

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



**ASSESSMENT OF THE QUALITY OF PACKAGED DRINKING WATER SOLD IN
KUMASI METROPOLIS, IN THE ASHANTI REGION OF GHANA**

By

AKORLI, MAWUENYEGA ELAH (BSc. Hons.)

Biological Sciences, KNUST- Kumasi

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DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

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DECLARATION

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

Akorli, Mawuenyega Elah

Student Name

Signature

Date

Certified by:

Dr. R. B. Voegborlo

Supervisor's Name

Signature

Date

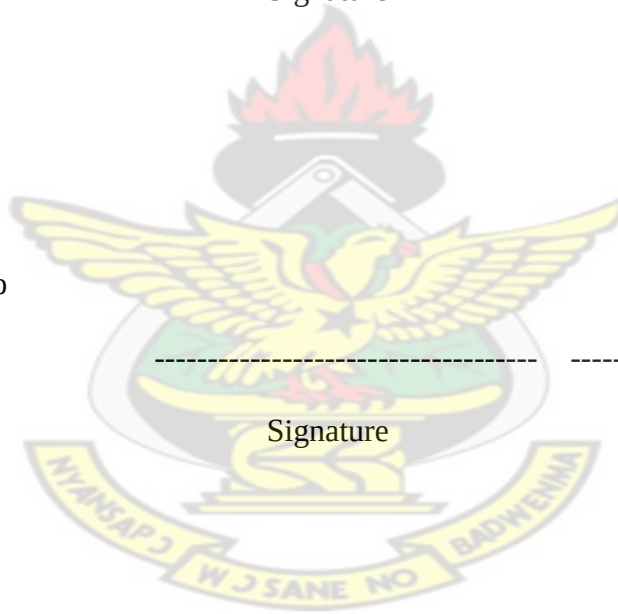
Certified by:

Dr. P. K. Baidoo

(Head of Department)

Signature

Date



DEDICATION

First and foremost, I dedicate this thesis to the Lord Jesus Christ for having paved the way for my academic pursuits.

Finally, to my precious wife, Mrs. Gloria Akorli, for her steadfast support and encouragement, and my marvelous daughter, Etornam.

KNUST



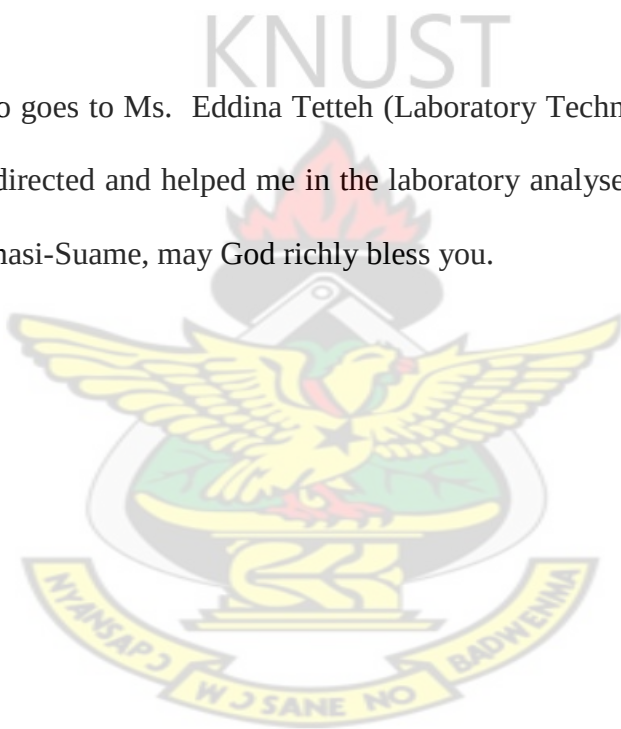
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ABSTRACT

The inhabitants of Kumasi have over the years mistrusted their pipe water hence relied on packaged water as a source of good drinking water. The high demand for the packaged drinking water has led to the situation where producers may have compromised the product quality for quantity. This study was conducted in the Kumasi metropolis, Ghana to examine the suitability of packaged water for consumption by evaluating their bacteriological, physical and chemical characteristics. These were total coliform, faecal coliform, pH, turbidity, apparent colour, conductivity, total dissolved solids, dissolved oxygen, ammonia, nitrite-nitrogen, nitrate-nitrogen, sulphate, chloride, phosphate, total alkalinity, manganese, total hardness, calcium and magnesium hardness and their ions. Water samples were analysed according to Standard Methods for the Examination of Water and Wastewater. The results have shown that the physical and chemical parameters investigated were all within the Ghana Standards Board (1998) and World Health Organization permissible limits. The bacteriological analysis showed that brands of bottled water were not contaminated with total coliforms, faecal coliforms or *Escherichia coli*. Unfortunately, 55.6% of the brands of sachet water were contaminated with total coliforms, faecal coliforms and *Escherichia coli* bacteria. All the bottled water and 44.4% of sachet water examined were suitable for consumption.

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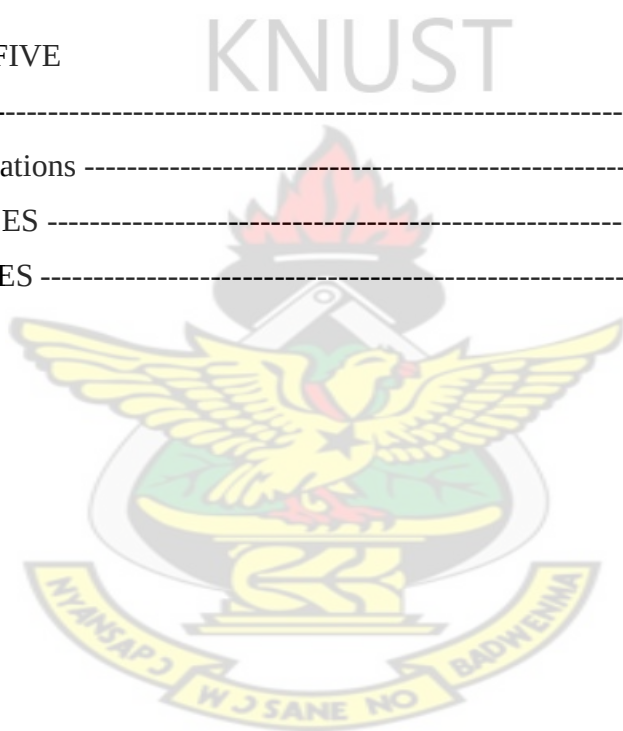
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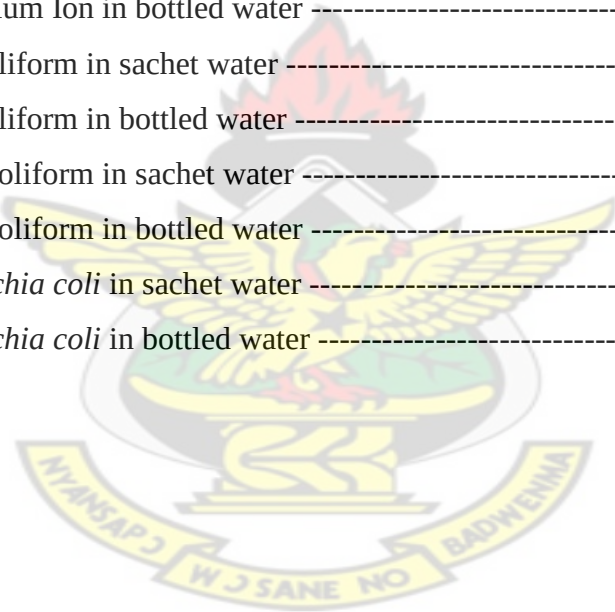
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CHAPTER ONE

1. INTRODUCTION

Water is one of the most essential and abundant commodities of man occupying about 70% of the earth's surface. A greater percentage of the world's population most especially in developing countries live without access to safe water (Hazen and Toranzos, 1990) because much of the water is not fresh and potable. Water for drinking should be free of disease-causing microorganisms, harmful chemicals, objectionable taste and odour, excessive levels of colour and suspended materials. Ideally, the characteristics of water should not impair its aesthetic values (Maher *et al.*, 1997).

The hourly toll from biological contamination of drinking water is 400 deaths of children below age five (Gadgil, 1998). The growing population of most developing countries occurs exclusively in urban areas. In developing countries, the considerable pressure on already overburdened budgets makes it difficult to increase the water supply infrastructure (Gadgil, 1998; DeVilliers, 2002; Helwey, 2002).

In Ghana, the Ghana Water Company Limited (GWCL) is in charge of the provision of urban water supply and has water coverage of only 59% (Ainuson, 2009). During an orientation visit to six peri-urban communities in Kumasi, it was found that there were two main problems that limited the access to potable water, namely, that whereas some communities lacked access to pipe-borne water, others had pipe-borne systems that were not functioning (Asare *et al.*, 2007).

The main goal of the water sector reform has been geared towards introducing private sector participation (PSP) into the water supply sector (United Nations, 1992). The introduction of

packaged water to consumers was to provide safe, hygienic and affordable instant drinking water to the public (Addo *et al.*, 2009). The increase in demand for packaged water has also been attributed to changes in fashion towards the consumption of designer water, increased concerns about the safety of municipal water and an increased influx of people into major urban areas with a dire need for good drinking water (Hunter, 1994). In addition, convenience has also made the products meet the requirements of any lifestyle when needed (Gardner, 2004).

The weather has a significant impact on both the quantity and quality of water available in most developing countries (Gadgil, 1998). During the rainy season, faeces are washed away into rivers and springs, leading to contamination with microorganisms and unwanted chemicals, which amplify the possibility of water-borne diseases (Gadgil, 1998). Some of the elements in potable water play vital roles in metabolism (Asare *et al.*, 2007). For instance, sodium, potassium and chloride are common chemicals found in most waters and these elements play a role in body metabolism. Calcium is also an important determinant of water hardness, it functions as a pH stabilizer because of its buffering qualities, and it gives drinking water a good taste.

