KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ENGINEERING

FACULTY OF CHEMICAL AND MATERIALS ENGINEERING

DEPARTMENT OF MATERIALS ENGINEERING

THE QUALITY OF WATER IN GOO RESERVOIR AND A WATER SUPPLY WELL IN NAVRONGO, KASSENA NANKANA MUNICIPALITY OF UPPER EAST REGION OF GHANA

A THESIS SUBMITTED TO THE DEPARTMENT OF MATERIALS ENGINEERING, COLLEGE OF ENGINEERING KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ENVIRONMENTAL RESOURCES MANAGEMENT.

BY

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(BSc. AGRIC TECH)

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DECLARATION

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

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DEDICATION

I dedicate this work to the almighty God and to my beloved wife Vivian Aditorem and my two lovely daughters.

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

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ABSTRACT

The study was conducted to assess the quality of water in GOO reservoir and vegetables irrigated at the site as well as a water supply well located close by. The reservoir and water supply well are close to each other and located in Navrongo, the capital of the Kassena Nankana Municipality of the Upper East Region of Ghana. Water quality was based on physicochemical parameters, concentration of heavy metals and microbial analysis of samples collected from the reservoir and water supply well.

Generally, many of the physicochemical parameters analyzed were well within the Ghana Standards Board (GSB) and standards values for drinking water quality. Total dissolved solids ranged from 167 to 172 averaging 16.9 mg/l from a total of four mean values, with conductivity ranging from 280 to 295 with an average of 286 µS/cm. Sulphate ranged from 16.9 to 30.5 mg/l averaging 21 mg/l and pH ranged from 7.0 to 7.4 averaging 7.1 with nitrate-nitrogen ranging from 2.9 to 13.2 with an average of 7.7 mg/l. Turbidity of the water ranged from 506 to 704 averaging 589 NTU while iron concentration ranged from 3 to 6.9 averaging 4.7 mg/l and manganese ranged from 0.8 to 2.2 averaging 1.4 mg/l. However, zinc concentrations were low and that of copper and lead were below detection limits of 0.020 and 0.005 respectively. The microbial loads of the water from the reservoir and that of the lettuce and garden eggs were very high. Total coliform in water from the reservoir ranged from 120,268 to 272,871 /100ml averaging196,310/100ml. Faecal coliform on the other hand ranged from 258 to 125,000 averaging 62,440 /100ml. Total coliform in the lettuce and garden eggs are 155,291 and 465,199 CFU/g respectively and that of faecal coliform is 95,021and 130,062 CFU/g. The water from the water supply well was free of total and faecal coliforms as well as having low turbidity of 1 NTU and very low heavy metals concentration except manganese.

The level of microbial pollution of the reservoir was very high and therefore makes it a potential source of contaminating the vegetables. The water from the water supply well is generally safe for consumption based on the Ghana Standards Board standards for drinking water.

Key words: storm runoff, water quality, heavy metal pollution, coliforms, Goo reservoir, and water supply well.

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CHAPTER ONE

1.0 INTRODUCTION

Water is a common chemical substance that is essential for the survival of all known forms of life. Water resources occupy a special place among other natural resources. It is the most widely distributed substance on our planet and plays a vital role in both the environment and human life. Of most importance is fresh water. Human life itself is impossible without fresh water because it cannot be substituted by anything. Human beings have always consumed fresh water and used the various natural surface water bodies for a whole range of purposes. In typical usage, water refers only to its liquid form or state, but the substance also has a solid state, ice, and a gaseous state, water vapour or steam. Water covers 71% of the Earth's surface (Shiklomanov and UNESCO, 1998). On Earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapour, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Saltwater oceans hold 97% of surface water, glaciers and polar ice caps 2.4%, and other land surface water such as rivers, lakes and ponds 0.6%. A very small amount of the Earth's water is contained within biological bodies and manufactured products. Other water is trapped in ice caps, glaciers, aquifers, or in lakes, sometimes providing fresh water for life on land. Water moves continually through a cycle of evaporation or transpiration (evapotranspiration), precipitation, and runoff, usually reaching the sea. Winds carry water vapour over land at the same rate as runoff into the sea. Over land, evaporation and transpiration contribute to the precipitation over land. Clean, fresh drinking water is essential to human and other life. Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemical substances and facilitates industrial cooling and transportation. Approximately 70 percent of freshwater is consumed by agriculture (Kulshreshtha, 1998).

Water can appear in three states; it is one of the very few substances to be found naturally in all three states on earth.

Water can dissolve many different substances, giving it different tastes and odours.

The magnificent properties of natural waters – their renovation during the water cycle and their ability for self purification allows a state of relative purity, quantity and quality of fresh waters to be retained for a long time. This gave birth to an illusion of immutability and inexhaustibility of water resources. Under these preconceptions a tradition has arisen of careless attitude in the use of water resources.

In many parts of the world, the unfavourable results of man's long term misuse of water resources have now been discovered. The extent of water resources, their spatial and temporal distribution, is determined not only by natural climate variations as previously, but now also by man's economic activities (Shiklomanov and UNESCO, 1998).

In many parts of the world water resources have become so depleted and much contaminated that they are already unable to meet the ever- increasing demands made on them. This has become the main factor impeding economic development and population growth (Shiklomanov and UNESCO, 1998).

Water should be free of tastes and odours that would be objectionable to the majority of consumers.

Storm water runoff is rainfall or snowmelt that runs off the ground or impervious surfaces such as buildings, roads and parking lots and drains into natural or manmade drainage ways.

Storm water is a leading cause of water pollution. It runs off solid surfaces and collects pollutants such as oils, pesticides, sediments, bacteria and other chemicals and then deposits them into our water bodies.

Untreated storm water entering our streams can result in the contamination of our drinking water supplies or prohibition on swimming, fishing or injury to aquatic plants and animals. Pollutant levels are typically much higher in the first flush. Studies have shown that approximately 90% of the pollutant loading is contained in the first flush of one-inch rainfall (Hartwell et al,2010).Water quality is impaired and does not meet water quality standards. A leading source of this impairment is polluted runoff.

Small amount of some substances may cumulatively degrade an aquifer if a significant proportion of contaminated runoff is percolated into the water table.

The percolation of contaminated runoff can cause unacceptable consequences to ground water resources.

The storm water pollution problem has three main components: the increased volume and velocity of surface runoff and the concentration of pollutants in the runoff. All components are directly related to development in urban and urbanizing areas. Together, these components cause changes in hydrology and water quality that result in a variety of problems including habitat loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion, as well as effects on our health, economy, and social well-being.

1.1 PROBLEM STATEMENT

Water quality is impaired by pollution and does not meet water quality standards. A leading source of this impairment is polluted runoff.

Urban –related runoff has been documented to contain numerous substances such as motor vehicles fluids, pesticides, heavy metals and faecal coliform known to have toxic or pathogenic properties. Spilled fuel, solvents, waste oils, paints, and other maintenance fluids pose risk to the environment but may be especially harmful if they enter the drinking water supply. Small amounts of some substances may cumulatively degrade an aquifer, if a significant proportion of contaminated runoff is percolated to the water table.

The percolation of contaminated runoff can cause unacceptable consequences to ground water resources. If there is a water supply well near a source of contamination, that well runs the risk of becoming contaminated. In areas surrounding pumping wells, the potential for contamination increases because when pumping starts, ground water stores are depleted in the vicinity of the well, creating a cone of depression in the hydraulic head. If a new water source such as a river or stream is available close by, the well may capture (draw water from) that source and increase its recharge rate. Some drinking water wells actually draw water from nearby streams, lakes or rivers. Contaminants present in these surface waters can contribute contamination to the ground water system. Some wells rely on artificial recharge to increase the amount of water infiltrating an aquifer, often using water from storm runoff, irrigation, industrial processes, or treated sewage. In several cases, this practice has resulted in increased concentrations of nitrates, metals, microbes, or synthetic chemicals in the water. Goo reservoir is one of the reservoirs in the Kassena Nankana Municipality meant for small scale irrigation. Its catchment area covers the entire NavrongoTownship which is the capital of the municipality. This is so because all the storm drains within the township are channeled into the reservoir. Along the streams that go to the reservoir, people openly defecate and this is washed alongside to the reservoir. Surprisingly, a mechanized borehole which supplies the Navrongo Township with potable water is located a few meters away from the reservoir. The first flush from urban runoff can be extremely dirty. Storm water may become contaminated while running down the road or other impervious surfaces. Water running off these impervious surfaces tends to pick up gasoline, motor oil, heavy metals, trash and other pollutants from roads ways and parking lots, mechanics shops as well as fertilizers and pesticides from farms.

Urban runoff is a key element in the urban ecosystem and has been a crucial front in the fight for water resource protection. Rapid change in the nutrient concentrations and temperature of runoff flow is one of urban runoffs hydrological characteristics (Gnecco et al, 2006; Gobel et al 2007; McLeod et al, 2006).

This storm runoff therefore poses a serious threat to the reservoir, vegetables farms and the mechanized borehole because of the relation between surface and ground water.

1.2JUSTIFICATION FOR THE RESEARCH

Access to safe drinking water is important as a health and development issue at the national, regional and local levels. The importance of water, sanitation and hygiene cannot be over emphasized.

The importance of water, sanitation and hygiene for health and development has been reflected in the outcomes of a series of international policy fora. These have included health-oriented conferences such as the International Conference on Primary Health Care, held in Alma-Ata, Kazakhstan (former Soviet Union), in 1978. They have also included water-oriented conferences such as the 1977 World Water Conference in Mar del Plata, Argentina, which launched the water supply and sanitation decade of 1981–1990, as well as the Millennium Development Goals adopted by the General Assembly of the United Nations (UN) in 2000 and the outcome of the Johannesburg World Summit for Sustainable Development in 2002. Most recently, the UN General Assembly declared the period from 2005 to 2015 as the International Decade for Action, "Water for Life."

The importance of ground water is often over looked. It is a mysterious resource- out of sight out of mind (Mac Donald et al, 2009). With the exception of frozen water in glaciers, 97% of all fresh water found on earth is stored underground.

Over 1.5 billion people depend on it for their drinking water and many more will in the future if the Millennium Development Goals are to be met (Calow et al, 2010). According to the World Bank (2012) over 48% of the Ghanaian population lives in the rural areas where their only access to potable water is ground water.

The people of the Kassena Nankana Municipality in the Upper East region depend solely on ground water and since there is interplay between ground and surface water. There is the need to assess the quality of water in the reservoir and water supply well since they are close by to ensure that people using this resource are actually drinking safe water. This is so because access to safe drinking water is essential to health, a basic human right and a component of development of effective policy for health protection.

It is therefore important to carry out the study to determine the physicochemical as well as the microbial parameters of the reservoir, water- supply well and the vegetables being irrigated. Also heavy metal concentration of the reservoir, water supply well and the vegetables being irrigated at the site would be determined since no such study has been conducted.

1.3RESEARCH QUESTIONS

In view of the problems outlined, the study is designed to answer among others the following questions:

- Is Goo reservoir polluted at all?
- Has the reservoir polluted the water supply well?

1.4 RESEARCH OBJETIVES

The main objective of the study/research was to assess the quality of water in Goo reservoir and the vegetables irrigated from it as well as a water supply well located close by in the Kassena Nankana Municipal Assembly of the Upper East Region of Ghana.

1.5SPECIFIC OBJECTIVES

The study/ research sought to:

- ➢ Determine the physicochemical parameters of the reservoir and the water supply well.

- Determine the microbial parameters of the water supply well and the reservoir.
- Determine the presence of adverse chemicals and microbial organisms in the vegetables grown on site.

- Determine the presence of heavy metals in the reservoir and water supply well.

1.6 SCOPE OF THE STUDY

The study was conducted in the Kassena Nankana Municipal Assembly of the Upper East Region of Ghana. The study focused on the drainage basin of the reservoir and was carried out purposely to assess the impact of municipal storm runoff on Goo reservoir, the water supply well and vegetables grown at the site.

The focus of the study was to determine the physicochemical parameters of the reservoir as well as the water supply well, microbial parameters of the water supply well and the reservoir, the presence of heavy metals in the reservoir and water supply well and the presence of microbial and adverse chemicals in the vegetables grown at the site.

1.7 ORGANISATION OF THE STUDY

The study has been organized under five main chapters. Chapter one focuses on the general introduction to the study and defines the research problem, objectives, scope and justification. The second chapter reviews literature on the concept of water resources, water resource situation of Ghana, ground water and storm water runoff. This chapter also covers water and climate change and water and health.

Chapter three covers the profile of the study area as well as the methodology that has been employed to carry out the research. The fourth chapter presents an in-depth analysis and discussion of results.

The fifth and final chapter covers the major findings and management recommendations and conclusions.

CHAPTER TWO

WATER RESOURCES

Water resources comprise atmospheric water (precipitation), surface waters (including rivers, sea etc) and groundwater (including soil moisture). They occur in gaseous form (mainly atmospheric), liquid (surface and subsurface) and solid (mainly surface in the form of icebergs, snow, sleet, hail) (Pollack 2011).

Current estimates are that the earth's hydrosphere contains a huge amount of water about 1386 million cubic kilometres. However, 97.5% of this amount is saline water and only 2.5% is fresh water. The greater portion of this fresh water (68.7%) is in the form of ice and permanent snow cover in the Antarctic, the Arctic and in the mountainous regions (UNESCO and Shiklomanov, 1998). Next, 29.9% exists as fresh groundwater. Only 0.26% of the total amount of fresh waters on the earth is concentrated in lakes, reservoirs and river systems where they are most easily accessible for our economic needs and absolutely vital for water ecosystems.

For shorter time intervals such as a single year, a couple of seasons , or a few months, the volume of water stored in the hydrosphere will vary as water exchanges take place between the oceans, land and the atmosphere. This exchange is usually called turnover of water on the earth or the global hydrological cycle as shown below.

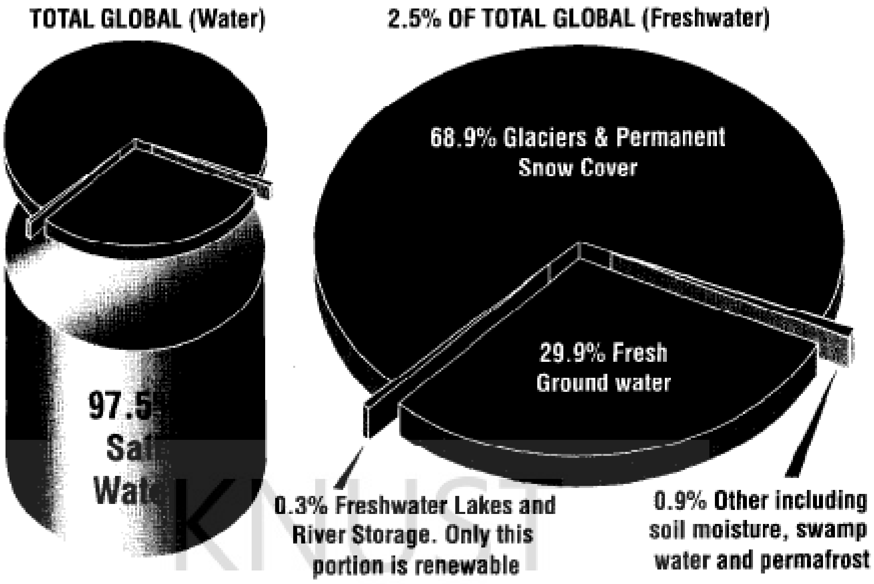

Fig2.1: Global turnover of water
Source: Shiklomanov and UNESCO, 1998

During their constant cycling between land, the oceans and the atmosphere, water molecules pass repeatedly through solid, liquid and gaseous phases but the total supply remains fairly constant. Indeed, the total amount of water on earth today is nearly the same as it was millions of years ago at the beginning of the earth- with possible exceptions of the recent discovery of "imports'' of significant amounts of water from the outer space by "cosmic snow balls'' (Sawyer, 1997).

