichia coli* or thermotolerant Coliform Forming Units (CFU's) per 100 ml for all drinking water supplies (WHO, 2004). 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).



### **3.1.2 Climate**

The area covered by the three townships received an annual rainfall averaging 600mm, considered enough for a single farming season. The annual rainfall pattern is erratic at the beginning of the raining season, starting in April, intensifying as the season advances raising the average from 600mm to 1000mm. Temperatures are usually high, averaging 34°C. The maximum temperature could rise as high as 42°C and the minimum as low as 16°C. The low temperatures are experienced from December to late February, during which the North-East Trade winds (Harmattan) greatly influence the weather in the District. The generally high temperatures as well as the low humidity brought about by the dry harmattan winds favour high rates of evaporation and transpiration, leading to water deficiencies.

### **3.1.3 Geology and Vegetation**

The Middle and Upper Voltaian sedimentary formation characterizes the geology of the District. The middle Voltaian covers the northern part of the district and comprises sandstone, shale and siltstone. The Upper Voltaian covers the southern part of the District and consists of shale and mudstone. Underground water potential is generally determined by this underlying rock formation. Consequently, borehole drilling is expected to have a higher success rate in the northern rather than the southern section.

The District finds itself in the interior (Guinea) Savanna woodland which could sustain large scale livestock farming, as well as the cultivation of staples such as rice, groundnuts, yams, cassava, maize, cowpea and sorghum. The trees found in the area are drought resistant and hardly shed their leaves completely during the long dry season. Most of these are of economic value and serve as important means of livelihood especially for women. Notable among these are shea trees, (the nuts of which are used for making sheabutter) and dawadawa that provides seeds used for condimental purpose. The sparsely populated north has denser vegetation mostly with secondary forest. The populous south on the other hand is depleted by human activities such as farming, bush burning and tree felling among others.

### **3.1.4 Water resources**

The main drainage system in the district consists of the White Volta and its tributaries. The effect of the drainage system is felt mostly in the northern part of the district covering the areas between Nabogu and Kukuobilla (Plate 2). These areas are prone to periodic flooding during the wet season, thus making them suitable for rice cultivation. One of the tributaries of



the White Volta, Kuldaalnali, stretches to constitute a natural boundary between the District and Tolon/Kumbungu district.

The main sources of water are boreholes, rivers, dug-outs, dams and rainwater harvesting to buck-up their domestic water needs. At present, Savelugu has seven boreholes, treated pipe-borne water in some households and two dams whilst Nanton also has two dams, seven hand-dug wells and seven boreholes. Pong Tamale has four boreholes, ten dugouts, treated pipe-borne water in some households and two dams.

### **3.2 Survey of water sources**

A survey of water resources was carried out at Savelugu, Pong Tamale and Nanton to determine the sources of water in the three communities. A total of one hundred and fifty (150) household representatives/heads were interview using the pre-tested questionnaire. The household were asked to respond to questions on a variety of issues including socio-economic, water collection, smell, taste and health related issues. A dital camera was also used to capture images of water sources in the communities.

### **3.3 Water Sampling**

Sample containers were soaked in nitric acid ( $\text{HNO}_3$ ) overnight and washed with distilled water, rinsed with deionised water and dried in a drying cabinet. Some of the dry containers were selected, filled with distilled water and the pH determined and adjusted to pH 7.0 before use. Sample containers were clearly labelled to enhance record keeping. Pipe borne water samples collected from Savelugu and Pong Tamale were labelled SPB and PPB, respectively. Borehole water samples from Savelugu, Pong Tamale and Nanton were labelled as follows SBH, PBH and NBH, respectively. Dam water samples from Savelugu, Pong Tamale and Nanton were labelled as follows SDM and PDM and NDM, respectively. Dug out well water samples from Savelugu, Pong Tamale and Nanton were also labelled as follows; SDO, PDO and NDO, respectively. All the samples were labelled with the site, date and time of sampling on the plastic bottles.

Water samples were collected from taps, boreholes, dams and dug-out wells in the selected communities for laboratory analysis. Water samples collected were immediately placed in an 'ice chest' with ice packs and transported to the laboratory where analyses were performed within 12 hours. The samples were collected every two weeks for the six months period. Thus, each station was sampled 12 times in six months, from January 2013 to June 2013. Pumping machines were run for 5 minutes prior to sampling to ensure collection of a

representative sample. For water samples to be collected from the dams and hand-dug wells, the surface of the water was whirled before fetching. Water sampling from the boreholes, taps and dams were repeated for the sample sites. Three hundred and thirty six (336) water samples were collected for the period.

**Table 1: Water sampling scheme for water sources**

TOWN	Number of samples from the four water sources				Total number of samples
	Borehole	Pipe borne water	Dam	Hand-dug wells	
Savelugu	36	36	24	36	132
Pong-Tamale	24	36	24	36	120
Nanton	36	-	24	24	84
GRAND TOTAL					336

### **3.4 Determination of physico-chemical and biological parameters.**

The physicochemical and biological parameters were determined according to procedures and protocols outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1992).

#### **3.4.1 Temperature**

Temperature was determined in the field *in situ*, using mercury-in-glass thermometer. The probe end of the thermometer was cleaned with de-ionized water and immersed into the sample, swirled for mixing and equilibration for at least one minute. The thermometer was dipped in the middle away from the sides of the container.

#### **3.4.2 Measurement of pH**

PH was determined *in situ* using a pH meter JENWAY 3071, model pH 82 (degree of accuracy 0.01) equipped with a temperature probe. The pH meter was initially calibrated by dipping the electrode into a buffer solution of known pH (pH 4) and the asymmetric potential control of the instrument altered until the meter read the known pH value of the buffer solution. The standard electrode after rinsing with distilled/deionised water was then immersed in a second buffer solution (pH 9) and the instrument adjusted to read the pH value of this buffer solution. With the pH meter calibrated, it was immersed in the water sample,

allowed to stabilize and the pH value read from the instrument. Once the readings have stabilized, the readings were recorded. The beaker and the electrode were washed in between samples with deionised water in order to prevent contamination by other samples. Duplicate pH values were taken.

### **3.4.3 Dissolved oxygen**

For dissolved oxygen (DO) determinations in the laboratory, separate samples were collected into plain glass bottles and the DO fixed, using the azide modification of the Winkler's method (APHA, 1998). The oxygen was fixed on- site because the amount of dissolved oxygen in the water can change rapidly after the sample has been collected.

### **3.4.4 Determination of Turbidity**

Turbidity of the water samples were determined in situ with a microprocessor turbidimeter JENWAY 3071, model HI93703 (0.0001 degree of accuracy). The instrument was first calibrated by dipping the probe into standard solution with turbidity values of 0.00 and 10.00 Nephelometric Turbidity Unit (NTU) and calibrated before determining the turbidity values of the samples.

### **3.4.5 Electrical conductivity**

The Hi 9032 Microprocessor Bench Conductivity Meter was calibrated before the measurements were taken (by pressing the TDS key the display showed "TDS" to confirm the measurement mode). Once the measurement reading stabilized, the conductivity button on the instrument was pressed to display its value which was recorded on the data sheet.

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

Fluoride was determined potentiometrically using a fluoride Ion-Selective Electrode (ISE) in conjunction with a standard single-junction reference electrode, and an ISE meter capable of being calibrated directly in terms of fluoride concentration. The standards and samples were mixed 1:1 with a Total Ionic Strength Adjustment Buffer (TISAB), which buffers pH to 5 - 5.5. Calibration was performed by analyses of a series of standards and calibrating the ion meter directly in terms of fluoride concentration (Appendix 2A).

### 3.4.7 Chloride (Cl<sup>-</sup>)

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. The chloride concentration was determined as follows:

$$\text{Chloride, mg/l} = \text{Titre value} \times 10$$

### 3.4.8 Sulphate (SO<sub>4</sub><sup>2-</sup>)

The Turbidimetric Method was used. Sulphate ion is precipitated in an acidic medium with barium chloride to form a barium sulphate crystal with uniform size. The absorbance of the BaSO<sub>4</sub> 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).

### 3.4.9 Nitrate

An aliquot of 2 ml of 0.1 M NaOH solution and 1.0 ml of colour developing reagent was added to a sample. The mixture was then allowed to stand for 20 minutes. The nitrate concentration was determined at wavelength of 543 nm of absorbance using a 5500 photometer. A blank analysis was also performed with all the reagents without sample for all the analysis (Appendix 2B).

### 3.4.10 Phosphate

The stannous chloride method was used.

One drop of phenolphthalein indicator was added to 100 ml of sample. The sample was discharged by adding an acid, drop wise until it turned pink, then 4 ml of molybdate reagent I

and 10 drops of stannous chloride reagent I was added and mixed thoroughly. Absorbance was then read after 10 minutes at a wavelength of 690 nm.

#### **3.4.11 Iron**

A 250 ml of the samples was filtered through 0.45 µm cellulose membrane filter paper. The samples for iron determination were digested by adding 20 ml each of concentrated HNO<sub>3</sub> to 200 ml samples and heated on a mantle till the volume decreased to 50 ml. The samples were filtered and analyzed for iron using the flame Atomic Absorption Spectrophotometer (AAS). Triplicate determinations were made for the iron concentration to be determined. A calibration curve was obtained with standard solutions of 1, 3 and 5 mg/l for iron (Milner and Peterside, 1984).

#### **3.4.12 Total Alkalinity**

Hundred milliliters of the water sample was measured into 250 ml conical flask. Methyl orange indicator (2 drops) was added. The resulting yellow solution was titrated with standardized HCl acid solution to immediate orange colour. A reagent blank was performed without the sample (Appendix 2C).

The total alkalinity of the water sample was then calculated as follows:

$$\text{TOTAL ALKALINITY} = \frac{\text{volume of HCl used} \times 1000}{\text{Volume of water sampled used}} \text{ (mg/l)}$$

#### **3.4.13 Total Hardness**

EDTA titrimetric method was used.

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) (Appendix 2D)

#### **Calculations**

Total Hardness as CaCO<sub>3</sub> (mg/l) = titre value x 20.

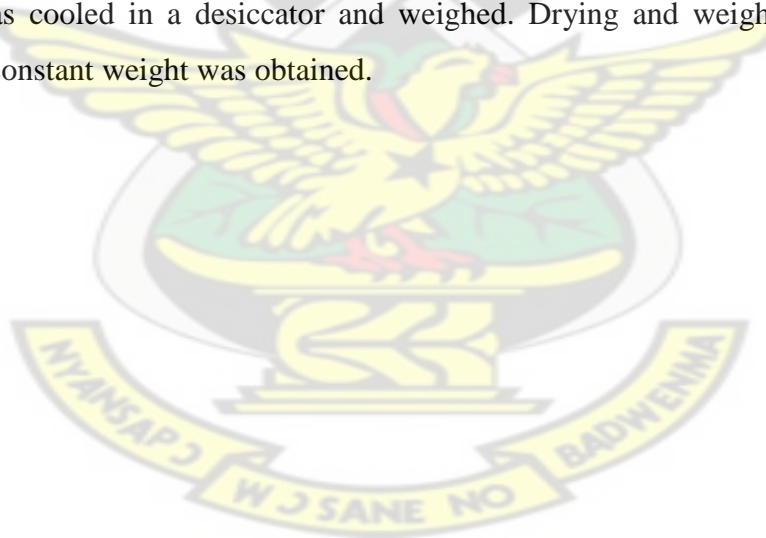


#### **3.4.14 Sodium**

The Flame Photometric method was used. Twenty milligrams per litre (20 mg/l) NaCl standard was prepared for standardization of the flame photometer. The filter selector of the photometer was used to select Sodium after the photometer was switched on and the 20 mg/l standard was set. The machine was calibrated to ensure the standard concentration of 20mg/l set was obtained. Sample readings were then taken, ensuring that after every ten sample readings, the machine was re-calibrated to ensure readings within the 20 mg/l range.

#### **3.4.15 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.



### 3.4.16 Calcium

EDTA Titrimetric method was used to determine calcium. 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.

The calcium content was calculated as follows:

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

Volume of sample

Where A = ml of EDTA titrant used

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

ml of EDTA titrant

The results were expressed as mg/l Ca to 3 significant figures.

### 3.4.17 Magnesium ion

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.

Calcium hardness as mg CaCO<sub>3</sub>/l =  $\frac{A \times B \times 1000}{\text{ml sample}}$

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

Then calcium hardness as mg CaCO<sub>3</sub>/l =  $\frac{\text{concentration of Ca}}{0.4}$

0.4

Where;

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

Molecular weight of CaCO<sub>3</sub>

The total hardness concentration was recorded as mg/l CaCO<sub>3</sub>.

Magnesium hardness as mg/l CaCO<sub>3</sub> = total hardness – calcium hardness.

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

Where 0.243 = atomic weight of Mg / molecular weight of CaCO<sub>3</sub>.

The magnesium concentration was expressed as mg Mg/l to one decimal place. (APHA et al, 1995).

### 3.4.18 Manganese ( $Mn^{2+}$ )

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)

### 3.5 Faecal coliform

The Coliscan medium was poured into a sterilized petri-dish, which was labelled with the code of sampling site and the quantity of sample water used from each site. A 250 ml of water from the sampling bottle was measured and transferred onto the petri-dish using a sterilized pipette. The water samples was swirled around the Petri dish to ensure even distribution. The petri-dish was covered with lid and set aside at room temperature until the solution solidified. The procedure was repeated for all the samples, the petri-dishes were incubated at 44 °C for 24 hours. The petri-dishes were then taken out from the incubator, and all developed dark-blue and pink colonies were counted separately.

The fecal coliform was calculated calculation as:

$$FC = \frac{C_c}{V_f} \times 100 / \text{CFU}/100\text{ml}$$

$V_f$

Where; FC= Fecal coliform, Coliform Faecal Unit (CFU) per 100 ml, CC = Colonies counted and  $V_f$  = Volume of sample filtered (litres).

### 3.6.Data analysis

The data collected from the laboratory analysis was checked and entered into the computer. The mean values of parameters were computed using Microsoft Excel software. In order to establish variations between and within the water bodies under investigation, a one way analyses of variance (ANOVA) was used to analyze the data. Descriptive statistics was presented using charts and the means values were compared with WHO (2006) drinking water guidelines.





## CHAPTER 4

### RESULTS

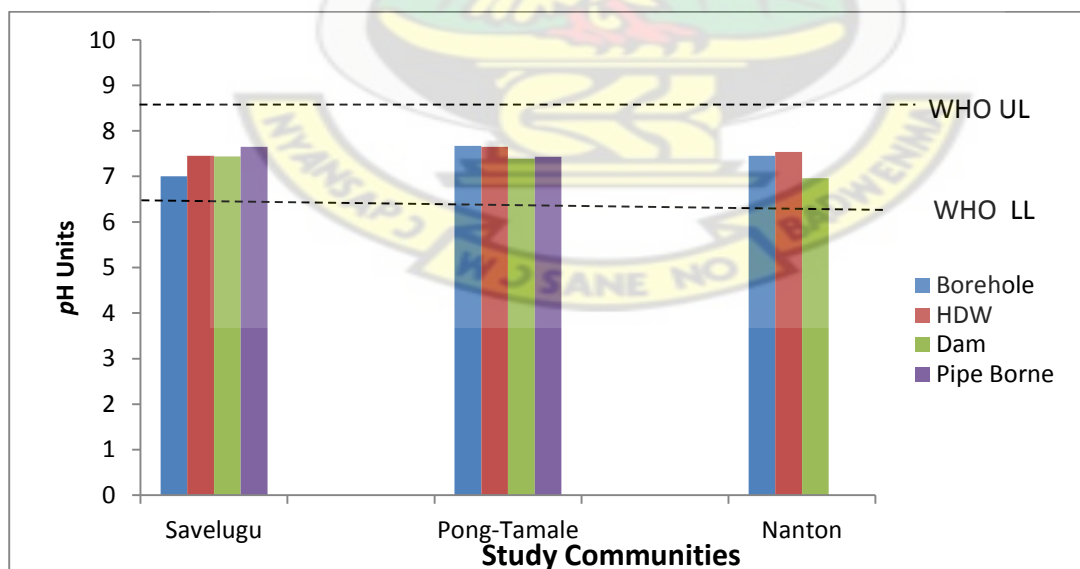
#### 4.1 Water Quality Analysis

Three hundred and thirty six water samples were collected from boreholes, hand-dug wells, taps and dam sources for a period of six months. This section presents the results from the laboratory analysis in terms of physico-chemical and biological parameters to ascertain their quality for domestic purposes.

##### 4.1.1 Water pH

The mean pH of the water samples ranged from 6.63 to 7.67. Water samples of boreholes from Savelugu, Pong- Tamale and Nanton were 7.10, 7.67 and 7.45 for the six months period. Water from hand-dug wells from Savelugu, Pong-Tamale and Nanton had mean pH values of 7.45 and 7.65 and 7.54, respectively (Fig.1). Pipe borne water in Savelugu and Pong-Tamale also had mean pH of 7.65 and 7.43, respectively.

