KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

INSTITUTE OF DISTANCE LEARNING

ENVIRONMENTAL SCIENCE

THE QUALITY OF WATER CONSUMED IN THE WASSA AMENFI WEST DISTRICT- A CASE STUDY OF ASANKRAGWA TOWNSHIP

A THESIS PRESENTED TO THE DEPARTMENT OF ENVIRONMENTAL SCIENCE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE IN MASTER OF SCIENCE, ENVIRONMENTAL SCIENCE

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DECLARATION

I hereby declare that this thesis is the result of my own work towards the MSc. award and was done 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. It is also dedicated to the entire community members of the Asankragwa township who use pipe borne water in the township as their major source of water for drinking and other domestic purposes.

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ABSTRACT

The quality of pipe borne drinking water in the Asankragwa township, with reference to their physicochemical and microbiological parameters were studied (total coliforms, feacal coliforms, E. coli, pH, electrical conductivity, Total Dissolved Solids, Total Suspended Solids, Iron, sulphate, and among others). These were compared to acceptable levels such as the World Health Organisation's Guidelines on Drinking Water Quality. A total of 10 sampling points were determined and studied over a period of three months (March to May, 2012) with samples collected for analysis once every month. These samples comprised water from four (4) stand pipe points, the two (2) main sources where pipe borne water is obtained in the Asankragwa township, water from the tank where water is stored before treatment (1), water after treatment (1), and water from 2 wells for comparative analysis. The results of the study revealed high microbial indicator counts in all the water bodies at levels above the World Health Organisation's Guidelines on Drinking Water Quality, thus suggesting bacterial pollution of the waters. The microbiological quality assessment of the water samples revealed that water samples from all the sampling points contained total coliforms with some containing E. *coli* and feacal coliforms, indicating contamination of the water by organisms of feacal origin. The result also showed that all the investigated physicochemical parameters of water samples from the sampling points were within the minimum permissible limits for drinking water as suggested by WHO except colour (60.33-850.00), turbidity(3.39-6.00 NTU) and the pH of the water collected from the wells (5.7600-5.9300). Analysis of samples for dissolved trace metals indicated that levels of the investigated metals were within WHO permissible limits except for iron (0.1500 – 3.800mg/l). Pipe borne drinking water from the Asankragwa township was therefore found to be unsuitable for drinking and for other domestic purposes. Comparatively, water from pipe borne server water was better than that from the wells in the Asankragwa township.

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CHAPTER ONE

INTRODUCTION

1.1 Background

The essence of water to all forms of life is invaluable. Safe drinking-water is required for all usual domestic purposes, including drinking, food preparation and personal hygiene. Water of higher quality may also be required for some special purposes, such as renal dialysis and cleaning of contact lenses, or for certain purposes in food production and pharmaceutical use (WHO, 2004). Water is therefore essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. In contrast, almost 1 billion people in the world lack access to an improved supply of safe drinking water and over 884 million people have also been estimated to use unsafe drinking water sources (WHO and UNICEF JMP, 2010). More so, one-sixth of humanity lack access to any form of safe and improved water supply within 1 kilometre of their home (WHO and UNICEF JMP 2000). As a result, outbreaks of waterborne diseases continue to occur in both developed and developing countries, leading to loss of life, disease and economic burden for individuals and communities. In effect, water-related diseases alone accounts for half of the world's hospitalizations (WHO and UNICEF JMP, 2008).

According to the World Health Organisation (2012), diarrhoeal diseases account for 2 million annual deaths attributable to unsafe water, sanitation and hygiene; more than 50 countries still report to the WHO cholera and incidences of cancer, tooth and skeletal damage as a result of millions exposed to unsafe levels of naturally-occurring arsenic and fluoride. Even in the

developed nations like the United States of America, cases of outbreaks associated with contaminated water are reported (CDC, 2012). Endemic and epidemic diseases derived from unsafe water supply continue to affect all nations. It is therefore very clear that improving access to safe drinking-water can result in tangible benefits to health and every effort should be made to achieve drinking-water that is practically safe.

Safe drinking-water, as defined by WHO (2011), does not represent any significant risk to health over a lifetime of consumption and this includes different sensitivities that may occur between life stages. Safety may also be compromised by chemical and radiological constituents and microbial risks to drinking-water. Those at greatest risk of waterborne diseases are infants and young children, people who are debilitated and the elderly, especially when living under unsanitary conditions. Those who are generally at risk of waterborne illness may need to take additional steps to protect themselves against exposure to waterborne pathogens, such as boiling their drinking-water. However, as a result of poor management of water resources coupled with growing population with its adverse effects on the environment, especially in developing countries, access to safe drinking water by several communities and even countries has become very difficult to achieve.

The Millennium Development Goals articulated by the General Assembly of the United Nations in 2000, include a commitment to reduce by half the proportion of the World's population who are unable to reach or afford safe drinking-water by 2015 (WHO, 2005). The definition of what is safe is therefore of key importance in assessing whether this target has been achieved (WHO, 2005). Furthermore, the right to water by the United Nations (2003) places a clear responsibility

on Governments to ensure access to safe and adequate water supplies. In this regard, water suppliers have a duty of care to persons utilizing the water or service that they supply and therefore, need to be aware of the regulatory and policy framework within which they must operate including common law (where appropriate), statute, policy, guidelines and best management practice which in many cases, is not done (WHO, 2005).

The instances cited above are no different from the situation in Africa, and more specifically, Ghana. According to the 2010 annual report of the Ghana Ministry of Health, water and sanitation related diseases, like typhoid and diarrhoeal alone recorded, 22,420 and 40,335 cases respectively in 2009 and 21,649 and 51,478, respectively in 2010. These figures unveil the disheartening nature of the situation in Ghana. According to information found on the WASH Journalists Blog (2009), the Ghana National Health Insurance Scheme spent over GH¢ 70 million on water and sanitation related diseases in 2008.

1.2 Problem Statement

The role water plays in the life of an individual is indispensable and safe drinking-water can result in tangible benefits to health if there is an improved access. There are several sources of water for drinking which include streams, rivers, boreholes and even rain water harvested, but most people find it safer to drink water drawn from the stand pipe. All these sources of water can have serious health implications if not treated well to remove or reduce to acceptable levels, hazards posed by drinking untreated water.

Acceptable standard for drinking can be measured in terms of its taste, odour and appearance.

It is however, alarming that pipe borne water which serves as a major source of water for most residents of Asankragwa has a brownish colour, dissolved particles, and at times a weird taste. This raises the room for questions as to whether the very component of water distributed through the means purported by most individuals to be safe is really safe for drinking. Records from the statistical office of the Asankragwa Catholic Health Hospital, the major and main hospital in the Asankragwa Township indicates that quite a number of people in the Asankragwa Township and its surroundings are affected by various kinds of diseases as a result of food and water taken (Asankragwa Catholic Hospital, 2012).

Previous concerns have also been raised by the Department of Water and Sanitation in the district concerning high concentration of iron and manganese in the water which could make it unacceptable for drinking. Thus, an iron removal device has been installed to filter the water before distributions but could this also be effective?

An investigation is therefore, very essential to help assess the quality of the pipe borne water distributed in the township and also to assess the quality and effectiveness of treatment strategies employed by the district. This investigation is intended to support the development and implementation of risk management strategies that will ensure the safety of drinking-water supplied in Asankragwa through the control of hazardous constituents of pipe borne water.

1.3 Objectives

1.3.1 General Objectives

The main objective of this work was to assess the quality of pipe borne water consumed in the Asankragwa township.

1.3.2 Specific Objectives

The specific objectives of the study were to:

1. assess the quality of water based on acceptable parameters.
2. assess the effectiveness of water treatment of pipe borne water distributed for drinking in the Asankragwa Township.
3. assess the capacity of the district institutions to provide a safe drinking water.
4. assess the risks throughout a drinking-water supply system- from the taping source of water through to the consumer.
5. compare the quality of the pipe borne water to the quality of water from wells in Asankragwa.

CHAPTER TWO

LITERATURE REVIEW

2.1 Drinking Water

The quality of drinking-water is a powerful environmental determinant of health and an assurance of drinking-water safety is a foundation for the prevention and control of waterborne diseases (WHO, 2012).