Very little water is consumed in the sense of actually taking it out of the water cycle permanently, and unlike energy resources such as oil, water is not lost as a consequence of being used. However, human interventions often increase the flux of water out of one store of water into another so it can deplete the stores of water that is most usable. For example, pumping ground water for irrigation depletes aquifers by transferring the water to evaporation or river flow. Our activities also pollute water so that it is no longer suitable for human use and is harmful to ecosystems.

Supplies of fresh water exist because precipitation is greater than evaporation on land. Most of the precipitation that is not transpired by plants or evaporated infiltrates through the soil and becomes groundwater, which flows through rocks and sediments and discharges into rivers. Over the oceans evaporation is greater than precipitation so the net effect is a transfer of water back to the atmosphere. In this way fresh water resources are continually renewed by counterbalancing differences between evaporation and precipitation on land and at sea (http; //www.leaner.org/courses/envsci/). The mean value of renewable global water resources is estimated at 42,700km^3 per year, and they are variable in space and time. In absolute values, the largest volumes of water occur in Asia and South America (13,500 and 12,000 km^3 per year respectively). The smallest are typically those of Europe and Australia (Shiklomanov and UNESCO, 1998).

These water resources are not distributed evenly in the world and not depended on where they are needed. They are affected by human interventions and hence the need for management.

In 2010, only 61% of Africans had access to clean water and 31% to adequate sanitation (WHO/UNICEF, 2012). In urban areas, the situation was slightly better with 83% access to water and 43% access to sanitation. Globally, the world will reach the Millennium Development Goals (MDGs) for water, but not sanitation. However, in Africa, despite the significant number of people that have gained access to water since 1990, the MDG for water will not be met. Between 2000 and 2010, 84million urban Africans gained access to improved water supply and 42million to improved sanitation. This is an impressive 3.9% average increase in access over the decade. However, urban population also grew by an average of 3.9%, so that the proportion of urban dwellers with accesses to water and sanitation services remained static (WHO/UNICEF, 2012).

While water demand grows, water resources are becoming scarcer. More than 40% of Africans live in arid, semi-arid and dry sub-humid areas. The amount of water available per person in Africa is far below the global average and is declining – with annual per capita availability of 4,000 m^3 compared to a global average of 65,000 m^3 (UNEP, 2010). The increase in solid waste and wastewater generated by urban areas will place further pressure on water quality and on urban drainage which will further complicate efforts to secure an adequate supply of water to a thirsty population.

One possible solution to this problem is increased reliance on ground water. Ground water is a potential source of water for many scarce areas where surface water is unavailable or too costly to tap. A recent report from the British Geological Society estimates that ground water availability in aquifers in Africa is 100 times the amount found on the surface (MacDonald et al, 2011, McGrath, 2012).

2.1 WATER RESOURCES SITUATION OF GHANA

Ghana has considerable water resources and is well above the water scarcity level of 1000m^3/capita/year. Water availability however, changes markedly from season to season as well as from year to year. Also the spatial distribution within the country is not uniform with the South-Western and coastal parts having more water than the Northern regions.

Another problem is that availability of water per capita is decreasing due to rapid population growth. This is aggravated by increased environmental degradation, pollution of rivers and draining of wetlands and rainfall variability (Climate change), (WRC, 2009).

The projected water demand for consumptive water use of 5billion m^3 in 2020 constitutes only 12% of total surface water resources while the projected demand for hydropower generation of 378,430m^3 by 2020 is less than 22% of the projected water supply (MWRWH, 2007). Hence sufficient water will be available to meet future needs, but the difference in their distribution within the country could mean that this will not apply to all regions and also the activities of illegal small scale mining are a threat to our water resources.

Domestic and industrial urban water supplies are based almost entirely on surface water, either impounded behind small dams or diverted by weirs in rivers. The quality of this surface water is increasingly becoming a concern due to mining activities, urban and industrial pollution problems and agriculture development.

In rural areas ground water is an important water source as more than 28,000 boreholes and hand dug wells mostly fitted with hand pumps have been developed by different programmes country wide. Despite these efforts over 30% of the population still depends on unsafe surface water or shallow wells (MWRWH, 2007).

2.2 GROUND WATER

Increasing reliable water supplies throughout Africa will depend on the development of ground water (Giordano, 2009). Ground water responds much more slowly to meteorological conditions than surface water and as such provides a natural buffer against climate variability, including drought (Calow et al 2010).

Ground water does not generally require treatment since it is naturally protected from pathogenic contaminants, although in some environments elevated iron, fluoride, or arsenic concentrations can be a problem (Edmunds and Smedley, 2005).

Various studies of fluoride presence in Ghana has revealed that groundwater in some areas contains high fluoride content. Bongo District in the Upper East Region is one of such areas reported to have elevated fluoride content especially in the Bongo granite (Apambire et al., 1997).

Smedley et al. (1995) also documented that the granite in Bongo contains a mean fluoride of 1.88 mg/L and a maximum value of 4.4 mg/L which is significantly above the WHO (1984) standard value of 1.5 mg/L for drinking water. It implies that health related issues could be possible within the area. The high fluoride content in the groundwater has raised several problems. Among such are boreholes capped preventing people from using the water, revenue lost as a result, children commonly having coloured teeth, high dental fluorosis (brown weak teeth).

In general, groundwater quality in the Upper East Region is good but localized groundwater quality problems are present. Some of these concerns include high concentrations of fluoride (Dapaah-Siakwan et al., 2006), manganese, and iron (Carrier et al., 2009).

Ground water can also be found in most environments using appropriate exploration techniques, so supplies can be located close to the point of need minimizing the requirements for exclusive reticulation systems (MacDonald and Calow, 2009).

Ground water, however, is neither a universal panacea to water problems nor invulnerable to degradation.

Water beneath the land surface occurs in two principal zones, the unsaturated zone and the saturated zone. In the unsaturated zone, the voids, that is the spaces between grains and of gravel, sand, silt, clay and cracks within rocks contain both air and water. Although a considerable amount of water can be present in the unsaturated zone, this water cannot be pumped by wells because it is held too tightly by capillary forces (United States Geological Survey, 1999).

The upper part of the unsaturated zone is the soil-water zone. The soil-water zone is crisscrossed by roots, voids left by decayed roots and animal and worm burrows, which enhances the infiltration of precipitation into the soil.

In contrast to the unsaturated zone, the voids in the saturated zone are completely filled with water. The upper surface of the saturated zone is referred to as water table. Below the water table, the water pressure is great enough to allow water to enter wells, thus permitting ground water to be withdrawn for use (Environment Canada, 2004). The depth to the water table is highly variable and can range from zero, when it is at the land surface to hundreds of even thousands of feet in some types of landscapes. Usually, the depth to the water table is small near permanent bodies of surface water such as streams, lakes and wetlands (Winter et al, 1998). An important characteristic of the water table is that its configuration varies seasonally and from year to year because ground water recharge, which is the accretion of water to the upper surface of the saturated zone, is related to the wide variation in the quantity, distribution, and timing of precipitation. The figure below shows how water exists in the ground.

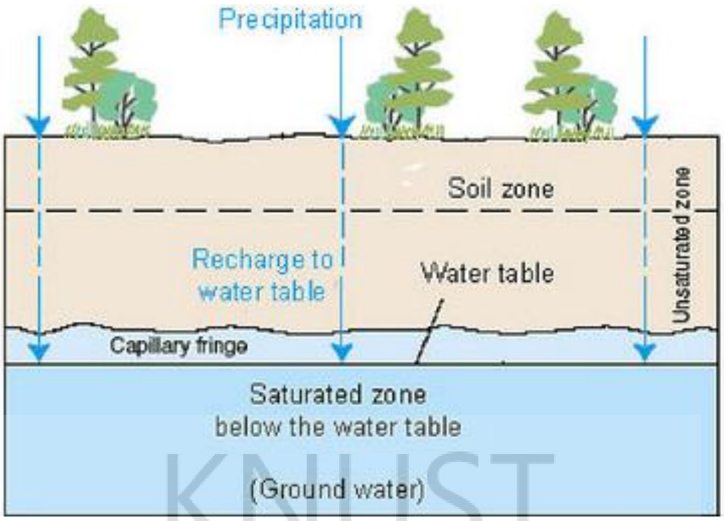

Figure 2.2.Water in the ground.
Source; United States Geological Survey, 1999.

2.3 GROUND WATER HYDROLOGY

Groundwater occurrence depends primarily on geology, geomorphology/weathering and effective rainfall (both current and historic). The interplay of these three factors gives rise to complex hydrogeological environments with innumerable variations in aquifer transmissivity (the permeability of the rocks integrated over) (MacDonald et al, 2012)

The pore structure of the soil, sediments and rocks has a central influence on ground water movement. Hydrologists quantify this influence primarily in terms of porosity and permeability

- Porosity describes the proportion of total volume that is occupied by voids, like the spaces within a pile of marbles. Porosity is not a direct function of the size of soil grain. It tends to be larger in well sorted sediments where the grain sizes are uniform and smaller in mixed soils where smaller grains fill voids between larger grains. Soils are less porous at deeper levels because the weight of the overlaying soils packs grains closer together.

- Permeability on the other hand tells how readily the medium transmits water, based on the size and shape of its pore spaces and how interconnected its pores are.

Materials with high porosity and high permeability, such as sand, gravel, sandstone, fractured rocks and basalt produce good aquifers. Low- permeable rocks and sediments that impede ground water flow include granite, shale and clay (The Habitable Planet, unit 8)

Ground water recharge enters aquifers in areas at higher elevations than discharge areas, so the overall movement of ground water is downhill. However, within an aquifer water often flows upward toward a discharge area.

2.4 GROUND WATER ABSTRACTION

Groundwater is extracted in northern Ghana using hand dug wells, boreholes, and piped systems. While actual groundwater extraction is not properly monitored. Martin and van de Giesen (2005) estimated the groundwater production in the Volta River basin to be around 88 million m^3/yr which is equivalent to less than 5% of the average annual groundwater recharge to the basin. This value suggests that further development of groundwater is possible. Martin and van de Giesen (2005) mentioned that groundwater potential in the region is constrained by availability, accessibility, and economics. The percentage of successful boreholes in the Upper East region is considerably high at 93.8% compared to 60.9% and 90.8% from the

Northern region and the Upper West region (Carrier et al, 2009). The drilling success depends mainly on the yield of the well or the quality of groundwater.

In many parts of the world people are extracting water from aquifers more quickly than the aquifers can replenish by recharge. In addition to draining aquifers, excessive ground water pumping changes the ground water flow patterns around wells and can drain nearby rivers and streams. This happens because pumping changes the natural equilibrium that exists in an undeveloped aquifer with discharge balancing recharge (Leonard and Eloise, 2005).

When pumping starts, ground water stores are depleted in the vicinity of the well, creating a cone of depression in the hydraulic head. If a new water source such as a river or stream is available close by, the well may capture (draw water from) that source and increase its recharge rate until this inflow matches the pumping rate. If no such source is available and pumping draws the water table down far enough, it will dry up the aquifer or deplete it so far that it is not physically possible or affordable to pump out the last stores of water.

Overuse of ground water can also reduce the quality of the remaining water if wells draw from contaminated surface sources.

Generally, both ground and surface water can provide safe drinking water, as long as the sources are not polluted and water is sufficiently treated. Ground water is preferable over surface water for a number of reasons. First of all, ground water is reliable during droughts, while surface water can be quickly depleted. Ground water is in general easier and cheaper to treat than surface water because it tends to be less polluted. Through wells ground water can be tapped where it is needed, whereas, surface waters are concentrated in lakes and streams.

2.5 GROUND WATER CONTAMINATION

Ground water contamination is nearly always the result of human activities. In areas where population is high and land use is intensive, ground water is especially vulnerable. Virtually any activity where chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute ground water. When ground water becomes contaminated, it is difficult and expensive to clean up (Forster, 1996).

Depending on its physical, chemical and biological properties, a contaminant that has been released into the environment may move within an aquifer in the same manner that ground water moves. Ground water contaminants can move rapidly through fractures in the rocks. Contaminants can also move into the ground water system through macro pores – roots system, animal burrows, abandoned wells and other systems of holes and cracks that supply pathways for contaminants (Thomas, 2003).

In areas surrounding pumping wells, the potential for contamination of ground water increases because water from the zone of contribution, a land area larger than the original recharge area is drawn into the well and the surrounding aquifer (Ground water foundation, 2007).

Some drinking water wells actually draw water from nearby streams, lakes or rivers. Contaminants in these surface waters can contribute contamination to the ground water system. Some wells rely on artificial recharge to increase the amount of water infiltrating an aquifer often using water from storm runoff, irrigation, agricultural activities, residential and industrial processes (US EPA, 2006)

In several cases, this practice has resulted in increased concentration of nitrates, metals, microbes or synthetic chemicals in water.

Generally, the greater the distance between a source of contamination and ground water source, the more likely that natural processes will reduce the impacts of contamination.

Processes such as oxidation, biological degradation and adsorption may take place in the soil layers of the unsaturated zone and reduce the concentration of contaminant before it reaches ground water. But also some substances found naturally in rocks or soils such as iron, manganese, arsenic, chlorides, and sulphates can become dissolved in ground water.

2.6 STORM WATER RUNOFF

Storm water runoff is rainfall or snowmelt that runs off the ground or impervious surfaces such as buildings, roads and parking lots and drains into natural or manmade drainage ways. In most cases, it drains directly into streams, rivers, lakes or the ocean.

Urban storm water runoff is a typical landscape and water resource management problem in cities around the world. It is especially relevant in fast-growing areas. Urbanization converts largely pervious landscapes into buildings, roads, parking lots, and other impervious surfaces that increase runoff volume and contaminant loads. Natural features such as geology, soil conditions and topography contribute to the occurrence of floods to some extent, but the majority of the flooding problem is created by the inadequate storm water drainage system, in combination with the growing urbanization of the metropolis and the resultant impact of decreased infiltration and increased surface water run-off (AMA, 2006)

Urban runoff is a key element in the urban ecosystem, and has been a crucial front in the fight for water resource protection. Rapid change in nutrient concentrations and temperatures of runoff flow is one of urban runoff's hydrological characteristics (Gnecco et al., 2006; Gobel et al., 2007; McLeod et al., 2006). Urban runoff has been one of the leading causes and sources of impairment in rivers, lakes, and estuaries (Boller, 1997; USEPA, 2000). Studies have shown that urban runoff pollutant contributes to the deterioration of water quality (Jeng et al., 2005; Lee and Bang, 2000; Li et al., 2007; Taebi and Droste, 2004). In the United States, billions of dollars have been invested in new wastewater treatment facilities to control water pollutions. Despite this effort, many of the lakes and streams are still plagued with pollution and cannot be used for swimming and fishing. Urban storm water runoff causes property damage, adds pollutants to receiving bodies of water, and increases the cost of infrastructure maintenance. Urbanization and the resulting increase in impervious surfaces are also associated with reduced groundwater recharge because of reduced infiltration.