The raw water for the production of bottled and sachet water in Ghana is mostly obtained from pipe-borne water, springs and ground water. There is possible contamination of these sources by surface runoff or leachate from sewage systems (Obiri-Danso *et al.*, 2003). The presence of faecal coliforms observed in packaged drinking water has been reported to be due to poor hygienic practices of producers and ignorance about effective water treatment technologies (Coroler *et al.*, 1996). Poorly maintained filter systems are also a possible source of contamination because bacteria can grow on filters if they are not changed regularly, and thereafter enter the water supply (Hunter and Burge, 1987). In the public opinion, the bottled

water is considered completely suitable for drinking, but chemical and biological agents can contaminate the bottled water sometimes (Armas and Sutherland, 1999).

In a similar study, Abayasekara *et al.* (2007), surveyed 34 different brands of bottled water in Sri Lanka and found that five (5) out of thirty-four (34) brands (15%), tested positive for faecal coliforms, indicating concern over the microbiological quality of bottled water. The production of sachet water has increased tremendously with over 300 registered producers and 600 unregistered in Ghana (Lindsay, 2005). Besides, sachet water has long been implicated in the outbreak of water-borne diseases (Dufour *et al.*, 2003).

1.1. Statement of the Problem

Ghana like most developing countries struggles to improve access to potable water and sanitation by its urban population. The major sources of drinking water in the Kumasi metropolis are boreholes, wells, pipe-borne water and traditional sources such as springs and rivers. Rapid urbanization, increasing intensity of animal production and the volume of wastes being generated are leading to concerns about decreasing security of water supplies, even in those supplies which are regarded as treated or which are disinfected (Maher *et al.*, 1997).

The sale and consumption of packaged water continues to grow rapidly in Kumasi and other places in Ghana. Drinking water, regardless of its source, is usually subjected to one or more of a variety of treatment processes intended to improve its safety and aesthetic quality. Several studies on the microbial quality of bottled and sachet water have reported violations of international quality standards (Oyedeki *et al.*, 2009).

Adherence to production and analytical standards are doubtful as most of the factories are observed to lack the appropriate technology and expertise for achieving these. While some employ sophisticated techniques such as ozonization and reverse osmosis, most use ordinary boiling of well water and exclusion of particles by use of unsterilized filtration materials (Oyedeki *et al.*, 2009). It is also reported that some unscrupulous producers just bag and seal pipe-borne or well water without any form of treatment (Nwosu *et al.*, 2004).

Many packaged water manufacturers initially comply with the standard processes of drinking water treatment outlined by the Ghana Standard Board and the Food and Drugs Board of Ghana, but later revert to ineffective treatment processes because of lack of monitoring. Besides, some products do not bear the stamp of approval of the Food and Drugs Board (2005).

Leaking of caps due to defective seals had also been observed for some brands of bottled water and this could be one of the possible reasons for contamination of bottled water. The bouncing movements of bottles and packs of sachet in delivery trucks and during handling are other possible causes of contamination (Kassenga, 2007).

Even if no sources of anthropogenic contamination exist, there is the potential for natural levels of minerals and other chemicals to be harmful to human health (Anawara *et al.*, 2002). Chemical parameters of drinking water have the propensity to pose more of a chronic health risk, even though some components like nitrates and nitrites may have an acute impact. Examples of chronic health effects include cancer, liver and kidney damage, disorders of the nervous system, damage to the immune system, and birth defects (Zaslow and Glenda, 1996). Physical parameters affect the aesthetic value of the drinking water and might complicate the removal of microbial pathogens.

Factory-bagged sachet and bottled drinking water sold in Kumasi metropolis should therefore be analysed regularly to determine their physical, chemical, and bacteriological quality with the aim of re-assuring the public of their safety.

The present study aimed to determine the safety of some packaged drinking water sold in the Kumasi metropolis. The drinking water quality data would be essential for the implementation of responsible drinking water quality regulations, for characterizing and remediating contaminations and consequently to protect the health of the consumers. This research will also give an insight into the effectiveness of the water treatment processes and hence the extent to which the quality of the packaged water sold in Kumasi metropolis met the recommendations of the Ghana Standards Board (1998) and World Health Organisation guidelines (2007).

1.2. General Objectives of the Study

This study sought to assess the general quality of packaged drinking water sold in Kumasi metropolis.

1.3. Specific Objectives of the Study

The specific objectives were to determine:

- The bacteriological quality of sachet and bottled drinking water sold in the Kumasi metropolis.

- The physical and chemical characteristics of sachet and bottled drinking water sold in the Kumasi metropolis.
- The suitability for consumption of nine (9) brands of sachet and three (3) brands of bottled water sold in the Kumasi metropolis by comparing measured parameters to the Ghana Standards Board (1998) and the World Health Organisation (2007) guideline values for drinking water.

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CHAPTER TWO

2. LITERATURE REVIEW

2.1. The Importance of Drinking Water Quality

Water is one of the indispensable resources for the continued existence of all living things including man. The provision of an adequate supply of safe drinking water was one of the eight components of primary health care, identified by the International Conference on Primary Health care in 1978 (Edema *et al.*, 2001). The changes in physical characteristics like temperature, transparency, suspended solids and chemical characteristics of water such as dissolved oxygen, chemical oxygen demand, nitrate and phosphate provide valuable information on the quality of the water (Mustapha, 2008). The existence of elevated levels of elements and organisms in drinking water constitutes poor water quality, which is a recipe for disease outbreaks (Ntengwe, 2003).

In the effort to protect citizens in urban areas, governments the world over must augment the quality of urban drinking water that is to be provided to their citizens (World Health Organisation, 1993). However, in the bid to maintain the quality of urban drinking water, the manufacturers have had to spend huge sums of money to pump, treat, package and distribute the water to the customers (Ntengwe, 2003). Any attempts that result in the reduction of costs to levels below the optimum costs would bring about abysmal drinking water quality.

A daily per capita consumption of two (2) liters is the generally accepted value for a person weighing 60 kg (World Health Organisation, 1998). This is the value used in estimating ingestion exposure to potentially hazardous chemicals in drinking water.

The actual water intake, however, varies considerably from individual to individual and according to climate, physical activity and culture (Gadgil, 1998). Young children, pregnant and lactating women, the elderly, and people with certain illnesses may have increased fluid requirements (Howard *et al.*, 2003).

Dehydration is the adverse consequence of inadequate water intake (Greenleaf and Harrison, 1986). The symptoms of acute dehydration vary with the degree of water deficit. For instance, fluid loss at 1% of body weight impairs thermoregulation and thirst occurs at this level of dehydration. Vague discomfort and loss of appetite appear at 2% (Adolph, 1947).

Moreover, water consumption plays an important role in the digestion of solid foods in the body. Nutrients required for growth and repair of muscle tissues are also transported with the help of water in the blood stream. A copious amount of water is required daily to keep this entire process going on (World Health Organisation, 2005). Health consequences of micronutrient deficiencies include increased morbidity, mortality due to reduced immune defense systems and impaired physical and mental development. These nutritional deficiencies decrease worker productivity and increase the rates of disease and death in adults (World Health Organisation, 2005).

2.2. The Consequences of Poor Drinking Water

Although water-related diseases have largely been eliminated in wealthier nations, they remain a major concern in much of the developing world (Gleick, 2002). The most dangerous form of water pollution occurs when faecal contaminants enter the water supply. Pathogens such as *Salmonella* species, *Shigella* species, *Vibrio cholera* and *Escherichia coli* being shed in human

and animal faeces ultimately find their way into water supply through seepage of improperly treated sewage into ground water and other sources of drinking water (DiPaola, 1998).

A significant proportion of water-borne illnesses are likely to go unnoticed by the communicable diseases surveillance reporting systems. The symptoms of gastrointestinal illness (nausea, diarrhoea, vomiting and abdominal pain) are usually mild and generally last a few days to a week and only a small percentage of those affected will visit a health facility (Dufour *et al.*, 2003). Since many illnesses are undiagnosed and unreported, the true extent of these diseases is in the oblivion.

The minimum infectious dose, which represents the smallest number of ingested pathogens necessary to cause disease, for the average healthy adult varies widely for various microorganisms. This dose ranges from just a few organisms for *Salmonella typhi* to produce typhoid, several hundred organisms for *Shigella flexneri* to cause dysentery, several million cells of *Salmonella* serotype needed to cause Gastroenteritis, to as many as a hundred million cells of *Vibrio cholera* needed to produce Cholera (World Health Organisation, 1998). The minimum infectious dose also varies by the age, health, and nutritional and immunological status of the exposed individual. The infective doses are appreciably lower for debilitated, sick and elderly than for the general adult population (World Health Organisation, 1998).

2.3. The Physical and Chemical Indicators of Drinking Water Quality

Water, whether available in bottles or in the sachet, always contains a certain amount of minerals and trace elements, collected throughout their geological course and from anthropogenic sources. These inorganic elements and their interaction are essential for the functioning of the human body (World Health Organisation, 1996). However, certain range of these factors enhance microbial growth. Poor water clarity, high colour, extreme pH, odour and taste affect the palatability and general acceptability of drinking water and often result in consumer complaints. Water supplies containing high suspended solids greatly reduce the efficiency of disinfection (NHMRC–ARMCANZ, 1996).

2.4. pH of Drinking Water

It is a measure of the hydrogen ion (H^+) concentration in water. The lower the pH value the more acidic the water, and the higher the pH value the more alkaline the water. At pH levels of less than 7.0, corrosion of metallic water receptacles may occur, releasing metals into the drinking water. The toxicity of metals is dependent on their solubility and on the presence of different types of anions and other cations (Abulude *et al.*, 2007). This is undesirable and can cause health concerns if concentrations of such metals exceed recommended limits (Putz, 2003).

pH is important as an operational parameter, particularly in terms of the efficacy of chlorination or optimizing coagulation. At pH levels above 8.0, there is a progressive decrease in the efficiency of the chlorine disinfection process. Acceptable pH for drinking water is between 6.5

and 8.5 and this is the range proposed as the guideline value (World Health Organisation, 1984; Ghana Standards Board, 1998).