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

2.2 Water Pollution

Water quality can be affected by different forms of pollution: chemical, biological and physical. These polluting factors can influence natural and human environment whether directly or

indirectly by creating conditions that limit water utilization for specific purposes. Indicators of water quality degradation include physical, chemical and biological parameters. Examples of physical and chemical parameters include dissolved solids, pH, suspended solids, turbidity and nutrient concentration.

Due to open accessibility of surface waters, they easily receive foreign materials from various sources which negatively impact on the quality of the water. Pollution of surface water occurs when the quantity of waste entering a body of water overwhelms the capacity of the water to assimilate the pollutants these waste contains. Thus the natural cleansing ability is compromised and water may no longer break down organic pollutants (Buchholz, 1993).

There are two sources of water pollution;

- Point source of Pollution
- Non Point source of pollution

According to Buchholz (1993), point sources are those that come from industrial facilities and municipal sewage system. They can be said to be pollution that can be traced to a particular source. Non point source is diffused and cannot be traced. Some main causes of non point pollution are; agriculture, urban runoff, construction sites and waste disposal. Cunningham (1999) suggested that often the best way to control non point pollution is through improved land use practices. Polluted water contains significant levels of pollutants, usually at levels above WHO certified water quality standards and these are able to cause significant problems when ingested by humans.

2.3 Water Quality

Water quality is a term used here to express the suitability of water to sustain various uses or processes. Water quality is affected by a wide range of natural and anthropological (human) influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quality and quantity of water available (UNEP/WHO, 1996).

The importance of water quality has been enhanced in the last few years by the increased awareness and attendant publicity afforded to pollution of water courses, estuaries and coastal areas (Shaw, 1998). Globally, the United Nations (UN) declared an international Drinking Water Supply and Sanitation decade between 1981 and 1991(WHO, 2003). This provided Ghana the impetus, to identify and provide solution to the existing water supply and sanitation systems, and also to expand the coverage so that more people would enjoy the benefits of good drinking water and adequate sanitation (Mensah, 2011).

In the United States of America (USA), the quality of water is regulated by the Safe Drinking Water Act of 1974, as amended in 1977 and 1986. This gives the EPA authority to set national standards to protect drinking water. These standards represent the maximum contaminant levels (MCL) allowable and consist of numerical criteria for specified contaminants (Buchholz, 1993). Water supply especially in developing countries have been focused on quantity at the expense of quality and there are calls for marked improvements in quality-better management of chemical and microorganism content (Barrow, 2005). It is important to note, however that issues of water quantity cannot be considered separate from water quality.

In assessing the quality of drinking water, consumers usually rely completely on their senses in the matter of quality judgment. The absence of any sensory effects therefore does not guarantee the safety of drinking water. In the submission of the drinking water quality control in small community supplies, WHO explains that although in the rural areas of developing countries, it is expected that a great majority of water quality problems are related to bacteriological contamination, a significant number of very serious problems may occur as a result of chemical contamination of water sources from agricultural practices and malpractices.

The traditional emphasis on chemical indicators of water quality must be supplemented by more comprehensive indicators based on the total properties of a water body including: chemical, physical, biological and ecological parameters. It must also be recognized that freshwater quality is impacted directly by natural and human activities outside the water sphere such as land use practices, erosion and deforestation, acid deposition or natural contamination. Such problems often require monitoring and protection at the local level, while some have significant trans-boundary components which are addressed at national and international levels (Young et al.., 2003).

2.4 Natural Processes Affecting Water Quality

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

Seasonal overturn of the water in some lakes can bring water with little or no dissolved oxygen to the surface. Such natural events may be frequent or occasional. Permanent natural conditions in some areas may make water unfit for drinking or for specific uses such as irrigation (UNEP/WHO, 1996). The nature and concentration of chemical elements and compounds in a fresh water system are subject to change by various types of natural processes, that is, physical, chemical, hydrological and biological (Balek, 1977). Some chemical elements have a strong affinity for particulate matter and, as a result of precipitation/dissolution and adsorption /desorption reactions, they may be found in only trace amounts in solution. Other elements, however, are highly soluble and rarely, if ever, present in water in particulate form. The tendency for a chemical to be present in the soluble form rather than associated with particulate is expressed as the Soluble Transport Index.

In small watersheds, local geological conditions can lead to wide variations in the concentration of trace elements in particulates and that within any one water body quality can differ with time and with place (UNEP/WHO, 1996). Point sources emanate from a pipe or other definable point of discharge or release representing a specific location. Non-point sources, however, are more diffuse and they have many origins and numerous routes by which contaminants enter ground and surface waters. It is very difficult to identify, let al.one monitor and control urban wastewater, agricultural runoff and urban runoff. Point sources include industrial discharges, hazardous waste facilities, mine drainage, spills and accidental releases. Point discharges associated with a facility are usually regulated.

The impact of waste water on a receiving stream depends on the stream's ability to assimilate pollutants. The assimilative capacity of a stream refers to its ability to self- purify naturally (Chapman, 1996). Wastewater discharges are a major source of nutrients, bacteria, viruses, parasites and chemical contamination. Discharged treated wastewater with elevated levels of ammonia and nitrogen may support algal growth.

2.5 Water and Environmental Sanitation in the Wassa Amenfi West District

The environmental situation in some communities within the district is not all that encouraging. In the major communities heaps of refuse are easily sighted when entering the community. Due to lack of proper drainage system erosion has exposed the foundation of buildings in some of the communities in the district.

Access to potable water is inadequate. Pipe borne water is located in Asankrangwa and Samreboi. Other facilities are boreholes and hand dug wells. Some communities do not have access to any of the above facilities. The district has 120 boreholes, 76 hand dug wells and water coverage of 37% of the population (District Planning Unit, 2010).

Most of the households do not have toilet facilities in their homes. They rely on public toilets where available. This actually put pressures on the few public places of convenience resulting in frequent breakdown of such facilities. The consequence is that there is often indiscriminate

defecation which must be addressed. The poor sanitation coupled with inadequate potable water has resulted in occasional outbreak of diarrhoea.

2.6 Water Treatment

In the past, primary emphasis of disinfection was to control water borne diseases through the control of associated bacteriological indicator organisms such as coliforms. According to Bryant et al.. (1992), two findings in the 1970s have, however, resulted in significant evaluation of this long established disinfection practice. These are: disinfection by-products, formed in the reaction of disinfectants and certain water organic matter may be harmful to human health. The discovery of newly recognized water-borne diseases causing organisms that could be effectively controlled by the then accepted disinfection procedure. The latter invention proven that the use of discrete indicator organisms was not sufficient to provide proves of inactivation of a broad range of pathogenic microbes. Modern water treatment methods, however, look beyond just preventing water born diseases but goes on to consider all other constituents whether, biological or physicochemical.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

Asankragwa is the district capital of the Wassa Amenfi West district of Ghana. Wassa Amenfi West District is located in the middle part of the Western Region of the country. It is bounded to the west by Sefwi Wiawso and Aowin - Suaman districts, to the south by Jomoro and Nzema East, to the south-east by Wassa West and to the north by Bibiani-Anhwiaso-Bekwai and to north-east by Wassa Amenfi East. It lies between latitude 5 30^0N and 6 15^0N and longitudes 1 45^0W and 2 11^0W. It has a total land area of 3,464.61 Square Kilometres (District Planning Unit, 2010).

The Wassa Amenfi West District occupies the central-western portion of the Western Region of Ghana. It lies in the evergreen forest belt of Ghana. The Wassa Amenfi West District is predominantly rural. 17.22% (36 communities) of communities in the district have population less than 75 people, 77.55% (162 communities) have population ranging from 75-2000 people, whiles 3.82% (8 communities) have population ranging from 2000-5000 people and 1.43% (3 communities) have population ranging from 5,000 – 50,000 people (District Planning Unit, 2010).

3.2 Scope

A total of 10 water points in the Asankragwa Township were studied over a period of 3 months in three batches to ascertain its quality with reference to the World Health Organization Guideline on drinking water, focusing on the microbiological quality and physicochemical parameters. These points comprised 4 pipe borne water points, 2 sources where the pipe borne water is obtained, 1 sample of the water in the tank where the pipe borne water is stored before treatment, 1 sample of water after treatment and 2 wells for comparative analysis. Thus 10 water samples were collected and studied per each month over a period of 3 months, from March to May, 2012. The township was also divided into two areas, Newtown and Old Town to enhance the collection of data.