Retention/detention ponds have been widely used for runoff control, providing storage for increased runoff and settling out of particulate pollutants (Hong et al., 2006). However, with the acceleration of substituting pervious landscape with concrete and the increasing cost of urban lands, retention /detention ponds have become the last resort for urban runoff control especially in developed metro areas. Instead, bio-retentions have been tested in laboratory and used for the removal of nutrient and heavy metals (Davis et al., 2001; Davis et al., 2006; Davis et al., 2003;Hsieh and Davis, 2005a; Hsieh and Davis, 2005b; Hunt et al., 2006; Kim et al., 2003; McIntyre, 2006). More recently, storm water treatment cells have been developed for the removal of storm water pollutants from parking lots, streets, and other pavement areas in California USA. (Glass and Bissouma, 2005; Sonstrom et al., 2002). These systems use soil, sand, organic materials, microbes, and vegetation to remove pollutants from runoff or wastewater (Seelsaen et al., 2006). A replaceable surface mulch layer and filter soil layer performed well in removing pollutants from runoff (Coffman and Siviter, 2007; Hsieh and Davis, 2005b).

Engineered soil, a mixture of stones and soil provide pore space for water and air that promotes deep rooting to reduce the heaving of sidewalks, curbs and gutters by tree roots (Grabosky and Bassuk, 1995; Grabosky and Bassuk, 1996; Smiley et al., 2006). Engineered soils are friendly to trees in urban environments and have higher porosity as compared with regular urban soil (Smiley et al., 2006). The larger volume of pore space provided by the highly porous engineered soil, can support larger growing trees and provide more space for temporarily storing surface runoff. Polluted urban soils have caused environmental problems, such as a growing risk for heavy metal uptake by human and livestock (Camobreco et al., 1996; Moller et al., 2005) and groundwater contamination (Mikkelsen 1997). Vegetation has been used as one of the Best Management Practices (BMPs) to clean pollutants and thus improve water quality (Barrett et al., 1998; Cheng, 2003; Liu et al., 2007; Matteo et al., 2006). For example California in America used it in 2003. Reducing surface runoff will reduce pollutants travelling downstream or into the receiving water body.

Rapidly flushing storm water can increase erosion from all land, not just stream banks and stream beds. Storm water then transports the eroded sediment downstream into the receiving waters. Eventually, when sediment-laden water is stilled, that sediment settles to the bottom of the stream, river, lake, or estuary. When sediments settle out, they may cover or destroy important habitat such as spawning beds or submerged aquatic vegetation. Pollutants such as excess phosphorus attach to sediment particles and become suspended or dissolved in receiving waters. This excess phosphorus leads to eutrophication.

Siltation and sedimentation has economic impacts as well. These excess deposits of sediment clog harbours and other water transport routes and reduce the storage capacity of reservoirs, obliging governments to spend billions of dollars each year to dredge and maintain those channels and facilities

2.7 IMPACT OF STORM WATER RUNOFF

Storm water is a leading cause of water pollution. It runs off solid surfaces and collects pollutants such as oils, pesticides, sediments, bacteria and other chemicals and then deposits them into our water bodies. This runoff can kill aquatic life and make our water bodies unhealthy place to live, work and play.

Untreated storm water entering our streams can result in the contamination of our drinking water supplies or shell fishing waters, prohibition on swimming, fishing or injury to aquatic plants and animals.

Pollutant levels are typically much higher in the first flush. Studies have shown that approximately 90% of the pollutant loading is contained in the first flush of one-inch rainfall (Hartwel et al, 2008). Water bodies are impaired and do not meet water quality standards. A leading source of this impairment is polluted runoff. Small amount of some substances may cumulatively degrade an aquifer if a significant proportion of contaminated runoff is percolated into the water table.

The percolation of contaminated runoff can cause unacceptable consequences to ground water resources

Adverse impacts on receiving waters associated with storm water discharges have been discussed by EPA (1995) in terms of three general classes namely: Short- term changes, Long- term impacts and physical impacts due to erosion.

- Short-term changes in water quality during and after storm events including temporary increases in the concentration of one or more pollutants, toxics or bacteria levels.
- Long-term water quality impacts caused by the cumulative effects associated with repeated storm water discharges from a number of sources.
- Physical impacts due to erosion, scour, and deposition associated with increased frequency and volume of runoff that alters aquatic habitat.

As described in the Terrene Institute's Fundamentals of Urban Runoff Management (Horner et al, 1994), pollutants associated with urban runoff potentially harmful to receiving waters, fall into the categories listed below:

- Solids
- Oxygen-demanding substances
- Nitrogen and phosphorus
- Pathogens
- Petroleum hydrocarbons
- Metals
- Synthetic organics.

These pollutants degrade water quality in receiving waters near urban areas, and often contribute to the impairment of use and exceedences of criteria included in State water quality standards. The quantity of these pollutants per unit area delivered to receiving waters tends to increase with the degree of development in urban areas.

Both water quality and water quantity impacts associated with urban storm water combine to impact aquatic and riparian habitat in urban streams. Higher levels of pollutants, increased flow velocities and erosion, alteration of riparian corridors, and sedimentation associated with storm water runoff negatively impact the integrity of aquatic ecosystems. These impacts include the degradation and loss of aquatic habitat, and reduction in the numbers and diversity of fish and macro invertebrates.

Public health impacts are for the most part related to bacteria and disease causing organisms carried by urban storm water runoff into waters used for water supplies, fishing and recreation. Water supplies can potentially be contaminated by urban runoff, posing a public health threat. Bathers and others coming in contact with contaminated water at beaches and other recreational sites can become seriously ill. Beach closures caused by urban runoff have a negative impact on the quality of life, and can impede economic development as well. Similarly, the bacterial contamination of shellfish beds poses a public health threat to consumers, and shellfish bed closures negatively impact the fishing industry and local economies.

Aesthetic impacts in the form of debris and litter floating in urban waterways and concentrated on stream banks and beaches are quite visible to the general public. Storm water is a major source of floatables that include paper and plastic bags and packaging materials, bottles, cans, and wood. The presence of floatables and other debris in receiving waters during and following storm events reduces visual attractiveness of the waters and detracts from their recreational value. Nuisance algal conditions including surface scum and odour problems can also be attributed to urban storm water in many instances.

2.7.1 NUTRIENTS

Nutrients, primarily phosphorus and nitrogen, increase plant growth in streams, reservoirs, and lakes in a process called eutrophication. In many parts of the country, storm water containing a large concentration of nutrients enters lakes, causing nutrient enrichment, reduced water clarity, and increased presence of undesirable blue-green algae and other plants. Upon decomposition and oxidation of the plant matter, dissolved oxygen in the water body is consumed, and can be reduced to zero or near zero levels.

Because of urban sprawl, residential land is now the dominant land use in 64% of the nation's water supply reservoirs (Robbins et al, 1991). Eutrophication caused by nutrients in storm water often impairs municipal drinking water supplies. One example is the New Croton Reservoir in New York State, which provides daily drinking water to about 900,000 New York City residents. Due to excessive phosphorus loading from storm water, the reservoir suffers from algae blooms, low dissolved oxygen, and poor taste. As a result, it is common for the use of this reservoir to be reduced or temporarily suspended in the summer (NYSAGO, 2011).

Excessive nutrient loading can also stimulate the growth of undesirable rooted aquatic plants in streams. The US EPA reports that approximately 11% of the nation's assessed stream miles are threatened or impaired due to excess nutrients (US EPA, 2000). With only 26% of the total stream miles assessed, the total number of stream miles that are threatened or impaired is likely significantly higher.

2.7.2 HEAVY METALS

A large number of potentially toxic substances, including heavy metals, occur in storm water. Metals of primary concern (based on toxicity and occurrence) are cadmium, copper, zinc, and lead (Jang et al, 2005; Rangsivek and Jekel, 2005), with roughly 50% of the metal load in dissolved form. Lead concentration in the environment has declined since the 1970s, when lead in gasoline and paint was banned, but there is still substantial degrading lead paint present in the urban environment, making this a continuing concern.

Large concentrations of metals can be lethal, and moderate concentrations can reduce growth, reproduction, and survival in aquatic organisms. Small concentrations of metals also have been documented to alter the behaviour and competitive advantage of invertebrates, a result that could change the balance of ecosystems (Clements and Kiffney, 2002). Kayhanian et al, (2008) investigated the toxicity of storm water runoff from urban highway sites near Los Angeles, USA. Results indicated that the toxicity to water fleas and flathead minnows of the most toxic samples was mostly, but not entirely, due to copper and zinc. Study conducted by Boamponsem et al, (2010) showed that Sb, Mn, Cu, Al, Hg, As and Cd levels in Angonabeng and Bediabewu river water samples in Tarkwa- Ghana exceeded the WHO maximum allowable concentrations in drinking water

Pelig Ba *et al.*, (1991) assessed the level of contamination of drinkable ground-water from the Accra plains and upper regions of Ghana and found that in some areas Pb, Cr and Fe concentrations exceeded the WHO guideline limits for drinking water.

Once in an aquatic environment, metals can accumulate in freshwater biofilms to such an extent that the biofilm concentrations are larger than sediment metal concentrations. Fish and invertebrates feed on biofilms, as a result, the metals can be transferred through the food chain (Ancion et al, 2010), and bioaccumulation will continue to occur.

Of the stream miles assessed in the USA as of 2011, approximately 7% have been categorized as threatened or impaired due to metals other than mercury.

Mercury, which is a metal more common to runoff from industrial land uses and atmospheric deposition, has threatened or impaired approximately 5% of assessed stream miles (US EPA, 2011).

Biney and Beeko (1991) conducted a survey of metals in fish and sediments from the River Wiwi in Kumasi and found a positive correlation between mercury concentration and body weight of fish. They also reported higher levels of cadmium and mercury in fish than in sediment. Studies on the distribution of Hg, Cd, Pb, Cu, Zn and Fe in water, finfish and shellfish, macrophytes and sediments from Kpong head pond and lower Volta River (Biney, 1991) showed the highest concentration of iron and lead in sediments and of manganese and cadmium in macrophytes. Finfish had the lowest concentrations of the metals, except for lead.

2.7.3 BACTERIA AND VIRUSES

The potential for bacterial contamination of water is generally measured by the concentration of faecal coliforms, Escherichia coli, or enterococci. Although most faecal coliforms are not pathogenic, they are currently the best established representative surrogate, or indicator, of human pathogens.

Rain and increased runoff increase the presence of microbial pathogens in marine and estuarine waters, an effect that can be a direct health threat to humans and can contaminate shellfish. In fact, urban storm water is the cause of 40% of shellfish closures in US waters (Mallin et al, 2009). One outcome of elevated coliform levels is beach closings.

A study of the Densu River (Karikari and Ansa-Asare, 2005) showed that total and faecal coliforms pollution was widespread, and the entire river basin as sampled is not suitable for domestic use without treatment. For agricultural purposes there is a possibility of contamination from vegetables and other crops eaten in their raw state.

The mean total coliforms ranged between 1136 and 1880 CFU/100 ml while the faecal coliforms ranged between 336 and 739 CFU/100 ml. The results suggest that the general sanitary qualities of the water source, as indicated by total coliforms counts, were unacceptable. Faecal coliform concentrations are generally largest immediately after rainstorms. A study of Minnehaha Creek in Minnesota (Wenck, 2003) reported that faecal coliforms in excess of 2000 CFU/100 mL were found only within 3 days of a rainstorm. Faecal streptococci and E. coli were found in 94% and 95.5%, respectively, of municipal separate storm sewer system (MS4) outfalls monitored (Clark and Pitt, 2007). This indicates that a large percentage of faecal coliforms are result of storm water runoff.

Faecal coliforms are excreted from the bodies of warm-blooded animals. For urban storm water, sources may include humans (via illicit sewage connections to storm water conveyances), dogs, cats, geese, raccoons, and other wildlife.

Although generation rates (number of coliforms excreted per day) for various organisms (dogs, geese, humans) are well known (Schueler, 2000), there is little information regarding “delivery ratios” (the fraction of excreted coliforms that enters runoff) for urban storm water.

Potential for groundwater contamination by bacteria and pathogens depends on the soil chemical properties, adsorption capability, the ability of the soil to physically strain the pathogens, and pathogen survival. Bacteria survive longer in low pH (acidic) soils and in soils with large organic content. Bacteria and viruses can move through soil media and may be transported to aquifers by infiltrating storm water.

The transport distance of bacteria seems to be a function of bacteria density and water velocity through the soil (Unice and Logan, 2000). Pitt et al, (1996) rate enteroviruses as having high groundwater contamination potential for all surface and subsurface infiltration/injection systems and a variety of other pathogens as having high groundwater contamination potential for subsurface infiltration/injection systems.

Although documented cases of groundwater contamination do exist, bacteria are generally removed by straining at the soil surface and sorption to solid particles. Once removed from the water, the ability of bacteria to survive is a function of factors such as temperature, pH, and presence of metals, among others. Bacteria survival may be between two and three months, but survival for up to 5 years has been documented (Pitt et al, 2009). Although not readily modelled in natural environments, faecal coliforms can also regrow in the environment under warm conditions with a supply of organic matter for food, conditions commonly found in wetlands or storm water ponds. As part of the National Urban Runoff Program, faecal coliforms were evaluated at 17 sites for 156 storm events, and based on the results, it was concluded that coliform bacteria in urban runoff may exceed US EPA water quality criteria during and after storm events (US EPA, 1999a). There existed a high degree of variability within the data, but land use did not appear to correlate with coliform concentration. During warmer months, concentrations were approximately 20 times larger than cold months.

A study by the National Academy of Sciences (NAS, 2000) noted that very large removal rates—on the order of 99% would be needed to reduce coliforms from the levels observed in urban storm water (15,000–20,000/100 ml) to the EPA's 200/100 ml criterion for recreational water. Their review indicated that bacterial removal rates in several types of storm water treatment practices were significantly less than 99 **%**

2.7.4 TEMPERATURE

Urbanization generally requires removing crops, trees, and native plants from parcels of land and replacing them with roads, parking lots, lawns, and buildings.

Along with the impacts previously mentioned, these changes in land use affect riparian shading and heating of runoff in these areas which results in increases in summertime temperatures of nearby streams. This can significantly impact relatively cool waters, such as trout streams that are fed by groundwater, because increases in the volume and temperature of runoff from impervious surfaces will dilute the colder groundwater, lower the volume of groundwater entering the water body, and reduce coldwater fish habitat.

In most temperate climates, the risk to salmon and trout populations due to increased temperature is of concern. Water temperature affects many areas of fish health, such as migration, disease resistance, growth, and mortality (Sullivan et al, 2000).

The US EPA reports that, of the 935,393 stream miles assessed nationwide, approximately 5% (46,786 miles) are threatened or impaired due to thermal pollution (US EPA, 2011). With only 26% of the nation's stream miles assessed, the total length of impaired streams is certain to increase. In a study of 39 trout streams in

Wisconsin and Minnesota, stream temperatures increased 0.25^{o}C per 1% increase in watershed imperviousness (Wang et al, 2003).