Water from the dams in Nanton, Pong-Tamale and Savelugu recorded a mean pH values of 7.44, 7.45 and 6.63, respectively. However, the pH levels for all the water sources were within the WHO guideline level of 6.5 to 8.5

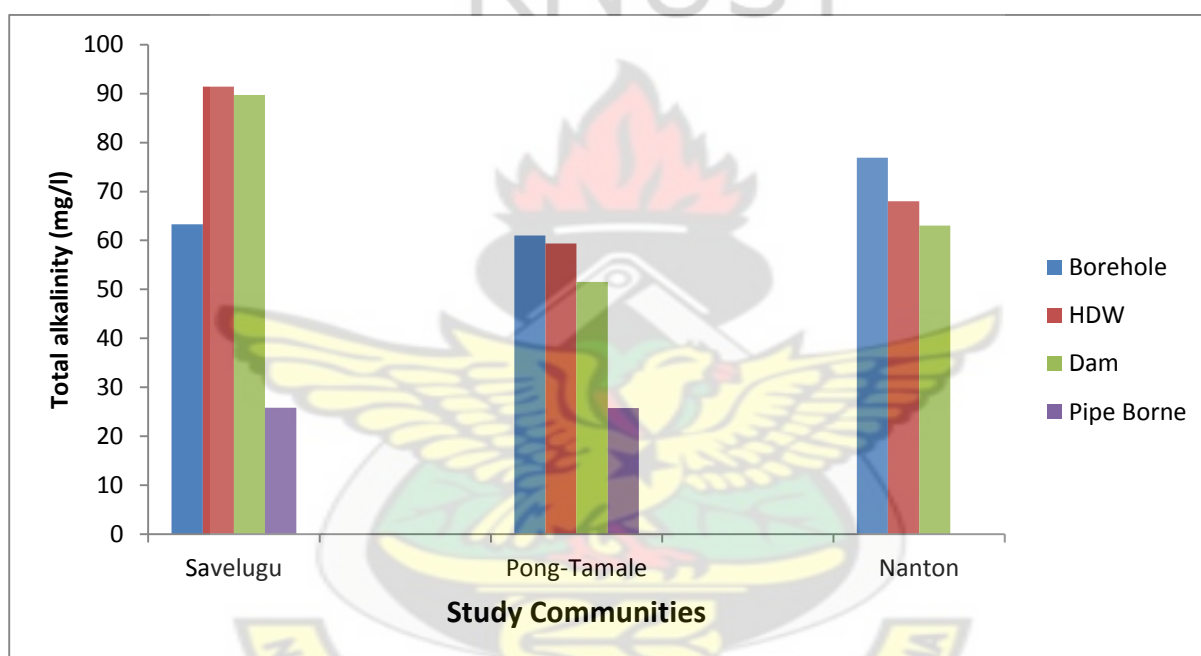


**Fig. 1: Comparative pH values of the water sources and the WHO acceptable value**

\*WHO LL- LIMIT, WHO UL-UPPER LIMIT.

#### 4.1.2 Total Alkalinity

Figure 2, shows that the lowest value for total alkalinity was found in the pipe borne water of Pong-Tamale (25.78mg/l) and Savelugu (25.81mg/l) followed by hand-dug wells (59.37mg/l), boreholes (61.03mg/l) and dams (61.53mg/l) of Pong-Tamale. The highest level was found in hand-dug wells (91.4mg/l) and dams (89.73mg/l) of Savelugu followed by boreholes (76.88mg/l) in Nanton. However, Savelugu boreholes had mean value of 63.32mg/l, hand-dug wells and dam of Nanton also had mean alkalinity values of 68.03 and 63.32mg/l, respectively.

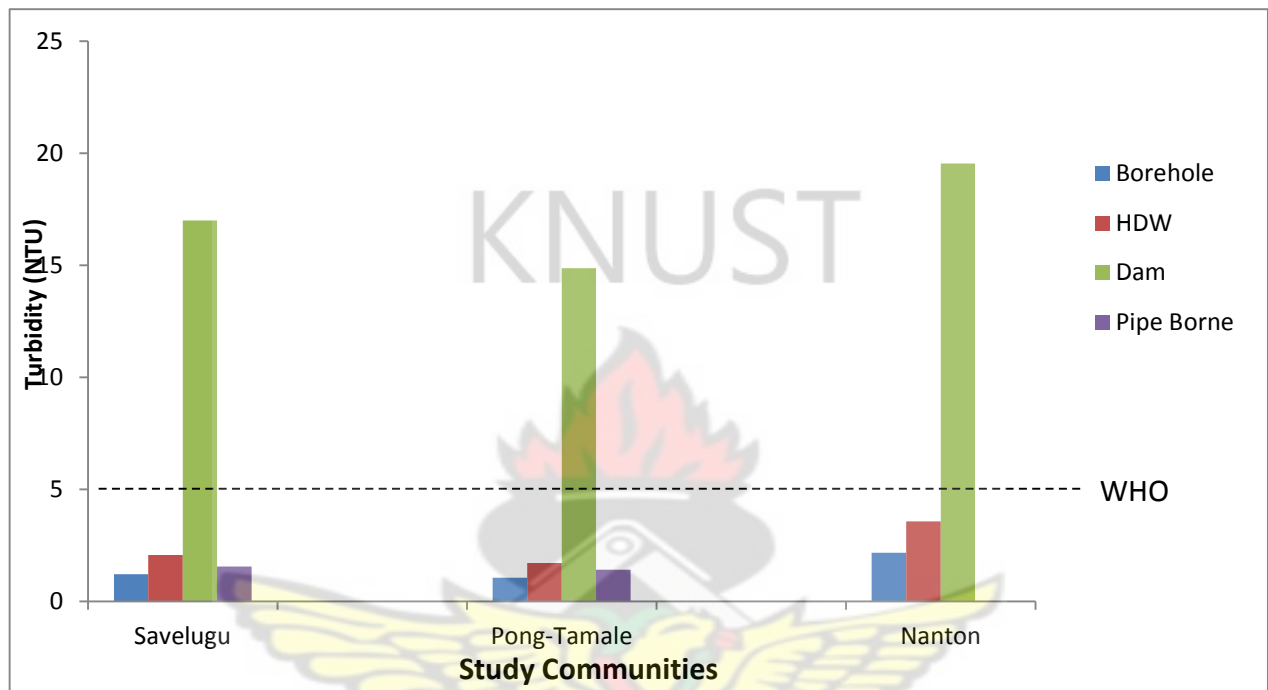


**Fig.2: Comparison of water sources of the sampling communities in terms of Total Alkalinity (TALK)**

#### 4.1.3 Turbidity

From figure 3, only one out of the four sources had their levels of turbidity above the limit of acceptable standard of drinking water of 5NTU according to WHO (2004). The level ranged from 1.06 to 19.55NTU. The highest mean turbidity was found in the dams of Nanton (19.55NTU), Pong-Tamale (17.00NTU) and Savelugu (14.87NTU).

The lowest mean turbidity was found in the borehole water of Pong-Tamale (106NTU) and Savelugu (1.22NTU) followed by the pipe borne water in Pong-Tamale (1.41NTU), Savelugu (1.55NTU) and Pong-Tamale hand-dug wells (1.77NTU). At Nanton, the hand-dug wells and boreholes had mean turbidity values of 3.57NTU and 2.17NTU.

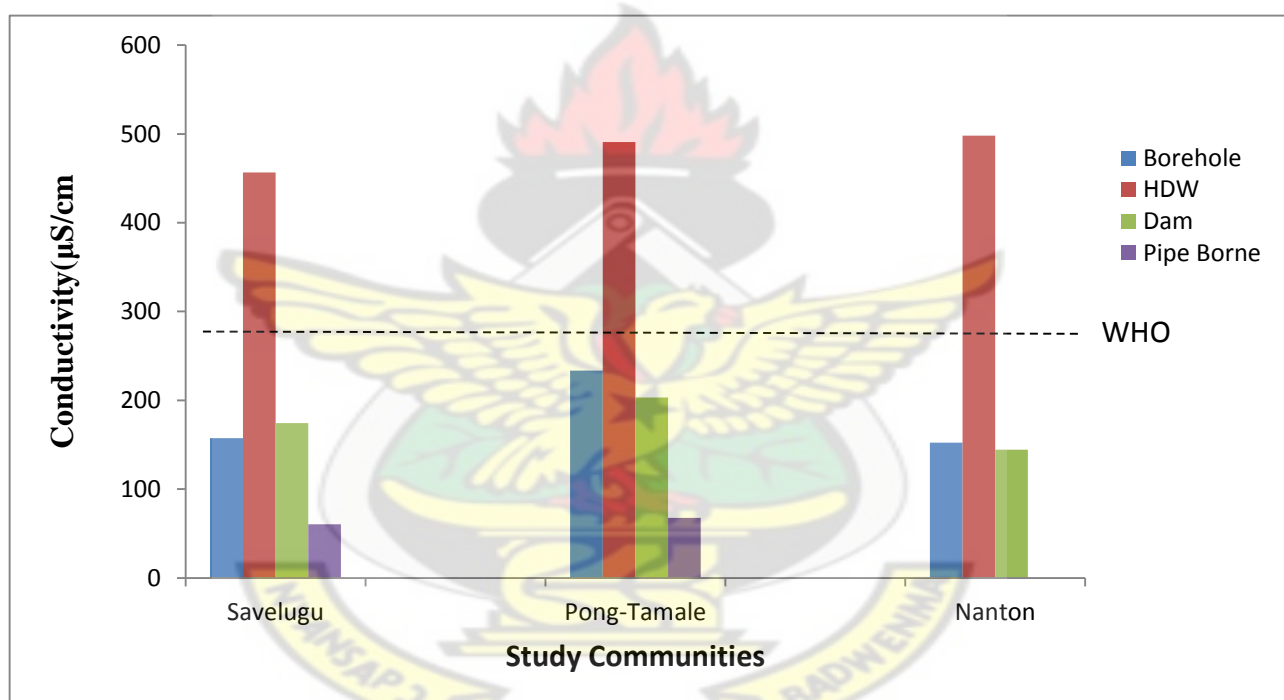


**Fig. 3: Comparison of water sources in terms of turbidity in the study communities.**

#### 4.1.4: Electrical Conductivity of water from study communities

The conductivity of water samples from the various sources ranged from 60.3 to 497.97 $\mu\text{S}/\text{cm}$  (Figure 4). The least level of conductivity was observed in pipe borne water of Savelugu (60.43  $\mu\text{S}/\text{cm}$ ) and Pong-Tamale (67.69  $\mu\text{S}/\text{cm}$ ) followed by Nanton dam (144.32 $\mu\text{S}/\text{cm}$ ), Nanton boreholes (152.50 $\mu\text{S}/\text{cm}$ ), Savelugu boreholes (157.45  $\mu\text{S}/\text{cm}$ ) and Savelugu dams (174.18 $\mu\text{S}/\text{cm}$ ).

The highest mean conductivity was found in hand-dug well water from Nanton (497.97  $\mu\text{S}/\text{cm}$ ), Pong-Tamale (490.71 $\mu\text{S}/\text{cm}$ ) and Savelugu (456.6  $\mu\text{S}/\text{cm}$ ) followed by Pong-Tamale dams (203.27 $\mu\text{S}/\text{cm}$ ).

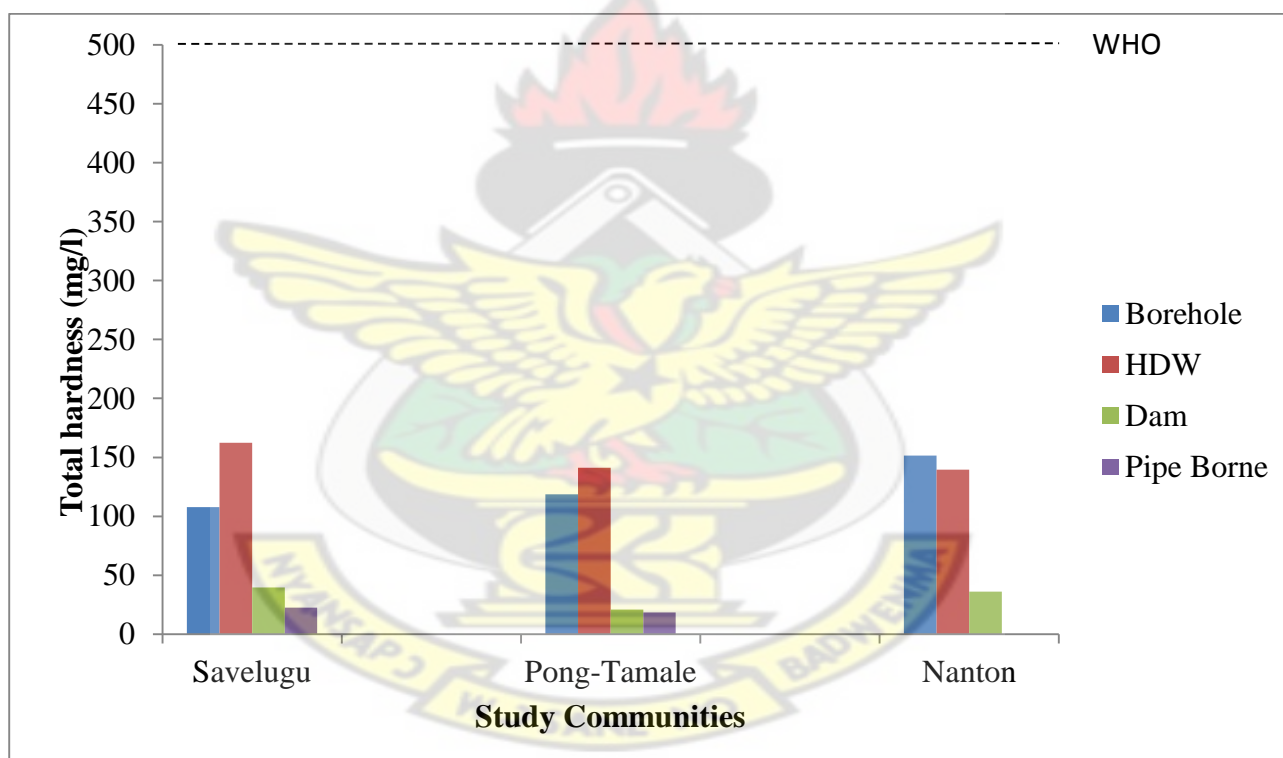


**Fig.4: Comparison of water electrical conductivity (EC) from the study communities.**

#### 4.1.5 Total hardness

Water hardness in this study from the boreholes for the three sampling communities were 107.67mg/l, 118.85mg/l and 151.5mg/l for Savelugu, Pong-Tamale and Nanton, respectively.

The minimum mean total hardness value was recorded at Nanton hand-dug well and the maximum at Savelugu. The mean total hardness of water from hand-dug wells for the three sampling sites were 139.67mg/l, 141.35mg/l and 162.33mg/l for Nanton, Pong-Tamale and Savelugu, respectively. The hand-dug well water from the three sampling communities is classified as medium and hard water sources. At savelugu and Pong-Tamale, the pipe-borne water had a total hardness 22.47mg/l and 18.33mg/l respectively. Mean total hardness of the dam water from Savelugu, Pong-Tamale and Nanton were 39.67mg/l, 20.83mg/l and 36.00 mg/l, respectively.