3.3 Sample Collection

Purposive sampling was used in selecting 2 pipe borne water source points (boreholes), 1 pipe borne water treatment point and 1 pipe borne water distribution point in Asankragwa while relying on random sampling to collect samples from 4 pipe borne water points (2 each from Newtown and Old Town) and 2 hand dug well points (1 each from Newtown and Old Town) for comparative analysis.

Water from the taps, the boreholes, the storage tank and the distributing tunnel were all collected by turning the taps on and allowing the water to flow for about 5 minutes to avoid picking stored water samples in the system. All samples were collected in 1.5 litre sterile plastic bottles and stored in ice chest for immediate transportation to the laboratory. Sampling was done in batches of 3, once every month, between the months of March and May 2012 for all identified points of

water. All the water samples collected were analyzed at the Ghana Water and Sewage Corporation Laboratory at Suame, Kumasi.

3.4. Determination of Physicochemical Parameters

3.4.1 The pH

The pH values were determined using the calibrated WTW 323 pH meter, at the laboratory (Ghana Water and Sewage Corporation Lab., Suame-Kumasi). The probe was rinsed with distilled water and immersed in the samples. Readings were recorded after stabilization.

3.4.2 Total Suspended Solid (TSS)

Marked evaporating crucibles, labeled appropriately, were heated in an oven and cooled in a desiccator. The clean crucibles were weighed with an analytical balance and 20ml of each of the water samples was measured with a measuring cylinder. These were poured into crucibles and placed on the water bath to evaporate to dryness. Upon drying, the crucibles were, removed and placed in an oven at 105^0C for one hour after which they were cooled in a desiccator for 20 minutes. They were reweighed using an analytical balance. The weights were recorded as A2, B2, C2, etc. The differences in the weights, ie A2-A1, B2-B1, C2-C1, etc., were then calculated as total solids. Ts (mg/l) = (Weight of Sample in Dish – Weight of empty Dish) Volume of Sample.

3.4.3 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) was determined using Gravimetric method in which the sample was vigorously shaken and 100 ml of sample transferred into a 100 ml graduated cylinder by means of a funnel. The sample was filtered through a glass fibre filter and a vacuum applied for three minutes to ensure that water was removed as much as possible. The sample was washed with de-ionised water and suction continued for three minutes. The total filtrate was transferred (with washings) to a weighed evaporating dish and evaporated to dryness on a water bath. The evaporated sample was dried for one hour. The dried sample was cooled in a desiccator and weighed. Drying and weighing process was repeated until a constant weight was obtained.

3.4.4 Turbidity

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

3.4.5 Determination of Colour

Apparent and true colours were determined with HACH DR/2010 Portable Data logging Spectrophotometer. The water samples were filtered and their pH adjusted to 7.6. Water samples which had their pH value less than 7.6 were adjusted with 1 or 2 drops of 1.0N NaOH(aq) depending on the pH. The wavelength used for the colour determination was 465nm. The stored programme was calibrated in colour units based on APHA recommended standard of one colour unit equal to 1mg/l platinum as the chroroplatinate ion. True colour of the samples was measured

after filtering out suspended particles, but for apparent colour measurement, the samples were not filtered.

3.4.6 Determination of Ammonia- Nitrogen (NH_4^+ - N)

Direct Nesslerization Method was used to determine NH_4^+ - N. The water sample was allowed to settle and 50 ml pipetted into conical flask. For turbid samples, the samples were filtered and the filtrate used for analysis. Two drops of Rochelle salt solution was added to the diluted sample and five drops in the case of undiluted samples. Samples were mixed well and 2 ml of Nessler reagent was added. A blank (50ml ammonia-free water plus five drops Rochelle salt and 2ml Nessler reagent) was prepared. Samples were allowed to stand for 10 minutes for colour development and its absorbance was determined using a UV/VIS Spectrophotometer at a wavelength of 410 nm (400 to 425 nm) using a 1 cm light path cuvette. The spectrometer was zeroed with the blank solution. The prepared calibration curve was used to determine the concentration of ammonia- nitrogen in the unknown water sample. The results were expressed in mg/l.

3.4.7 Determination of Nitrite- Nitrogen (NO-2 – N)

Diazotization Method

50 ml of sample was placed in a Nessler tube and set aside until preparations of standards were completed. 2 ml of buffer- colour reagent was added to each standard sample. These were mixed and colour was allowed to develop for about 15 minutes. The pH of the solutions at this stage was between 1.5 and 2.0. The absorbance in the spectrophotometer was measured at 540 nm against the blank and concentration of nitrite- nitrogen plotted against absorbance. The

concentration of nitrite- nitrogen was directly read from the calibration curve. The results were expressed in mg/l.

3.4.8 Determination of Nitrate- Nitrogen (NO3- - N)

Hydrazine Reduction Method

An amount of 10.0 ml of the sample was pipetted into a test-tube. 1.0 ml of 1.3 M NaOH (aq) was added and mixed gently. 1.0 ml of hydrazine mixture was added and mixed gently. It was then heated at 60^0C for 10 minutes in a water bath, and allowed to cool to room temperature and 1.0 ml of nitrate nitrogen colour developing reagent added. It was shaken to mix and the absorbance read. Sample concentrations were directly computed from calibration curve. Sample concentration was equal to the sum of $NO^-_3 - N$ and $NO^-_2 - N$. The concentration of $NO^-_3 - N$ was obtained by determining the concentration of $NO^-_2 - N$ separately and subtracted. The result was expressed as $NO^-_3 - N$ in mg/l.

3.4.9 Determination of Phosphate

Stannous Chloride Method

0.05 ml (1 drop) phenolphthalein indicator was added to a 100ml water sample free from colour and turbidity. Strong acid solution was added drop wise to discharge the colour, if sample turned pink. When more than 0.25 ml (5 drops) was required, a smaller volume of sample was taken and diluted to 100 ml with de-ionised water and then a drop of phenolphthalein indicator added and discharged if sample turned pink colour with the acid. 4.0 ml molybdate reagent and 0.5 ml (10 drop) stannous chloride reagent were added with thorough mixing after each addition.

After 10 minutes, the absorbance was measured at wavelength of 690 nm on a Spectrophotometer. The Spectrophotometer was zeroed with a blank solution. From the calibration curve, the concentrations of the samples were determined using measured absorbances. The results were expressed in mg/l.

3.4.10 Determination of Sulphate (SO_4^{2-})

Turbidimetric Method

Sulphate ion was precipitated in an acidic medium with barium chloride to form a barium sulphate crystal with uniform size. The absorbance of the $BaSO_4$ suspension was measured by a photometer at 420 nm and the sulphate concentration was determined by comparison of the reading with a standard curve.

Determination

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

3.4.11 Total Alkalinity

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

Alkalinity as $CaCO_3$ (mg/l) = A x N x 50,000

T

Where

A = volume of acid used (ml)

T = volume of water sample (ml)

N = normality of standard acid used.

3.4.12 Total Hardness

EDTA Titrimetric Method

A 100ml of the water sample was put into a 250ml conical flask. Two drops of Erichrome black T indicator was added. The content in the conical flask was titrated against a standard EDTA solution (0.01M) until the contents of the flask changed from wine-red to blue at the end point. Titration was repeated until a consistent titre was obtained. The value of the average titre was recorded. The values were obtained as; Total Hardness, $CaCO_3$ (mg/l) = titre value x 20.

3.4.13 Calcium Hardness

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

Calcium Hardness as $CaCO_3$ (mg/l) = Average titre value x 20.

3.4.14 Magnesium hardness

Magnesium hardness of a sample was calculated as the difference between the total harness and calcium hardness values obtained from analysis of the sample.

3.4.15 Calcium

EDTA Titrimetric Method

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

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

Where A = ml of EDTA titrant used

B = ml of standard calcium solution

ml of EDTA titrant

The results were expressed as mg/l

3.4.16 Magnesium Ions

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

Determination

Follow Total hardness and Calcium determinations.

From the calcium titration, calcium hardness was calculated.

Calcium hardness as mg $CaCO_3$/l = A x B x 1000 ml sample

Where;

A= ml titrant for sample

A = mg CaCO3 equivalent to 1.00 ml EDTA titrant at the calcium indicator endpoint.