The temperature of storm water runoff is controlled by the initial rainfall temperature and by the heating/cooling processes with the land and other surfaces during runoff. The temperature of land surfaces is controlled by several processes including solar radiation during the daytime, atmospheric long wave radiation, long wave back radiation from the surface, evaporative heat flux, and sensible heat flux. Land surfaces are heated above ambient air temperature primarily by solar radiation

The largest runoff temperatures are typically observed at the beginning of storm events, when the land surfaces are warmest. Because the amount of heat available to heat surface runoff is finite, land surfaces have more impact on runoff temperatures for smaller storms.

Vegetated, pervious surfaces produce relatively little thermal pollution per unit area, because both runoff rates and runoff temperatures are lower than pavement temperatures. Vegetated surfaces, however, can produce thermal pollution for storms of large volume and dew point temperature (Herb et al, 2007a).

Aquatic organisms have specific water temperature preferences and tolerance limits. Changes in water temperature can have a serious impact on aquatic ecosystems. Water that infiltrates the ground and flows beneath the surface is usually much cooler than surface runoff. Not only do impervious surfaces prevent infiltration; they often warm storm water as it runs off. Unshaded rooftops, parking lots, and other impervious areas can be 5^{0}C–6^{0}C warmer than fields and forests and consequently can heat the storm water passing over them, often to 32.2^{0}C or more, even before it reaches a stream or lake. Research has found that the average stream temperature increases directly with the percentage of impervious cover in the watershed.

Furthermore, trees shade water bodies keeping them cool, while development often replaces trees with impervious surfaces

2.7.5 HYDROCARBONS

Hydrocarbons are organic compounds consisting entirely of hydrogen and carbon molecules. Some attributes of hydrocarbons are that, hydrocarbons can reduce the ability of some organisms to reproduce, they can negatively impact the growth and development of various aquatic species, and that they can be lethal at high concentrations. For example, fish kills have been attributed to high levels of polycyclic aromatic hydrocarbons (PAHs) (Watts et al, 2010). When consumed, hydrocarbons can bioaccumulate in aquatic organisms, and, when collected in bottom sediment, degradation of hydrocarbons can consume oxygen which can negatively impact the entire aquatic ecosystem.

In storm water runoff, hydrocarbons originate from vehicle coolants, gasoline, oils, lubricants, coal tar-based asphalt sealants (a source of PAHs), atmospheric deposition, and other sources. Thus, gas station runoff and vehicles in general are a major source of the hydrocarbon load in runoff (Mijangos- Montiel et al, 2010).

Once in storm water, hydrocarbons often attach to particulates

2.8 WATER AND CLIMATE CHANGE.

- Water resources are natural resources of water supply origin (e.g., rivers, streams, wetlands) and forming part of the hydrological cycle which describes the flows of water on the planet between oceans, land and atmosphere. Thus water resources constitute the supply side of the water cycle and involving the transformation of water into different forms (liquid, gas, solid). The water cycle is driven by the radiant energy from the sun and it includes a number of processes as follows (FWR 2005):

- *Evaporation* involves the loss of water from the oceans, lakes and soil into the atmosphere.
- *Condensation* is a process whereby water vapour rises, cools down and condenses to form clouds.
- *Precipitation* is water falling from the atmosphere onto the surface of the Earth (land or ocean).
- *Infiltration* defines the entering of water into the pore space of unsaturated soil.
- *Runoff* describes the water that flows along the surface of the earth to a water body (lake or ocean).
- *Evapotranspiration* is the sum of evaporation (movement of water from the liquid to the gas phase) and transpiration (loss of water from the stomata in the leaves of a plant).

Competition among agriculture, industry and cities for limited water supplies is already constraining development efforts in many countries. As populations expand and economies grow, competition for limited supplies will intensify and so will conflicts among water users. The extent to which a region or country is vulnerable to water depends on the quantity of water, temporal distribution, quality, and the extent of its use and requirements. While climate is the principal factor in determining water quantity and its inter-temporal distribution, human population and economic development are the main influences on quality and demand (FAO 1995).

Water is the key medium that links atmospheric temperature rises to changes in human and physical systems. Climate change will alter the hydrological cycle in many ways. The trigger is the warming of the atmosphere and oceans, which will change major weather systems. This will alter the temporal and spatial patterns of rainfall with consequences for runoff, surface and groundwater storage, river flow regimes and its estimated greater likelihood of extremes e.g., droughts and floods in different parts of the world (Meehl et al. 2007). Thus, water is the first sector to be affected by changes in climate. Climate change (e.g., temperature increases) speeds up the processes of the hydrological cycle and subsequently imposing serious effects on the frequency and intensity of extreme events. Increased evaporation, unpredictable precipitation and prolonged droughts are some manifestations of climate variability, directly impacting water availability and quality.

Ghana is vulnerable to climate change and variability by virtue of its location in the tropics. About 35 percent of the land mass is desert and desertification is currently proceeding at an estimated 20,000 ha per year (EPA 2003, 2009). Ghana's geographic location, bordering the Atlantic Ocean to the south is exposed to contrasting oceanic influence and atmospheric changes that can by far be receptive to extreme weather events (Dovie 2009, EPA 2009)

Because of the rather small land surface of Ghana, the whole country may be exposed to such changes and this can lead to important rainfall deficits, dry spells and drought variability, or rain sufficiency depending on the type of oceanic oscillation particularly the Inter-Tropical Convergence Zone.

Severe drought, prolonged dry spells, variable rainfall regimes and rain floods, of 1983, 1998, 2005 and 2007, respectively, in Ghana, are examples of extreme weather events due potentially to changes in climatic conditions. These are often accompanied by intermittent shocks experienced in most parts of the country. These events alter the quality and availability of natural resources, and generally impact on human security through water and food insecurity (Dovie 2009). Rainfall patterns show great fluctuations over the years and across vegetation zones. However there is gradual decrease in rainfall distribution in all parts of the country and this affects water resources (WRI 2000, Minia et al. 2004, World bank 2009), with specific rainfall decreases in the Volta Basin (Owusu et al. 2008).

Warmer temperatures, altered patterns of precipitation and runoff, and rising sea levels are increasingly compromising national ability to effectively manage water supplies, floods, agricultural production systems and other natural resources. However, adapting water management systems in response to climate change remains a significant challenge.

Weather figures from four representative river catchments across Ghana produced under the Netherlands Climate Change Studies Assistance Project (NCAP), Phase 1 showed:

- Reductions in flows between 5-20% and 30-40% for the years 2020 and 2050, respectively
- Vulnerability, measured in persons/mill m^3 of the renewable resource would put the White Volta Basin under water stress in 2020 and in scarcity by 2050 (NCAP / EPA 2004).

While pressures resulting from increasing demands on water resources caused by population growth and economic development are far greater than those caused by climate change, the added complications that climate change brings cannot be ignored and it brings on board challenges and pressure on water resources.

As summarized by the Intergovernmental Panel on Climate Change (IPCC) in 2008, "Water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change" (Bates et al. 2008). Examples of established expected impacts of climate change on water resources are:

- *Flooding*: Increased precipitation intensity and variability are projected to increase the risks of flooding and inundation in many areas.
- *Drought*: At the same time, the proportion of land surface in extreme drought at any one time is projected to increase (likely)
- *Runoff and stream flow*: By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics. A reduction in runoff will be perhaps the most serious impact of global warming on the water environment.
- *Changing groundwater recharge and storage*: If the runoff from rainfall that flows into rivers and streams is affected by changes in temperature and land use, so too is the infiltration of water into underground formations.
- *Water quality*: Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution.

2.9 WATER AND HEALTH

Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking-water can result in tangible benefits to health. Every effort should be made to achieve a drinking-water quality as safe as practicable. The quality of water, whether used for drinking, domestic purposes, food production or recreational purposes has an important impact on health. Water of poor quality can cause disease outbreaks and it can contribute to background rates of disease manifesting themselves on different time scales. Initiatives to manage the safety of water do not only support public health, but often promote socioeconomic development and well-being as well

Water has a profound influence on human health. At a very basic level, a minimum amount of water is required for consumption on a daily basis for survival and therefore access to some form of water is essential for life. However, water has much broader influences on health and wellbeing and issues such as the quantity and quality of the water supplied are important in determining the health of individuals and whole communities.

The first priority must be to provide access for the whole population to some form of improved water supply. However, access may be restricted by low coverage, poor continuity, insufficient quantity, poor quality and excessive cost relative to the ability and willingness to pay. Thus, in terms of drinking-water, all these issues must be addressed if public health is to improve. Water quality aspects, whilst important, are not the sole determinant of health impacts.

The quality of water does, however, have a great influence on public health; in particular the microbiological quality of water is important in preventing ill-health.

Poor microbiological quality is likely to lead to outbreaks of infectious water-related diseases and may causes serious epidemics to occur.

Chemical water quality is generally of lower importance as the impact on health tends to be chronic long-term effects and time is available to take remedial action. Acute effects may be encountered where major pollution event has occurred or where levels of certain chemicals are high from natural sources, such as fluoride, or anthropogenic sources, such as nitrate.

Various studies of fluoride presence in Ghana revealed that groundwater in some areas contain high fluoride content. Bongo District in the Upper East Region is one of such areas reported to have elevated fluoride content especially in the Bongo granite (Apambire et al., 1997).

Contaminated water serves as a mechanism to transmit communicable diseases such as diarrhoea, cholera, dysentery, typhoid and guinea worm infection. WHO estimates that in 2008 diarrhoeal disease claimed the lives of 2.5 million people worldwide. For children under five, this burden is greater than the combined burden of HIV/AIDS and malaria (WHO/UNICEF, 2009).

A total of 58 countries from all continents reported a cumulative total of 589 854 cholera cases in 2011, representing an increase of 85% from 2010. The greatest proportion of cases was reported from the island of Hispaniola and the African continent. These trends reflect the need to shift from basic responsiveness to a comprehensive, multidisciplinary approach that works with communities to improve access to safe drinking-water and sanitation encourages behavioural change and promotes the targeted use of oral cholera vaccines where the disease is endemic (WHO, 2012)

Although consumption of contaminated water represents the greatest risk, other routes of transmission can also lead to disease and contribute to the disease burden. For example, WHO estimates that more than 200 million people are affected by schistosomiasis and around 800 million more are at risk of infection. The disease burden attributable to bathing water exposures is significant, largely due to the high exposed population at recreational beaches world-wide (Steinmann et al, 2006).

In many parts of the world, insects that live or breed in water serve as vectors of disease. Water quality is not a major determinant, although anopheline vectors of malaria breed only in clean water and culicine vectors of lymphatic filariasis prefer organically polluted water. However, an immediate link exists between household water storage and vector breeding. Dengue fever outbreaks have increased fourfold since 1995, with 2.5 billion people at risk today. WHO (2011) estimates that 50-100 million dengue infections occur worldwide each year.

Providing such barriers to the spread of faecal pathogens by improving water supply, sanitation facilities and hygiene behaviour has been shown to decrease the transmission of diarrhoea, reduce the overall burden of disease and result in higher child survival rates (Esrey et al, 1990; Fewtrell et al, 2005).

Improved management of water, sanitation and hygiene, is a critical component of the seven-point strategy agreed by WHO and UNICEF for comprehensive diarrhoea control, which includes promotion of hand washing with soap, household water treatment and safe storage and community-wide sanitation promotion

Access to safe drinking water is therefore important as a health and development issue at the national, regional and local levels

2.9.1 GEOLOGY OF THE KASSENA NANKANA DISTRICT

The geology of the district comprises granite and shale, although the rock formations are actually of a diverse nature. Two main types of soils are present within the district namely, the savannah ochrosols and ground water laterite.

The northern and eastern parts of the districts are covered by the savannah ochrosols, while the rest of the district has ground water laterite. The savannah ochrosols are porous, well drained, loamy, and mildly acidic and interspersed with patches of black or dark-grey clay soils. This soil type is suitable for cultivation and hence accounts for the arable land sites including most parts of Tono Irrigation Project sites where both wet and dry season farming are concentrated.

The ground water laterites are developed mainly over shale and granite and cover approximately 60% of the district's land area. Due to the underlying rock type (granite), they become waterlogged during the rainy season and dry out during the dry season, thus causing cemented layers of iron-stone (hard pan) which makes cultivation difficult.

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CHAPTER THREE

PROFILE OF STUDY AREA AND RESEARCH METHODOLOG

3.1. LOCATION

The Kassena-Nankana District (KND) lies within the Guinea Savannah woodlands and falls approximately between latitude 11^0 10^1 and 10^0 3^1 North and longitude 10^0 1^1 West. The district has a total area of about 1,674 sq.km and stretch about 55 km North-South and 53 km East-West. It shares boundaries to the North with Burkina Faso, to the East with Bongo and Bolgatanga districts, West, with the Builsa and Sissala districts and in Southwest with Mamprusi district in the Northern region.

KASENA- NANKANA DISTRICT MAP

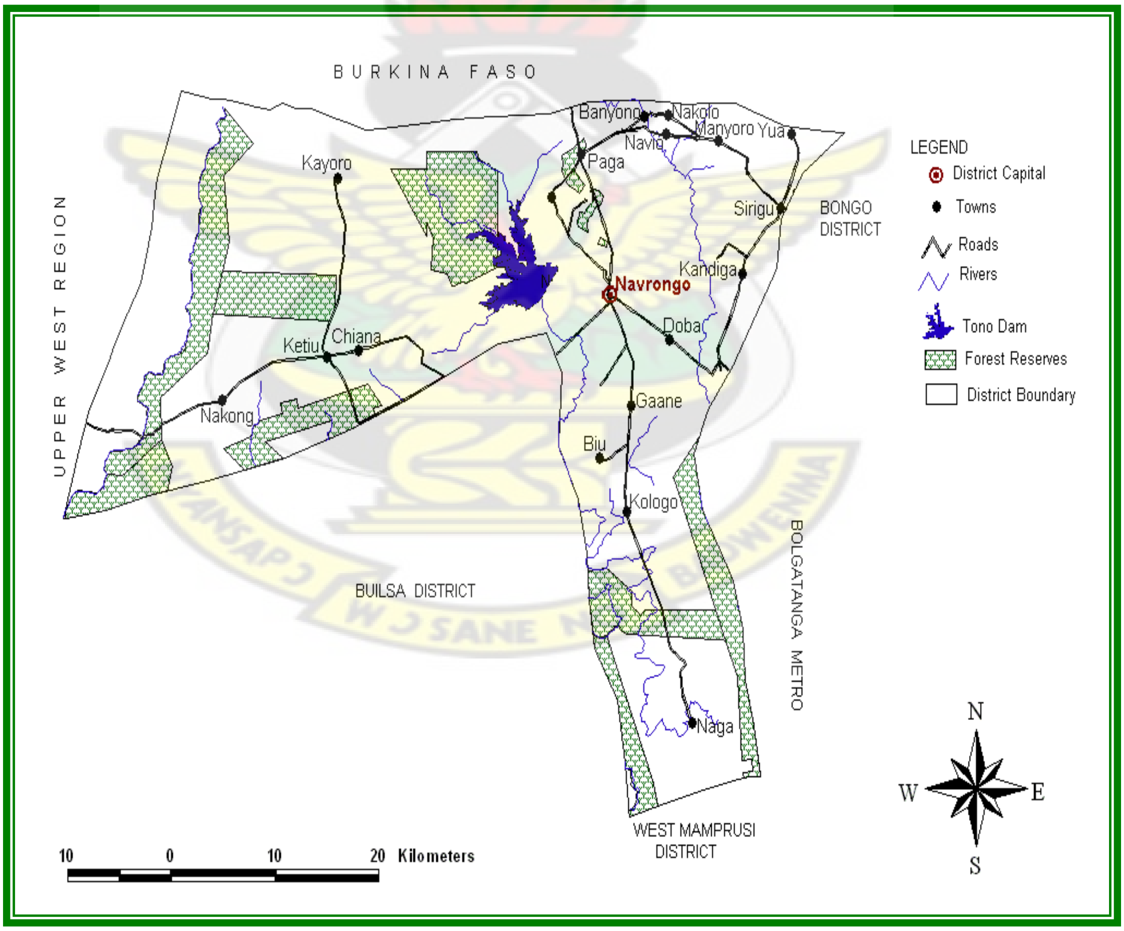

Fig 3.1: Map of Kassena Nankana District.