2.5. Apparent Colour of Drinking Water

Colour in water systems may be the result of the precipitation of soluble iron or manganese when they react with dissolved oxygen, chlorine disinfectant, and other oxidizing agents during water treatment. Consumers may turn to alternative, perhaps unsafe sources when their water is coloured to an aesthetically displeasing degree, hence it is desirable that drinking water should be colourless (World Health Organisation, 1984). The term true colour is used to mean the colour of water from which turbidity has been removed. The term apparent colour includes not only the colour due to substances in solution but also that due to suspended matter (Putz, 2003). The guideline value of apparent colour is 15 Hazen units (Ghana Standards Board, 1998; World Health Organisation, 2007).

2.6. Conductivity of Drinking Water

Conductivity (Specific Conductance) is the ability of the water to conduct electricity. Contrary to popular belief, pure water will not conduct electricity. This property is related to the total concentration of the ionized substances in water. The temperature at which the measurement is made, the nature of the various dissolved substances, their actual and relative concentrations and the ionic strength of the water sample vitally affect the conductivity (Putz, 2003). Conductivity is therefore an indirect measure of the total dissolved solids (TDS) content of water, and there is

usually an approximately linear relationship between TDS and conductivity. Increasing conductivity over time in water indicates that one or more inorganic constituents are also increasing and this situation should trigger further investigations (World Health Organisation, 2007). However, there is no guideline value proposed for conductivity (Ghana Standards Board, 1998; World Health Organisation, 2007).

2.7. Turbidity of Drinking Water

The turbidity of water is the reduction of transparency due to the presence of particulate matter such as clay or silt, finely divided organic matter, plankton or other microscopic organisms (Putz, 2003). Turbidity is commonly used as an indicator for the general condition of the drinking water. Particles in drinking water (suspended solids) are aesthetically objectionable, and can serve as shields for pathogenic microorganisms. Moreover, many toxic chemicals such as pesticides and heavy metals are selectively adsorbed on suspended particulate matter (Putz, 2003). The efficiency of disinfection may be reduced in the presence of high suspended solids and the disinfectant is unable to contact the target organism because of a physical barrier or chemical reactions with suspended solids, consequently decreasing the available disinfectant concentration (NHMRC–ARMCANZ, 1996). More chlorine is required to effectively disinfect turbid water. Turbidity above five NTU may be noticeable and consequently objectionable to consumers. The guideline value for turbidity is five (5) Nephelometric turbidity units (Ghana Standards Board, 1998; World Health Organisation, 2007).

2.8. Total Dissolved Solids in Drinking Water

Total dissolved solids refers to the residue remaining in a weighed dish after the sample has been passed through a standard fiber glass filter and dried to constant mass at 103 to 105 degrees Celsius. Many dissolved substances are undesirable in water (Putz, 2003). Dissolved minerals, gases and organic constituents may produce aesthetically displeasing colour, taste and odour. Some dissolved organic chemicals may deplete the dissolved oxygen in the receiving waters and some may be inert to biological oxidation, yet others have been identified as carcinogens. Water with higher dissolved solids content often has a laxative and sometimes the reverse effect upon people whose bodies are not adjusted to them (Putz, 2003).

As far as health aspects are concerned, there is no evidence of adverse physiological reactions at TDS levels greater than 1000 mg/L (World Health Organisation, 1993). The guideline value for TDS in drinking water is 1000 mg/L (Ghana Standards Board, 1998; World Health Organisation, 2007).

2.9. Dissolved Oxygen in Drinking Water

Dissolved oxygen is an important indicator of water quality. This is due to its importance as a respiratory gas, and its use in biological and chemical reactions (Mustapha, 2008).

Dissolved oxygen in water primarily affects oxidation-reduction reactions involving iron, manganese, copper and compounds containing nitrogen and sulphure. The dissolved oxygen content of water depends on its source, temperature, chemical and biological processes taking

place in the water distribution system. Therefore, measurements can only be used in a relative, not an absolute sense (World Health Organisation, 1984).

However, large declines in dissolved oxygen in water could indicate high levels of microbiological activity, and should trigger further sampling for microorganisms (World Health Organisation, 2007). No guideline value is recommended because the acceptability of low levels of dissolved oxygen depends on the presence of other water constituents. The relationship between dissolved oxygen levels and water quality was studied by Ramachandra and Solanki (2006) and is cited in the table below.

Table 2.1: Dissolved oxygen level and water quality (Ramachandra and Solanki, 2006).

Dissolved Oxygen (mg/L)	Water Quality
Above 8.5	Good
6.6-8.5	Slightly polluted
4.5-6.5	Moderately polluted
4.0-4.5	Heavily polluted
Below 4.0	Severely polluted

However it is desirable that dissolved oxygen levels be maintained as near saturation point (8 mg/L) as possible (World Health Organisation, 1984; Ghana Standards Board, 1998).

2.10. Chloride in Drinking Water

Chloride is one of the major inorganic anions in drinking water. In potable water, the salty taste is produced by the chloride concentrations and it is variable and dependent on the chemical composition (Putz, 2003). There is no known evidence that chlorides constitute any human

health hazards. For this reason, chlorides are generally limited to 250 mg/L in supplies intended for public use. In many areas of the world where water supplies are scarce, sources containing as much as 2000 mg/L are used for domestic purposes without the development of adverse effects, once the human system becomes adapted to the water. However high chloride content may harm metallic pipes and structures (Putz, 2003). The guideline value of chloride in drinking water is 250 mg/L, based on taste considerations (Ghana Standards Board, 1998; World Health Organisation, 2007).

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2.11. Sulphate in Drinking Water

The ingestion of water containing high concentrations of sulphate can have a laxative effect, which is enhanced when the sulphate is consumed in combination with magnesium (World Health Organisation, 1984). The major physiological effects resulting from the ingestion of large quantities of sulphate are catharsis, dehydration, and gastrointestinal irritation. Water containing magnesium sulphate at levels above 600 mg/L acts as a purgative in adult humans. The presence of sulphate in drinking water can also result in a noticeable taste. The human body only absorbs small amounts of sulphates, but these amounts are sufficient to stimulate peristalsis by binding magnesium and sodium to water in the intestine. Sulphate may also contribute to the corrosion of distribution systems (Putz, 2003). The World Health Organisation (2007) guideline value for sulphate in drinking water is 400 mg/L but the Ghana standards set it at 250 mg/L (Ghana Standards Board, 1998).

2.12. Ammonia in Drinking Water

Ammonia is present in most waters because of the biological degradation of nitrogenous organic matter, although it may also reach groundwater and surface waters from industrial waste discharges. Ammonia may be present in drinking water because of disinfection with chloramines (World Health Organisation, 2003). The presence of ammonia at higher concentrations is an important indicator of faecal pollution (World Health Organisation, 2003). Taste and odour problems as well as decreased disinfection efficiency are to be anticipated if drinking water contains more than 0.2 mg/L of ammonia. When such water is chlorinated, as much as 68% of the chlorine may react with the ammonia and become unavailable for disinfection (World Health Organisation, 2007). The presence of the ammonium cation in raw water may result in drinking water containing nitrite as the result of catalytic action or the accidental colonization of filters by ammonium-oxidizing bacteria. The guideline value for ammonia in drinking water is 1.5 mg/L (Ghana Standards Board, 1998; World Health Organisation, 2007).

2.13. Nitrate-Nitrogen and Nitrite-Nitrogen in Drinking Water

Nitrate may be naturally occurring, although its presence in drinking water is more often associated with contamination by excessive use of fertilizers (both inorganic and organic), in addition to inappropriate farming practices and sewage. The high nitrate level in drinking water is also associated with the simultaneous presence of bacterial contamination (World Health Organisation, 1996).

The primary health hazard from drinking water with nitrate-nitrogen occurs when nitrate is transformed to nitrite in the digestive system. The nitrite oxidizes iron in the haemoglobin of the red blood cells to form methaemoglobin, which lacks the oxygen-carrying capacity of haemoglobin. This creates the condition known as methaemoglobinaemia (sometimes referred to as "blue baby syndrome"), in which blood lacks the ability to carry sufficient oxygen to the individual body cells causing the veins and skin to appear blue (World Health Organisation, 1996). Most humans over one year of age have the ability to rapidly convert methaemoglobin back to oxyhaemoglobin. However, in infants under six months of age, the enzyme systems for reducing methaemoglobin to oxyhaemoglobin are incompletely developed and methaemoglobinaemia can occur. This also may happen in older individuals who have genetically impaired enzyme systems for metabolizing methaemoglobin. The guideline value of nitrate-nitrogen is 50 mg/L and that of nitrite-nitrogen is 1.0 mg/L (World Health Organisation, 2007).

2.14. Total Alkalinity of Drinking Water

The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of natural waters is due to the salts of carbonates, bicarbonates, borates, silicates and phosphates along with the hydroxyl ions. However, the major portion of the alkalinity in natural waters is caused by hydroxide, carbonate and bicarbonate (Ramachandra and Solanki, 2006). However, the ratio of these ions is a function of pH, mineral composition, temperature and ionic strength. Alkalinity is not considered detrimental to humans but is generally associated with high pH values, hardness and excess dissolved solids. High alkalinity waters may also have a distinctly flat,

unpleasant taste (Ramachandra and Solanki, 2006). Alkalinity is expressed as mg/L and there are no guideline value proposed by the World Health Organisation (Ghana Standards Board, 1998; World Health Organisation, 2007).

2.15. Phosphate in Drinking Water

Phosphate occurs in traces in many natural waters, and often in appreciable amounts during periods of low biological productivity. Traces of phosphate increase the tendency of troublesome algae to grow in reservoirs (Putz, 2003). Phosphates are water treatment chemicals used to solve specific water quality problems resulting from inorganic contaminants (iron, manganese, calcium, etc.) in groundwater supplies and also to maintain water quality (inhibit corrosion, scale, biofilm, reduce lead and copper levels) in the distribution system. The guideline value for phosphate in drinking water is 400 mg/ L (World Health Organisation, 2007).