**Fig. 5: Comparison of water of total hardness (TH) from the sampling communities.**



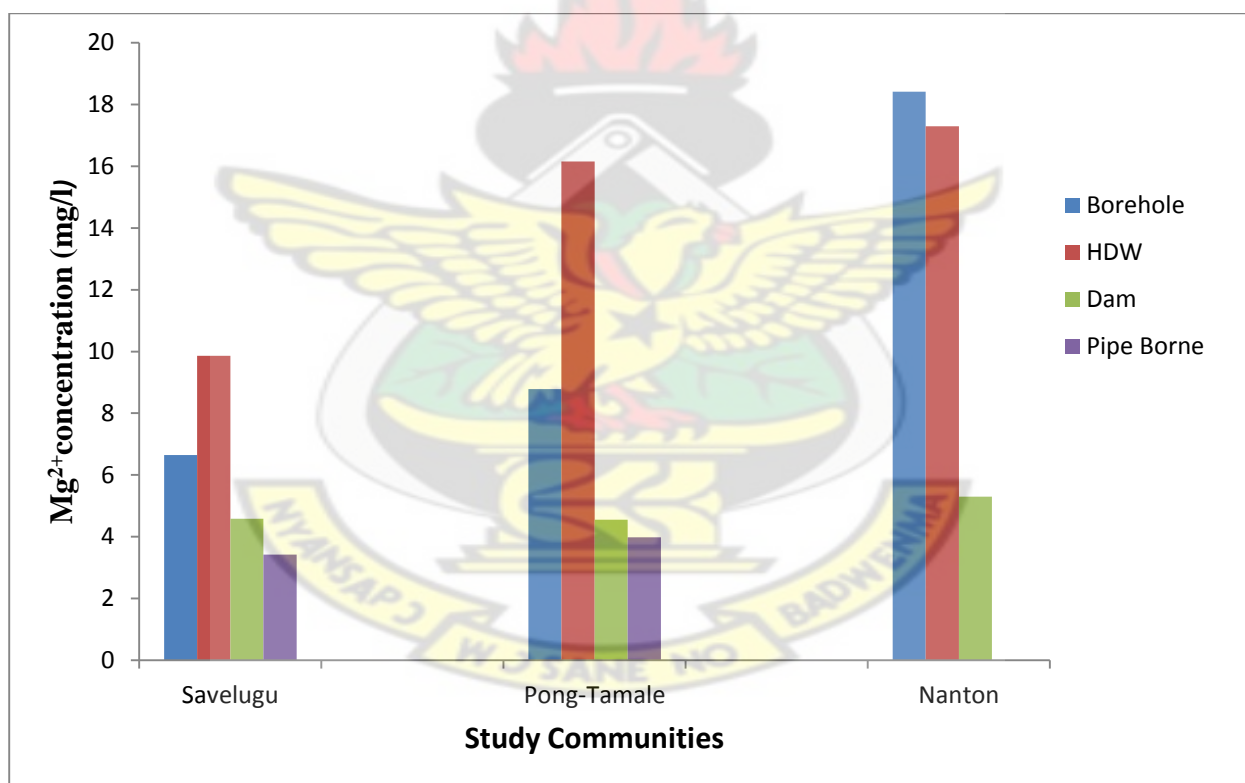
#### 4.1.6 Magnesium Ion $Mg^{2+}$

Magnesium ion concentrations of all the sources of water were within the WHO acceptable guideline value of 150mg/l (Figure6). The concentration ranged from 3.42 to 18.42mg/l

The mean magnesium ion concentration values for borehole water recorded for the sampling communities were 6.65mg/l, 8.78mg/l and 18.42mg/l for Savelugu, Pong-Tamale and Nanton, respectively.

The magnesium ion recorded for hand-dug well water from Savelugu, Pong-Tamale and Nanton were 9.86mg/l, 16.16mg/l and 17.30mg/l, respectively. However, pipe borne water for Savelugu and Pong-Tamale were 3.42mg/l and 3.98mg/l.

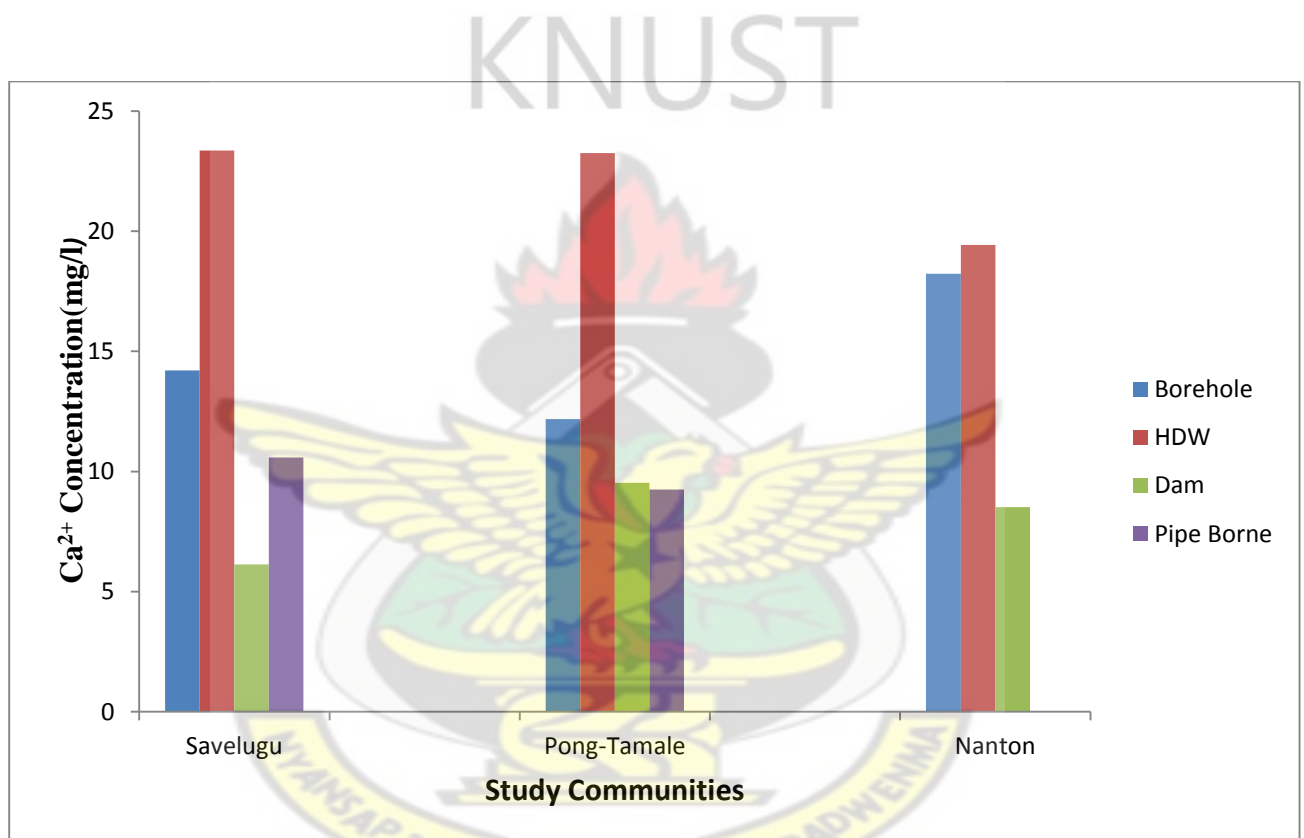
Dam water from Savelugu, Pong-Tamale and Nanton had a mean  $Mg^{2+}$  concentration of 4.58mg/l, 4.55mg/l and 5.30mg/l, respectively.



**Fig.6: Comparison of water sources in terms of magnesium ion concentrations of the three sampling communities.**

#### 4.1.7 Calcium ion ( $\text{Ca}^{2+}$ )

The mean calcium ion concentration ranged from 6.13 to 23.35mg/l. The mean  $\text{Ca}^{2+}$  concentrations for Savelugu and Pong-Tamale were recorded as 14.20mg/l and 12.18mg/l, respectively. The lowest calcium ion concentration was found in Savelugu dams (6.13mg/l), Nanton dams (8.52mg/l), Pong-Tamale dams (9.53mg/l), pipe borne water from Pong-Tamale (9.25mg/l) and Savelugu (10.58mg/l). The highest mean calcium ion concentration was also found in hand-dug well water from Savelugu (23.35mg/l), Pong-Tamale (23.25mg/l), Nanton (19.43mg/l) and Nanton dam borehole (18.22mg/l).

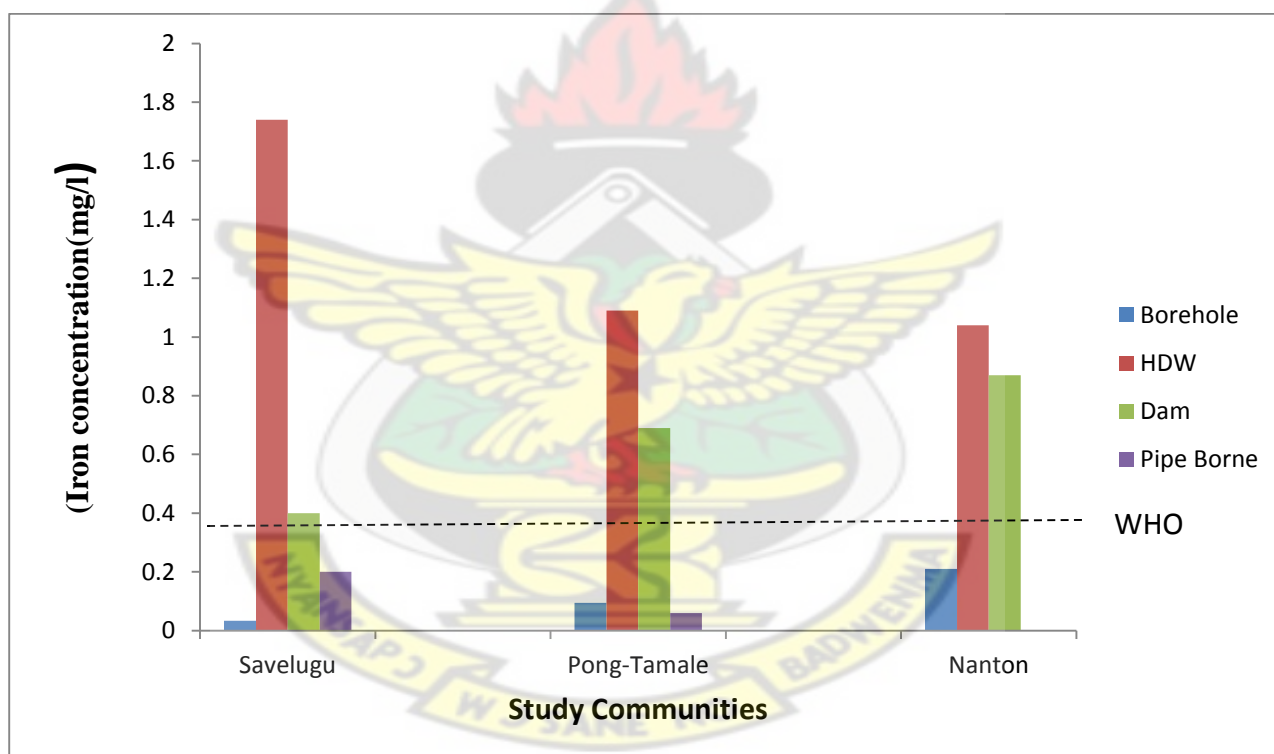


**Fig 7: Comparison of  $\text{Ca}^{2+}$  levels in water from the different water sources.**

#### 4.1.8 Iron

The mean concentration of iron in the water sampled from the sampling points ranged from 0.03 to 1.74mg/l. Mean concentration of iron for the Savelugu borehole (0.033mg/l), Pong-Tamale borehole (0.095), Nanton boreholes (0.21mg/l), Savelugu pipe-borne water (0.2mg/l) and Pong-Tamale pipe borne water (0.06mg/l) were within the WHO guideline limit of 0.3mg/l.

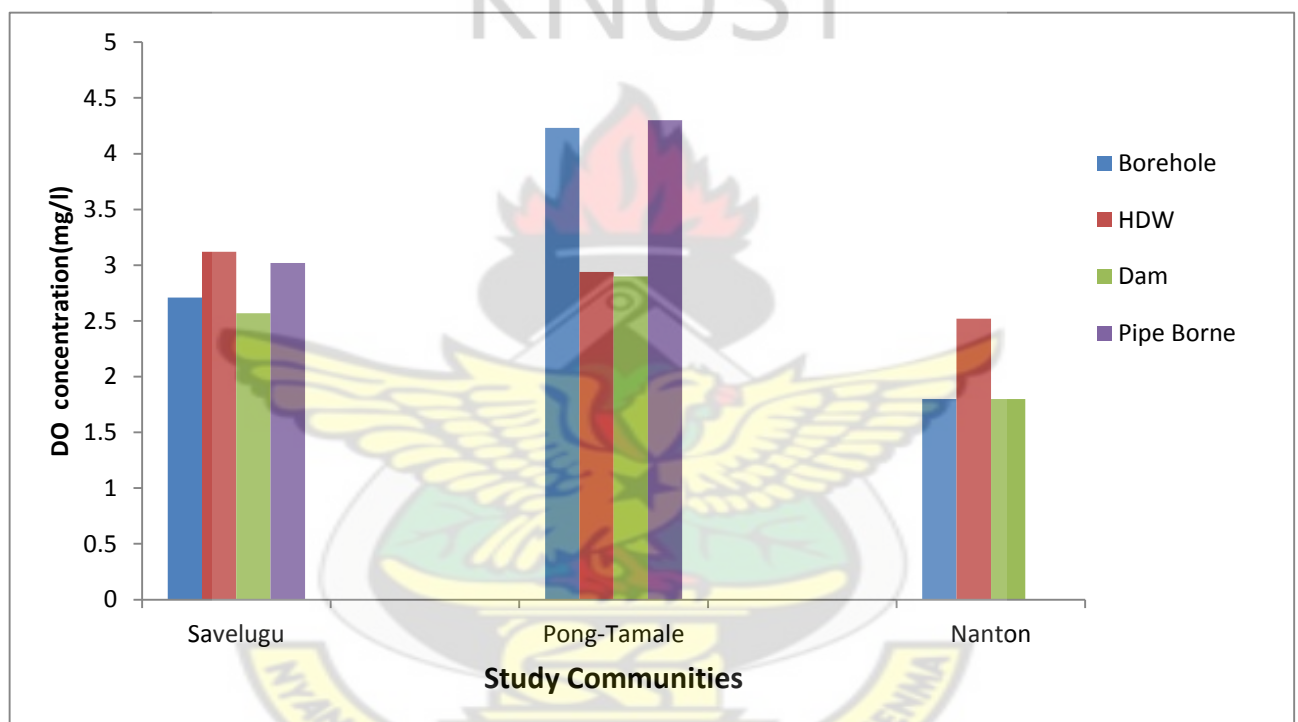
At Savelugu, Pong-Tamale and Nanton, the mean iron concentrations of water from hand-dug wells, recorded for the period were 1.74mg/l, 1.09mg/l and 1.04mg/l, respectively. The dam water from Savelugu, Pong-Tamale and Nanton were also found to be 0.4mg/l, 0.69mg/l and 0.87mg/l, respectively. Dam water from these sampling communities was above the WHO guideline limit of 0.3mg/l.



**Fig. 8: Comparison of iron concentration in water from the study communities.**

#### 4.1.9 Dissolved Oxygen (DO)

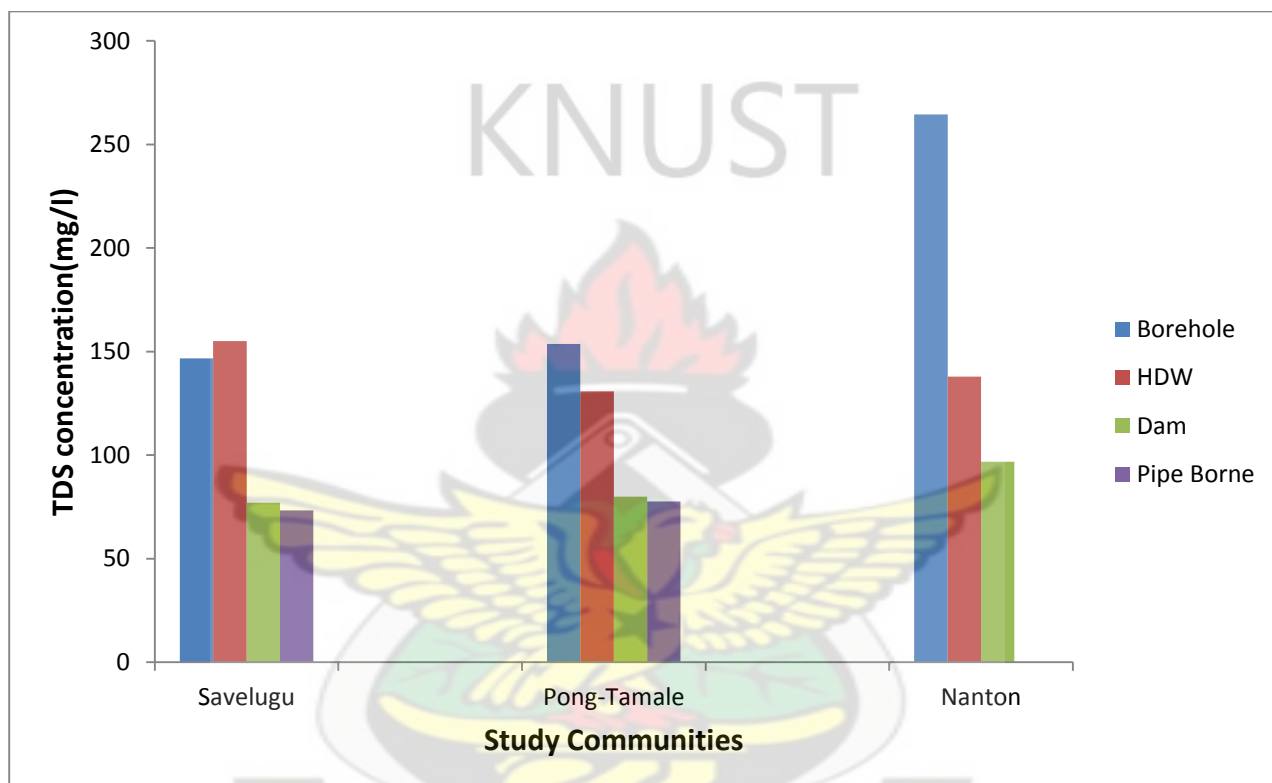
The lowest mean value for dissolved oxygen content was found in Nanton borehole (1.80mg/l), Nanton dam (1.80mg/l), Nanton hand-dug well (2.52mg/l) and Savelugu dam (2.57mg/l). The highest was found in Pong-Tamale pipe borne water (4.30mg/l) and borehole (4.23mg/l), Savelugu borehole (3.12mg/l) and Savelugu pipe borne water (3.02mg/l). At Savelugu and Pong-Tamale, the mean dissolved oxygen recorded from hand- dug well water was 3.12mg/l and 2.94. However, the mean dissolved oxygen of Pong-Tamale dam was 2.90mg/l.