3.2 CLIMATIC CONDITIONS

The climatic conditions of the district are characterized by the dry and wet seasons, which are influenced mainly by two (2) air masses – the North-East Trade winds and the South Westerlies (Tropical Maritime). The Harmattan air mass (North-East Trade Winds) is usually dry and dusty as it originates from the Sahara Desert. During such periods, rainfall is virtually absent due to low relative humidity which rarely exceeds 20 per cent and low vapour pressure less than 10mb. Day temperatures are high recording 42° Celsius (especially February and March) and night temperatures are as low as 18° Celsius. The District experiences the tropical maritime air mass between May and October. This is a moisture laden air mass that originates from the Atlantic Ocean and brings with it rainfall averaging about 950mm per annum.

It is only between the months of May and October that the Northern parts of Ghana come under the rainy season. That leaves November to April as dry months. This is particularly important as most of the people in this part of the country are mainly subsistence farmers who depend largely on rainfall for their agricultural produce.

3.3 DRAINAGE AND RELIEF

The District is generally low-lying with occasional undulation averaging about 1000 metres above sea level. The drainage system of the district centres mainly on the tributaries of the Sissili River – Asibelika, Afumbeli, Bukpegi and Beeyi. A tributary of the Asibelika River (Tono River) has been dammed to provide irrigation facilities, which is of great economic importance to the entire district. In addition to these rivers, there are some few dugouts and ponds, which are used for livestock watering, dry season farming and domestic purposes, among which is the Goo dam constructed on the Wurisi stream.

3.4 VEGETATION

The district mainly comes under the Sahel and Sudan-Savannah types of vegetations; comprising open savannah with fire-swept grassland and deciduous trees. Human activities over the years have affected the original vegetation cover. This has invariably affected the soil quality which is already not well endowed for agricultural purposes. The district easily becomes waterlogged during the rainy season and dries up quickly in the dry season. Common trees of commercial value found in the district are dawadawa, baobab, sheanut and mango.

3.5 GOO RESERVOIR

According to the Ghana Irrigation Development Authority (GIDA), the Goo reservoir which was created by damming the Wurisi stream was originally constructed in 1959 by the then Irrigation, Reclamation and Drainage Authority (IRDA). Though one of the purposes of the dam was dry season gardening, it was mainly just a dugout with gardeners expected to draw water by the use of buckets to water their crops. This was an extremely laborious process and severely limited the productive capacity of the farmers. However, with its potential to contribute meaningfully to the improvement of the livelihoods of the people in the area, the government through the International Fund for Agricultural Development rehabilitated it in 1996 with the requisite facilities for irrigation using canal to distribute the water to the various cultivated plots. It has a catchment area of about 544 hacters with a reservoir length of 240m.

3.6 COLLECTION AND ANALYSIS OF WATER SAMPLES

The reservoir was divided into north, south, east and west where samples were taken randomly from each zone. Water samples from the reservoir were taken at a depth of 0.5metres. Samples were equally taken from the water supply well. Sampling was done between December 2013 and March 2014. A total of seventy-five water samples were collected from the water supply well and the reservoir over a period of four months from the study area. Sample bottles were rinsed with deionised water twice before samples were collected. Collected samples were preserved in ice chest with ice at temperature of 4^oC. Samples were taken in separate containers for physicochemical and heavy metal analysis respectively. The samples were analyzed for various parameters including electrical conductivity, pH, total dissolved solids, turbidity and heavy metals such as Lead (Pb), Copper (Cu), Manganese (Mn), total iron (Fe) and zinc (Zn). Physical parameters like conductivity and total dissolved solids of the samples were measured using conductivity meter. pH and turbidity were recorded using pH meter and turbidimeter respectively.

Determination of metals (Fe, Pb, Zn, Mn and Cu)

Fifteen milliliters (15 ml) of concentrated HNO_3 was added to 50 ml of sample collected. The mixture was heated slowly to evaporate to a lower volume of 15 – 20 ml after which 5 ml of concentrated HNO_3 was again added to the 15 ml of the mixture obtained. The mixture was then diluted to 50 ml with distilled water. This was then heated slowly to obtain a gentle refluxing action.

Further heating continued until digestion was complete (a light coloured solution). The sample was then transferred to a 50 ml volumetric flask and diluted to the mark after allowing it to cool for about 30 minutes

Trace metals (Fe, Pb, Zn, Mn and Cu) analysis was done using the Shimadzu model AA 6300 in accordance with APHA (1998) standard methods.

Physico-chemical parameters such as total dissolved solids (TDS), electrical conductivity (EC), pH, concentration of sulphate (SO_4), Turbidity and Nitrate were used to determine the water quality.

MEASUREMENT OF pH

pH was measured 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 reads 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. 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

Measurement of Electrical Conductivity (EC)

A high powered microcomputer conductivity meter JENWAY 40710 model HI 9032 with a degree of accuracy of 0.01 as used to measure the conductivity of the water samples in situ. The instrument was initially calibrated using standard solution of conductivities 500 µs/cm and 1500 µs/cm. Duplicate values were taken and units were in micro siemens per centimeter.

Total Dissolved Solids (TDS)

TDS was measured in situ using a JENWAY 40710, model HI 9032 (0.01 degree of accuracy) (MAKE/MODEL). One hundred milliliters of the sample was poured into a 250 ml beaker .The probe was then immersed into the sample and the value read on the digital screen.

Turbidity

Turbidity of the water samples was measured 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 taking the turbidity values of the samples.

Total and faecal coliform loads were determined by filtering 100 ml of sample water through HA-type Millipore, cellulose filters with a pore size of 0.45 μm using a Welsh Thompson vacuum pump. Serial dilutions were used for the water samples to bring the load to readable levels through a trial run. Sample water dilutions (10^1 to 10^9) were prepared with 0.1% buffered peptone water (BPW) (Oxoid CM 509). The filter was then placed on a Petri dish containing M-FC agar and incubated for 24 hr at 44 ± 1°C for faecal coliforms and 36 ± 1°C for total coliforms.

3.7.1 COLLECTION AND PREPARATION OF VEGETABLE SAMPLES.

Vegetable samples (garden eggs and lettuce) were aseptically collected from the farms and kept in separate polythene bags and placed in an ice chest and transported together with the water samples to the laboratory. Sample vegetables meant for heavy metal determination were transferred into a crucible and oven dried at 105 ^oC

for 24 hr. The dried samples were poured in a mixer grinder and grind into fine powder. Powdered samples were accurately weighed and placed in silica crucible and few drops of concentrated nitric acid were added to the solid as an ashing aid. Dry-ashing process was carried out in a muffle furnace by stepwise increase of the temperature up to 550 ^{o}C and then left to ash at this temperature for 4 hr. The ash was left to cool and then decomposed using concentrated nitric acid (10 ml). The ash suspension was filtered into a 25 ml volumetric flask using Whatman filter paper No. 41 and the solution was completed to the mark using deionised water.

3.7.2 ATOMIC ABSORPTION SPECTROPHOTOMETER DETERMINATION

Analysis of heavy metals of interest was performed using a Shimadzu Model AA 6300. Atomic Absorption Spectrophotometer. Measurements were made using a hollow cathode lamp for copper (Cu), iron (Fe), lead (Pb) manganese (Mn) and zinc(Zn) at wavelengths of324.8, 248.3, 217.0, 279.5 and 213.9 nm respectively. The slit width was adjusted for all metals at 0.5 nm. The calibration curves were prepared from standards by dissolving appropriate amounts of the metal salts in purified nitric acid, diluting with deionised water and storing as stock solutions in a quatz flask. Fresh working solutions were obtained by serial dilution of stock solutions.

3.8 MICROBIAL ANALYSIS

25 g of each vegetable sample were weighed and blended in 100 ml of sterile saline solution for 2 min under sterile conditions. The blender was carefully disinfected to prevent any cross contamination. The homogenates were collected in sterile bottles

and stored at -20°C until needed. Aliquots (0.5 ml) of each homogenate were serially diluted in sterile saline solution. The diluent of buffered peptone water was then inoculated on to the respective media. Total coliform and faecal coliform were determined using standard APHA9222A and APHA9222D methods respectively.

3.9 DATA ANALYSIS

Microsoft excel was used in analyzing the range, mean and standard deviation of the data.

CHAPTER FOUR

RESULTS AND DISCUSSION

PHYSICOCHEMICAL PARAMETERS

4.1.1 TOTAL DISSOLVED SOLIDS (TDS)

The mean Total Dissolved Solids (TDS) of the water samples from the reservoir ranged between 167.4 mg/l and 172.5 mg/l. The NORTH recorded the highest mean value while the lowest mean was recorded at the EAST. The TDS values of the samples from the reservoir were below the EPA-Ghana maximum allowable limit of 1000 mg/l. The borehole water however recorded a mean value of 292.5 mg/l which was higher than the water from the reservoir. The TDS values of the borehole water samples were however, relatively far below the Ghana Standards Board (GSB) maximum allowable limit of 1000 mg/l. According to WHO (2008), there is no health based limit for TDS in drinking water. However the palatability of water with TDS level of less than 500 mg/l is generally considered to be good. Drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/L. TDS greater than 1200 mg/l may be objectionable to the consumer. High mineralization resulting in high TDS is a problem with groundwater. Mean values of TDS in water from boreholes passing through granitic formation was found to be 387.4mg/l (Kortatsi, 1994). Thomas (2003) reported that as water moves slowly through the ground it can remain for extended periods of time in contact with minerals present in the soil and bedrock and become saturated with TDS from these minerals. This accounts for the relatively high levels of TDS in the borehole water. On the other hand the surface water rushes over the ground and thus spends less time in contact with the minerals and bedrock hence has low TDS. Cobbina et al (2013) recorded mean values of 460 mg/l for TDS in boreholes in Talensi in the Upper East

Region of Ghana which is higher than what is recorded in this research. The reason for the difference in TDS value could be attributed to the mining in Talensi which involves breaking of the rock ores making them easy to dissolve. The spill way at the North of the reservoir could be reason for the high TDS at that side since the water flows to that side and carry along sediments that get settled within that side.

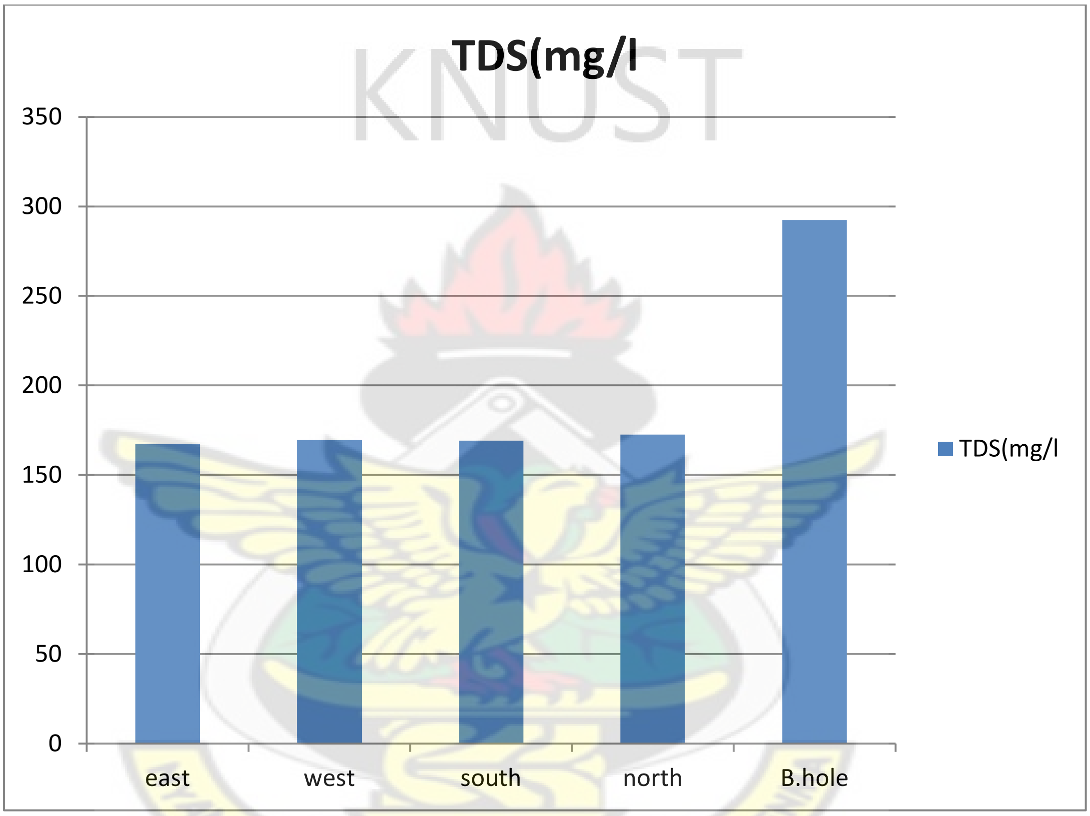

Table 4.1; A graph of TDS of the reservoir and well

4.1.2 pH

Mean pH levels of all the water samples from the reservoir varied between 7.00 and 7.43 as shown in Table1, with the sample from the WEST recording the highest mean pH value of 7.43 and the lowest at the EAST with a value of 7.00. The water from the borehole recorded the least pH of 6.78. All the sample sites from the reservoir recorded mean pH values that were within the EPA value of 6-9 for waste water. Generally, the mean pH values of all the water samples from the borehole were within the GSB standard of 6.50 - 8.50.

The pH of surface water forms part of a dynamic system controlled by a range of buffering reactions occurring in solution and at the solid–solution interface, which produce or consume H^+ (Neal et al, 1997). The mean values of pH recorded from the reservoir shows that the water is neutral and therefore well buffered.