2.16. Manganese in Drinking Water

Manganese occurs in ground waters and surface waters that are low in oxygen and usually it occurs with iron. The intake of manganese can be high as 20 mg/day without apparent ill effects (Putz, 2003). Manganese salts may impart an astringent taste to drinking water supplies and can give an aesthetically displeasing brown colouration to the water. When it is oxidized in aerobic waters, manganese precipitates as a black slimy deposit, which can build up in distribution to cause severe discolouration at concentrations above 0.05 mg/L. The health based

guideline value is 0.4 mg/L (World Health Organisation, 2007) and 0.1 mg/L (Ghana Standards Board, 1998).

2.17. Calcium Ion and Hardness of Drinking Water

Calcium is a major constituent of various types of rock. It is one of the most common constituents present in natural waters ranging from zero to several hundred milligrams per liter depending on the source and treatment of the water (Putz, 2003). Calcium is largely responsible for water hardness, and may negatively influence toxicity of other compounds. Elements such as copper, lead and zinc are much more toxic in soft water. Calcium carbonate has a positive effect on lead water pipes, because it forms a protective lead (II) carbonate coating. This prevents lead from dissolving in drinking water, and thereby prevents it from entering the human body. Calcium phosphate is a supporting substance and it causes bone and tooth growth, together with vitamin D. Bones decalcify (osteoporosis) and fractures become more likely if a body is not getting enough calcium. Since a guideline value is proposed for total hardness, no guideline value is proposed for calcium concentration in drinking water (World Health Organisation, 2007).

2.18. Magnesium Ion and Hardness of Drinking Water

Magnesium is a common constituent in natural water. Magnesium salts are important contributors to the hardness of water which break down when heated, forming scale in boilers. Chemical softening, reverse osmosis, electrodialysis, or ion exchange reduces the magnesium

and associated hardness to acceptable levels (Putz, 2003). Magnesium ion is important for the regulation of muscle contractions and the transmission of nerve impulses, and it activates energy-producing enzymes. Nervousness, lack of concentration, dizziness, and headaches or migraines may result from magnesium deficiency. Since a guideline value is proposed for total hardness, no guideline value is proposed for magnesium concentration in drinking water (World Health Organisation, 2007).

2.19. **Total Hardness of Drinking Water**

The hardness of water is caused by dissolved polyvalent metallic ions principally calcium and to a lesser extent magnesium. Public acceptability of the degree of hardness of water may vary considerably from one community to another depending on local conditions and in some instances, hardness in excess of 500 mg/L is tolerable (Putz, 2003). Hard water may assist in strengthening bones and teeth because of its high calcium concentration. It may also decrease the risk of heart diseases. Drinking water hardness must be above 8.4 mg/L (Putz, 2003). Depending on the interaction with other factors such as pH and alkalinity, water with hardness above approximately 200 mg/L may cause scale deposition in the distribution system and may result in excessive soap consumption and subsequent “scum” formation. The guideline value for total hardness is 500 mg/L (Ghana Standards Board, 1998; World Health Organisation, 2007).

2.20. Bacteriological Indicators of Drinking Water Quality

Coliform bacteria describe a group of enteric bacteria that includes *Escherichia coli*, *Klebsiella* species and *Enterobacter* species (Chao *et al.*, 2004). They are gram negative, facultative anaerobes and non-sporing rods that may be motile or not which ferments lactose with the production of acid and gas when incubated at 37°C (Edberg *et al.*, 2000). Faecal coliform (thermotolerant coliform) is a smaller group within the total coliform family, which inhabits the intestine of mammals and has a relatively shorter life span (Edberg *et al.*, 2000). Detection of coliforms is used as an indicator of sanitary quality of drinking water or as a general indicator of sanitary condition in the food-processing environment. However, *Escherichia coli* are the most preferred faecal coliform used in assaying water quality. It also does not grow and reproduce in the environment. As a result, it is considered to be the species of coliform bacteria that is the best indicator of faecal pollution (Edberg *et al.*, 2000). They also indicate the possible presence of pathogenic bacteria, viruses and protozoans (Kara *et al.*, 2004). Almost all the methods used to detect total coliforms, fecal coliforms and *Escherichia coli* are enumeration methods that are based on lactose fermentation (American Public Health Association, 1992). The Most Probable Number (MPN) method is a statistical, multi-step assay consisting of presumptive, confirmed and completed phases. In the assay, serial dilutions of a sample are inoculated into broth media. Analysts score the number of gas positive (fermentation of lactose) tubes, from which the other two phases of the assay are performed and then use the combinations of positive results to estimate the number of bacteria present. Typically, only the first two phases are performed in coliform and fecal coliform analysis, while all three phases are done for *Escherichia coli* (American Public Health Association, 1998).

According to the World Health Organisation standards (1997), potable water for human consumption must be free of microbial indicators of faecal contamination and the coliform count per 100 ml of drinking water must be zero. The World Health Organisation (2004) states that a zero *Escherichia coli* count per 100 ml of water sample is classified as “excellent” and belong to category ‘A’. Bacteria counts of 1-10 per 100ml belong to category ‘B’ and are classified as “acceptable”. Bacteria counts of 10-50 per 100ml belong to category ‘C’ and is unacceptable. Finally, counts greater than 50 per 100ml belong to category ‘D’ and is grossly polluted.



CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of Study Area

The Kumasi metropolis is the most heavily populated district in the Ashanti Region. It is situated in south-central zone of Ghana and during the 2010 population and housing census, it recorded a total population of 4,725,046 inhabitants (Ghana Statistical Services, 2010). It serves as an important commercial, educational and nodal city with major arterial routes, hence has a swiftly growing population size. It is located between latitude 6° 42 North and longitude 1° 35 West and lies approximately 260 metres above sea level (Ghana Statistical Services, 2010). The city covers an area of 22,300 hectares with two main seasons (dry and wet). The city is characterised by stumpy level of environmental sanitation, poor housing, insufficient safe drinking water and improper management of wastes, especially in the indigenous core areas characterised by high density of low-income populations.

The major rainy (wet) season starts in March with a peak in May and the second in July ending in November. The dry season starts from December and ends in February and it is usually hot, dry and dusty. The annual rainfall of Kumasi metropolis measures about 1,300mm and a mean temperature of 28°C (Meteorological Services Department, Kumasi Airport Weather Station, 2000).

3.2. SAMPLING

The study was undertaken for six months, between September, 2010 and February, 2011. At monthly intervals, triplicate samples each of nine (9) brands of sachet water and triplicate samples each of three (3) brands of bottled water, all from different manufacturers were purchased from retail outlets in the Kumasi metropolis. They were transported on ice in ice-chests to the Quality Control Laboratory of Ghana Water Company Limited, Suame branch in Kumasi immediately after sampling. They were then subjected to bacteriological, physical and chemical quality analyses which were completed within a day. The brands of packaged water were as listed in Table 3.1.

Table 3.1: Brands of Packaged Water Analysed

Brands of Sachet Water (500ml)	Brands of Bottled Water (500ml)
Nyakus	Safina
EMAS	BonAqua
Cool	Voltic
Sukyeremma	
Pasky	
Girls-Girls	
Nkwa	
Still-Pd	
Choice	

3.3. Quality Assurance

In order to ensure that the results of analysis obtained were accurate, quality assurance measures were observed as follows:

- ✚ All the instruments used in this research were calibrated with standards of known concentrations, according to the manufacturer's instruction.
- ✚ Samples were analysed based on Standard Methods for Examination of Water and Wastewater (American Public Health Association, 1998).
- ✚ The average value of three triplicate samples was taken for each determination of water quality parameter.
- ✚ The concentrations of some ions measured in the analyte samples by colorimetric and photometric methods were determined from standard calibration curves after their respective transmittance were determined. Suitable blanks were also prepared and analysed accordingly.
- ✚ Defined methods for storage of water samples were also complied with, for example, the use of ice cubes for sample preservation and minimization of time between sample collection, storage and analysis.
- ✚ All the glassware were thoroughly cleansed with appropriate detergent and rinsed with distilled water, otherwise autoclaved as in bacteriological quality analysis. Pair of scissors, automatic pipette, single strength MacConkey broth, tryptone water and distilled water were all autoclaved at 121°C for 15 minutes.
- ✚ The tips of each sample of sachet and bottled water were disinfected with 70% ethanol before opening and inoculation.
- ✚ Where bacteriological analysis was to delay, the samples were refrigerated at 4°C but analysed within 24 hours after collection.

3.4. PHYSICAL AND CHEMICAL ANALYSIS

3.4.1. Determination of pH

In the laboratory, pH meter (HANNA model 209) was used to determine the pH of water samples. Buffer solutions of pH 4.0, 7.0 and 9.0 prepared from tablets of BDH buffer were used to calibrate the pH meter.

Procedure: About 50ml of water sample was poured into a clean glass beaker and the electrode inserted into it. The button selector of the pH meter was turned and the pH was read and recorded. This was repeated three times for all other water samples.

3.4.2. Determination of Apparent Colour

The apparent colour of water samples were determined by HACH Lange Spectrophotometer (model DR-5000) after calibration.

Procedure: The Spectrophotometer was first zeroed, using distilled water in the 25ml nessler cell at a wavelength of 455nm and platinum-cobalt unit of 50mm. The 25ml cell was then filled to the mark with water sample and the outside wiped dry with tissue paper to eliminate figure prints and moisture. The cell was inserted into the cell chamber and the lid closed. After five (5) minutes the apparent colour was read and recorded in Hazen units

3.4.3. Determination of Conductivity

Conductivity meter (HANNA model HI 9032) was used to determine the conductivity of water samples in the laboratory. It was calibrated by using standard sodium chloride solution of 12880 $\mu\text{S}/\text{cm}$. The conductivity meter was then returned to the operation mode for measurement.