**Fig. 9: Comparison of DO concentrations of the water from the sampling communities.**

#### 4.1.10 Total Dissolved Solids (TDS)

The total dissolved solids for the boreholes in Savelugu, Pong-Tamale and Nanton were 146.72mg/l, 153.65mg/l and 264.47mg/l, respectively. For hand-dug wells the mean TDS were 155.1mg/l, 130.81mg/l and 137.93mg/l. Mean total dissolved solids for pipe borne water in Savelugu and Pong-Tamale were found to be 73.25mg/l and 77.70mg/l respectively. 77.10mg/l, 79.96mg/l and 96.83mg/l recorded for Savelugu, Pong-Tamale and Nanton dam respectively.



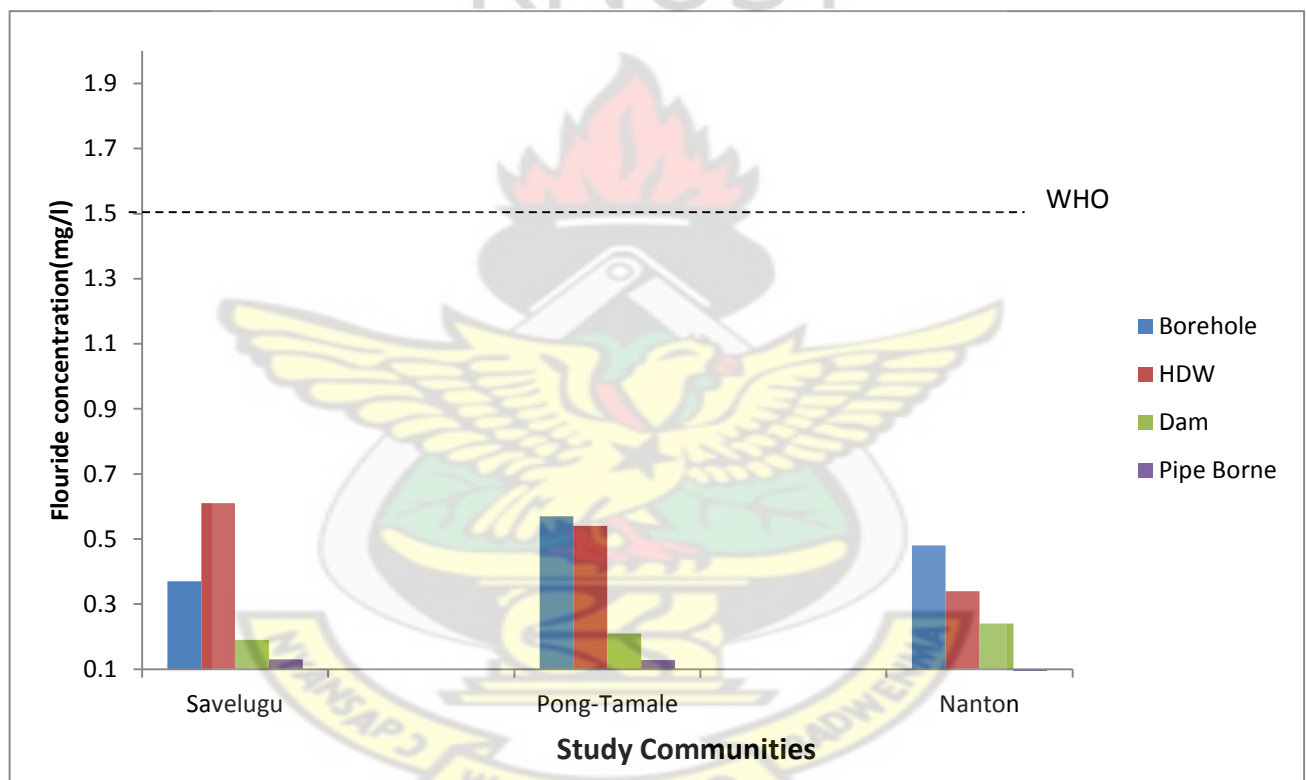
**Fig. 10: Comparison of Total dissolved solids (TDS) in water from the three sampling communities.**



#### 4.1.11 Fluoride

Fluoride content value recorded range between 0.19 to 0.61mg/l. All the sources of drinking water in the sample communities had acceptable levels of fluoride as prescribed by the WHO guideline (value of 1.5 mg/l). The lowest level was found in pipe borne water of Savelugu and Pong-Tamale (0.13mg/l), dams of Savelugu (0.19mg/l), Pong-Tamale (0.21mg/l) and Nanton (0.24mg/l). Borehole water had mean fluoride concentration of 0.37mg/l for Savelugu, 0.57mg/l for Pong-Tamale and 0.48mg/l for Nanton.

The highest fluoride content was found in water from hand-dug wells in Savelugu (0.61mg/l). However, hand-dug wells from Pong-Tamale and Nanton had values of 0.54mg/l and 0.34mg/l, respectively.

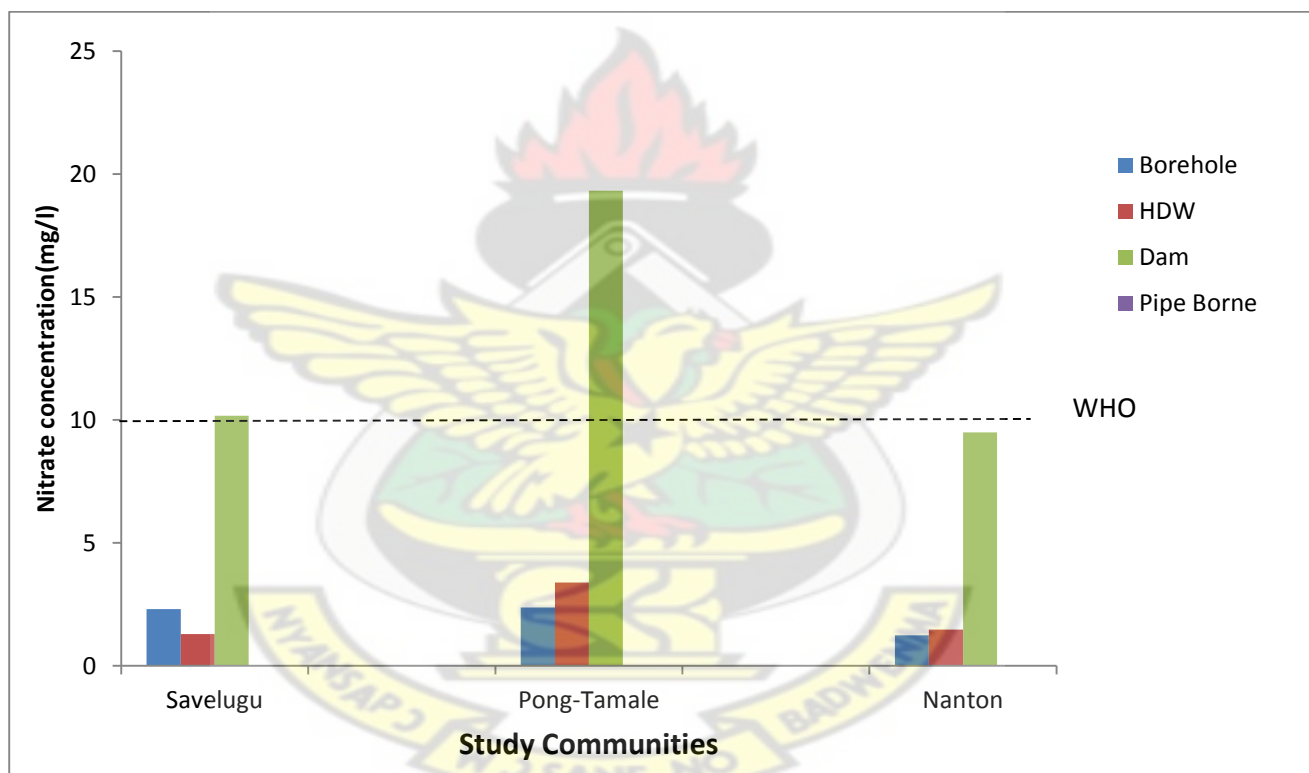


**Fig 11: Comparison of fluoride concentrations of water in the sampling communities.**

#### 4.1.12 Nitrate

From Figure 12, all the sources of water had levels of nitrate content which met the WHO guideline standard value of 10 mg/l except dam water from Savelugu (19.33mg/l) and pong-Tamale (10.17mg/l). The mean nitrate content values ranged from 0.005 to 19.33mg/l. The borehole water from Savelugu, Pong-Tamale and Nanton towns had mean nitrate concentrations of 2.31mg/l, 2.37mg/ and 1.24mg/l, respectively.

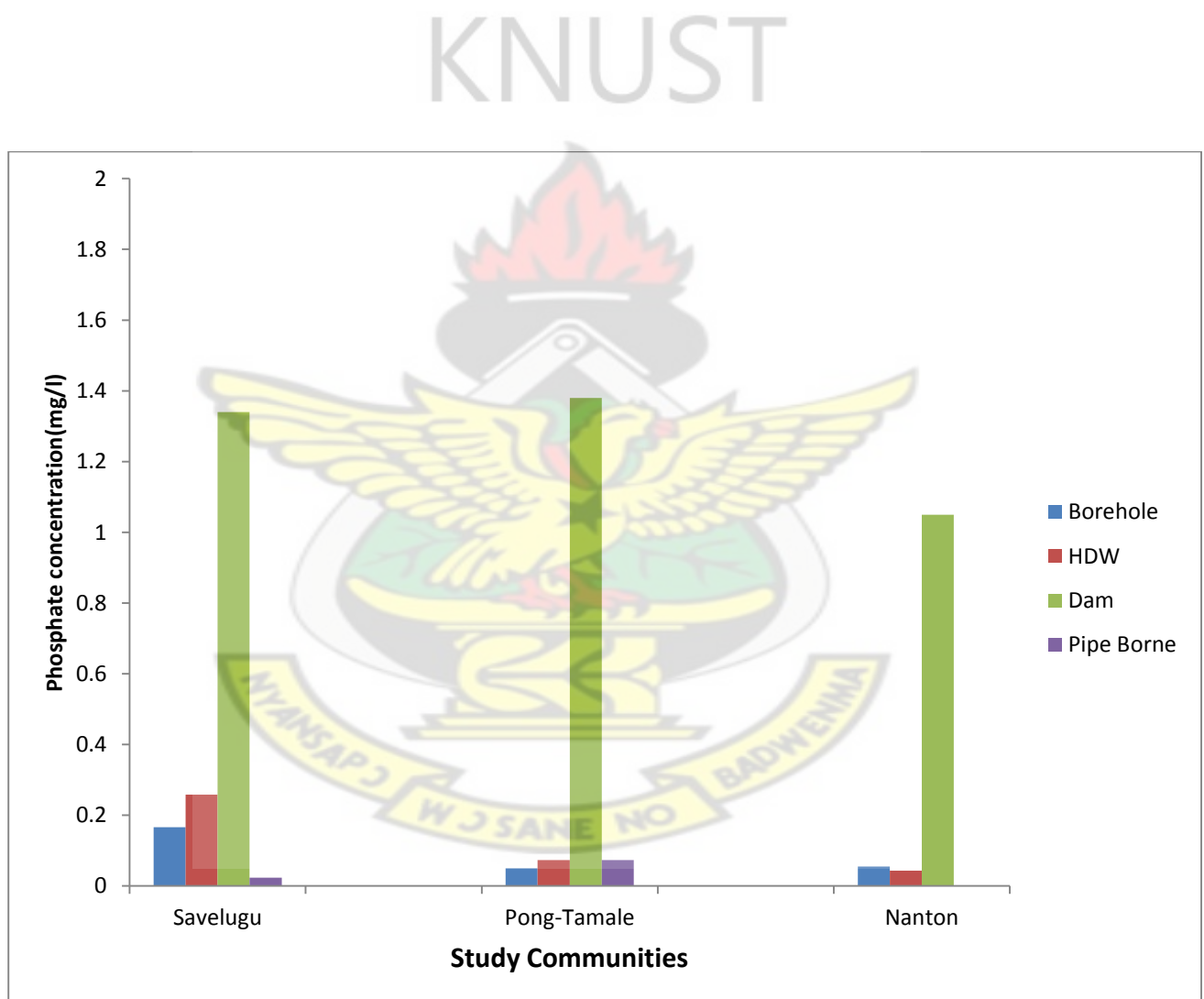
Savelugu and Pong-Tamale taps had the lowest mean nitrate concentrations values of 0.005mg/l and 0.005mg/l, respectively. At Savelugu, Pong-Tamale and Nanton towns, the hand-dug wells water recorded mean nitrate concentrations of 1.29mg/l, 3.39mg/l and 1.48mg/l, respectively. Mean nitrate concentration of Nanton dam was 9.50mg/l.



**Fig.12: Comparison of Nitrate concentrations of water in the sampling communities.**

#### 4.1.13 Phosphate

As indicated in figure in 13, the level of phosphate ranged from 0.023 to 1.38mg/l. The lowest value was found in Savelugu pipe borne water (0.023mg/l), Pong-Tamale boreholes (0.050mg/l), Nanton hand-dug wells (0.043mg/l) and Pong-Tamale taps (0.073mg/l). The highest mean phosphate concentrations were found in the dams of Pong-Tamale (1.38mg/l), Savelugu (1.34mg/l), Nanton (1.11mg/l) and Savelugu hand-dug wells (0.258mg/l). However, boreholes in Savelugu and Nanton had phosphate content of 0.166mg/l and 0.055mg/l, respectively.

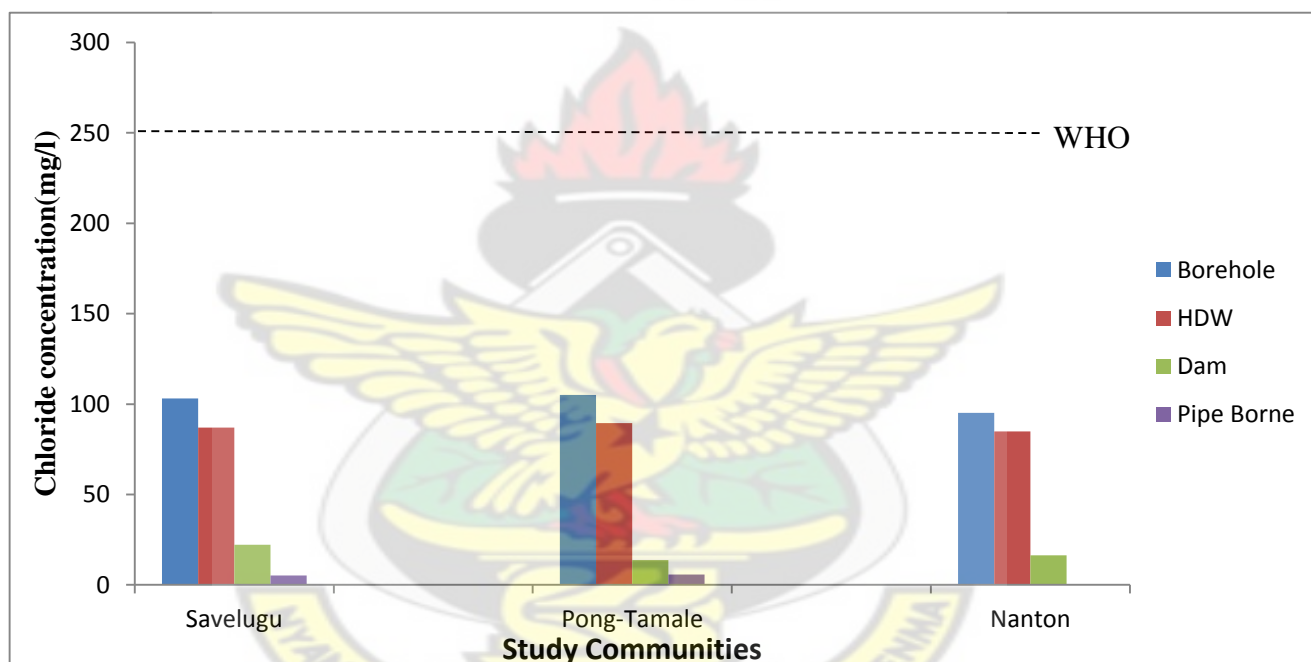


**Fig.13: Comparison of water sources in terms of phosphate concentration**

#### 4.1.14 Chloride

The highest chloride concentration was found in the boreholes of the sampling communities. The mean chloride concentration of borehole water from Savelugu, Pong-Tamale and Nanton were 103.17mg/l, 105mg/l and 95.17mg/l, respectively. The hand-dug well water from Savelugu, Pong-Tamale and Nanton followed the boreholes with mean concentrations of 87.00mg/l, 89.5mg/l and 84.83mg/l, respectively.