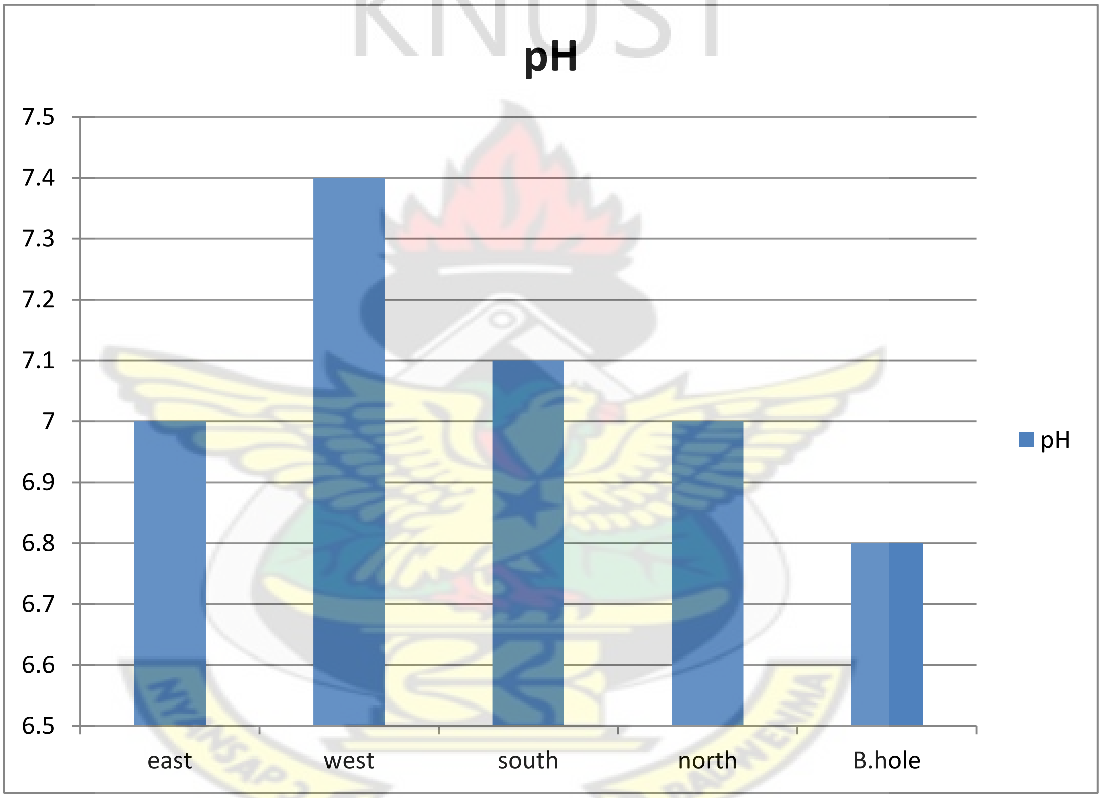

Table 4.2; A graph showing pH of the water from the reservoir and well

4.1.3 CONDUCTIVITY LEVELS

Electrical conductivity of the samples from the reservoir was in the range of 280 to 295.1 µS/cm with the minimum value of 280 from WEST and the maximum value 295.1 µS/cm from NORTH but a higher value of 465.4 was recorded in the sample from the borehole. However, the mean conductivity values recorded in all the water samples were comparatively lower as far as the GSB standard value for drinking water quality of 1000 µS/cm is concerned as well as that of the EPA standards of also 1500 µS/cm for waste water.

Electrical conductivity (EC) is a measure of water's ability to conduct an electric current. This is due to the presence of some dissolved minerals which have ionised in the water. Electrical conductivity therefore indicates presence of ionised minerals but it does not give an indication of which element is present. High value of EC is a good indicator of the presence of contaminants such as sodium, potassium, chloride or sulphate (Orebiyi et al, 2010). It is therefore not surprising that the sample from the borehole recorded the highest mean value of conductivity because it also recorded a high mean value of total dissolved solids indicating more dissolved ions. Most of the sediments get settled around the North because there is a spill way at that side and water flows to that direction when water level in the reservoir is increasing.

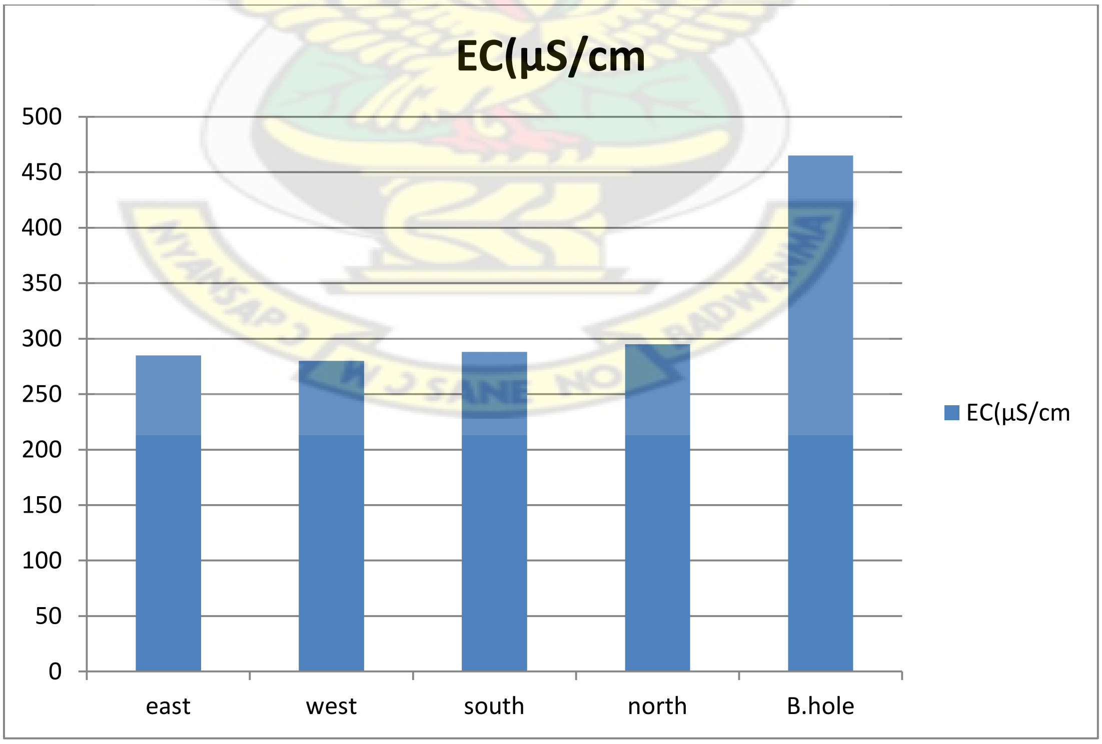

Table 4.3; A graph of conductivity of the reservoir and the well.

4.1.4 TURBIDITY

Monitored turbidity levels of the water samples from the reservoir varied between 506 and 704 NTU with samples from the SOUTH recording the highest mean value of 704 NTU whilst the lowest value of 506 NTU was recorded at the EAST. All mean values recorded in the reservoir far exceeded the Ghana Standards Board standards for waste water quality of 75 NTU. However, mean values of turbidity of water sampled from the borehole had a value of 1 NTU which was below the GSB standard value of 5 NTU for drinking water quality.

Turbidity is a measure of cloudiness of water. It has no health effects. However, turbidity can interfere with disinfection and provide a medium for microbial growth. Elevated turbid water is often associated with the possibility of micro-biological contamination as high turbidity makes it difficult to disinfect water properly (DWAF, 1998). The high turbidity in the samples from the reservoir was due to run off pollution from the municipality because all the storm drains within the Navrongo municipality are channeled into the reservoir

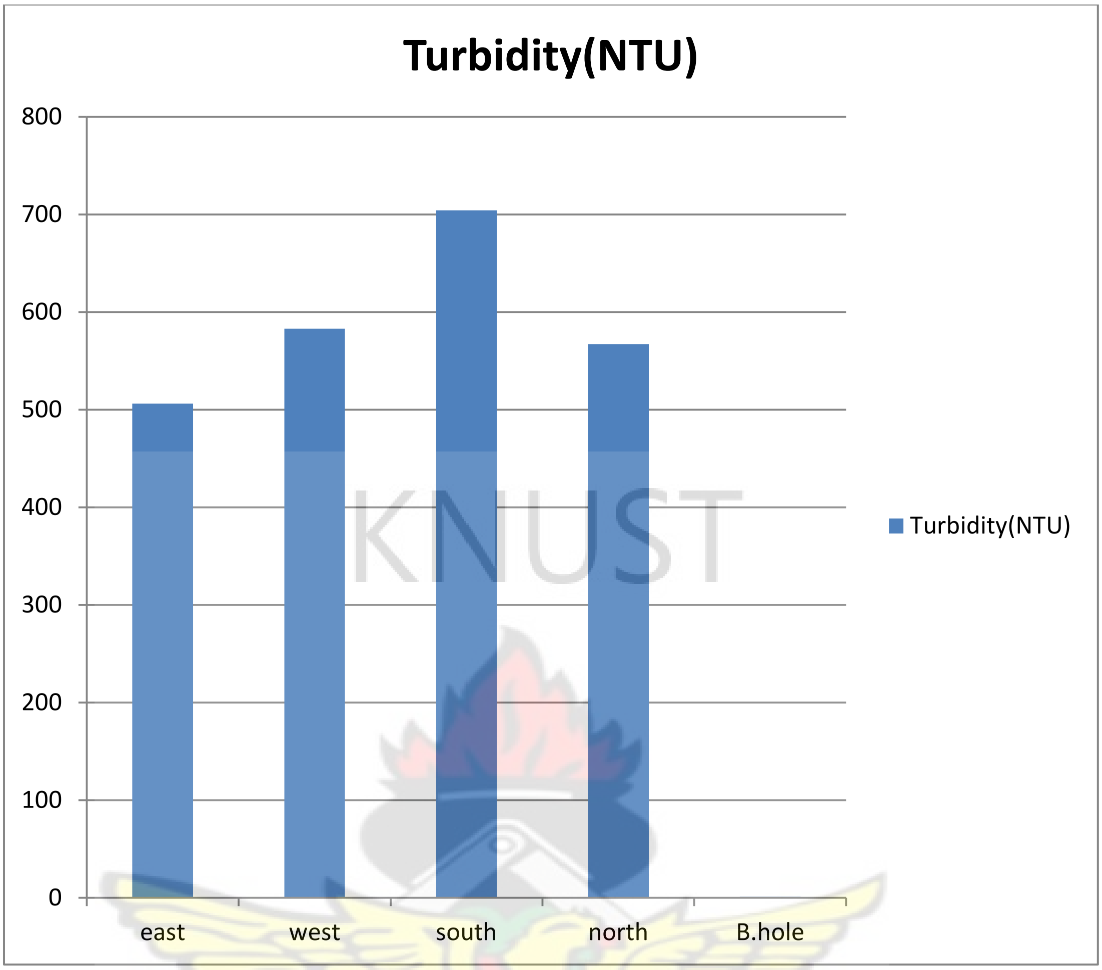

Table 4.4 Graph of turbidity levels of the reservoir and the well.

4.1.5 NITRATE-NITROGEN CONCENTRATION

It was generally observed from the mean Nitrate-nitrogen concentrations of all the water samples that nitrate pollution in all the sample sites of the reservoir was very minimal and the SOUTH recorded the highest mean concentration of 13.5 mg/l whilst the lowest was recorded at the WEST with a mean value of 2.9 mg/l. All the values recorded were far below the EPA standard of 100 mg/l. Also the mean value of 1.3 mg/l of nitrate-nitrogen of the water sampled from the borehole was equally below the GSB maximum admissible limit of 50 mg/l for drinking water quality.

The low level of nitrate concentration could be attributed to the low use of mineral fertilizers within the catchment area because most of the area is used for residential purposes and also the land there is fertile.

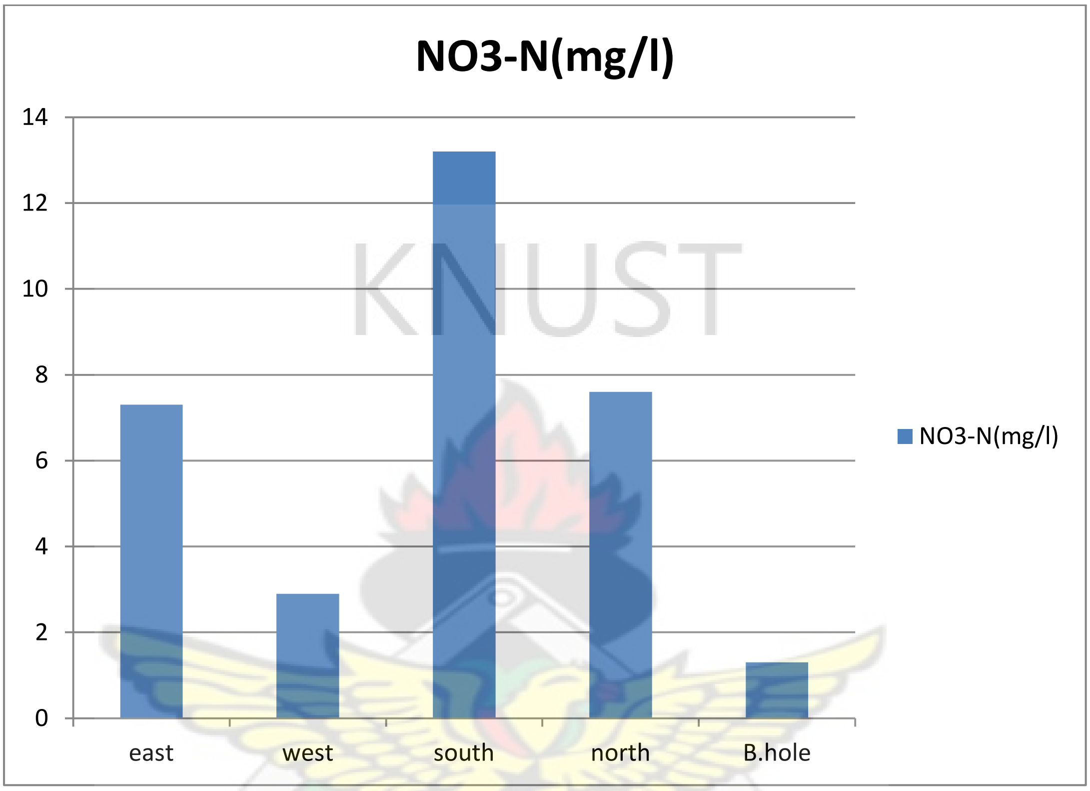

Table 4.5; A graph of nitrate-nitrogen concentration of the reservoir and the well.

4.1.6. SULPHATE (SO_4^{2-}) CONCENTRATION

Sulphate concentration levels for all the sample sites of the reservoir showed that sulphate pollution was generally very minimal. The SOUTH had the highest mean value of 30.5 mg/l whereas the WEST had the lowest mean value of 16.9 mg/l. All values recorded were far below the EPA standard of 2,000 mg/l for waste water. Also the water sample from the borehole recorded a mean sulphate concentration value of 12.6 mg/l which is far below the GSB standard values of 200 mg/l for drinking water quality.

According to WHO (2008), no health-based guideline is proposed for sulphate. However, because of the gastrointestinal effects resulting from ingestion of drinking water containing high sulphate levels, it is recommended that health authorities be notified of sources of drinking water that contain sulphate concentrations in excess of 500 mg/l. The low level of sulphate in the water samples could be a result of the low use of mineral fertilizer within the catchment area because the land around there is fertile and also most of the area is used for residential purposes.