Then calcium hardness as mg CaCO3/l = concentration of Ca (0.4)

Where;

0.4 = Atomic weight of Ca

Molecular weight of $CaCO_3$

The total hardness concentration was recorded as mg/l $CaCO_3$.

Magnesium hardness as mg/l $CaCO_3$ = total hardness – calcium hardness.

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

Where 0.243 = atomic weight of Mg / molecular weight of $CaCO_3$.

The magnesium concentration was expressed as Mg mg/l

3.4.17 Chloride (Cl^-)

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

3.4.18 Total Iron (Fe) and Manganese (Mn)

An aliquot of 5 ml of concentrated Nitric acid was added to 50 ml of sample of water in a 100 ml beaker. This was heated to boil until its volume got to 20 ml. Another 5ml of concentrated nitric acid was added and the beaker was covered with a watch glass and the heating continued for 10 minutes. A final 5 ml of concentrated nitric acid was used to rinse the sides of the beaker. The solution was poured into a 50 ml volumetric flask and topped with distilled water to the mark. A blank solution was similarly prepared.

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

3.4.19 Conductivity

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

3.4.20 Determination of Dissolved Oxygen

Winkler Method

Biological Oxygen Demand bottles were filled with the undiluted water samples. 1ml of manganous sulphate solution was added to the samples in the BOD bottle followed by 1ml of Alkaline-Iodide Azide reagent. The bottle was stoppered and its content mixed by inverting it several times. Shaking was repeated when the precipitate had settled leaving a clear supernatant solution above the manganese hydroxide floc. The precipitate was allowed to settle again leaving at 100ml clear supernatant. The stopper was carefully removed and immediately 1ml of sulphuric acid was added by allowing the acid to run down the neck of the bottle. The bottles were restoppered and contents mixed by gentle inversion until the solution was complete, with iodine uniformly distributed throughout the bottle. The Dissolved Oxygen in two of the bottles was determined by the Winkler method.

203ml of the samples in the BOD bottle was decanted and titrated with 0.025N Sodium thiosulphate to pale straw colour. About 1-2 ml of freshly prepared starch solution was added. Titration was continued to the first disappearance of the blue colour. The burette reading was recorded. The other two bottles were incubated at 20^{o}C for 5 days and dissolved oxygen was determined in the incubated samples on the fifth day.

Calculation

203 ml of sample used for titration = 200ml of original sample

1ml of 0.025N Na_2So_3 = 0.2 mg O_2

1mg/l = 1ml of titrant used34

mg/l BOD = $\frac{DO_i - DO_f}{P}$

Where,

DO_i = Initial Dissolved Oxygen in water sample after preparation

DO_f = Final Dissolved Oxygen after incubation

P = Decimal fraction of sample used (P =1)

3.5 Determination of Microbiological quality

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

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

Escherichia coli counts were made by incubating the membrane filter on Hichrome media at 44^{o}C for 24 hours.

Total heterotrophic bacteria (THB) count for each of the water samples were determined using nutrient agar (NA). One millilitre (1 ml) each of the samples were separately used as inocula on NA plates and incubated at 37^{o}C for 48 hours. The colonies were counted with the aid of microscope. Where they were more, they were counted per square on the membrane filter and multiplied by the number of squares on the filter membrane.

The colonies were however calculated as;

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

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

3.6 Statistical Analysis

The data were analysed using Statistix Version 9.0 and Excel. The mean content of the different bacteriological and physicochemical parameters in each source of water was computed with corresponding ANOVA and least significant differences (LSD) value at 5% degree of confidence using Statistix Version 9.0. Results were mainly presented in cross – tabulations.

CHAPTER 4

RESULTS

4.1 Physicochemical Quality of Water Samples

4.1.1 pH

Mean pH levels of all the 10 water samples collected for analysis varied between 5.76 to 6.90 (Table 1), with water from the Source Point B, Borehole, recording the highest mean pH value of 6.90 and the lowest at Well 2 (Old Town) . Water samples collected from stand pipes ranged between 6.59 and 6.65. Generally, the differences in pH for all the water samples were not statistically ($P > 0.05$) significant (Table 1).

Mean pH values of all the water samples, except water samples collected from the wells (New Town and Old Town), were within the WHO guideline value of 6.50 - 8.50.

4.1.2 Colour

The mean true colour values of all the 10 water samples ranged from 60.33 Hz and 850.00 Hz, with the source point 'A' recording the highest value whilst water from the well 2, Old Town recorded the least (Table 1). These values were statistically ($P > 0.05$) significant (Table 1). Water from the standpipes (Tap 1&2 (Old Town) and Tap1&2 (New Town) recorded values ranging between 88.67 Hz and 349.33 Hz. The colours of all the water samples collected were very high and above the WHO guideline value of 15.00 Hz.

Table 1: The mean values of pH, Colour, Turbidity and Total Dissolved Solids of 10 water samples from the Asankragwa Township

Parameters/ Samples/	**pH**	**Colour (Hz)**	**Turbidity (NTU)**	**Conductivity (us/cm)**	**Total Dissolved solids (mg/l)**
Tap 1 (Old Town)	6.6567	119.67	14.467	326.60	89.633
Tap 2 (Old Town)	6.5967	98.333	12.900	322.60	156.33
Tap 1 (New Town)	6.6400	88.667	10.867	327.43	86.633
Tap 2(New Town)	6.6467	349.33	50.947	314.00	68.733
Well (New Town)	5.9300	98.00	13.000	297.03	147.83
Well(Old Town)	5.7600	60.333	8.3900	205.80	203.83
Source Point (A)	6.5633	850.00	144.67	318.63	84.633
Source Point (B)	6.9033	335.67	35.967	296.23	112.63
Untreated Water in Tank	6.6733	412.33	62.967	323.80	397.83
Treated Water for Distribution	6.7300	255.67	29.567	333.93	432.83
WHO /Acceptable Standards	6.5 – 8.5	15.00	5	1000	1000
LSD(0.05)	0.1074	109.62	16.728	122.48	0.2357

4.1.3 Turbidity

Monitored turbidity levels of the water samples varied between 8.39 and 144.67 NTU with samples from Source Point A (SP/A), borehole, recording the largest value of 144.67

NTU whilst the least value was recorded from Well 2, Old Town (W2/OT) (Table 1). Turbidity values recorded in all the water samples were statistically significant (P>0.05) (Table 1). Turbidity of the 4 pipe borne water points studied ranged between10.87 and 50.95 NTU with the largest value recorded from Tap 2, New Town (T2/NT) and least from Tap 1, New Town (T1/NT). All turbidity values recorded in the study far exceeded the WHO guidelines for drinking water quality of 5 NTU. Though turbidity was generally, high in all the water samples studied, the turbidity of water from Tap 2, New Town, exceeded those of water treated for distribution and the Taps.

4.1.4 Conductivity

Electrical Conductivity Levels for all the water samples ranged from 205.8 µs/cm to 333.930µs/cm (Table 1). The highest conductivity value was recorded at Treated Water for distribution (Treated H_2O) whilst the least was at Well 2, Old Town (W2/OT) (Table 1). These variations in conductivity within the different water samples were statistically significant (Table 1). However, the mean conductivity values recorded in all the water samples were comparatively lower and negligible as far as the WHO guideline value for drinking water quality of 1500 µs/cm is concerned.

4.1.5 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) of the water samples ranged from 68.73 mg/l to 432.00 mg/l (Table 1) with treated water for distribution (Treated H_2O) recording the largest value whiles the lowest value was recorded at Tap 2, New Town (T2/NT) (Table 1). These differences, however, were statistically significant (P > 0.05). TDS values of all the water samples showed

relatively negligible levels of below 500 mg/l which was far below the WHO maximum allowable limit of 1000 mg/l.

4.1.6 Dissolved Oxygen

Dissolved Oxygen (DO) of water samples ranged between 2.27 mg/l and 4.49 mg/l (Table 2) with Well 1, New Town (W1/NT) recording the highest mean value whiles the lowest DO was recorded at Source Point A (SP/A) (Table 2). These differences, however, were statistically significant ($P > 0.05$). There was however no guideline on the maximum amount of DO in water. Generally, water with high levels of DO tastes better than those without.

4.1.7 Temperature

The mean temperature of the 10 water samples analysed ranged from 24.5^0C to 24.8^0C (Table 2). The differences were not significant.