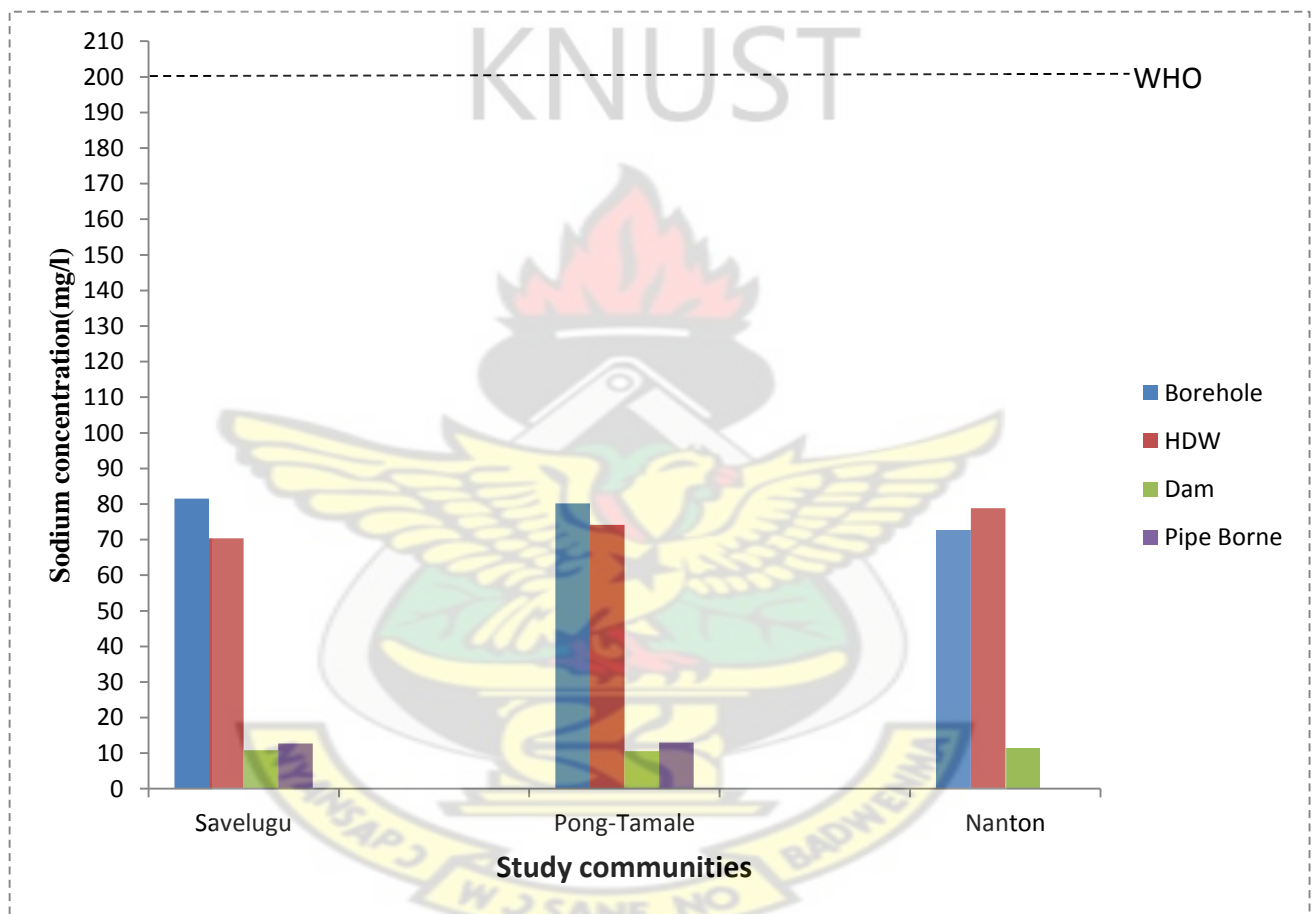
Chloride concentrations in pipe-borne water from Savelugu (5.17mg/l) and Pong-Tamale (5.67mg/l) had the lowest values. The dams in the three sampling communities had mean chloride concentrations of 22.17mg/l for Savelugu, 13.67mg/l for Pong-Tamale and 16.33mg/l for Nanton.



**Fig. 14: Comparison of chloride concentration in water from the various water sources in the three sampling communities.**

#### 4.1.15 Sodium

The sodium levels of the various sampling points ranged from 10.67 to 81.50mg/l. They were all within the WHO acceptable standard (200mg/l). The highest level was found in Savelugu borehole (81.50mg/l) followed by Pong-Tamale borehole (80.17mg/l), Pong-Tamale hand-dug well (78.83mg/l), Savelugu hand-dug well (74.17mg/l), Nanton borehole(72.73mg/l) and Savelugu hand-dug wells(70.33mg/l). The least Sodium concentration was found in the dams of Pong-Tamale (10.67mg/l), Savelugu (10.83 mg/l), Nanton (11.50mg/l) and pipe-borne water from Savelugu (12.69mg/l) and Pong-Tamale (12.96mg/l).

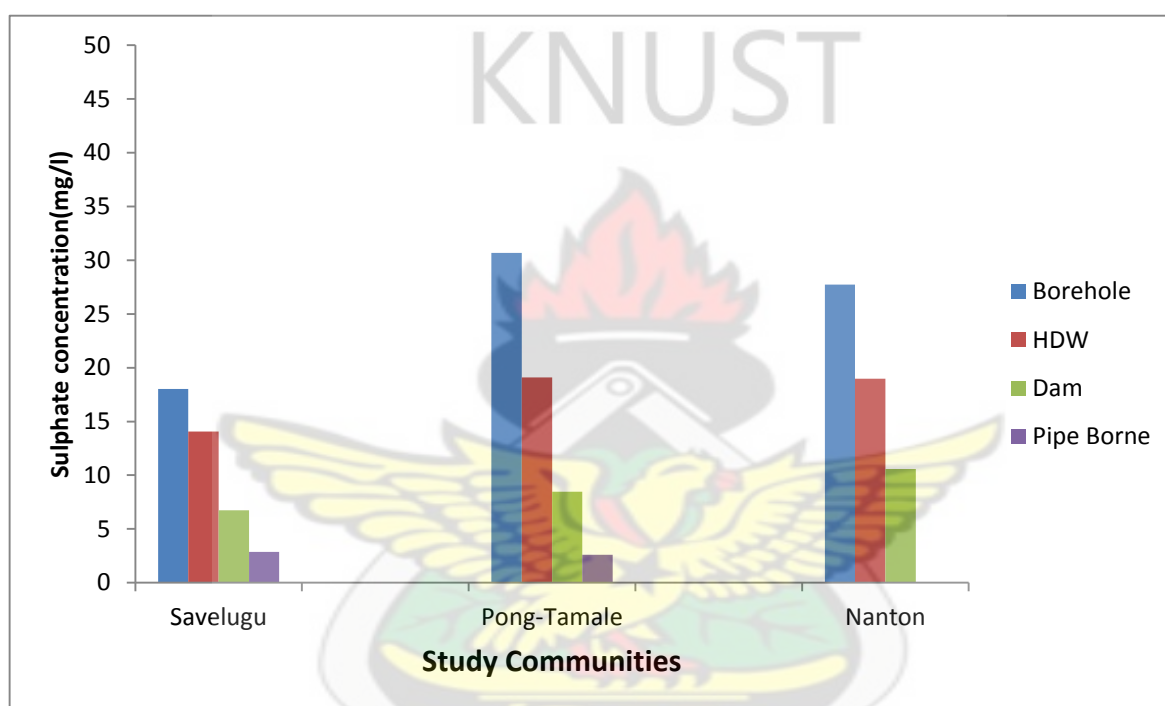


**Fig.15: Comparison of sodium concentration in different water sources in the three sampling communities.**



#### 4.1.16 Sulphate ion

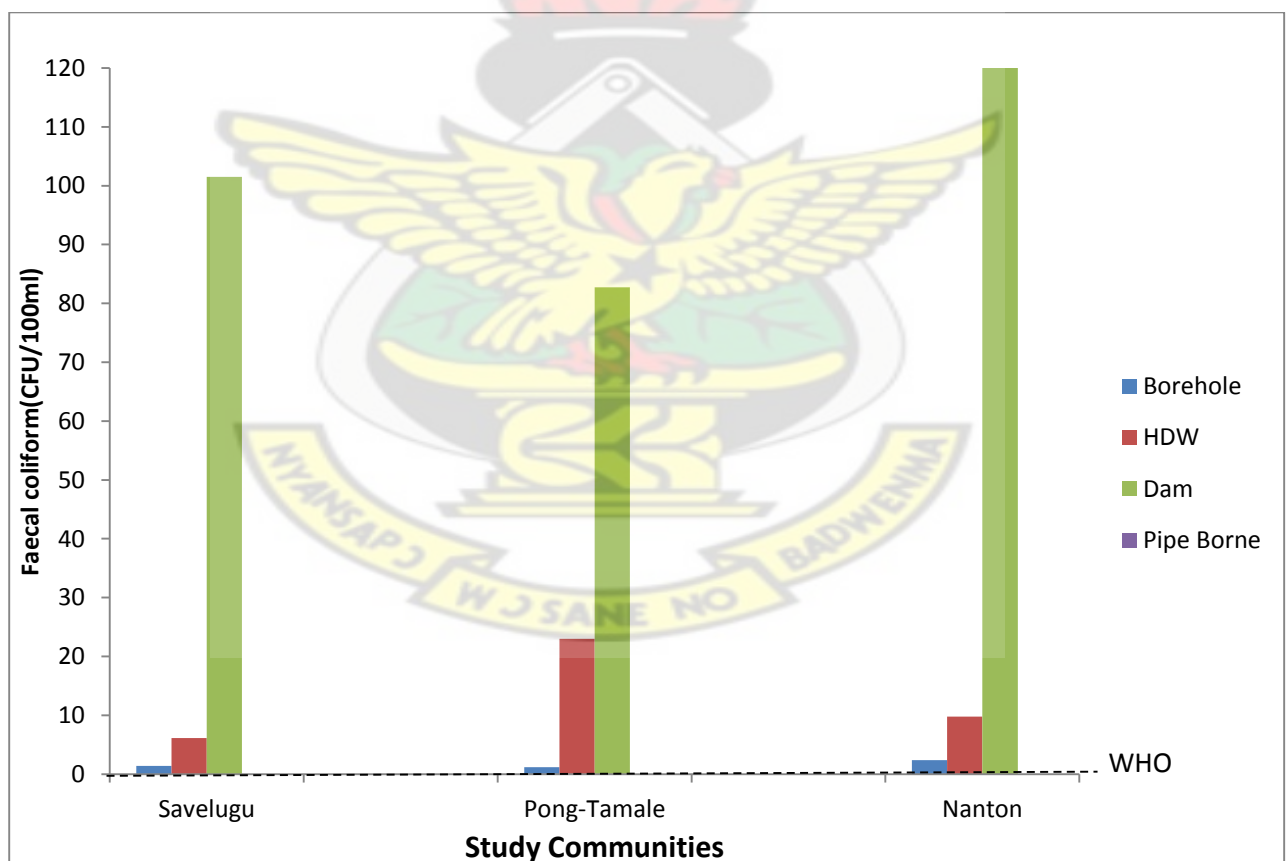
The concentration of phosphate in the water sampled from the sampling points ranged from 2.61 to 30.68mg/l (figure 16). The high levels were observed in Pong-Tamale borehole (30.68mg/l) followed by Nanton dam (27.74mg/l), Pong-Tamale hand-dug wells (19.09mg/l), Nanton hand-dug wells (18.98mg/l) and Nanton boreholes (18.03mg/l). The least was observed in the pipe borne water from Savelugu (2.86mg/l) and Pong-Tamale (2.61mg/l). The dam water had mean sulphate concentrations of 6.74mg/l, 8.45mg/l and 10.57mg/l for Savelugu, Pong-Tamale and Nanton ,respectively.



**Figure 16: Comparison of sulphate concentration in the water from the different water sources in the three sampling communities.**

#### 4.1.17 faecal coliform

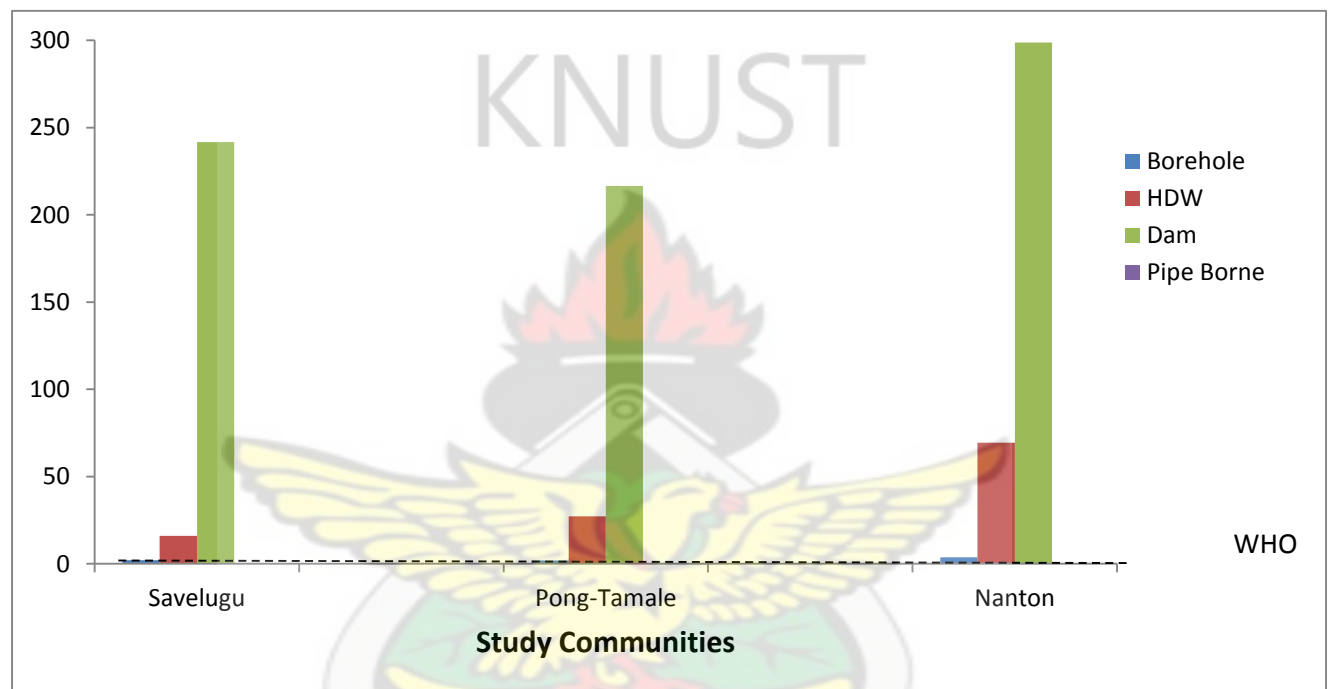
Faecal coliforms were not detected in the pipe- borne water from Savelugu and Pong-Tamale. From figure 17, the highest mean faecal coliform counts were found in the dams and hand-dug wells. The borehole water from Savelugu recorded 1.4 cfu/100ml. Pong-Tamale and Nanton had a mean faecal coliform count of 1.2cfu/100ml and 2.2cfu/100ml, respectively. The hand-dug wells had mean faecal coliform for Savelugu, Pong-Tamale and Nanton as 6.12cfu/100ml, 23cfu/100ml and 9.77cfu/100ml, respectively. The dams in Savelugu, Pong-Tamale and Nanton also had mean faecal coliform counts of 101.52cfu/100ml, 82.75cfu/100ml and 120.29cfu/100ml, respectively.