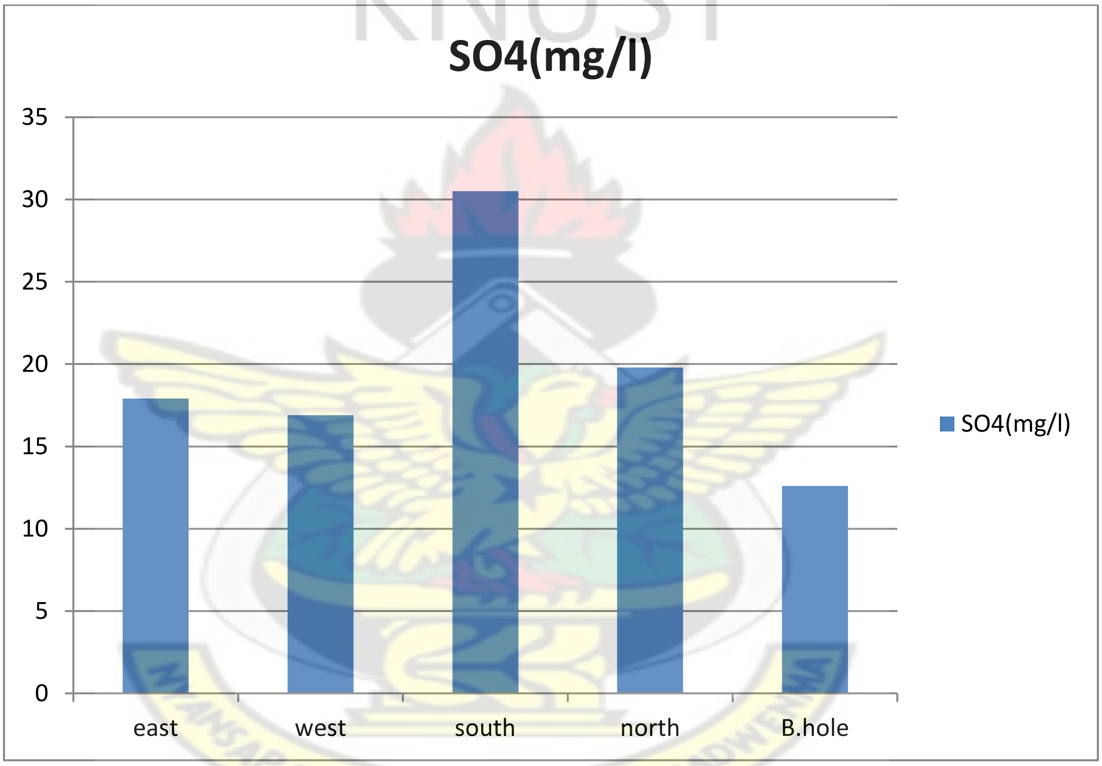

Table 4.6 A graph of sulphate concentration of the reservoir and the well.

4.2 HEAVY METAL CONCENTRATION

Heavy metal loads such as iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and lead (Pb) investigated in the study area showed that the concentration of zinc was generally low in the water samples but the mean value of iron and manganese concentrations were high. However, copper and lead were both below detection in the water and vegetable samples.

4.3.1 IRON (FE) CONCENTRATION

Iron concentration in all the water samples in the reservoir was high ranging from 3.6 mg/l to 6.93 mg/l. The highest mean concentration occurred at the NORTH and the lowest at the EAST. The mean value of iron concentration at the North exceeded the EPA standard of 5.0 mg/l for waste water. However, the mean value of iron concentration of the water sample from the borehole was 0.3 mg/l and within the GSB standard value of 0.3 mg/l for drinking quality. The lettuce and garden eggs recorded iron mean value concentrations of 1.71 µg/g and 1.33 µg/g respectively which are below figures recorded by USDA (2013) which are beneficial to human health.

The Goo basin is basically granite and analyses of rocks in Ghana (Kerbyson and Shandorf, 1966) have shown that Fe_2O_3 composition in granite is about 2.8%. Corrosive materials also contribute significantly to the amount of iron in water. These could primarily be the source of iron in the water. The concentration of iron in the lettuce and garden eggs was 1.71 µg/g and 1.33 µg/g respectively. Iron is ubiquitous in the earth's crust and an essential element in human nutrition. No health-based guideline value is proposed for iron (WHO, 2008). However, at levels above 0.3 mg/l, iron stains laundry and plumbing fixtures by turning them brown. Because of the spill way at the North all manner of debris including corroded metals were seen at that side after the level of water had gone down. This deposition of corroded metals could account for the high levels of iron at the side.

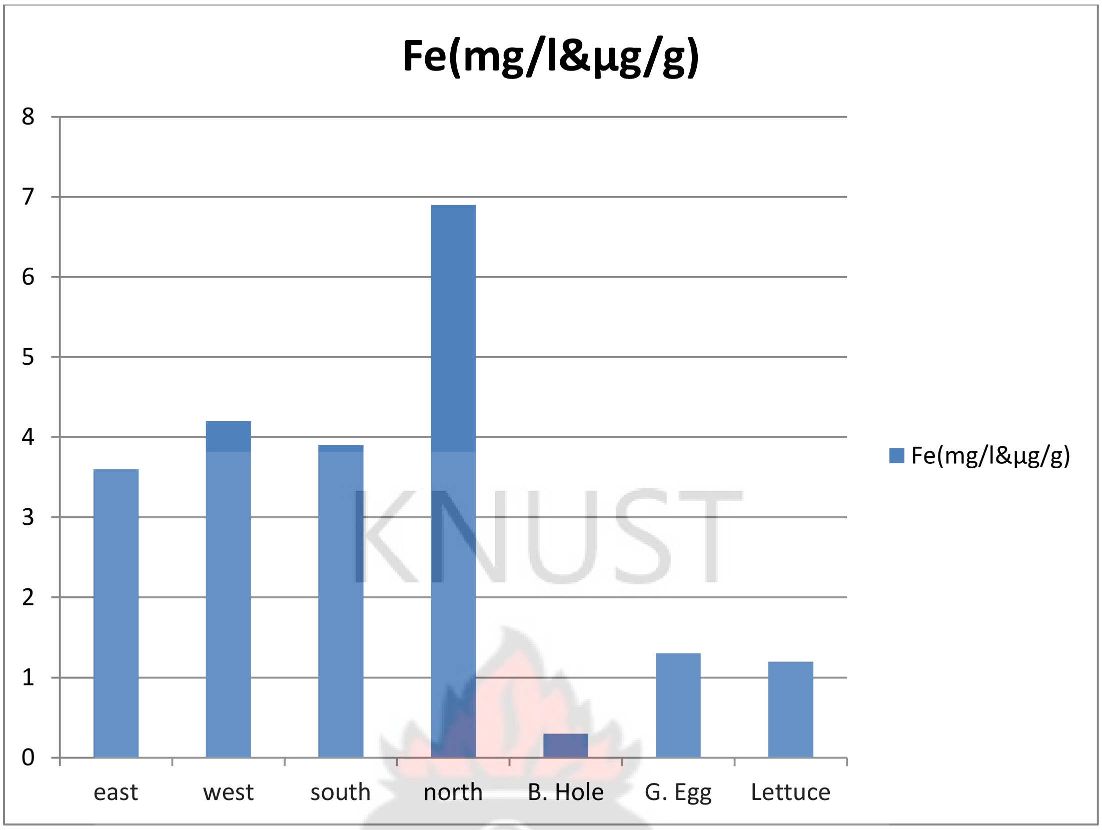

Table 4.1a; Iron concentration of the reservoir, well and vegetables

4.3.2 MANGANESE (MN) CONCENTRATION

Manganese (Mn) concentration in all water samples from the reservoir was generally moderate ranging from 0.81 to 2.15 mg/l. The highest mean concentration value occurred at the WEST and the lowest from the NORTH. The mean values of all the samples were below the EPA standard of 2.5 mg/l. Also mean value of Mn concentration in the borehole water was 0.13 mg/l and little above the GSB maximum permissible limit of 0.1mg/l. The lettuce and garden eggs recorded values of 0.08 and 0.21 µg/g respectively which are low and good for consumption.

At levels exceeding 0.1 mg/l, manganese in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry by turning them black. Concentrations below 0.1 mg/l are usually acceptable to consumers. Manganese is an essential element for humans and other animals by ensuring healthy bone structure and metabolism. However, there have been epidemiological studies that report adverse neurological effects following extended exposure to very high levels in drinking water (WHO, 2008).

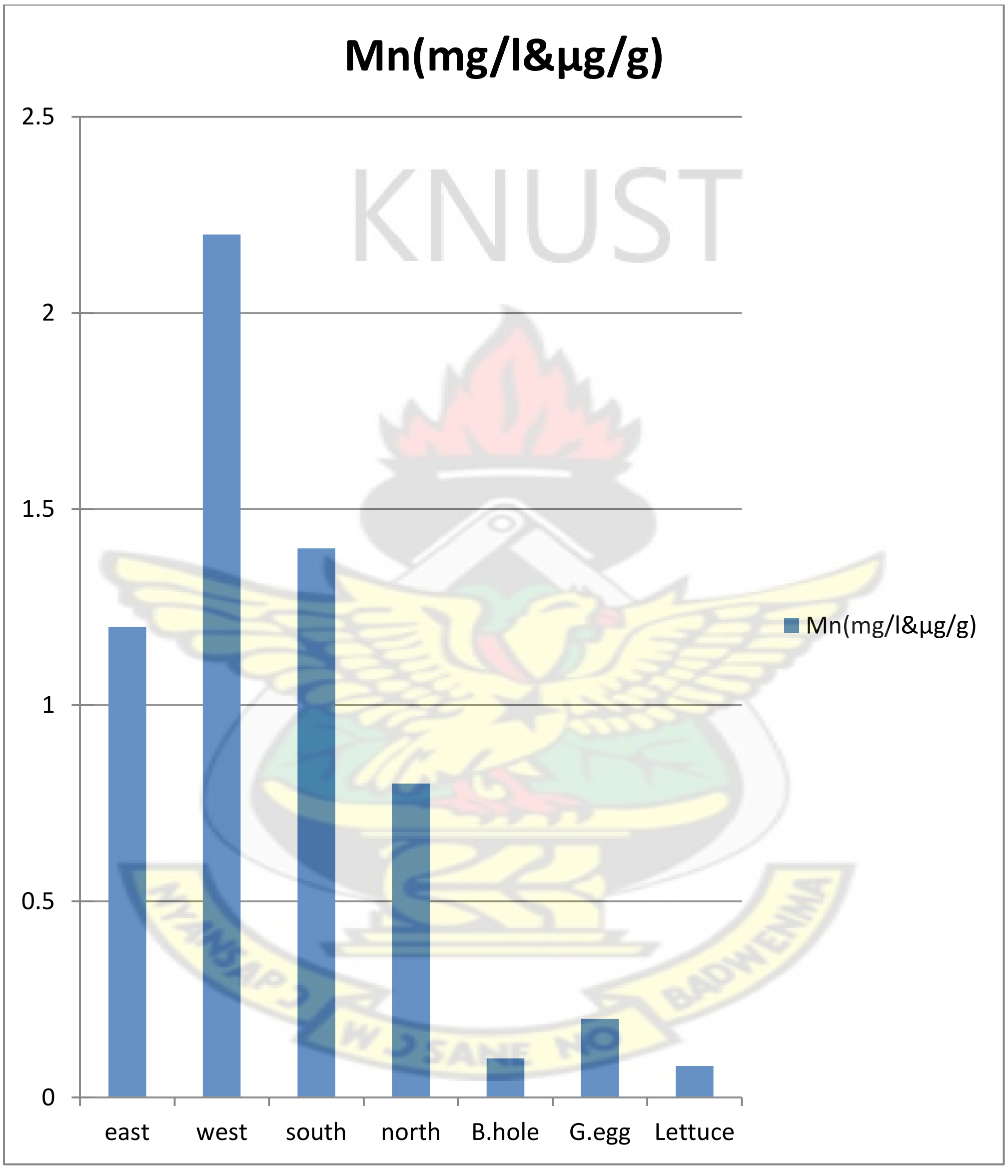

Table 4.2a; Mn concentration in the reservoir, well and vegetables

4.3.3 ZINC (ZN) CONCENTRATION

Zinc concentration in all water samples from the reservoir were very low ranging from 0.1 to 0.4 mg/L. The highest mean concentration of Zn was recorded at the WEST whilst the lowest was recorded at the EAST as shown in Table4.2. The recorded mean values were all below the EPA standard of 5 mg/l for waste water. The mean Zn concentration of the water sample from the borehole was 0.2 mg/l and thus far below the GSB standard value of 1.5 mg/L for drinking water quality. Also the lettuce and garden eggs had mean values of Zn concentration of 0.18 and 0.17 µg/g respectively.

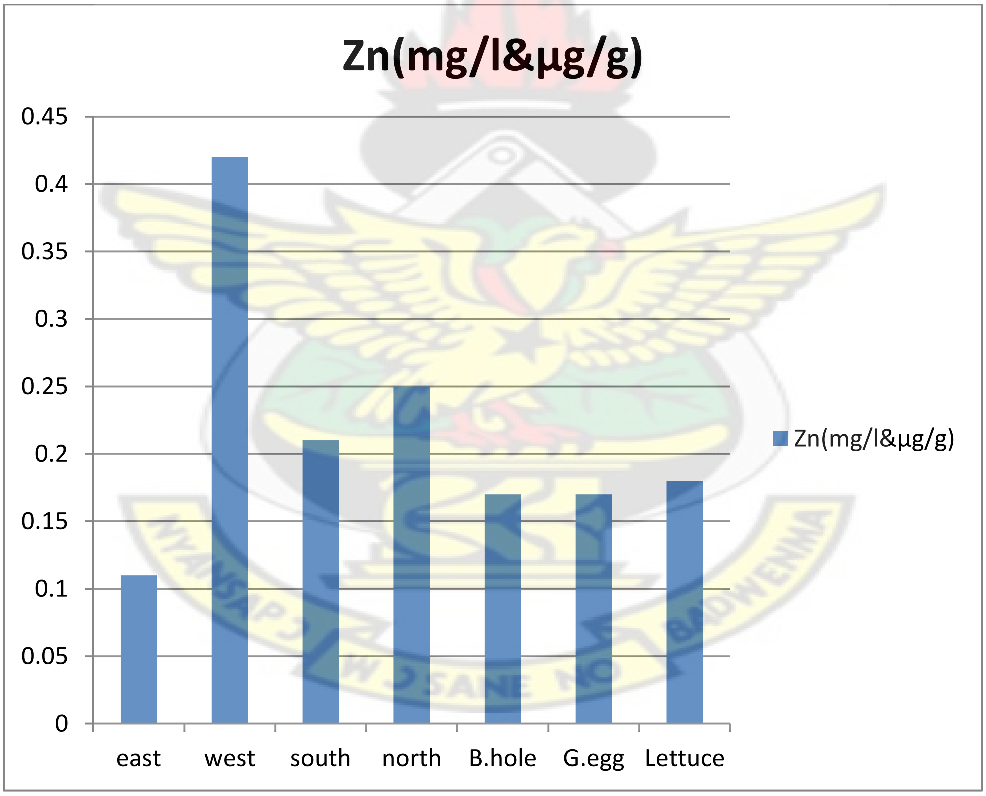

Table 4.3a; Zn concentration of the reservoir, well and vegetables

4.3.4 COPPER (CU) AND LEAD (PB) CONCENTRATIONS

Cu and Pb concentrations in all the samples from the reservoir, the borehole as well as samples from the lettuce and garden eggs were below detection limit

4.4 MICROBIAL QUALITY OF WATER AND VEGETABLES SAMPLES

Total coliform (Tc) numbers for the water sample from the reservoir ranged from 120,268-272,871/100ml with the highest mean Total coliform count occurring at the WEST whilst the lowest mean count was recorded in the NORTH. The water sample from the borehole recorded a mean total coliform value of 0.0/100ml. The samples of lettuce and garden eggs recorded mean total coliform counts of 465,199 CFU/g and 155,291 CFU/g respectively.