Procedure: About 50ml of water sample was poured into a clean glass beaker and the conductivity meter electrode was then inserted into the water. The value was read and recorded after five (5) minutes in $\mu\text{S}/\text{cm}$. The same procedure was repeated three times for all other water samples.

3.4.4. Determination of Turbidity

Turbidity of water samples was determined with HACH turbidimeter (model CO 150). The turbidity meter was first calibrated with Formazin standard solutions of 0.2 NTU, 10 NTU, 100 NTU and 1000 NTU by filling consecutively a clean dry cuvette with the well mixed standard solutions. It was then returned to the measurement mode and used.

Procedure: A clean dry cuvette was rinsed three times with the water sample to be tested. The cuvette was filled with the water sample to be analysed and then covered with light shield cap. The outer surface of the cuvette was wiped dry with a clean tissue paper. It was then pushed firmly into the optical well and the lid closed. The NTU values were measured by pressing and releasing the arrow and the value was recorded after the display has stopped flashing.

3.4.5. Determination of Total Dissolved Solids

A multifunctional HANNA meter (model HI 9032) was used to determine the total dissolved solids of water samples in the laboratory after calibration.

Procedure: About 50ml of water sample was poured into a clean glass beaker. The electrode was then immersed into the sample and stirred to ensure uniform mixture. After the reading stabilised the value was read and recorded in mg/L.

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3.4.6. Determination of Dissolved Oxygen

Dissolved oxygen concentration in the water samples were determined with DO-meter (TOA model 14P). Measurement was done after the meter was calibrated according to the manufacturers instruction.

Procedure: Using a clean pipette, 50ml of the water sample was dispensed into a clean glass beaker. The electrode of the DO-meter was then immersed into the water sample and stirred to ensure uniform mixture. After reading stabilised, the value was read and recorded in mg/L.

3.4.7. Determination of Ammonia

Palintest Photometer (model 5000) was used to determine the concentration of ammonia in the water samples after calibration.

Procedure: Using pipette, a clean test tube was filled to the 10ml mark with the water sample. One tablet each of Ammonia No. 1 and No. 2 were added, crushed and mixed to dissolve. The mixture was allowed to stand for 10 minutes for colour development. The transmittance (%T) of the mixture was taken at wavelength of 640nm. Ammonia (Indophenol) calibration chart was used to obtain the ammonia concentration in mg/L.

3.4.8. Determination of Nitrite-Nitrogen

The Lovibond Nessleriser (model 2150) was used to measure nitrite-nitrogen by comparator method after the instrument was calibrated.

Procedure: Using a clean pipette, 50ml of the water sample was poured into a clean Erlenmeyer flask and 2 ml each of Griess-Ilosvays No. 1 and 2 were added, swirled and allowed to stand for fifteen (15) minutes. If colour changed to pink, a nessler's tube was filled with the mixture and then inserted into the chamber. The value was read by matching colour using the nitrite disc and comparator.

NB.: The markings on the disc represent the actual amount of nitrogen (N) present as nitrite.

Calculation:

$$N \text{ (mg/L)} = \frac{\text{Disc Reading} \times 0.5}{\text{Sample Volume (ml)}}$$

$$NO_2 \text{ (mg/L)} = N \text{ (mg/L)} \times 3.284 \text{ (American Public Health Association, 1998).}$$

3.4.9. Determination of Nitrate-Nitrogen

Palintest photometer (model 5000) was used to determine nitrate-nitrogen after the meter was calibrated.

Procedure: A clean nitrate test tube was filled with 20ml of water sample. One level spoonful of Nitrate test powder and one tablet of Nitrate test were added, capped and the tube shaken well for a minute and then allowed to stand for another one minute. It was again inverted several times to allow flocculation and then allowed to stand for extra two minutes to enable complete settlement. The clear solution was then decanted into a clean test tube to 10ml mark. One tablet of Nitricol was added, crushed and mixed to dissolve and allowed to stand for an extra 10 minutes for colour development. A wavelength of 570nm was selected on the Photometer and the tube was inserted into the chamber and reading was then taken. The Nitrate test calibration chart was used to determine the nitrate-nitrogen and the nitrate concentration was multiplied by 4.4 to obtain mg/L of NO_3 .

3.4.10. Determination of Sulphate

Palintest photometer (model 5000) was used to measure sulphate by colorimetric method after the meter was calibrated. The Palintest Sulphate test is based on a single tablet reagent containing barium chloride in a slightly acidic formulation.

Procedure: Using pipette, a clean test tube was filled with water sample to the 10ml mark. One tablet of Sulphate Turb was added to the water in the test tube, crushed and mixed to dissolve.

A cloudy solution formed is an indication of the presence of sulphate and the mixture was allowed to stand for five minutes and remixed to ensure uniform mixture. A wavelength of 520nm was selected and the cell was inserted into the chamber and the transmittance (%T) read. The sulphate calibration chart was used for its corresponding concentration in mg/L.

3.4.11. Determination of Chloride

Argentometric method was used to determine chloride concentrations in water samples. Potassium chromate indicator solution was prepared by dissolving 50g of K_2CrO_4 in a little distilled water and 1.0M $AgNO_3$ solution was added until a definite precipitate was formed. The solution was allowed to stand for twelve hours, after which it was filtered and diluted to 1000ml. The silver nitrate titrant solution (0.0141M) was prepared by dissolving 2.395g $AgNO_3$ in distilled water and diluted to 1000ml.

Procedure: Using pipette, 50ml of water sample was poured into a clean conical flask. Then 1ml of 5% Potassium chromate (K_2CrO_4) indicator was added. This was titrated against 0.0141M $AgNO_3$ solution, with gentle swirling until the colour changed from yellow to brick red. The titre was read and recorded in millimeters. The concentration of chloride was calculated as:

$$Cl^- \text{ (mg/L)} = \frac{(A - 0.2) \times 0.5 \times 1000}{\text{Sample Volume (ml)}}$$

Where A = Titre value (American Public Health Association, 1998).

3.4.12. Determination of Phosphate

Palintest photometer (model 5000) was used to determine phosphate after the meter was calibrated.

Procedure: A clean test tube was filled with water sample to the 10ml mark. One tablet each of phosphate No.1 LR and No.2 LR were added, crushed and dissolved. The mixture was allowed to stand for ten minutes for full colour development. The test tube was inserted into the chamber and a wavelength of 640nm was selected and the sample transmittance (%T) read. The corresponding concentration on the phosphate LR calibration chart was read and recorded in mg/L.

3.4.13. Determination of Total Alkalinity

Total alkalinity was determined by titrimetric method using 0.02M H_2SO_4 as titrant, phenolphthalein and methyl orange as indicators.

Procedure: Using pipette, 50ml of water sample was measured into a clean conical flask and two drops of phenolphthalein indicator were added. The sample turned pink and was titrated against 0.02M H_2SO_4 , swirled gently until the pink colour just disappears. The titre value (Tv) was read and recorded. If the sample remained colourless after the addition of the phenolphthalein indicator, three drops of methyl orange indicator were added. The yellow sample was then titrated against 0.02M H_2SO_4 swirling gently until the colour changed from yellow to orange and the titre was read and recorded .

Calculation:

$$\text{Total Alkalinity as CaCO}_3 \text{ (mg/L)} = \frac{A \times T \times 1000}{\text{Sample volume (ml)}}$$

Where A = Titre of standard acid at phenolphthalein end point

T = Titre of standard acid at methyl orange end point

(American Public Health Association, 1998).

3.4.14. Determination of Manganese

Palintest photometer (model 5000) was used to determine manganese concentration by colorimetric method after the photometer was calibrated.

Procedure: A clean test tube was filled with 10ml of water sample and one tablet each of Manganese No. 1 and No. 2 were added, crushed and dissolved. The mixture was allowed to stand for 20 minutes for maximum colour development. The cell was inserted into the chamber and the lid closed. A wavelength of 640nm was selected and the transmittance (%T) was read. The manganese calibration chart was used to determine the corresponding concentration in mg/L.

3.4.15. Determination of Total Hardness

Procedure: Using a clean pipette, 50ml of water sample was dispensed into a clean conical flask and 1.0 ml of 0.5M Ammonium buffer solution (pH = 10.0) and 2 ml of Eriochrome Black-T indicator were added. The content in the conical flask was titrated with 0.01M EDTA solution (Ethylene Diamine Tetra Acetic acid), mixed gently until the colour changed from red to blue. Titration was repeated until a consistent titre was obtained. The average titre value was recorded and total hardness was calculated as:

$$\text{Total Hardness (mg/L)} = \frac{\text{Average titre} \times 1000}{\text{Sample Volume (ml)}}$$

(American Public Health Association, 1998).

3.4.16. Determination of Calcium Hardness and Calcium Ion

Procedure: Using a clean pipette, 50ml of the water sample was poured into a clean conical flask. About 1ml of aqueous solution of 1.0M NaOH was added to the contents of the flask, followed by the addition of about 0.2g powdered Ammonium murexide indicator. The content in the conical flask was titrated with 0.01M EDTA (Ethylene Diamine Tetra Acetic acid) solution, mixing gently until the colour changed from pink to purple indicating the endpoint. Titration was repeated until a consistent titre was obtained. The average titre value was read and recorded.

Calculation:

$$\text{Calcium hardness as CaCO}_3 \text{ (mg/L)} = \frac{\text{Average Titre} \times 1000}{\text{Sample Volume (ml)}}$$

The concentration of calcium ion was also calculated from the same titration as follows:

$$\text{Ca}^{2+} \text{ (mg/L)} = \text{Calcium hardness} \times 0.40 \quad (\text{American Public Health Association, 1998}).$$

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3.4.17. **Determination of Magnesium Hardness and Magnesium Ion**

The magnesium hardness was determined as the difference between the total hardness and calcium hardness. Calculation:

$$\text{Magnesium Hardness} = [\text{Total hardness}] - [\text{Calcium hardness}]$$

The concentration of magnesium ion was also obtained from the magnesium hardness as follows:

$$\text{Mg}^{2+} \text{ (mg/L)} = \text{Magnesium hardness} \times 0.243 \quad (\text{American Public Health Association, 1998}).$$

3.5. **Bacteriological Quality Analysis**

The bacteriological quality of the drinking water samples were assessed by using the total coliforms, faecal coliforms and *Escherichia coli* as indicators (American Public Health Association, 1998). Total coliforms, faecal coliforms and *Escherichia coli* were identified using

single strength MacConkey broth and tryptone water by the three tube Most Probable Number method.