4.1.8 Total Suspended Solids

Total Suspended solids ranged from 2.667 to 68.667 mg/l (Table 2) with water from the source point 'A' recording highest whilst water drawn from the Well 2 (Old Town) recorded the lowest mean value. The differences were statistically significant.

Table 2: The mean values of Dissolved Oxygen, Temperature, Total Suspended Solids, and Total Solids of 10 water samples from the Asankragwa Township

Samples/Parameters	**Dissolved Oxygen (mg/l)**	**Temperature (^{0}C)**	**Total Suspended Solids (mg/l)**	**Total Solids (mg/l)**
Tap 1 (Old Town)	2.7967	24.500	7.6667	97.467
Tap 2 (Old Town)	3.3167	24.767	6.3333	162.83
Tap 1 (New Town)	4.4267	24.633	5.0000	91.800
Tap 2(New Town)	2.4467	24.833	29.000	97.900
Well (New Town)	4.4900	24.633	5.3333	153.33
Well(Old Town)	2.8433	24.633	2.6667	206.67
Source Point (A)	2.2700	24.733	68.667	153.20
Source Point (B)	3.2267	24.733	22.667	135.47
Untreated Water in Tank	2.7067	24.633	40.667	334.67
Treated Water for Distribution	2.7700	24.567	29.667	342.33
WHO /Acceptable Standards	-	-	-	-
LSD(0.05)	0.1862	0.1807	13.198	72.207

4.1.9 Total Solids

The mean values for total solids ranged from 91.80 mg/l to 342.33 mg/l (Table 2) with water from the well 2, Old Town recording the highest mean value and water from tap 1, New Town recording lowest mean value. The differences were statistically significant. There was however no guideline on the maximum amount of total solids in water.

4.1.10 Total Hardness

The mean values for total hardness ranged from 48.00 to 142.67 mg/l (Table 3) with water from source point B recording the largest value of 142.67 mg/l whilst water from well 1 (New Town) recorded the least value of 48.00 mg/l. The values were statistically significant. There was however no guideline on the maximum amount of total hardness in water.

4.1.11 Total Alkalinity

Total alkalinity values ranged from 34.67 to 175.33 mg/l with water from the source point B recording the largest value whilst water from well 2 (Old Town) recorded the lowest value. The water drawn from the taps also had mean values ranging from 100.00 mg/l to 116.00 mg/l. The differences were statistically significant. There was however no guideline on the maximum amount of total alkalinity in water.

Table 3: The mean values of Total Hardness, Calcium Hardness, Magnesium Hardness and Total Alkalinity of 10 water samples from the Asankragwa Township

Samples/Parameters	Total Hardness (mg/l)	Total Alkalinity (mg/l)	Calcium Hardness (mg/l)	Magnesium Hardness (mg/l)
Tap 1 (Old Town)	104.00	114.00	56.667	47.333
Tap 2 (Old Town)	101.33	100.00	56.667	44.667
Tap 1 (New Town)	90.00	100.00	60.000	30.000
Tap 2(New Town)	95.333	116.00	55.333	16.000
Well (New Town)	48.000	36.667	36.667	12.000
Well(Old Town)	48.667	34.667	38.667	8.667
Source Point (A)	106.00	93.333	76.667	12.667
Source Point (B)	142.67	175.33	88.667	32.667
Untreated Water in Tank	94.667	107.33	56.667	50.000
Treated Water for Distribution	112.00	120.00	79.333	32.667
WHO /Acceptable Standards	500	-	-	-
LSD(0.05)	11.144	9.7114	10.146	15.756

4.1.12 Calcium Hardness

Calcium hardness in the 10 water samples studied ranged from 36.67 mg/l to 88.67 mg/l with water samples from Source Point 'B' recording largest whist water samples from Well 1 (New

Town) recorded lowest (Table 4). The differences were statistically significant. There was however no guideline on the maximum amount of calcium hardness in water.

4.1.13 Magnesium Hardness

Magnesium Hardness in the water samples ranged from 50.00 mg/l to 8.67 mg/l with untreated water in the tank recording the largest value whilst and water samples from the well (old town) recorded the least (Table 4). The differences were statistically significant. There was however no guideline on the maximum amount of calcium hardness in water.

4.1.14 Calcium

Calcium in the 10 water samples studied ranged from 11.47 mg/l to 35.40 mg/l with water samples from Source Point 'B' recording largest and water samples from Well 1 (New Town) recording lowest (Table 4). The values were statistically significant. These values were below the World Health Organisation's standard of 200mg/l

4.1.15 Magnesium

Mean values for magnesium in the water samples ranged from 2.100 mg/l to12.133mg/l with water samples from well 2 (Old Town) recording least values whilst water samples from the Untreated water in the Tank recorded the largest value (Table 4). These values were statistically significant and were far below the World Health Organisation's allowable limit of 150 mg/l.

Table 4: The mean values of Calcium, Magnesium, Chloride, Nitrite, and Iron (Total and Soluble) of 10 water samples from the Asankragwa Township- Statistix-Version 9.0

Parameters	**Calcium**	**Magnesium**	**Chloride**	**Nitrite**	**Iron (Total)**	**Iron (Soluble)**
Tap 1 (Old Town)	19.200	11.473	43.333	0.0033	1.3767	0.5833
Tap 2 (Old Town)	22.667	9.2167	44.333	0.0040	1.3867	0.5500
Tap 1 (New Town)	24.000	5.3500	44.333	0.0020	2.5000	1.4000
Tap 2(New Town)	22.133	3.8867	40.000	0.3520	3.3000	1.9500
Well (New Town)	11.467	2.9100	52.333	0.0173	0.1500	0.0000
Well(Old Town)	15.467	2.1000	36.333	0.0027	1.6667	1.1833
Source Point (A)	30.667	3.0733	45.667	0.0033	3.8000	1.8167
Source Point (B)	35.400	7.9067	27.000	0.0033	3.6333	1.9000
Untreated Water in Tank	22.667	12.133	30.000	0.0033	3.1000	1.7667
Treated Water for Distribution	31.733	7.9233	55.333	0.0100	3.7667	2.1333
WHO Standard	200	150	250	3	0.3	0.3
LSD(0.05)	4.9381	3.7461	14.627	0.1540	1.8531	1.2661

4.1.16 Chloride

Mean values of Chloride in the water samples analysed ranged from 27.000 to 55.333 mg/l with water samples from the Source Point 'B' recording the lowest value and water samples from the treated water for distribution recording the highest values (Table 4). The values were statistically significant and were below the World Health Organisation's standard of 250 mg/l.

4.1.17 Nitrite

The mean values of nitrite in the water samples ranged from 0.0020 to 0.3520 mg/l with water samples from Tap 2 (New Town) recorded the largest nitrate concentration whilst water samples from Tap 1 (New Town) recorded the least concentration (Table 4). The values were statistically significant and were below the World Health Organisation's Guideline for quality drinking water value 3mg/l.

4.1.18 Iron (Total and Soluble)

Mean values for Iron, total and soluble, in the water samples collected ranged from 0.1500 to 3.800mg/l and 0.000 to 2.1333 respectively (Table 4). Iron concentration in all the water samples was very high. The highest mean concentration was found in Source Point (A) and the lowest in Well 1 (New Town) (Table 4). The variation within the samples was not significant statistically. Generally, the mean concentrations far exceeded the WHO guideline value of 0.3 mg/l.

4.1.19 Manganese

Mean values of manganese in the water samples collected ranged from 0.0073 mg/l to 0.0427 mg/l with water samples from Source point (B) recording the largest value whilst water samples from Tap 1(Old Town) recorded the least value (Table 5). These values were statistically significant and were below the World Health Organization acceptable standard of 0.1mg/l

4.1.20 Phosphate

Mean values for Phosphate in the water samples collected ranged from 1.14 mg/l to 11.05 mg/l with water samples from the Well 2 (Old Town) recording least phosphate concentration while water samples from Source Point (A) recording largest concentration (Table 5). The differences were significant and were below the World health Organisation's standard of 400 mg/l.

4.1.21 Ammonia

Mean values for Ammonia in the water samples collected ranged from 0.0000 to 0.0633 mg/l with water samples from Tap1 (Old Town), Tap 2 (Old Town), Tap 1 (New Town), Well 1 (New Town), Well 2 (Old Town), Source Point (B) and Treated Water for Distribution recording the lowest value, and water from Source Point (A) recording the highest values (Table 5). These values were statistically significant and were below the World Health Organisation's standard of 1.5mg/l.