**Fig. 17: Comparison of faecal coliform (FC) counts in the water from different sources in the three sampled communities.**

#### 4.1.18 Total coliform

Figure 18 shows no total coliform in the tabs. Borehole water from Savelugu, Pong-Tamale and Nanton recorded 2.14cfu/100ml, 1.91cfu/100ml and 3.80cfu/100ml, respectively showing the lowest counts. Water from hand-dug wells in Savelugu, Pong-Tamale and Nanton had mean total coliform values of 16.02cfu/100ml, 27.20cfu/100 and 69.40cfu/100ml respectively. The dams had mean total coliform counts of 241.8cfu/100ml, 216.5cfu/100ml and 298.8 cfu/100ml for Savelugu, Pong-Tamale and Nanton, respectively indicating the highest.



**Fig.18: Comparison of Total coliform (TC) in the water from different water sources in the three sampled communities.**

## CHAPTER 5

### DISCUSSION

#### 5.1.1 Water pH

The pH of water from all the sources in the sampling communities varied between 6.63 and 7.67. The pH values of boreholes, hand-dug wells, tabs and dams of all the three sampling communities were within the WHO acceptable guideline value of 6.5 - 8.5 , although boreholes from the three communities were slightly basic which can be seen from its pH values. About 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 human health, all 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 significantly at all the sampling sources sampled in the district (ANOVA Table 1).

The pH of Hand-dug well water varied between 7.45 and 7.65 in the district. From the ANOVA Table 2, the concentration level of water from the hand-dug wells did not vary significantly at the three sampling communities in the district. This may be attributed to the almost homogeneous geological materials, mainly sedimentary rocks that underlie the study area (Dickson and Benneh, 2004). However, the pH of pipe borne water in Savelugu and Pong-Tamale ( $P = 0.376$ ) did not also show any significant difference. This may be attributed to the fact that the pipe borne water in the two towns is drowned from the same river at Naabogu. The pH values of the water from Savelugu, Pong-Tamale and Nanton dams were also within the WHO acceptable guideline value of 6.5 to 8.5, although the water from Pong-Tamale and Nanton dams were slightly alkaline but Savelugu dam was slightly acidic. The low mean pH may be due to the build-up of dissolved gasses such as  $\text{CO}_2$  and  $\text{NO}_2$  from decaying aquatic plants and animals in the dam body. These dissolved gasses are acidic and might have reacted with the  $\text{OH}^-$  ions in the dam. In this study, the mean pH of the boreholes, dugouts, pipe borne water and dam water sources in Savelugu, Pong-Tamale and Nanton areas were within the WHO acceptable guideline value of 6.5-8.5 which indicates the “safe range” of drinking water in these communities. No skin diseases were recorded in the 2011/2012 annual report of Savelugu Municipal Hospital.

### 5.1.2 Total Alkalinity

Drinking water from the sampling areas generally had low total alkalinity concentration ranging from 25.78 to 91.4mg/l and fell within the WHO acceptable maximum limits for drinking water (1000mg/l). From the ANOVA Table 3, there was a significant difference between the means of all the sampled sources of water from Savelugu, Pong-Tamale and Nanton. The higher level of alkalinity observed in the dams and hand-dug wells of savelugu may be due to the leaching of  $\text{CaCO}_3$  in to the ground as a result of agricultural activities around the dams.

The total alkalinity value was increasing as the rains start coming, this could be attributed to the leaching of  $\text{CaCO}_3$  from limestone and alkaline fertilizers from cultivated fields by rainwater percolation into the soil, and this may have increased the total alkalinity of the hand-dug well water. In terms of geographical location, no significant difference of total alkalinity was recorded between the borehole water from the three communities in the district at 0.05 significant levels. This may be attributed to the almost homogeneous geological materials, mainly sedimentary rocks that underlie the study area (Dickson and Benneh, 2004). The sedimentary rocks are sources of  $\text{CaCO}_3$  which makes borehole water alkaline in the study towns.

### 5.1.3 Turbidity

Turbidity levels as a result of amount of suspended solids present in the water body was, however, very much lower than WHO guideline value of 5NTU, in exception of water from dams in the three communities. The mean turbidity levels in all the sources sampled vary significantly (ANOVA Table 4). The means turbidity of the borehole water for the three communities ranged from 1.06 to 2.17NTU. The low recharge in the dry season may have resulted in lower turbidity of the borehole water. Generally, the low turbidity of the borehole water from the communities may be due to the fact that groundwater is naturally filtered by the soil and extracted by filter-aided mechanical pumps.

Savelugu, Pong-Tamale and Nanton hand-dug well water had mean turbidity values of 2.07 and 3.57NTU. The relatively high turbidity at Pong-Tamale and Nanton as compare to Savelugu may be due to the high dependency on the hand-dug wells. In this study, the mean turbidity of the borehole, hand-dug well and pipe borne water sources in Savelugu, Pong-Tamale and Nanton areas were within the WHO acceptable guideline value of 5 NTU which indicates the “safe range” of drinking water.



Water from the dams of Pong-Tamale, Savelugu and Nanton had the highest turbidity. During rainfalls, it is possible runoffs erode soil particles and nutrients from farmlands into the dam water. The presence of the nutrients can enhance the growth of micro-organisms and aquatic plants in the dam. In the dry season, the recession in water level coupled with the decay of micro-organisms and aquatic plants may have contributed to the high turbidity of water in the dam. During water scarcity period, humans and cattle herd activities also contribute significantly to high turbidity in the water. Turbidity like total suspended solids (TSS) is higher in surface water samples, followed by shallow well samples and lowest in borehole samples confirming a relationship between turbidity and total suspended solids (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.

#### **5.1.4 Electrical Conductivity of water from study communities.**

According to WHO (2006) electrical conductivity of water above 300 $\mu$ S/cm can affect its suitability for domestic use. The mean conductivity varied significantly in all the sampling points (ANOVA table 5). According to literature conductivity is affected by temperature. Since the samples were taken in the dry season conductivity of the borehole water was higher. High temperatures might have enhanced the mobility of the inorganic particles in the aquifer. However, the presence of carbonates, for instance NaHCO<sub>3</sub> in the aquifer may give salty taste to the borehole water leading to its rejection. However, alkali carbonates resulting from meteoric water dissolving Na<sup>+</sup> from sodium-bearing silicates (eg. Albite) or reverse cation exchange where Ca<sup>2+</sup> is taken up from the groundwater, in return for Na<sup>+</sup> may help to refresh the water quality and prevent it from having salty taste (Dickson and Benneh, 2004).

The hand-dug wells in the three communities 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).

The sampled dams recorded relatively low conductivity values which were below WHO guideline value of 300 $\mu$ S/cm. Conductivity recorded in Savelugu and Pong-Tamale tabs were

also within the guideline value. The recession in water level and the settlement of dissolved solids at the bottom of the dam might have resulted in the low conductivity in the season. Payne (1993) in his study farm waste and nitrate pollution established that low inflows and high temperature in the dry season decreases the conductivity of dam water.

#### **5.1.5 Total hardness**

According to WHO (2006) domestic water of total hardness above 500 mg/l is not recommended due to potential scale formation. Water hardness in this study varied widely with values ranging from 18.33 to 162.3mg/l. These values were, however, within WHO maximum contaminant value of 500mg/l.

Water hardness in this study for the boreholes of the three sampling communities ranged from 107.67 to 151.5mg/l. The relative higher values recorded for the hardness of water from Pong-Tamale and Nanton borehole may be due to the presence of higher concentrations of dissolved calcium and magnesium in these water sources (Fig 6&7). From ANOVA table 6, there was no significant difference in all the water sources from the three communities in the district. 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, Savelugu borehole (107.67mg/l) and Pong-Tamale borehole (118.85mg/l) are classified as medium hard water sources whilst Nanton borehole is also classified as hard water source. Soft water lathers well with soap where as hard water does not. In general, all the sampled sites fell within WHO guidelines for drinking water quality even though they are far below the recommended value of 500 mg/l.

Total hardness of water from hand-dug wells in the study communities varied between 139.67 and 162.33mg/l. These notwithstanding, all the values fell within the WHO guidelines for drinking water quality. A study by Olobaniyi (2007) of groundwater established that  $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  ions are usually released into groundwater by the dissolution of limestone, feldspars and micas which increases water hardness. The low total hardness in the season may be the result of low aquifer recharge, hence less dissolution of the mineral composition of the aquifer. The hand-dug well water from the three sampling communities is classified as medium and hard water sources. The total hardness recorded for pipe borne in the two sampling communities were very small and were far below the WHO guideline values for drinking water quality.

Mean total hardness of the dam water from Savelugu, Pong-Tamale and Nanton were 39.67mg/l, 20.83mg/l and 36.00 mg/l, respectively. The high temperatures combined with the recession in water level of the dams may have concentrated the calcium and magnesium ions in the dam. However, there was significant difference of total hardness between dam water from Savelugu, Pong-Tamale and Nanton ( $P=0.0002$ ) at 0.05 significance level. The difference may be because of the activities that take place at the dams at different times. In general, the total hardness values recorded in all the sampling communities were negligible and far below the WHO guideline values for drinking water quality.

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

All the samples recorded low magnesium ion concentration which were far below the WHO recommended guidelines of drinking water quality (150mg/l). There was no statistically significant difference in magnesium ion concentration in the water sources from Savelugu, Pong-Tamale and Nanton ( $P=0.149$ ). This may be attributed to the almost homogeneous geological materials in the study towns. 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 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.

Water from the hand-dug wells from the three communities had magnesium ion concentration far below the WHO guideline limit of 150mg/l. Pipe-borne water for Savelugu and Pong-Tamale had the lower magnesium ion concentration (Fig.6). Dam water from Savelugu, Pong-Tamale and Nanton had a mean  $Mg^{2+}$  concentration ranged of 4.55 and 5.30mg/l. The magnesium ion concentration of the dam was far below the WHO recommended value for drinking water. This may also result in the dams having soft water sources which are mostly preferred by the people for washing.

However, no significant difference of magnesium ion between dam water from Savelugu, Pong-Tamale and Nanton ( $P=0.876$ ) at 0.05 significance level.

#### **5.1.7 Calcium ion ( $Ca^{2+}$ )**

Drinking water from the study areas were characterized by low  $Ca^{2+}$  concentrations all of which fell within the WHO maximum acceptable limits for drinking water (200mg/l). At 0.05 significance level, Savelugu, Pong-Tamale and Nanton ( $p=0.0078$ ) water sources varied

significantly. However, there was no significant difference of calcium ion concentration of borehole water from Savelugu, Pong-Tamale and Nanton ( $p=0.822$ ) at 0.05 significance level. This may be attributed to the almost homogeneous geological nature, mainly sedimentary rocks which are sources of Calcium ion that underlie the study area (Dickson and Benneh, 2004). However, the highest mean calcium ion concentration was found in hand-dug well water from Savelugu, Pong-Tamale. Nanton. In terms of the geographical location, there was no significance difference of calcium concentration in the hand-dug wells of the sampling communities (ANOVA table 7). There was no significant difference in calcium ion concentration in pipe borne water from Savelugu and Pong-Tamale ( $p= 0.283$ ) at 0.05 significance level. The statistically insignificant difference of the calcium concentration of pipe borne between Savelugu and Pong-Tamale may be because both have the same source of treatment. Between Savelugu, Pong-Tamale and Nanton ( $p = 0.705$ ), there was no significant difference at 0.05 significant level in calcium ion concentration of water from the dams. The level of  $\text{Ca}^{2+}$  ion 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.

#### **5.1.8 Iron**

Iron concentrations below 0.2mg/l are safe, but the taste of water is affected when it exceeds 0.3mg/l (WHO, 2006). Mean concentration of iron for the boreholes of the three sampling communities ranged from 0.033 to 0.21mg/l. There was a significant difference of iron concentration of water from boreholes in Savelugu, Pong-Tamale and Nanton ( $p = 0.013$ ) at 0.05 significance level.

The absence of heavy rainwater percolation at the time of the sample collection might be a reason for the relatively lower iron concentration of the borehole water. A study by Olobaniyi (2007) of the quality of groundwater and rainwater indicated that the occurrence of iron in the boreholes is due to the dissolution of iron from metallic wastes and scraps, and lateritic iron within the soil particles. Concentrations of iron in borehole and pipe borne water fell within the WHO maximum acceptable limit. However, Tay (2004) also reported low concentration of iron ranging from 0.001 to 1.94mg/l in ground water.

At Savelugu, Pong-Tamale and Nanton, the mean iron concentrations of water from hand-dug wells recorded for the period was high (Fig.8). The high iron concentrations recorded may



have resulted from the materials used in the construction of the hand-dug wells and the type of soil in which the wells have been constructed. However, sampled water from the hand-dug wells in the study area was characterised by high concentration of total iron and were above WHO maximum acceptable limits of 0.3mg/l.

The dam water from these sampling communities was above the WHO guideline limit of 0.3mg/l. There was a significant difference of iron concentration in dam water from; Savelugu, Pong-Tamale and Nanton ( $p = 0.056$ ) at 0.05 significance level. The relatively high iron level was due to run-offs that carried sediments containing iron particles into the dam.

#### **5.1.9 Dissolved Oxygen (DO)**

Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water. The mean concentration level of dissolved oxygen was significantly different in all the sources from the sampling communities (ANOVA 8). This could be attributed to the fact that dissolved oxygen content differs in surface and ground water. The mean dissolved oxygen content in the borehole water from Savelugu, Pong-Tamale and Nanton were 2.71mg/l, 4.23mg/l and 1.8mg/l, respectively. These results were comparable to those by Tiimub *et al.*, (2012). They reported a dissolved oxygen range from  $5.57 \pm 0.12\text{mg/L}$  -  $6.27 \pm 0.12\text{mg/L}$  for borehole water from both Achiase and Wabiri in the Ejisu Juabeng Municipality of the Ashanti region in Ghana. Dissolved oxygen content is typically low in deep aquifers, particularly if the aquifer contains organic matter. Stagnant water contains less dissolved oxygen accounting for low dissolved oxygen in the hand-dug wells.

There was no significant difference in the dissolved oxygen of pipe-borne water from Savelugu and Pong-Tamale ( $p = 0.151$ ) at 0.05 significance level. The pipe-born water in Savelugu and Pong-Tamale had high dissolved oxygen values (Fig.9). The high dissolved oxygen may be attributed to the treatment the pipe borne water might have undergone.

The dams in the sampling communities had low dissolved oxygen concentration throughout the period. In the dam the dissolved oxygen is used by aquatic organisms resulting in the reduction of the concentrations. High temperatures in the dry seasons may have also contributed to the low dissolved oxygen concentrations in the dams.

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

The total dissolved solids for the boreholes in Savelugu, Pong-Tamale and Nanton ranged from 73.25 to 264.47mg/l for all the water sources. The range of TDS values for the water



sources in the sampling area were comparable to 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 the Ashanti Region of Ghana. The total dissolved solid values obtained in this study were within WHO acceptable maximum contaminant limit of 1000mg/l.

The mean concentration of total dissolved solids of water from all the sources in the sampling communities varied significantly (ANOVA table 9) at 0.05 significance level. Generally, the surface water 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>).

#### **4.1.11 Fluoride**

WHO (2006) recommends that drinking water should ideally contain 0.5 - 1.5 mg/l fluoride to help prevent dental carries. The borehole water had mean fluoride concentration range of 0.37 and 0.57mg/l from the three sampling communities. This is in conformity with a range between 0.01 and 0.65mg/l observed for boreholes in the central Gonja District by Zakaria (2011). No significant difference occurred between the towns in terms of fluoride concentrations of the borehole water. There was no significant difference in fluoride concentration from borehole water in Savelugu, Pong-Tamale and Nanton ( $p = 0.111$ ) at 0.05 significant level. The presence of fluoride in the borehole may be indicative of granitic rock formation of the aquifer in the study area. The dissolution of granitic rock by rainwater percolation in the soil may have contaminated groundwater with fluoride. However, fluoride is highly reactive and might have reacted with other reactive metals in the rock formation leading to the lower values recorded. Most part of the district is made of sedimentary rock formation which might have accounted for the lower concentration in the study towns. Drinking water from the various sampling communities was characterized by low fluoride ion concentrations and was within WHO acceptable limits of drinking and potable water of 1.5 mg/l.

The pipe-borne water from Savelugu and Pong-Tamale recorded the lowest fluoride concentration. The mean fluoride concentration of water from dam of Savelugu, Pong-Tamale and Nanton were 0.19mg/l, 0.21mg/l and 0.24mg/l, respectively. Fluoride is very reactive and high temperatures in the dry season may have favoured its reaction with other

species in the dam during the period of data collection. However, the boreholes, hand-dug wells and dams had fluoride concentration below 1.5 mg/l (Fig.11). This might have accounted for no cases of dental fluorosis reported by the Savelugu District Hospital in the study area. Generally, 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).