3.5.1. Preparation of Media

Purple MacConkey broth was prepared by dissolving 35g of the powder in 1.0 litre of distilled water. It was mixed well and dispensed into fermentation tubes with inverted Durham tubes. The bottles with their contents were autoclaved for 15 minutes at 121°C (American Public Health Association, 1998).

Tryptone water (Buffered) was also prepared by dissolving 15g of the powder in 1.0 litre of distilled water and mixed well. The mixture was distributed into final containers and sterilized by autoclaving for 15 minutes at 121°C.

Kovac's reagent was prepared by dissolving 5g of p-dimethylaminobenzaldehyde in 25ml of alcohol and 25ml of 1.0 M HCl was added slowly and finally stored at 4°C in the dark.

3.5.2. Total and Faecal coliform Identification and Enumeration

Serial dilutions of 10^{-1} , 10^{-2} , 10^{-3} and 10^{-4} were prepared for each water sample using distilled water. One milliliter aliquots from the raw water sample and each set of the dilutions were inoculated into three fermentation tubes containing 5ml of MacConkey broth with inverted Durham tubes. The tubes were closed firmly, agitated to distribute the sample evenly and

inverted gently to expel air from the Durham tubes. The first set of fermentation tubes were incubated at 35°C for 48 hours to determine total coliforms growth and the second set were incubated at 44°C for 24 hours to determine faecal coliforms growth. The tubes that showed colour change, from purple to yellow with gas collected in the Durham tubes after 24 and 48 hours were identified as positive for faecal and total coliforms respectively and quantified from the MPN tables as MPN per 100ml.

3.5.3. Identification and Enumeration of *Escherichia coli*

From each of the presumptive positive tubes identified, 1.0 ml was transferred into 5ml Tryptone water in a fermentation tube and incubated at 44°C for 24 hours. A drop of Kovac's reagent was then added to the tube of trypton water. All the tubes showing a red ring colour development after gentle agitation indicated the presence of indole and recorded as confirmed for *Escherichia coli* count. Counts of bacteria per 100 ml were calculated from the Most Probable Number (MPN) table.

3.6. Statistical Analyses

In order to establish whether differences existed in the parameters determined between the wet and dry season, students t-Test was performed on all the data obtained, using the statistical package of Microsoft Excel, 2007 edition. The statistical significance of readings between the wet and dry seasons was carried out at 95% confidence level ($\alpha \leq 0.5$). The summary of the data analysed are presented in Appendix I.

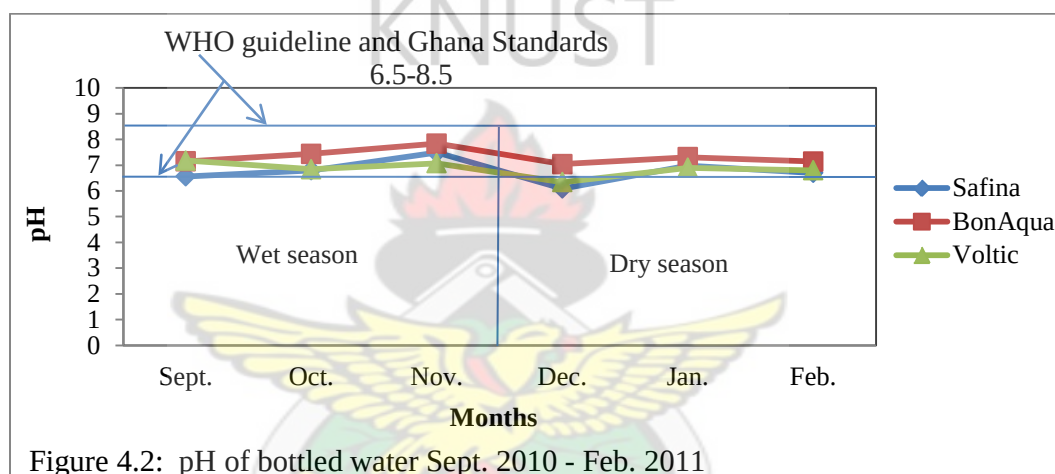
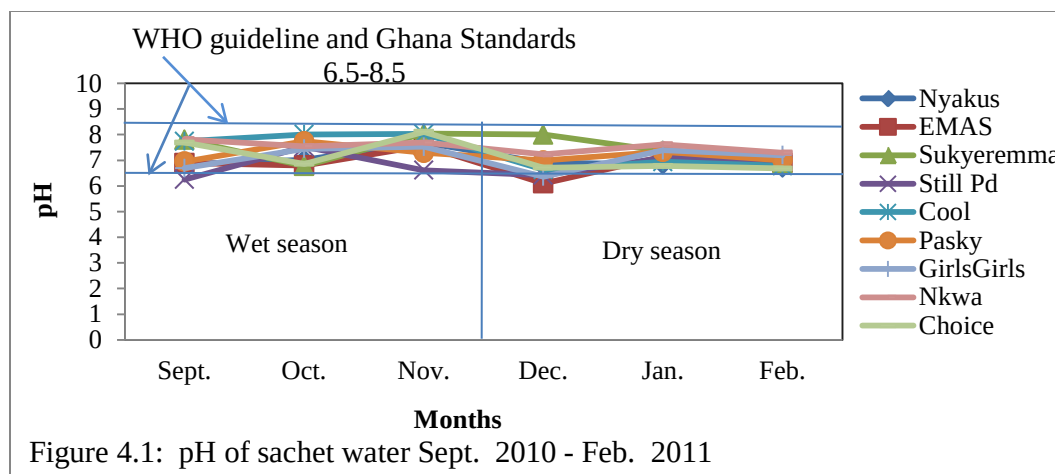
CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Physical and chemical Characteristics of Packaged Water

The physical, chemical and bacteriological quality of sachet and bottled water offered for sale in the Kumasi metropolis were examined in this study. Results obtained have shown that sachet and bottled drinking waters sold in the Kumasi metropolis under different brand names exhibited relatively similar characteristics in terms of their physical and chemical quality. The results have revealed a general decline in the concentrations of most of the parameters investigated, from the wet to the dry season.

The pH values of the brands of sachet water ranged from 6.10 to 8.11 (Fig. 4.1) and that of the brands of bottled water ranged from 6.09 to 7.84 (Fig. 4.2) as shown below. All the nine brands of sachet drinking water had their pH values below the Ghana Standards Board (1998) and the World Health Organisation (2007) upper permissible limit of 8.5, though many brands violated the lower permissible limit of 6.50. These below limit pH values were recorded for 'EMAS' (6.10), 'Girl-Girls' (6.42) and 'Still-Pd' (6.36) respectively, during the fourth month of analysis (December 2011) when the pressure of demand was high. This trend was also recorded for Safina and Voltic with their lowest pH as 6.09 and 6.34 respectively. It portrayed the behaviour of most packaged water producers to compromise quality when there is high demand for their products. According to the Safe Drinking Water Committee (2005), low pH levels are objectionable because of the corrosive effect on metallic water receptacles.



Low pH could result in the metallic taste frequently associated with some packaged water. High pH levels are undesirable since they may impart a bitter taste to the water (Safe Drinking Water Committee, 2005). Significant pH difference was recorded between the wet and dry season measurements for both sachet water ($p \leq 0.001$) and bottled water ($p \leq 0.042$) which may be due to higher values of dissolved anions during the wet season than in the dry season.

Turbidity measurements ranged from 0.21 NTU to 1.30 NTU for brands of sachet water and 0.15 NTU to 1.0 NTU for the brands of bottled water (Fig. 4.3 and 4.4). Individual turbidity values read were below the Ghana Standards Board and the World Health Organisation permissible

limit of 5.0 NTU. Slightly higher turbidities were recorded during the dry than in the wet season. The origin of turbidity in drinking water is due to inadequate filtration of water (Martin *et al*, 2008). The turbidity for the brands of bottled water were comparatively lower than those of sachet water. Turbidity in water is caused by the presence of suspended matter such as clay, silt, organic and inorganic matter, plankton, bacteria and other microscopic organisms (American Public Health Association, 1975). The consumption of highly turbid water may constitute a health risk as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants, and also stimulate the growth of bacteria during storage (Zvikomborero, 2005).