Table 5: The mean values of Manganese, Phosphate, Ammonia, and Sulphate of 10 water samples from the Asankragwa Township

Parameters	**Manganese (mg/l)**	**Phosphate (mg/l)**	**Ammonia (mg/l)**	**Sulphate (mg/l)**
Tap 1 (Old Town)	0.0073	6.1500	0.0000	21.667
Tap 2 (Old Town)	0.0097	1.7167	0.0000	18.000
Tap 1 (New Town)	0.0067	1.2667	0.0000	20.333
Tap 2(New Town)	0.0147	6.0267	0.0167	29.333
Well (New Town)	0.0223	5.1767	0.0000	8.6667
Well(Old Town)	0.0247	1.1367	0.0000	7.3333
Source Point (A)	0.0380	11.050	0.0633	57.333
Source Point (B)	0.0427	6.2767	0.0000	20.667
Untreated Water in Tank	0.0410	7.7733	0.0133	32.333
Treated Water for Distribution	0.0293	2.4567	0.0000	26.000
WHO Standard	0.1	400	1.5	400
LSD(0.05)	7.149E-03	3.3121	5.774E-03	5.5538

4.1.22 Sulphate

The mean values of the Sulphate concentration in the water samples ranged from 7.333 to 32.333 with water samples from Well 2 (Old Town) recording lowest value and the Untreated Water in

the tank recording the highest mean value (Table 5). These values were statistically significant and were below the World health Organisation's acceptable value of 400.

4.2 Microbiological Analysis

4.2.1 Total Coliform

Total coliform for the 10 water samples ranged from 1.000 to 66.667 CFU/100 ml with water samples from Tap 2 (New Town) recording the least value and water samples from the Untreated Water in the Tank recording largest value (Table 6). Generally, the differences were significant. The values obtained far exceeded the World Health Organisation's acceptable standard of 0.000 CFU/100 ml.

4.2.2 Feacal Coliform

The mean values for the presence of feacal coliforms in the water samples collected for the analysis ranged from 0.0000 to 1.3333 CFU/100 ml with water samples from the Tap1 (Old & New Town), Tap 2 (Old & New Town), Source Points (A&B) and Treated Water for Distribution recording the lowest value, and Well (Old Town) recording the largest value (Table 6). The values were statistically significant. The mean values of the water samples from the Taps, the Source Points and the treated water for distribution were within the World Health Organisation's standard of 0.0000 CFU/100 ml but the wells and the water before treatment were not.

Table 6: Results of the mean values of Total Coliform, Feacal Coliform and *E. Coli* of 10 water samples from the Asankragwa Township

Parameters	**Total Coliform (CFU/100ml)**	**Feacal Coliform (CFU/100ml)**	**E. Coli (CFU/100ml)**
Tap 1 (Old Town)	38.000	0.0000	0.0000
Tap 2 (Old Town)	34.333	0.0000	0.0000
Tap 1 (New Town	36.667	0.0000	0.0000
Tap 2(New Town)	1.0000	0.0000	0.0000
Well (New Town)	11.333	0.3333	1.0000
Well(Old Town)	24.000	1.3333	0.6667
Source Point (A)	3.0000	0.0000	0.0000
Source Point (B)	11.333	0.0000	0.0000
Untreated Water in Tank	66.667	0.6667	0.3333
Treated Water for Distribution	6.6667	0.0000	0.0000
WHO Standard	0.0000	0.0000	0.0000
LSD(0.05)	2.7063	0.2229	0.1948

4.2.3 Escherichia Coli

Mean values of the determination of *Escherichia coli* in the water samples analysed ranged from 0.000 CFU/100 ml to 1.000 CFU/100 ml with water samples from Taps 1&2 (Old & New Town), Source Points A&B and the Treated water for distribution recording the least values, whilst water samples from Well (New Town) recorded the largest values (Table 6). Generally,

the differences were statistically significant. However, with exception of water samples from the wells and water in the tank before treatment, water samples from the Taps, the Source points and the treated water in the tank for distribution were all within the World Health Organisation's acceptable value of 0.000 CFU/100 ml.

CHAPTER 5

DISCUSSION

5.1 Physicochemical Properties

Generally, the results indicated that the water samples analysed may not require more chlorine for the destruction of pathogens since it had acceptable levels of acidity. However, water from the wells may have corrosive effect on plumbing and faucets since it has pH levels of below 6.00 (Table 1).

Though pH has no direct effect on the human health, all biochemical reactions are sensitive to variation of pH. For most reactions as well as for human beings, pH 7.0 is considered as best and ideal. In the present study pH of water samples varied in a narrow range within the permissible limits in all the water samples except water from the wells. pH is of utmost importance in determining the corrosiveness of water. In general, the lower the value of pH, the higher the level of corrosion. In some cases decrease in pH is accompanied by the increase in bicarbonate, carbonate and hydroxyl ions. According to Gupta *et al.* (2009) decrease in pH can be caused by the increase in the amount of organic carbon, and total carbonate by the use of sewage. This could be the reason why in the current study pH of water samples from the wells were low.

Also, it was revealed from the study that, the mean values of colour were high above the WHO guideline value. The high mean values of colour in the samples studied may be indicative of dissolved organic materials, inadequate treatment, high disinfectant demand and the potential for the production of excess amounts of disinfectant byproducts. Inorganic contaminants, such as

metals, are also common causes of colour. For instance, the value of colour in Tap 2 (New town) relatively compared to the values of the other Taps (Table 1), was very high and could be as a result of clogging of iron in the water distribution system that impacts on the colour of the water during distribution. This assertion could be true since the mean value for colour of Tap 2 (New Town), 349.33 Hz, was far higher than the mean value of colour for the treated water for distribution which was 255.67 Hz. In this study, water from the source points 'A' and 'B' had high iron and this could be the reason why colour was high in water samples from these sources. According to Dvorak (2007) oxidation of dissolved iron particles in water changes the iron to white, then yellow and finally to red-brown solid particles (precipitates) that settle out of the water. Iron that does not form particles large enough to settle out and that remains suspended (colloidal iron) leaves the water with a red tint. Dvorak (2007) explicitly state that iron can affect the color of water, and in this current study, high levels of colour could be as a result of high content of iron in the water samples studied.

Though turbidity was generally, high in all the water samples studied, mean turbidity value of Tap 2, New Town, exceeded the mean values of water treated for distribution and the Taps. This may also be a reason why the mean colour value of the Tap 2, New Town, was also high in the same water sample. High mean turbidity for source points 'A' and 'B' may also be due to inorganic substances such as clay, rock flour, silts, calcium carbonate, silica, iron, manganese, finely dissolved organic and inorganic material microorganisms such as bacteria and viruses. According to information retrieved from the United States Environmental Protection Agency's website (Date accessed: 7th June, 2012), higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria and these

organisms can cause symptoms such as nausea, cramps, diarrhoea, and associated headaches. However, health effects from turbid water will depend upon the type of material in the water that is causing the turbidity. In this study high levels of turbidity in the water samples studied may call for treatment and disinfection of the water to keep turbidity levels low.

Again, the levels of salts such as Ca, Mg, Cl- and SO_4^{2} in the samples studied suggest that the water samples possessed low amounts of these components. It is well known that the conductance of water increases with salts, and the higher the concentration of electrolytes in water the more its electrical conductance (Gupta *et al*., 2009). Total dissolved solids and conductivity of the samples studied could also be used to delineate each other. Conductivity is proportional to the dissolved solids and in the study, both showed similar trends in the samples.

Total Dissolved Solids (TDS) in all the water samples studied were low based on the WHO standards. According to WHO (2004), TDS describes the inorganic salts and small amounts of organic matter present in solution, and the principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions. In this study, levels of TDS in water samples showed low levels of these components (magnesium, sulfate, chloride, calcium and others). This may be the reason why TDS was low in all the water samples studied. It may also indicate that the concentration of the dissolved ions in the water samples may not cause the water to be corrosive, salty or have a brackish taste, result in scale formation, and interfere or decrease the efficiency of hot water heaters. An elevated total dissolved solids (TDS) concentration is not a health hazard but a

secondary drinking water standard. However it may need to be regulated because it may have an aesthetic effect (United States Environmental Protection Agency, 2012).