#### **5.1.12 Nitrate**

All the sources of water had levels of nitrate concentration which met the WHO guideline standard value of 10 mg/l except dam water from Savelugu (19.33mg/l) and pong-Tamale (10.17mg/l). The mean content level of nitrate was significantly different in all the water sources from the sampling communities (ANOVA Table 10). The concentration of nitrate in these sources could be attributed to the natural occurrences of  $\text{NO}_3^-$  salts in the sediments of these sources. The values observed except dams of Savelugu and pong-Tamale falls within the reported WHO (2004) values that water naturally, contains less than 1 mg nitrate-nitrogen per litre. The borehole water from Savelugu, Pong-Tamale and Nanton towns had mean nitrate concentrations of 2.31mg/l, 2.37mg/l and 1.24mg/l, respectively. The presence of nitrates in the boreholes suggests the leaching of dissolved nitrogen from nearby farms facilitated by rainwater percolation into the groundwater. However, the low mean nitrate concentration in the borehole water may be due to the reduction of nitrate to nitrogen gas and ammonia by microbes (eg. nitrobacteria). A study on the modelling of groundwater flow and quality by Konikow and Glynn (2005) found that the presence of organic carbon in the soil may cause the reduction of  $\text{NO}_3^-$  to  $\text{NO}_2$  and sometimes to  $\text{NH}_4^+$  ions in the presence of denitrifying microbes. In Pong-Tamale, hand-dug wells are located within households and near gardens where fertilizer may dissolve and percolate to recharge groundwater.

Mean nitrate concentration in the dam water ranged from 9.50 to 19.33mg/l for the three sampling communities. The high nitrate concentration in the dam water of Pong-Tamale may be due to run-off that carried fertilizer particles from nearby cultivated land into the dams as indicated by Greenhalgh and Faeth (2001). The presence of nitrates may have facilitated the growth of water lily which was observed in the Pong-Tamale dam. The presence of nitrate can enhance the growth of aquatic plants by a process known as eutrophication in the rivers (Greenhalgh and Faeth, 2001).

### 5.1.13 Phosphate

Phosphate concentrations ranged from 0.023 to 0.258mg/l from all the sampling communities. The mean phosphate concentrations for hand-dug wells in Savelugu, Pong-Tamale and Nanton were lower than the dam water. Ansa-Asare *et al.*, (2006) recorded concentration ranging from <0.001 to 0.921mg/l in surface water in South Western Ghana. These results were comparable with those obtained in the present study. However, there was a significant difference in phosphate concentrations of water from all sources in Savelugu, Pong-Tamale and Nanton ( $p = 0.033$ ) at 0.05 significance level.

The higher levels of phosphate concentrations were observed in Pong-Tamale dam (1.38mg/l) and Savelugu dam (1.34mg/l). The least level was observed in Savelugu taps. Storm water runoff, agricultural runoff, erosion and sedimentation and direct input by animals/wildlife (Ricklef and Shluter, 1993) may have contributed to the relatively high levels of phosphate in the dam waters. However, concentrations in the groundwater may be due to natural decomposition of rocks and minerals that contain phosphates. The introduction of phosphorus in the form of phosphates in to aquatic environments is a major cause of eutrophication (Wagner, 1974; Lindsay *et al.*, 1960). Phosphorus is a vital nutrient for all living things, it occurs naturally, almost solely as phosphates. 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 potable water sources and usually not regulated (Nduka *et al.*, 2008).

### 5.1.14 Chloride

Chloride 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 water sources ( $p = 0.0004$ ). 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, chloride concentrations in pipe-borne water from Savelugu and Pong-Tamale were 5.17mg/l and 5.67mg/l, respectively. The pipe-borne water from the two sampling communities had the lowest chloride concentrations but did not also vary significantly ( $p = 0.0993$ ) at 0.05 significance level. The chloride concentration in the surface water was generally lower than that in the ground water. This result agrees with that of Hauser (2001),

which stated that chloride concentration is usually greater in ground water than in surface water.

#### **5.1.15 Sodium**

The water sources in the sampling communities had appreciably low sodium levels, ranging from 5.98 to 39.77mg/l but were below WHO maximum acceptable limits for drinking water (200mg/l). The highest level was found in Savelugu and Pong-Tamale boreholes though they were also below WHO maximum acceptable limits for drinking water. The higher level in Savelugu and Pong-Tamale may be due to mineral deposits in the sediment and the surrounding soil.

From the ANOVA Table 11, the average content of sodium was significantly different in all the source of water sampled in the district. In terms of geographic location water from boreholes of Savelug, Pong-Tamale and Nanton ( $P = 0.603$ ) were not significantly different. The lack of significant difference in the sodium concentration indicates that the study area had common sodium deposits. Sodium ion has positive correlation with chloride ion. This shows that factors that may have contributed to chloride ion may directly affect sodium values.

The pipe borne water from the two sampling communities had the lowest sodium concentrations (Fig.15).The water sources in the sampling communities had appreciably low sodium ion levels and were within WHO maximum acceptable limits for drinking water (200mg/l). The tendency of seriously aggravating ill effects due to high levels of sodium in drinking-water is low in the study area.

#### **5.1.16 Sulphate ion**

Drinking water from all the sampling communities generally had low  $\text{SO}_4^{2-}$  concentration ranging from 2.61to 30.68mg/l. They were all within the WHO acceptable maximum contaminant limits (250mg/l).

From ANOVA table 12, the average level of sulphate ion concentration was significantly different in all the sources of water sampled in the district. The values recorded for hand-dug wells during the study were also below the WHO acceptable limit (Fig. 16). 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 since most of the farms are located in the backyard of houses.

The pipe borne water from Savelugu and Pong-Tamale taps also had mean sulphate concentrations of 2.86 and 2.61mg/l, respectively. There was no significant difference in sulphate concentration of pipe borne water from Savelugu town and Pong-Tamale town ( $p = 0.611$ ) at 0.05 significance level. This may be because the two communities get the treated water from the same treatment plant and river.

There was a significant difference in the sulphate concentration of dam water from Savelugu, Pong-Tamale and Nanton ( $p = 0.008$ ) at 0.05 significance level. 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 reported 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). The level of sulphate concentration in the water from the various sources in the study area was within the WHO acceptable guideline limit of 250mg/l.

#### **5.1.17 faecal coliform**

For water to be considered as no risk for human health, the faecal coliform counts/100 ml should be zero (WHO, 2006). Although the water sources in the study communities were not tested for specific pathogens, the presence of faecal coliform suggests that it may be potentially harmful for human consumption.

There was a significant difference in faecal coliform of water from all the sources sampled in the district (ANOVA Table13). The taps in Savelugu and Pong-Tamale had zero counts of faecal coliform. However, the boreholes also had low faecal coliform counts. In the three sampling communities the boreholes were located within households and may have been the reason for the faecal coliform loads in the borehole water. The ingress of coliform bacteria into the groundwater might have been facilitated by rainwater percolation into the borehole. The highest mean faecal coliform counts were found in the hand-dug wells and dams. The high levels of faecal coliform in the hand-dug wells 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 faecal



pollution for much longer distance (Cairncross, 1987). Musa *et al* (1999), working on peri-urban and rural wells 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. The relatively high values of these microbial indicators recorded in the dams, might be due to anthropogenic activities such as defecation (by both humans and animals), swimming, washing and disposal of household waste along the banks of these water bodies. 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 sampling communities 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 the dams with their faeces.

However, the relatively stagnant nature of the dam may harbour micro-organisms resulting in higher faecal coliform loads. Faecal coliforms were not detected in the pipe-borne water from Savelugu and Pong-Tamale. The absence of coliforms can partly be explained by the treatment process at the plant. The laboratory results indicated faecal contamination of all the water sources except pipe-borne water. The unacceptable coliform counts in the boreholes, hand-dug wells and dams may be linked to the high rate of gastro-enteritis because many inhabitants rely on these water sources for domestic use. Currently, medical records from Savelugu municipal hospital in the study area indicate that diarrheal diseases placed 4<sup>th</sup> among ten top causes of out patients department (OPD) attendance in the Hospital's 2012 report.

#### **5.1.18 Total coliform**

For water to be considered no risk to human health, the total coliform bacteria and *E.coli* in water sample should be zero (WHO, 2004). The boreholes recorded low counts of total coliform compare to hand-dug wells and dams. The total coliform counts recorded may be due to the location of all the boreholes within households, some of which had poor or non-existent sewage systems or improper sanitary conditions in the sampling communities. However, there was a significant difference in the total coliform counts in all the water sources sampled in the district. The dams from the three communities had the highest total coliform counts. Livestock are allowed to graze and drink freely around and from these water bodies, and in the process indiscriminately contaminate these surface waters with their faeces, thus, contributing to the high incidence of Total and faecal coliform build up (Morgan, 1990).

## CHAPTER 6

### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

The study determined the domestic water quality of the Savelugu/Nanton district of the Northern region. The various sources of water for domestic use were analysed for physicochemical and biological properties in the study area.

The boreholes, stand pipes, hand-dug wells and dams from Savelugu, Pong-Tamale and Nanton 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 physico-chemical parameters were within WHO maximum contaminant levels. The pipe- borne water had the higher quality with WHO acceptable physico-chemical properties. The borehole water was also of higher quality than water from the wells, dams and so the latter water must be subjected to treatments such as filtration, chlorination and boiling before drinking. This agrees with Tiimub *et al*( 2012) who also reported that borehole water is generally of higher quality than water from the wells. All the water samples had values of the physico-chemical properties lower than WHO guideline values indicating the acceptability of the water for domestic use, but for the biological properties need further treatment before safe for consumption.

Responses from household interviews showed that the quality of water from the traditional water supply sources is very poor except borehole water and pipe borne water. Water from dams and hand-dug well exposes the users to water related health problems.

## 5.2 RECOMMENDATIONS

1. Minimizing faecal pollution of hand-dug wells, boreholes and dams within the community by developing sound water resource management programmes.
2. There is the need for greater community participation in water management.
3. Critical efforts should be made to improve the sanitation practices around the hand-dug wells and the boreholes in the district.
4. The hand-dug wells and boreholes should be fitted with hand pumps to offer a greater degree of protection from external sources of contamination and should thus be maintained.
5. Hand-dug wells should be sited at higher elevations so as not to serve as a sink during rainfall.
6. Hand-dug wells should be sited at least 30 metres away from septic tanks, latrines and rubbish dumps.
7. Constant or regular monitoring of the catchment area of these water bodies is required to ensure good water quality standards are achieved.
8. 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.
9. Above all, except for pipe borne water and borehole water, water must be treated before use for drinking.

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## APPENDICES

### 1. Appendix 1: QUESTIONNAIRE SURVEY FOR HOUSEHOLDS

**Introduction:** *This research is being carried out on domestic water quality. The aim of this research is to determine an appropriate water source for domestic use for this district. The purpose is to provide appropriate solution for save water use. Your kind cooperation, response and time are highly appreciated.*

#### SECTION 1: LOCATION AND BACKGROUND

1. Name of community.....
2. Sex of respondent.
  - (i) Male [ ]
  - (ii) Female [ ]
3. What is your educational level?
  - (i) None [ ]
  - (ii) Primary [ ]
  - (iii) Secondary [ ]
  - (iv) Post-secondary [ ]
  - (v) Others [ ] (specify).....
4. a) How many persons live in your household? .....
- b) How many of them are:
  - (i) Children (Below 18 years).....
  - (ii) Adults (Above 18 years).....
5. a) What are the main sources of income in your household?
  - (i) Farming [ ]
  - (ii) Trading [ ]



(iii) Fishing [ ]

(iv) Others [ ] (specify).....

b) Does your household regularly receive any remittances from others (eg. members of the family working outside the home)?

(i) Yes [ ]

(ii) No [ ]

c) What is the average seasonal income of your household in all?

(i) < Gh¢ 200 [ ]

(ii) Gh¢ 200 – 300 [ ]

(iii) Gh¢ 300 – 400 [ ]

(iv) Gh¢ 400 – 500 [ ]

(v) >Gh¢ 500 [ ]

d) How much of your income do you spend on water?

.....

## SECTION 2: COLLECTION AND USE OF WATER

6. a) What sources of water do you have in your community?

(i) Pipe borne [ ]

(ii) Borehole [ ]

(iii) Dam [ ]

iv. Dugout well [ ]

(iv) Others [ ] (specify).....

b) What is the distance from your house to the source of water in km?

- (i) Pipe borne .....
- (ii) Borehole .....
- (iii) Dam.....
- iv. Dugout well.....

c) How reliable is the source of water supply e.g. during dry seasons?

- (i) Not reliable at all [ ]
- (ii) Quite reliable [ ]
- (iii) Very reliable [ ]

d) If not reliable enough where do you go to collect water for household consumption?

e) Is it easy to collect water from that alternative source? .....

7. a) Who is responsible for collecting water in your household? .....

b) What time is taken for daily water collection in your household?

- (i) During wet season.....
- (ii) During dry season.....

c) What do you like/dislike about water collection?

.....  
 .....  
 .

d) Are you ever short of water?

- (i) Yes [ ]
- (ii) No [ ]

e) If yes, which months? .....

f) How do you cope during periods of water shortage?

.....

8.a) Which water resource smells good?

i. Borehole [ ]

ii. Dam [ ]

iii. Pipe borne water [ ]

iv. Dugout well [ ]

V. Others specify.....

b) Which water resource taste good?

i. Borehole [ ]

ii. Dam [ ]

iii. Pipe borne water [ ]

iv. Dugout well [ ]

V. Others specify.....

9. Which water source do you prefer for drinking and cooking?

i. Borehole [ ]

ii. Dam [ ]

iii. Pipe borne water [ ]

iv. Dugout well [ ]

V. Others specify.....

10. Why do you prefer the water sources specified for drinking and cooking?

i. It has good physical quality [ ]

ii. Good taste [ ]

iii. Good smell [ ]

iv. Convenient to reach source [ ]

v. Been in community for long [ ]

11. Which water sources do you prefer for bathing?

i. Borehole [ ]

ii. Dam [ ]

iii. Pipe borne water [ ]

iv. Dugout well [ ]

V. Others specify.....

12. Why do you prefer the water source specified for bathing?

i. It has good physical quality [ ]

ii. It does not waste soap [ ]

iii. It does not cause itching on the body [ ]

iv. Convenient to reach source [ ]

13. Which water sources is not good for washing?

i. Borehole [ ]

ii. Dam [ ]

iii. Pipe borne water [ ]

iv. Dugout well [ ]

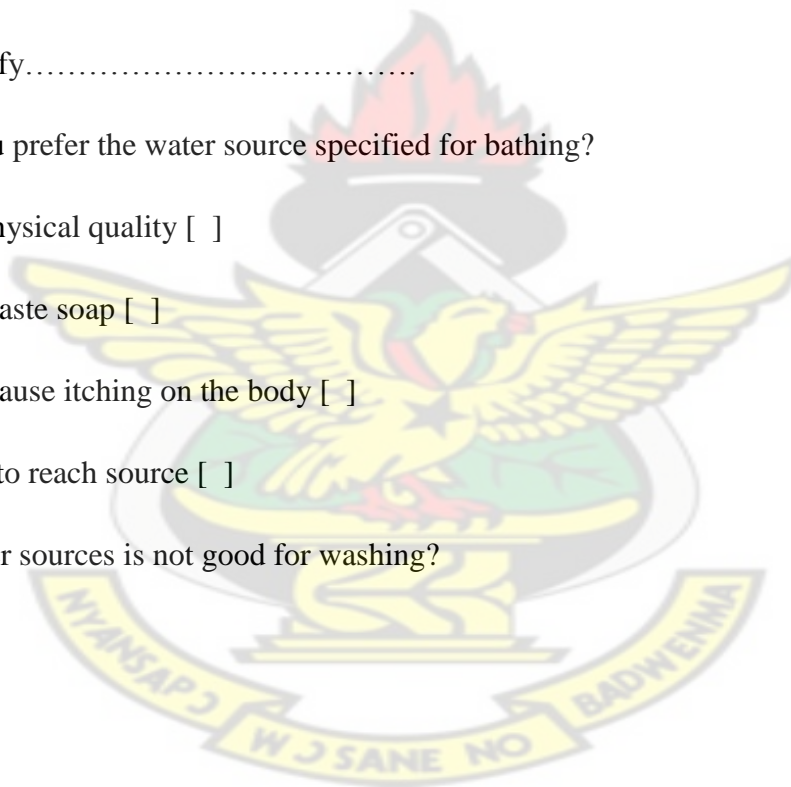
V. Others specify.....