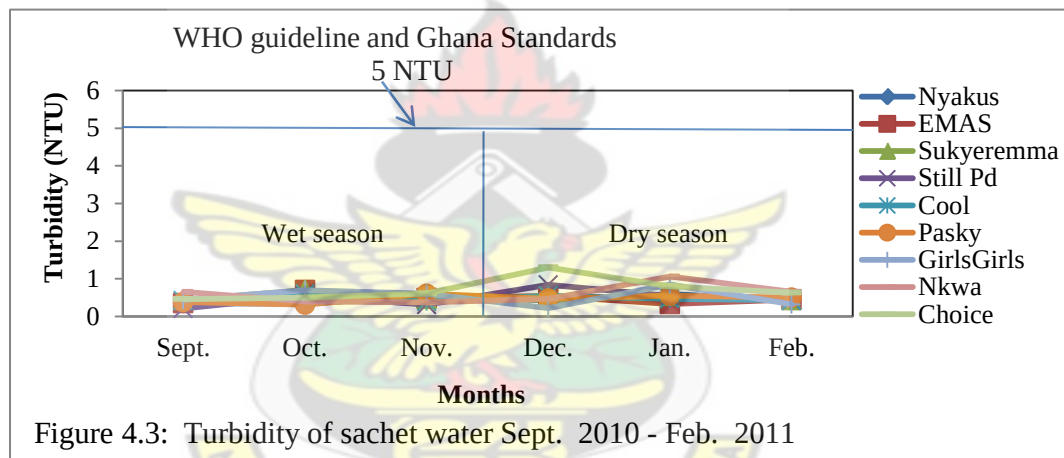


Figure 4.3: Turbidity of sachet water Sept. 2010 - Feb. 2011

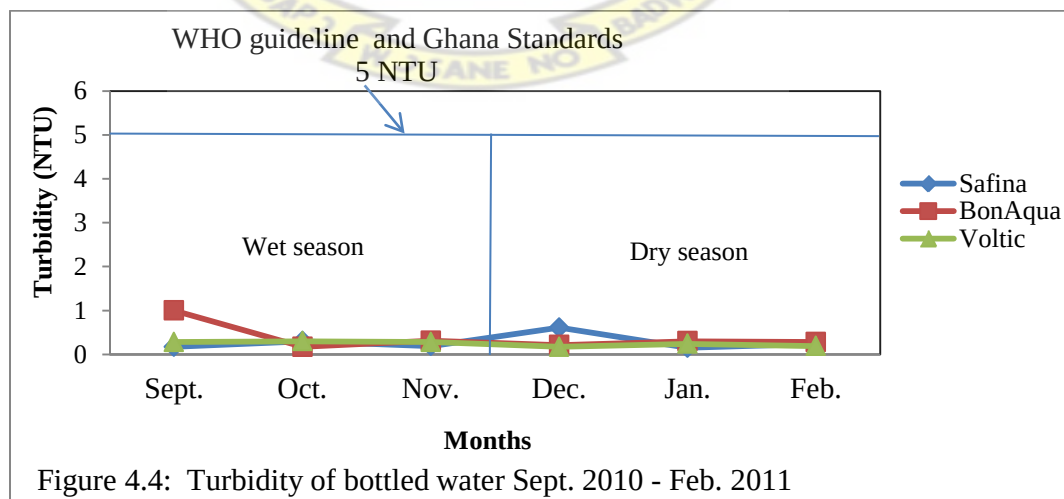
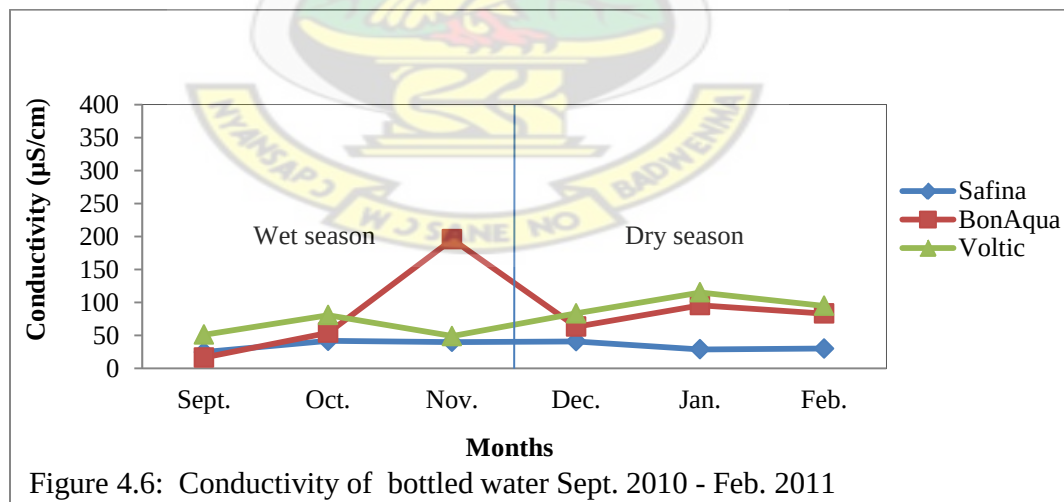
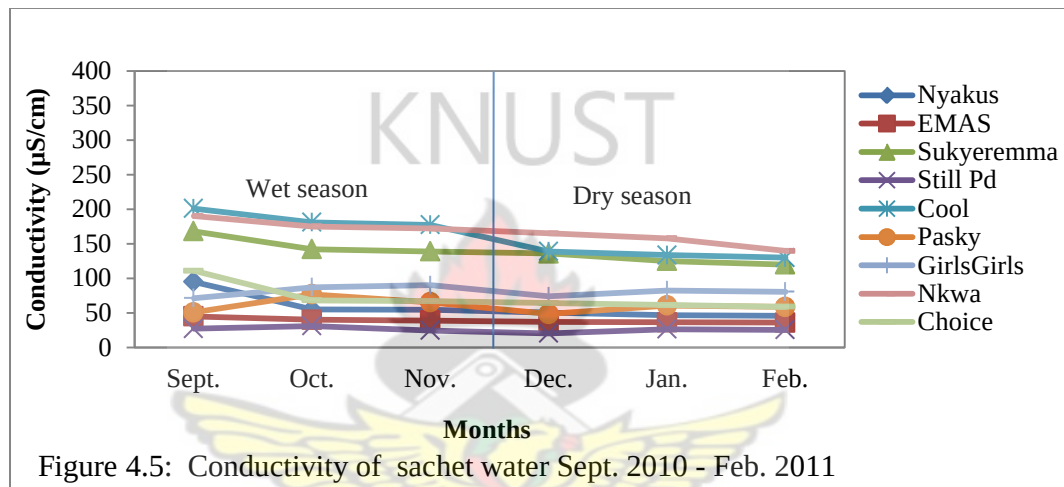


Figure 4.4: Turbidity of bottled water Sept. 2010 - Feb. 2011

The quality of the brands of packaged water could be classified as satisfactory. Differences in turbidity values between the wet and dry seasons in brands of sachet water was significant ($p \leq 0.045$), but not in brands of bottled water.

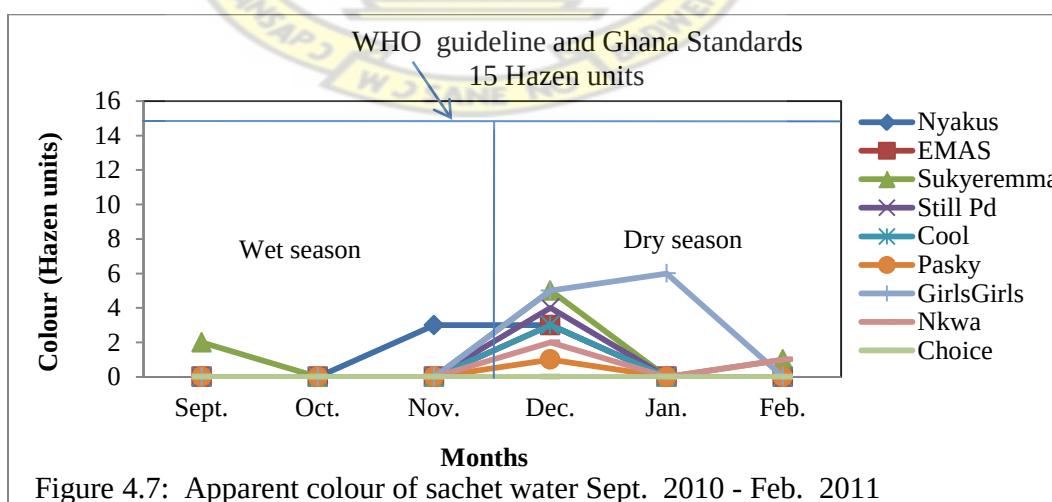
Conductivity measurements ranged from 20.4 $\mu\text{S}/\text{cm}$ to 201.0 $\mu\text{S}/\text{cm}$ for brands of sachet water and 16.4 $\mu\text{S}/\text{cm}$ to 195.8 $\mu\text{S}/\text{cm}$ for brands of bottled water (Fig. 4.5 and 4.6).

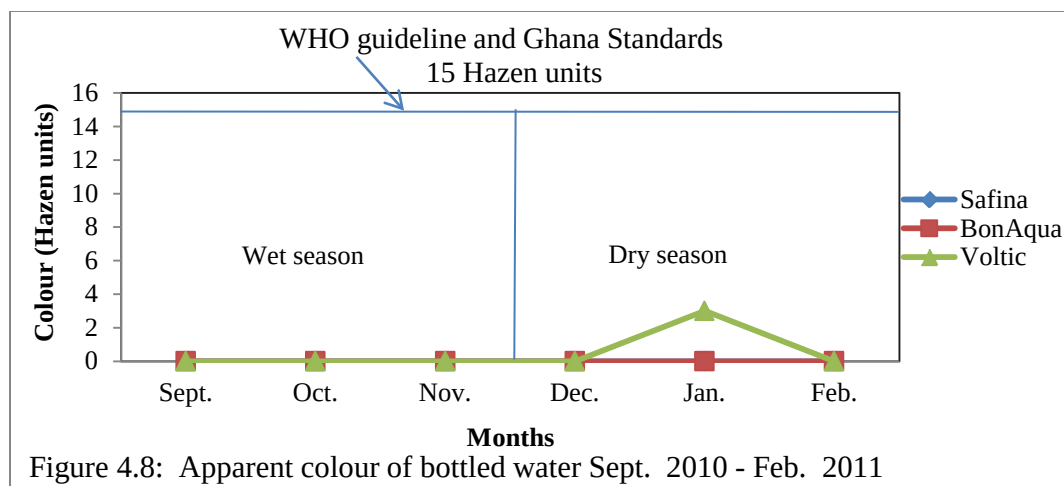


The electrical conductivity of water measures the capacity of water to conduct electrical current and it is directly related to the concentration of salts dissolved in water, and therefore to the total

dissolved solids (TDS). It was found that the conductivity of sachet water were higher during the wet season than in the dry season but a reverse trend was observed in bottled water (Table 4.6 and 4.7). The difference in readings between the wet and dry seasons were not statistically significant for both sachet water and bottled water.