Normally, when water is exposed to intense sunlight it can accelerate photosynthesis by phytoplankton, utilizing CO_2 and giving off oxygen. This accounted for the high levels of O_2 recorded in the wells. Similarly, the source points also recorded low DO probably because their exposure to direct sunlight was limited and this reducedt the activities of phytoplanktons.

Suspended solids absorb heat from sunlight, which increase water temperature and subsequently, decreases levels of dissolved oxygen (warm water holds less oxygen than cold water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels (Michigan Department of Environmental Quality/NPDES, 2012).

High concentrations of suspended solids can reduce water quality by absorbing light. Water then become warmer and reduces the ability to hold oxygen necessary for aquatic life. Because aquatic plants also receive less light, photosynthesis decreases and less oxygen is produced. The combination of warmer water, less light and less oxygen makes it impossible for some forms of life to exist (North Dakota Department of Health, 2012).

Total solids (TS) is a measure of all the suspended, colloidal, and dissolved solids in a sample of water. This includes dissolved salts such as sodium chloride, NaCl, and solid particles such as silt and plankton (Johnson et al., 2007).

Dissolved solids often make a significant contribution to the amount of total solids in water. In fact, the mass of the dissolved solids is sometimes higher than the mass of the suspended particles and this was evident in all the samples studied in this study. Dissolved solids in drinking water samples may include soluble salts that yield ions such as calcium, chloride, bicarbonate, nitrates, phosphates, and iron. In drinking water systems, if the levels of total solids are too high or too low, it may impact on the health of consumers (Johnson *et al.,* 2007). High levels of total solids may reduce the clearness of the water. This decreases the amount of sunlight able to penetrate the water, thereby decreasing the photosynthetic rate (which can adversely have an effect on the dissolved oxygen level), and also effective disinfection. Reduced clarity also makes the water less aesthetically pleasing. While this may not be harmful directly, it is certainly undesirable for many water uses. When water is cloudy, sunlight will warm it more efficiently. This occurs because the suspended particles in the water absorb sunlight which, in turn, warms the surrounding water. This leads to other problems associated with increased temperature levels (Johnson *et al.*, 2007).

Water hardness is the traditional measure of the capacity of water to react with soap; hard water requiring considerably more soap to produce lather. Hardness is one of the very important properties of ground water from the utility point of view for different purposes. In the present study, water hardness was within the permissible limits. It is well known that hardness is not

caused by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, although other cations likes barium, iron, manganese, strontium and zinc also contribute (WHO, 2004). The concentration of total hardness in the water samples studied may be due to dissolution of polyvalent metallic ions from sedimentary rocks, seepage and run off from soil.

Calcium hardness (CH) is a measure of the amount of lime dissolved in water. Water with a CH of less than 100 ppm (mg/l) is described as soft water. Water with a CH above 300 ppm (mg/l) is described as hard water and causes lime to be precipitated. Calcium hardness can be reduced by dilution with fresh mains water and increased with calcium chloride (Pahlen User's guide, 2012).

The acceptable limits for calcium and magnesium for domestic use are 75 ppm and 30 ppm, respectively, in ground water. Whereas in case of non-availability of water sources, calcium up to 200 ppm could be accepted. High value of hardness can also be attributed to decrease in water volume and increase of rate of evaporation (Pahlen User's guide, 2012).

Alkalinity is the buffering capacity of a water body. It measures the ability of water bodies to neutralize acids and bases thereby maintaining a fairly stable pH. Water that is a good buffer contains compounds, such as bicarbonates, carbonates, and hydroxides, which combine with H^+ ions from the water and thereby, raising the pH of the water. Without this buffering capacity, any acid added to water would immediately change its pH (Addy *et al*., 2004).

To maintain a fairly constant pH in a water body, a higher alkalinity is preferable. High alkalinity means that the water body has the ability to neutralize acidic pollution from rainfall or basic

inputs from wastewater. A well buffered lake also means that daily fluctuations of CO_2 concentrations result in only minor changes in pH throughout the course of a day.

Alkalinity comes from rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges (detergents and soap based products are alkaline). If an area's geology contains large quantities of calcium carbonate ($CaCO_3$, limestone), water bodies tend to be more alkaline. Granite bedrock is deficient in alkaline materials to buffer acidic inputs. Addition of lime as a soil amendment to decrease acidity in agricultural farms or even home lawns in households, can runoff into surface waters and increase alkalinity (Addy *et al*., 2004).

5.2 Microbiological Properties

The most basic test for bacterial contamination of water is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply. Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste (New York State Department of Health, 2012).

In the study, there was a clear indication from the results obtained from that all the water samples contained certain level of total coliforms that makes the water unacceptable based on the WHO guidelines for drinking water. In this regard, people use the water must treat it or boil it thoroughly before use.

It also became clear from the study that, water from the wells and the water in the tank contain levels of feacal coliforms. Feacal coliforms are the group of coliforms that are considered to be present specifically in the gut and feaces of warm-blooded animals. Because the origins of feacal coliforms are more specific than the origins of the more general total coliform group of bacteria, feacal coliforms may be considered a more accurate indication of animal or human waste than the total coliforms (New York State Department of Health, 2012).

In the case of the wells, pollution by feacal coliforms could possibly be due to seepage from nearby pit latrines or different individuals indiscriminately fetching water from the same well. In the case of the storage tank, the possible sources could be from bird dropping since some parts of the tank is not covered. The presence of the feacal coliforms could indicate that the respective polluted water samples may contain pathogenic organisms, which should not be overlooked.

Escherichia coli is the major species in the feacal coliform group. Of the five general groups of bacteria that comprise the total coliforms, only *E. coli* is generally not found growing and reproducing in the environment. Consequently, *E. coli* is considered to be the species of coliform bacteria that is the best indicator of feacal pollution and the possible presence of pathogens (New York State Department of Health, 2012).

In the study, water samples that were found to contain the feacal coliforms were the same water samples that indicated presence of E. coli. The level of E. coli far exceeded the WHO guideline value of zero.

Although all the samples analysed contained some levels of total coliforms, all the water samples drawn for the taps, the source points, and the distribution system showed no presence of feacal and *E. coli* in them. However, the very presence of total coliform in the water samples implies that the use of the water samples for drinking and performing other domestic purposes may not be safe.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the findings of the study, the following conclusions have been drawn.

All 10 water samples studied except the water drawn from the wells and the water in the tank, showed no indication of feacal coliform or *Escherichia coli*. However, all the samples had total coliforms present in numbers which cannot be overlooked, especially, from the pipe borne water points. On the basis of this, treatment of the pipe borne water from the source points through to the distribution point is doubtful and needs to be improved. The presence of total coliforms in the treated water suggests more investigation needs to be conducted on the distribution system of the pipe borne water supply to know possible causes of contamination. Unidentified coliform in the treated water may be pathogenic and may be harmful to consumers, especially, children, the aged and the sick whose system may be already compromised. Based on the results from the study it was suspected that the storage tank can be a possible cause of contamination. The presence of total coliforms, feacal coliforms and *Escherichia coli* in the storage tank, as indicated in the results of the study, indicates that the storage tank could be a possible cause of contamination of water from the two (2) source points.

Again, one-on-one interview with the personnel who manages the facility revealed that the district did not have trained personnel to manage the pipe borne water system. Treatment was not done frequently and there was no proper monitoring to ensure that quality water was produced

and distributed to users. Also, frequent testing of the water was not done, and the existing water treatment plant and distribution systems were not maintained regularly. These factors could be the possible cause of the risk of microbial and chemical pollution in the pipe borne water supply system in the Asankragwa Township.

In comparism, the wells were not treated but had a better colour than the pipe borne water and tasted better due to high levels of dissolve oxygen. The wells were more acidic than the pipe borne water. However, though it was suspected that the treatment of the pipe borne water was not done frequently and effectively, there could also be possible room for believing that the distribution system of the pipe borne water had residue of chlorine that enhances disinfection of organism in the pipe borne water supply system in the Asankragwa Township, and that was what was deficient in the wells. The study revealed important parameters of the samples such as total coliform, colour, turbidity, iron and others that did not meet the acceptable standards based on the WHO guidelines for drinking water quality.