14. Why is the water source specified not good for washing?

I . .....

ii. ....

KNUST



iii. ....

iv .....

### SECTION 3: KNOWLEDGE/PERCEPTION OF WATER QUALITY

15. a) How do you ensure good quality water? .....

b) Are there any common diseases associated with water consumption in this community?

(i) Yes [ ]

(ii) No [ ]

c) If **yes**, describe any of the diseases you know of.....

d) How would you describe your frequency of illness?

(i) Once in two weeks [ ]

(ii) Once a month [ ]

(iii) Once in 3 months [ ]

(iv) Rarely [ ]

e) How would you describe your frequency of illness during water scarcity periods?

(i) Once in two weeks [ ]

(ii) Once a month [ ]

(iii) Once in 3 months [ ]

(iv) Rarely [ ]

*Thank you so much for your time and ideas for completing this form. I am happy to answer any questions you may have relating to this study.*

### Appendix 2A: Fluoride-Sample preparation and calibration curve

Sample preparation: A 200 mL water sample together with 100 mg of ashless cellulose powder (Whatman) was evaporated to dryness in a porcelain dish on a steam bath and then under an infra-red lamp. The residue was cooled at room temperature in a desiccator for 1



hour. The powdered sample was then weighed and sealed in a polythene bag and stored in a desiccator. A 50 mg sample was pressed into a 10 mm diameter pellet with 3 tons of pressure in a graduated hydraulic press. The pellet was mounted on a 35 mm slide frame with adhesive tape and preserved in a desiccator until irradiated. 200 ml deionised water mixed with 100mg of cellulose was prepared as the blank and analysed for any contamination in sample preparation.

Concentration calibration: For concentration calibration, AnalaR grade NaF in the concentration range of 10-500 mg/kg in a CaCO<sub>3</sub> matrix was used. The nuclear reaction  $^{19}\text{F}(p, p' \gamma)^{19}\text{F}$  was used to construct the calibration curve. NaF standards were homogeneously dispersed in 100 mg of CaCO<sub>3</sub> with methanol, and the resulting matrices were dried under an infrared lamp.

#### **Appendix 2B: Nitrite-Preparation of standards**

Preparation of Standard NaNO<sub>3</sub>: A 1.232 g of NaNO<sub>3</sub> was weighed and dissolved with distilled water into a 100 ml volumetric flask and then diluted to the mark. 250 µg/L concentration of standard nitrite was prepared.

M NaOH: Four grams of NaOH pellets was weighed and dissolved in a small volume of distilled water before transferring to a 100 mL volumetric flask where it was diluted to the mark.

Colour developing reagent: A 300 ml distilled water, 50 ml concentrated Phosphoric acid, 7.5 g of sulphanilamide (H<sub>2</sub>N-C<sub>6</sub>H<sub>4</sub>SO<sub>4</sub>NH<sub>2</sub>) and 0.375 g of naphthyl-1, 1-amide was mixed and diluted to the mark in a 500 ml volumetric flask.

Calibration curve: Aliquots of 0.1, 0.2, 0.3 and 0.4 mL of the stock solution were measured into different 100 mL volumetric flasks. To these 2 mL of 0.1 M NaOH was added followed by the addition of 1, 2, 3, and 4 mL of colour developing reagent respectively. The mixtures were diluted to the 100 mL mark forming 0.25 µg/l, 0.50 µg/l, 0.75 µg/l and 1.00 µg/l of standard nitrite solution respectively (APHA, 1992). A straight line graph of absorbance at 543 nm versus concentration passing through the origin was obtained for the standard solutions.

#### **Appendix 2C: Alkalinity-Preparation of reagents**

M of HCl reagent: A 2.1 ml solution of concentrated HCl was added to a 200 ml of distilled water in a 1000 ml volumetric flask. To this mixture was added more distilled water until it got to the 1000 ml mark.

0.05 M  $\text{Na}_2\text{CO}_3$  reagent: one litre of  $\text{Na}_2\text{CO}_3$  solution was prepared by dissolving 4.5 g of dried  $\text{Na}_2\text{CO}_3$  in double distilled water and transferred into a 1 litre volumetric flask. The solution was made to the mark with distilled water.

### **Appendix 2D: Total hardness-Preparation of standards**

Preparation of standard solution: Buffer solution: Dissolve 17.5 g ammonium chloride ( $\text{NH}_4\text{Cl}$ ) in 142 mL concentrated  $\text{NH}_4(\text{OH})$  and dilute to 250 ml with distilled water.

Standard calcium solution: Place ~ 1.5 g anhydrous  $\text{CaCO}_3$  (in oven) into a beaker, and place in a dessicator for 10 minutes. Weigh exactly 1.000g anhydrous  $\text{CaCO}_3$  into a clean 600 mL Erlenmeyer flask and add 200 ml deionized water. Add a few drops of 6 M HCl until all  $\text{CaCO}_3$  has dissolved. Add 200 ml distilled water and boil for a few minutes to expel  $\text{CO}_2$ . Transfer quantitatively to a 1000 ml volumetric flask and dilute to the mark with distilled water. Dissolve 3.723 g disodium EDTA in distilled water and dilute to 1 litre.

Standardization of the EDTA solution: A known concentration of EDTA was used for titrating water sample. Measure exactly 15.0 ml of the  $\text{CaCO}_3$  solution into a 250 ml flask. Add approximately 30 ml of deionized water to the flask. Add 2.0 ml of the buffer solution. The remainder of the titration must be completed within 15 minutes of the time when the buffer is added. Add 4 drops of Eriochrome Black T indicator solution. Titrate using the EDTA titrant. At the end point the color should change from red to a pale blue. This procedure was repeated twice.

Water samples: 25.0 ml of the hard water sample was measured into a 250 ml flask. 25 ml of deionized water was then added to the flask. The remainder of the titration must be completed within 15 minutes of the time when the buffer is added. 4 drops of Eriochrome Black T indicator solution was added. EDTA titrant was used for titrating, and, at the end point the color should changed from red to blue. This procedure was repeated twice. This data from parts A and B was used to calculate the hardness of the water samples in mg /l.

### Appendix 3

Anova: Single  
Factor

#### SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	42.97	7.16166667	0.01169667
SPB	6	44.79	7.46566667	0.00839667
SHDW	6	44.97	7.49566667	0.00239667
SDM	6	43.24	7.20666667	0.20982667
PBH	6	45.85	7.64166667	0.00285667
PPB	6	46.03	7.67166667	0.36221667
PHDW	6	45.79	7.63166667	0.00229667
PDM	6	44.65	7.44166667	0.00021667
NBH	6	44.87	7.47833333	0.00133667
NHDW	6	45.34	7.55666667	0.00026667
NDM	6	44.72	7.45333333	0.00046667

#### ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1.619393939	10	0.16193939	2.9592221	0.004789282	2.00779177
Within Groups	3.0098	55	0.05472364			
Total	4.629193939	65				

ANOVA Table 1; Analysis of Variance of Mean PH concentration in the Sampled Sources of Water In the District.

Anova: Single Factor

#### SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SHDW	6	44.97	7.495	0.00239
PHDW	6	45.31	7.551667	0.004497
NHDW	6	45.31	7.551667	0.000217

ANOVA							
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>	
Between Groups	0.012844	2	0.006422	2.712342	0.098746	3.68232	
Within Groups	0.035517	15	0.002368				
Total	0.048361	17					

ANOVA Table 2; Analysis of variance of mean PH concentration of water from sampling communities.

Anova: Single Factor SUMMARY				
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	380.86	63.4766667	0.07770667
SPB	6	410.35	68.3916667	1086.39178
SHDW	6	549.05	91.5083333	0.04585667
SDM	6	538.38	89.73	0.02044
PBH	6	414	69	75.21296
PPB	6	410.44	68.4066667	1084.86451
PHDW	6	408.78	68.13	92.64868
PDM	6	418.34	69.7233333	62.0940667
NBH	6	461.07	76.845	0.02103
NHDW	6	414.4	69.0666667	0.00486667
NDM	6	420.36	70.06	56.45392

ANOVA							
<i>Source of Variation</i>	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>	
Between Groups	5068.019867	10	506.801987	2.26818318	0.026462877	2.0077917	
Within Groups	12289.17905	55	223.439619				
Total	17357.19892	65					

ANOVA Table 3; Analysis of variance of mean alkalinity concentration of the sampled sources in the District.

Anova: Single Factor

SUMMARY				
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	7.38	1.23	0.00016
SPB	6	63.4	10.56666667	97.7047067

SHDW	6	64.98	10.83	92.0852
SDM	6	89.22	14.87	0
PBH	6	65.32	10.88666667	90.8977067
PPB	6	63	10.5	99.15376
PHDW	6	63.93	10.655	95.80115
PDM	6	104.1	17.35	0.035
NBH	6	65.31	10.885	90.93259
NHDW	6	69.48	11.58	76.99216
NDM	6	117.45	19.575	0.00035

#### ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1317.100145	10	131.7100145	2.25109368	0.027599	2.007792
Within Groups	3218.013917	55	58.50934394			
Total	4535.114062	65				

ANOVA Table 4; Analysis of Variance of Mean turbidity Level of the sampled Sources of Water in the District

Anova: Single Factor

#### SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	1842.28	307.0466667	26851.80639
SPB	6	654.27	109.045	2812.81475
SHDW	6	2739.7	456.6166667	0.801666667
SDM	6	2016.21	336.035	31436.44939
PBH	6	2195.03	365.8383333	20925.30338
PPB	6	661.8	110.3	2157.328
PHDW	6	1944.72	324.12	33330.66872
PDM	6	2103.51	350.585	26038.51583
NBH	6	1828	304.6666667	27713.05867
NHDW	6	1697.55	282.925	55482.90091
NDM	6	1802.92	300.4866667	29258.53931

#### ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	635200.4183	10	63520.04183	2.729289514	0.00845898	2.007792
Within Groups	1280040.935	55	23273.47155			
Total	1915241.353	65				



ANOVA Table 5; Analysis Of Variance of Mean electrical conductivity Level of the sampled Sources of Water in the District

Anova: Single Factor

SUMMARY				
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	1842.24	307.04	26854.19988
SPB	6	1654.86	275.81	55562.92088
SHDW	6	2739.7	456.616667	0.801666667
SDM	6	1995.51	332.585	30110.57479
PBH	6	1402.81	233.801667	0.253616667
PPB	6	1676.67	279.445	53701.54639
PHDW	6	2945.31	490.885	0.01715
PDM	6	1219.77	203.295	0.00035
NBH	6	1828.6	304.766667	27676.69467
NHDW	6	2195.25	365.875	20926.34863
NDM	6	866.23	144.371667	0.001536667

ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	627537.9897	10	62753.799	3.213149	0.002563	2.00779
Within Groups	1074166.798	55	19530.3054			
Total	1701704.787	65				

ANOVA Table 6; Analysis Of Variance of Mean total hardness Level of the sampled Sources of Water in the District

Anova: Single Factor

SUMMARY				
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
PHDW	6	139.5	23.25	0
SHDW	6	140.1	23.35	1.51E-29
NHDW	6	136.18	22.69667	2.561067

ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between	1.486044	2	0.743022	0.870367	0.43891	3.68232

Groups

Within Groups 12.80533 15 0.853689

Total 14.29138 17

ANOVA Table 7; Analysis of Variance of Mean calcium concentration of water from hand-dug wells of Savelugu, Pong-Tamale and Nanton.

Anova: Single Factor

#### SUMMARY

Groups	Count	Sum	Average	Variance
SBH	6	20.8	3.48	0.67516
SPB	6	18.1	3.02	0
SHDW	6	21.6	3.61333	0.4745866
SDM	6	12.2	2.04333	1.3028266
PBH	6	25.3	4.23	0
PPB	6	21.2	3.545	0.68419
PHDW	6	21.7	3.62	0.55488
PDM	6	21.3	3.565	0.53067
NBH	6	18.0	3.015	1.77147
NHDW	6	20.2	3.375	0.87723

#### ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	17.68	2	1.96461	2.8592752	0.008451893	2.073351164
Within Groups	34.35	50	0.68710			
Total	52.03	59				

ANOVA Table 8; Analysis Of Variance of Mean dissolved oxygen level of the sampled Sources of Water in the District

Anova: Single Factor

### SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	880.37	146.728333	5.66667E-05
SPB	6	1013.16	168.86	10969.52652
SHDW	6	1258.71	209.785	3588.53907
SDM	6	1024.71	170.785	10532.25507
PBH	6	1254.36	209.06	3684.32172
PPB	6	1026.51	171.085	10464.90987
PHDW	6	784.86	130.81	9.69352E-28
PDM	6	705.18	117.53	1693.80588
NBH	6	1586.82	264.47	0
NHDW	6	879.09	146.515	88.44267
NDM	6	646.89	107.815	1088.29587

### ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	127326.8188	10	12732.6819	3.326031321	0.001944633	2.007791769
Within Groups	210550.4836	55	3828.19061			
Total	337877.3024	65				

ANOVA Table 9; Analysis Of Variance of Mean total dissolved solids (TDS) concentration of the sampled Sources of Water in the District

Anova: Single Factor

### SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	64.96	10.8266	86.768106
SPB	6	60.32	10.0533	103.98241
SHDW	6	7.74	1.29	0
SDM	6	88.5	14.75	25.17168
PBH	6	65.1	10.85	86.29248
PPB	6	7.005	1.1675	1.6217275
PHDW	6	20.34	3.39	0
PDM	6	115.9	19.33	0
NBH	6	61.71	10.285	98.17443
NHDW	6	62.43	10.405	95.58675
NDM	6	86.49	14.415	28.98867

## ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1964.2632	2	196.424	4.1031613	0.000300916	2.007791769
Within Groups	4597.2	55	47.8714			
Total	6561.4632	57				

ANOVA Table 10; Analysis of Variance of Mean nitrate concentration of the sampled Sources of Water in the District

Anova: Single Factor

## SUMMARY

<i>Groups</i>	<i>Coun</i>	<i>t</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
SBH	6	489	81.5	0	
		278.5			1366.0651
SPB	6	8	46.43	2	
		421.9			
SHDW	6	8	70.33	0	
		243.4			
SDM	6	8	40.58	1062.075	
		481.0			
PBH	6	2	80.17	0	
		279.3			1355.1552
PPB	6	9	46.565	3	
		457.0			
PHDW	6	2	76.17	9.6	
		272.5			
PDM	6	2	45.42	1449.075	
		436.3			
NBH	6	8	72.73	0	
		472.9			
NHDW	6	8	78.83	0	
		275.0			1414.6706
NDM	6	1	45.835	7	

## ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1712	4	1712.42	2.8297619	0.006595843	2.007791769

	3328		605.149
Within Groups	3	55	2
	5040		
Total	7	65	

ANOVA Table 11; Analysis of Variance of Mean sodium concentration of the sampled Sources of Water in the District

Anova: Single Factor

#### SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
		108.2	18.0433	0.0001466
SBH	6	6	3	7
		105.2	17.5433	156.22578
SPB	6	6	3	7
				3.7865E-
SHDW	6	84.42	14.07	30
		112.2		
SDM	6	6	18.71	171.93708
		184.0		1.5146E-
PBH	6	8	30.68	29
			12.2916	122.45793
PPB	6	73.75	7	7
		114.5		
PHDW	6	4	19.09	0
		117.3		
PDM	6	9	19.565	148.25187
		166.4		
NBH	6	4	27.74	0
		148.9		
NHDW	6	8	24.83	41.067
		114.9		
NDM	6	3	19.155	88.44267

#### ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
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	1829.		182.923	2.7625069		
Between Groups	2	10	8	5	0.007790847	2.007791769
	3641.		66.2165			
Within Groups	9	55	9			
	5471.					
Total	2	65				

ANOVA Table 12; Analysis of Variance of Mean sodium concentration of the sampled Sources of Water in the District

Anova: Single Factor

#### SUMMARY

Groups	Count	Sum	Average	Variance
		246.9	41.1633	3756.7136
SBH	6	8	3	3
		150.8	25.1483	2172.4648
SHDW	6	9	3	2
		609.1		
SDM	6	2	101.52	0
		246.3	41.0633	3766.2688
PBH	6	8	3	3
		332.5		2524.0917
PHDW	6	8	55.43	6
PDM	6	496.5	82.75	0
		249.3	41.5633	3718.7328
NBH	6	8	3	3
		169.1		
NHDW	6	4	28.19	2035.7784
		721.7		
NDM	6	4	120.29	0

#### ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
			6882.12	3.4460287		
Between Groups	55057	8	2	4	0.003554584	2.152132879
			1997.11			
Within Groups	89870	45	7			
	14492					
Total	7	53				

ANOVA Table 13; Analysis of Variance of Mean faecal coliform concentration of the sampled Sources of Water in the District