Faecal coliform count for the water samples from the reservoir ranged from 258-125,000(/100ml) with the highest mean faecal coliform occurring at the NORTH and the lowest at the WEST. The sample from the borehole recorded a mean faecal coliform count of 0.00(100/ml). The samples of lettuce and garden eggs recorded mean values of faecal coliform of 130,062 CFU/g and 95,021 CFU/g respectively. The concentrations of these microbial indicator counts in the water samples are an indication of serious bacterial contamination. These coliform bacterial may have several origins some of which could be attributed to the polluted runoff from the municipality that is channeled into the reservoir. It runs off solid surfaces and collects pollutants including bacteria and then deposits them into the water body. Additionally, livestock are allowed to graze and drink freely around and from this water body and in the process indiscriminately contaminate this surface water with their faeces thus contributing to the high incidence of Total and faecal coliform build up (Morgan, 1990).

Improper sanitary conditions like open defecation in most of the catchment areas also contributed to the high levels of total and faecal coliforms in the water samples. Ultimately this polluted water used for irrigating the vegetables undoubtedly contributed to the high levels of total and faecal coliforms in the vegetables sampled. In Ghana, like many developing countries, the discharge of untreated wastes into the environment is still a problem, despite the establishment of National laws (Weobong, 2001). The community members close to the reservoir are at risk since during the rainy season they dig behind the bank and fetch water for drinking. Also, those who use vegetables grown at the site are at risk due to the high loads of total and faecal coliforms. Total and faecal coliforms are indicator organisms and therefore, their presence is a sign of the potential presence of disease causing organisms.

The borehole water was however free of total and faecal coliform and all the samples from the borehole recorded zero values.

The polluted water in the reservoir has not been able to pollute the water supply well because the geology of the area consists of granite and shale rocks which have very low total and effective porosity. Granite has a total porosity of 0.5% and an effective porosity of 0.1% whilst shale has a total porosity of 1-10% and effective porosity of 0.5-5% (Croft et al, 1985). These materials serve as filtering media and therefore keeping the well water clean.

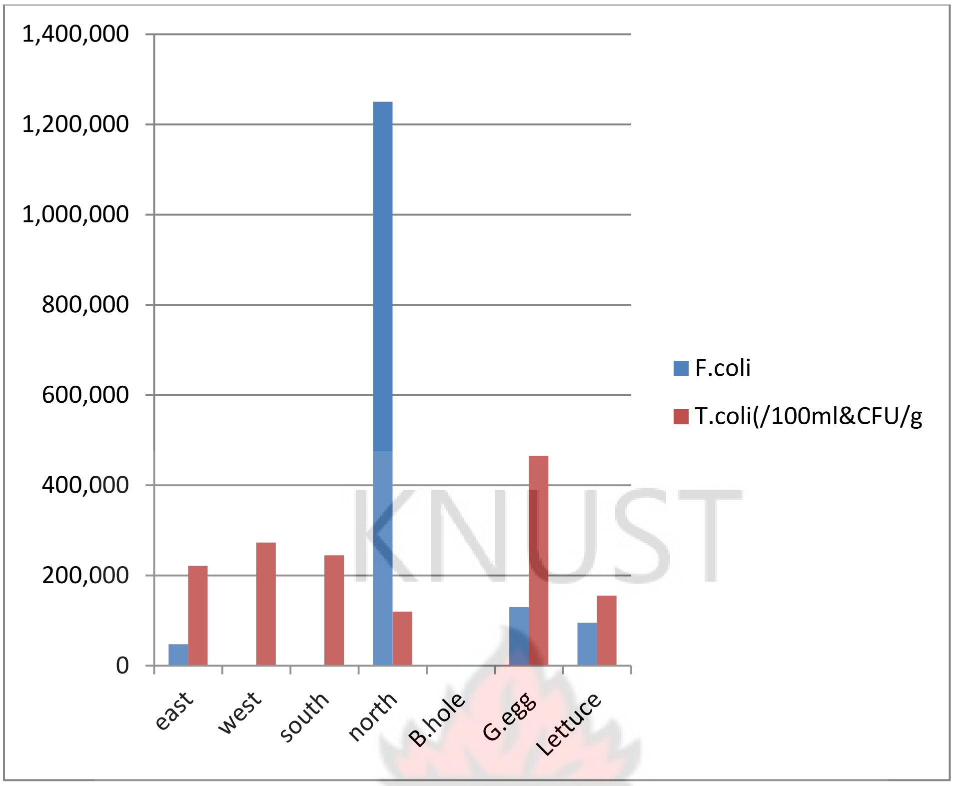

Table 4.4a; faecal and total coliform concentration of the reservoir, well and vegetables.

CHAPTER FIVE

CONCLUSION(S) AND RECOMMENDATIONS.

5.1 CONCLUSION

The main goal of the study was to assess the impact of municipal storm runoff on GOO reservoir and a water supply well in Navrongo, the capital of the KassenaNankana Municipal Assembly.

All samples were analyzed for physicochemical parameters and five heavy metals namely Fe, Mn, Zn, Cu and Pb. The results show that values of most of the physicochemical parameters were within the standards set by GSB and EPA-Ghana. However, the concentrations of turbidity in all the samples except the borehole were above the standards of the GSB and EPA.

The study revealed that the concentrations of Fe and Mn were a little high exceeding the GSB permissible values of 0.3mg/l and 0.1mg/l respectively. Iron concentration at certain points recorded mean value of 6.93mg/l which is higher than the EPA-Ghana standards of 5.0mg/l. Zinc concentrations were however, low but that of copper and lead were below detection limits.

The microbial loads of the water from the reservoir exceeded the EPA-Ghana standards but that of the borehole was zero. The microbiological parameters of the lettuce and garden eggs were very high and for that matter are not safe for consumption especially in their raw state.

5.2 RECOMMENDATIONS

The following mitigation measures are seriously recommended to prevent or minimize any further deterioration of water quality within the reservoir to avert serious health effects for the people in the Municipality:

1. There is the need for regular collection of waste within the municipality to prevent it from being carried in the storm runoff into the reservoir.
2. Open defecation popularly known as 'free range' in the communities especially those along the stream leading to the reservoir should be discouraged through education and enforcement of the Assembly by-laws.
3. The vegetables should be properly washed with clean water to remove or reduce the microbial loads in them.
4. There is the urgent need to embark on intensive educational campaign to stop the community around the reservoir from digging and drinking water at the site.
5. Further studies should be conducted on heavy metal concentration in the sediments and fish of the reservoir.

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APPENDICES

APPENDIX A

STATISTICAL ANALYSIS

EAST LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
TDS	167.4	28.6	57.2	3269.0	96.0	230.3	134.3
EC	285.4	39.8	79.6	6341.8	195.0	379.5	184.5
SO_4	17.97	1.63	3.27	10.66	15.00	22.63	7.63
pH	7.010	0.208	0.415	0.172	6.400	7.300	0.900
NO_3-N	7.27	4.94	9.88	97.68	0.16	21.60	21.44
TURBIDITY	506	355	711	505256	34	1550	1516
Ca	25.65	2.37	4.74	22.51	20.80	32.10	11.30
Na	37.52	2.55	5.10	26.00	31.50	42.00	10.50
Cl	34.5	13.0	26.1	679.8	17.0	72.5	55.5

WEST LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
TDS	169.5	28.4	56.9	3234.9	98.0	231.6	133.6
EC	280.0	42.3	84.5	7144.4	196.0	379.6	183.6
SO_4	16.965	0.700	1.400	1.961	15.710	18.750	3.04
pH	7.43	0.128	0.256	0.064	6.940	7.682	0.820
NO_3-N	2.89	1.49	2.98	8.89	0.16	5.81	5.64
TURBIDITY	583	429	857	735288	29	1850	1821
Ca	24.95	1.89	3.77	14.22	20.40	28.10	7.70
Na	38.92	3.88	7.75	60.09	33.00	50.00	17.00

Cl	35.8	14.4	28.8	829.7	15.9	77.4	61.5

SOUTH LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
TDS	169.2	30.7	61.3	3762.8	93.0	238.2	145.2
EC	288.1	44.2	88.3	7798.0	187.0	394.2	207.2
SO_4	30.5	17.3	34.7	1201.4	11.0	82.4	71.4
pH	7.142	0.116	0.233	0.054	6.800	7.310	0.510
NO_3-N	13.15	6.79	13.58	184.45	0.19	30.64	30.45
TURBIDITY	704	437	873	762763	31	1900	1869
Ca	24.52	2.91	5.82	33.93	19.20	32.10	12.90
Na	31.65	1.67	3.34	11.16	28.00	36.00	8.00
Cl	37.0	15.5	31.1	964.7	16.0	82.4	66.4

NORTH LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
TDS	172.5	31.3	62.6	3916.6	93.0	240.6	147.6
EC	295.1	43.0	86.0	7402.0	195.0	396.1	201.1
SO_4	19.86	1.01	2.01	4.05	17.43	21.63	4.20
pH	7.045	0.128	0.257	0.066	6.700	7.260	0.560
NO_3-N	7.61	3.73	7.46	55.58	0.24	17.90	17.66
TURBIDITY	565	414	828	685916	52	1800	1748
Ca	26.55	4.46	8.92	79.50	15.90	37.50	21.60
Na	46.5	14.5	29.0	843.7	30.0	90.0	60.0
Cl	33.8	14.7	29.4	861.5	15.9	77.4	61.5

BOREHOLE LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
TDS	292.5	41.1	82.2	6753.2	195.0	396.0	201.0
EC	465.4	25.7	51.5	2650.1	392.0	511.4	119.4
SO_4	12.56	1.65	3.29	10.85	7.63	14.50	6.88
pH	6.780	0.202	0.404	0.163	6.240	7.100	0.860
NO_3-N	1.32	1.26	2.52	6.34	0.01	5.10	5.09
TURBIDITY	1.000	0.408	0.816	0.667	0.000	2.000	2.000
Ca	31.30	8.35	16.69	278.63	12.00	49.60	37.60
Na	41.30	5.16	10.31	106.39	33.00	55.00	22.00
Cl	26.60	1.13	2.26	5.09	23.80	28.80	5.00

HEAVY METALS ANALYSIS

SOUTH LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
Fe	3.96	2.70	5.39	29.10	0.75	12.01	11.26
Mn	1.359	0.854	1.707	2.915	-0.436	3.676	4.112
Zn	0.2136	0.0849	0.1699	0.0289	0.0149	0.4236	0.4087
Cu	-0.107	0.133	0.266	0.071	-0.354	0.249	0.603
Pb	-0.4095	0.0936	0.1871	0.0350	-0.6301	-0.1807	0.4494

EAST LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
Fe	3.61	2.65	5.31	28.15	0.70	11.55	10.85
Mn	1.192	0.547	1.094	1.197	-0.055	2.608	2.663
Zn	0.1045	0.0681	0.1361	0.0185	-0.0594	0.2708	0.3302
Cu	-0.121	0.123	0.246	0.060	-0.332	0.211	0.542

Pb	-0.2719	0.0268	0.0535	0.0029	-0.3335	-0.2066	0.1269

NORTH LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
Fe	6.93	5.40	9.36	87.56	0.54	17.67	17.14
Mn	0.812	0.537	0.930	0.865	-0.123	1.737	1.860
Zn	0.2544	0.0522	0.0904	0.0082	0.1502	0.3121	0.1619
Cu	-227	227	393	154120	-680	0	680
Pb	-0.2110	0.0909	0.1574	0.0248	-0.3841	-0.0765	0.3076

WEST LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
Fe	4.15	3.02	5.24	27.45	0.68	10.17	9.50
Mn	2.156	0.856	1.483	2.199	1.107	3.853	2.746
Zn	0.419	0.264	0.457	0.208	0.030	0.921	0.892
Cu	-0.2501	0.0942	0.1632	0.0266	-0.3883	-0.0700	0.3183
Pb	-0.642	0.186	0.323	0.104	-0.950	-0.307	0.643

BOREHOLE LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
Fe	0.265	0.106	0.212	0.045	0.060	0.549	0.489
Mn	0.131	0.275	0.551	0.304	-0.572	0.762	1.334
Zn	0.170	0.193	0.334	0.111	-0.112	0.538	0.650
Cu	-716	715	1431	2047652	-2862	0	2862
Pb	-1104	1103	2206	4864878	-4412	-0	4412

G EGG LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
Fe	1.327	0.371	0.525	0.276	0.956	1.698	0.742
Mn	0.212	0.280	0.396	0.157	-0.068	0.493	0.561
Zn	0.171	0.290	0.410	0.168	-0.119	0.461	0.580
Cu	0.015	0.267	0.378	0.143	-0.252	0.283	0.535
Pb	-0.2977	0.0263	0.0372	0.0014	-0.3240	-0.2714	0.0526

LETTUCE LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
Fe	1.71	1.30	1.83	3.36	0.41	3.01	2.59
Mn	0.080	0.298	0.422	0.178	-0.218	0.379	0.596
Zn	0.179	0.217	0.306	0.094	-0.037	0.396	0.433
Cu	-0.070	0.358	0.506	0.256	-0.428	0.287	0.715
Pb	-0.1224	0.0238	0.0336	0.0011	-0.1461	-0.0986	0.0475

COLIFORM ANALYSIS

EAST LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
T.Coliform	221563	142032	284063	80691803876	252	600000	599748
F.Coliform	47750	47417	94835	8993583333	0	190000	190000

NORTH LOCATION

Variable	Mean	SE Mean	StDev	Variance	Minimum	Maximum	Range
T.Coliform	120268	74802	149603	22381145963	72	310000	309928
F.Coliform	125000	125000	250000	62499916667	0	500000	500000

SOUTH LOCATION

Variable	Mean	SE Mean	StDev	Minimum	Maximum	Range
T.Coliform	170540	122362	244723	61	520000	519939
F.Coliform	76753	74434	148868	0	300000	300000

WEST LOCATION

Variable	Mean	SE Mean	StDev	Minimum	Maximum	Range
T.Coliform	272871	213051	426101	485	900000	899515
F.Coliform	258	247	495	0	1000	1000

BOREHOLE LOCATION

Variable	Mean	SE Mean	StDev	Minimum	Maximum	Range
T.Coliform	0.00	0.00	0.00	0.00	0.00	0.00
F.Coliform	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

G EGG LOCATION

Variable	Mean	SE Mean	StDev	Minimum	Maximum	Range
T.Coliform	465199	464801	657328	398	930000	929602
F.Coliform	130062	129938	183760	124	260000	259876

LETTUCE LOCATION

Variable	Mean	SE Mean	StDev	Minimum	Maximum	Range
T.Coliform	155291	154709	218792	582	310000	309418
F.Coliform	95021	94979	134321	41	190000	189959

NOTE

SE Mean: Stands for standard error of the mean

StDev: Stands for standard deviation

APPENDIX B

Picture of GOO reservoir.

Picture of lettuce farm irrigated by Goo reservoir