In all, it can be said that the pipe borne water distributed in the Asankragwa Township is not suitable for drinking based on the WHO acceptable guidelines for drinking water quality. Notwithstanding this, the quality of the pipe borne water as a source of drinking may be better than that of the wells.

6.2 Recommendations

Based on the results of the study the following recommendations have been made;

1. The District Assembly should put in place proper monitoring mechanism to monitor the pipe borne water distribution system.
2. There should be frequent maintenance of the facilities to avoid possible forms of physicochemical and microbiological infections.
3. Frequent treatment of the pipe borne water must be ensured.
4. Frequent testing of the pipe borne water at various points in the distribution points must be done to enhance the identification of possible risks in the supply system and deal with them.
5. Competent and adequate personnel should be employed to manage the facility.
6. The District Assembly must ensure the development and implementation of risk management strategies that will ensure the safety of drinking-water supplied in Asankragwa through the control of hazardous constituents of pipe borne water.
7. For private wells in the Asankragwa Township, it is recommended that they are encouraged and monitored to take their water for testing. Users must also be sensitized to boil water from such sources, or use bottled distilled water.

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APPENDICES

Field Results-Annova

Appendix 1: Completely Randomized ANNOVA for pH

Source	DF	SS	MS	F	P
SAMPLE	9	3.67732	0.40859	23.62	0.0000
Error	20	0.34600	0.01730		
Total	29	4.02332			

Grand Mean 6.5160 CV 2.02

Appendix 2: Completely Randomized ANNOVA for True_Colour

Source	DF	SS	MS	F	P
SAMPLE	9	1577589	175288	9.73	0.0000
Error	20	360469	18023		
Total	29	1938059			

Grand Mean 266.80 CV 50.32

Appendix 3: Completely Randomized ANNOVA for Turbidity

Source	DF	SS	MS	F	P
SAMPLE	9	46993.2	5221.46	12.44	0.0000
Error	20	8395.2	419.76		
Total	29	55388.4			

Grand Mean 38.374 CV 53.39

Appendix 4: Completely Randomized ANNOVA for Conductivity

Source	DF	SS	MS	F	P
SAMPLE	9	38077	4230.7	0.19	0.9930
Error	20	450033	22501.7		
Total	29	488110			

Grand Mean 306.61 CV 48.92

Appendix 5: Completely Randomized ANNOVA for Total Dissolved Solids

Source	DF	SS	MS	F	P
SAMPLE	9	469198	52133.1	625597	0.0000
Error	20	2	0.1		
Total	29	469200			

Grand Mean 178.09 CV 0.16

Appendix 6: Completely Randomized ANNOVA for Dissolved Oxygen

Source	DF	SS	MS	F	P
SAMPLE	9	15.8513	1.76126	33.85	0.0000
Error	20	1.0407	0.05203		
Total	29	16.8920			

Grand Mean 3.1293 CV 7.29

Appendix 7: Completely Randomized ANNOVA for Temperature

Source	DF	SS	MS	F	P
SAMPLE	9	0.26667	0.02963	0.60	0.7786
Error	20	0.98000	0.04900		
Total	29	1.24667			

Grand Mean 24.667 CV 0.90

Appendix 8: Completely Randomized ANNOVA for Total_Suspended Solids

Source	DF	SS	MS	F	P
SAMPLE	9	12076.0	1341.78	5.14	0.0011
Error	20	5225.3	261.27		
Total	29	17301.4			

Grand Mean 21.767 CV 74.26

Appendix 9: Completely Randomized ANNOVA for Total_Solids

Source	DF	SS	MS	F	P
SAMPLE	9	227893	25321.5	3.24	0.0137
Error	20	156417	7820.9		
Total	29	384311			

Grand Mean 177.57 CV 49.80

Appendix 10: Completely Randomized ANNOVA for Total_Hardness

Source	DF	SS	MS	F	P
SAMPLE	9	21536.5	2392.95	12.85	0.0000
Error	20	3725.3	186.27		
Total	29	25261.9			

Grand Mean 94.267 CV 14.48

Appendix 11: Completely Randomized ANNOVA for Calcium_Hardness

Source	DF	SS	MS	F	P
SAMPLE	9	7575.5	841.719	5.45	0.0008
Error	20	3088.0	154.400		
Total	29	10663.5			

Grand Mean 60.533 CV 20.53

Appendix 12: Completely Randomized ANNOVA for Magnesium Hardness

Source	DF	SS	MS	F	P
SAMPLE	9	6562.7	729.185	1.96	0.1015
Error	20	7456.0	372.800		
Total	29	14018.7			

Grand Mean 28.667 CV 67.35

Appendix 13: Completely Randomized ANNOVA for Calcium

Source	DF	SS	MS	F	P
SAMPLE	9	1476.23	164.025	4.48	0.0025
Error	20	731.55	36.577		
Total	29	2207.77			

Grand Mean 23.540 CV 25.69

Appendix 14: Completely Randomized ANNOVA for Magnesium

Source	DF	SS	MS	F	P
SAMPLE	9	359.702	39.9669	1.90	0.1115
Error	20	420.990	21.0495		
Total	29	780.692			

Grand Mean 6.5973 CV 69.54

Appendix 15: Completely Randomized ANNOVA for Chloride

Source	DF	SS	MS	F	P
SAMPLE	9	2146.80	238.533	0.74	0.6666
Error	20	6418.67	320.933		
Total	29	8565.47			

Grand Mean 41.867 CV 42.79

Appendix 16: Completely Randomized ANNOVA for Nitrite

Source	DF	SS	MS	F	P
SAMPLE	9	0.32481	0.03609	1.02	0.4608
Error	20	0.71107	0.03555		
Total	29	1.03588			

Grand Mean 0.0401 CV 469.83

Appendix 17: Completely Randomized ANNOVA for Iron (Total)

Source	DF	SS	MS	F	P
SAMPLE	9	42.861	4.76233	0.92	0.5249
Error	20	103.019	5.15097		
Total	29	145.880			

Grand Mean 2.4680 CV 91.96

Appendix 18: Completely Randomized ANNOVA for Iron (soluble)

Source	DF	SS	MS	F	P
SAMPLE	9	14.2301	1.58112	0.66	0.7363
Error	20	48.0933	2.40467		
Total	29	62.3234			

Grand Mean 1.3283 CV 116.74

Appendix 19: Completely Randomized ANNOVA for Manganese

Source	DF	SS	MS	F	P
SAMPLE	9	0.00520	5.782E-04	7.54	0.0001
Error	20	0.00153	7.667E-05		
Total	29	0.00674			

Grand Mean 0.0236 CV 37.05

Appendix 20: Completely Randomized ANNOVA for Phosphate

Source	DF	SS	MS	F	P
SAMPLE	9	283.048	31.4498	1.91	0.1092
Error	20	329.092	16.4546		
Total	29	612.140			

Grand Mean 4.9030 CV 82.73

Appendix 21: Completely Randomized ANNOVA for Ammonia

Source	DF	SS	MS	F	P
SAMPLE	9	0.01079	0.00120	23.97	0.0000
Error	20	0.00100	0.00005		
Total	29	0.01179			

Grand Mean 9.33E-03 CV 75.76

Appendix 22: Completely Randomized ANNOVA for Sulphate

Source	DF	SS	MS	F	P
SAMPLE	9	5374.83	597.204	12.91	0.0000
Error	20	925.33	46.267		
Total	29	6300.17			

Grand Mean 24.167 CV 28.15

Appendix 23: Completely Randomized ANNOVA for Total_Coliform

Source	DF	SS	MS	F	P
SAMPLE	9	11610.3	1290.03	0.96	0.4998
Error	20	26902.0	1345.10		
Total	29	38512.3			

Grand Mean 23.300 CV 157.41

Appendix 24: Completely Randomized ANNOVA for Feacal_Coliform

Source	DF	SS	MS	F	P
SAMPLE	9	5.3667	0.59630	0.85	0.5800
Error	20	14.0000	0.70000		
Total	29	19.3667			

Grand Mean 0.2333 CV 358.57

Appendix 25: Completely Randomized ANNOVA for E. coli

Source	DF	SS	MS	F	P
SAMPLE	9	3.4667	0.38519	0.83	0.6007
Error	20	9.3333	0.46667		
Total	29	12.8000			

Grand Mean 0.2000 CV 341.57