The values for apparent colour in many samples of sachet water were below detection limit. Apparent colour measured ranged from 0.0 Hz to 6.0 Hz for brands of sachet water and 0.0 Hz to 3.0 Hz for brands of bottled water. Higher values for apparent colour were recorded during December 2011, than in other months in brands of sachet water. Again, apparent colour values were below the detection limit in two brands of bottled water, namely ‘Safina’ and ‘BonAqua’ (Fig. 4.7 and 4.8). The higher values for colour recorded during December could be due to changes in the quality of the water source used for packaged water production, the use of ineffective filtration processes of the water or defective filter materials. Potable water should be clear and free from compounds that can cause colour (Pritchard *et al*, 2007).

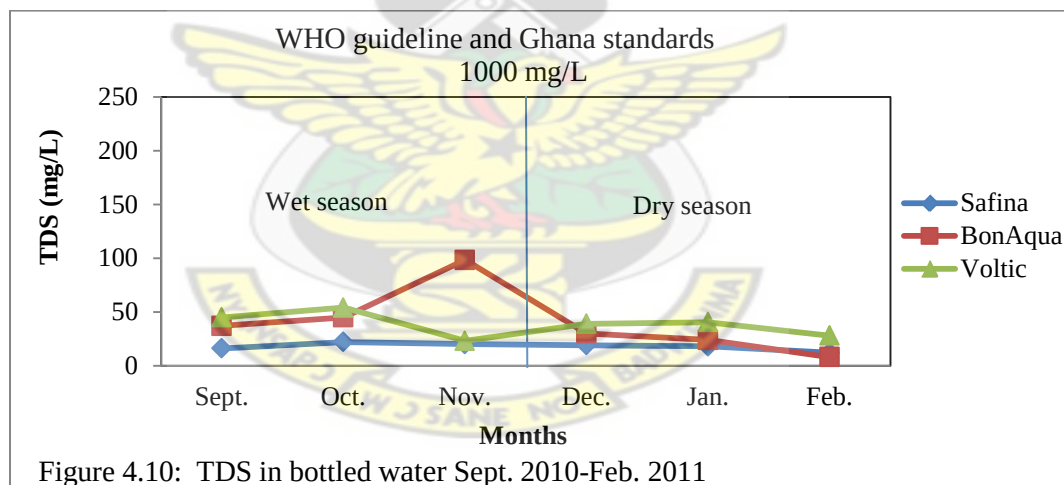
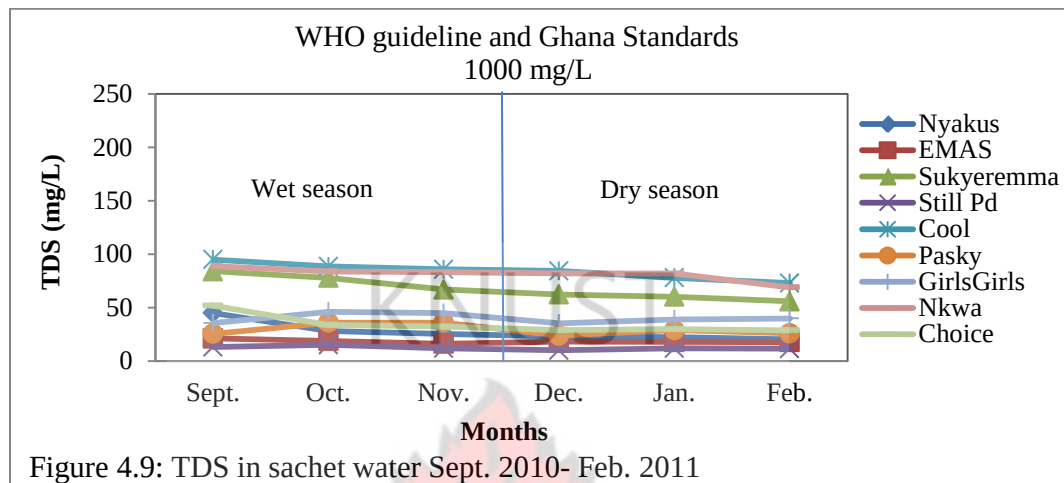




Although, colour itself is not usually objectionable from health perspectives, its presence is aesthetically objectionable and suggests that the water may need additional treatment (Safe Drinking Water Committee, 2005) and may lead to greater consumer complaints. Statistically, there was a significant difference in apparent colour between the wet and dry seasons for brands of sachet water ($p \leq 0.04$) but not for brands of bottled water. Convincingly, the packaged water sold in the Kumasi metropolis are of good quality with respect to colour since values were extremely below the Ghana Standards Board (1998) and World Health Organisation (1993) permissible limit of 15 Hazen units.

Total dissolved solids for sachet water ranged from 10.2 mg/L to 95 mg/L and 8.4 mg/L to 98.4 mg/L for brands of bottled water (Fig. 4.9 and 4.10). The concentration of total dissolved solids (TDS) indicated that all the brands of packaged water contained varied concentrations of dissolved mineral elements for the mineral nutrition of consumers. The source of TDS in drinking water is attributed to natural sources, domestic wastewaters, municipal runoffs and industrial wastewaters. Water containing TDS concentrations below 1000 mg/L is usually acceptable to consumers, although acceptability may vary according to circumstances (Bruvold and Ongerth, 1996). However, the presence of high levels of TDS in water may be objectionable

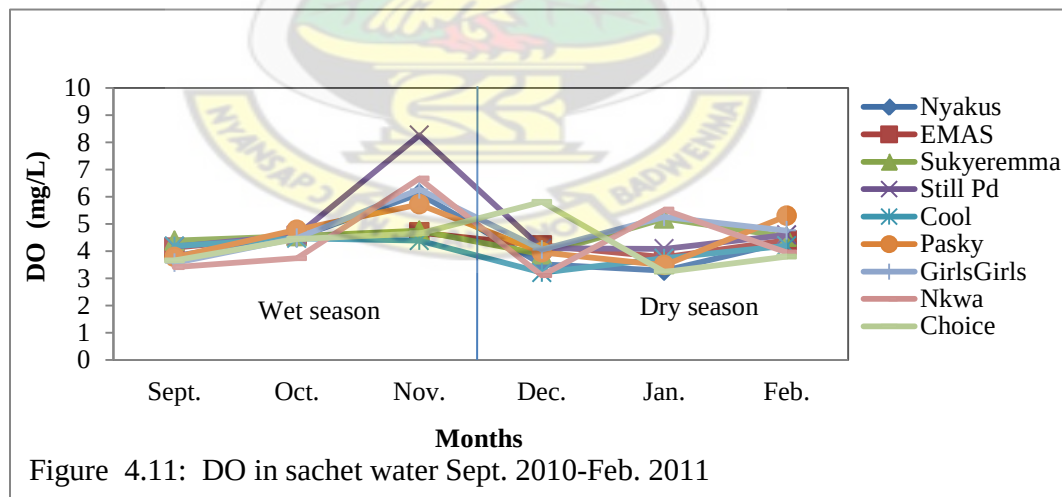
to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances. Water with extremely low concentrations of TDS may also be unacceptable to consumers because of its flat, insipid taste (Bruvold and Ongerth, 1996).

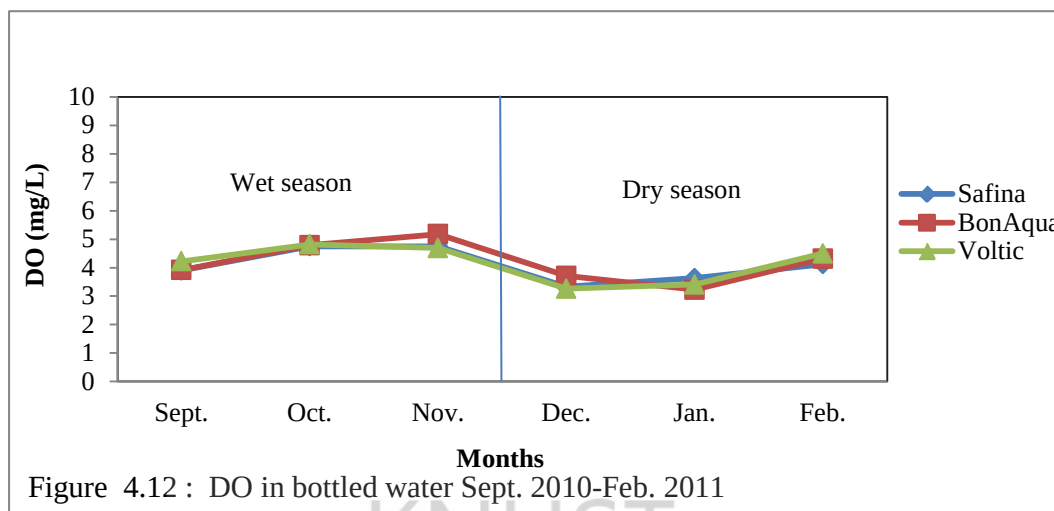


According to the Safe Drinking Water Committee (2005), high TDS values may be an indication of the presence of excessive concentrations of some specific substances. Comparatively, bottled water had lower TDS than sachet water hence softer. Relatively, the low TDS recorded for packaged water brands also indicated that they were soft drinking waters. Total dissolved solid concentrations recorded were far below the Ghana Standards Board (1998) and the World Health

Organisation (2007) permissible limit of 1,000 mg/L. There was no significant difference in total dissolved solids concentration between the wet and dry seasons in any packaged water.

Dissolved oxygen levels were generally low and ranged between 3.11 mg/L to 8.26 mg/L for brands of sachet water and 3.90 mg/L to 5.18 mg/L for brands of bottled water as shown below (Fig. 4.11 and 4.12). The presence of dissolved oxygen in drinking water adds taste and it is a highly variable factor in water (Ramachandra and Solanki, 2006). It was noted that higher concentrations of dissolved oxygen were recorded during the wet season than the dry season especially during the third month (November 2010). Although, the World Health Organisation (2007) and the Ghana Standards Board (1998) have not set any permissible limit for dissolved oxygen concentration in drinking water, brands could be classified as fairly good according to the classification by Ramachandra and Solanki (2006), who discovered that dissolved oxygen levels determine drinking water quality (Table 2.1).

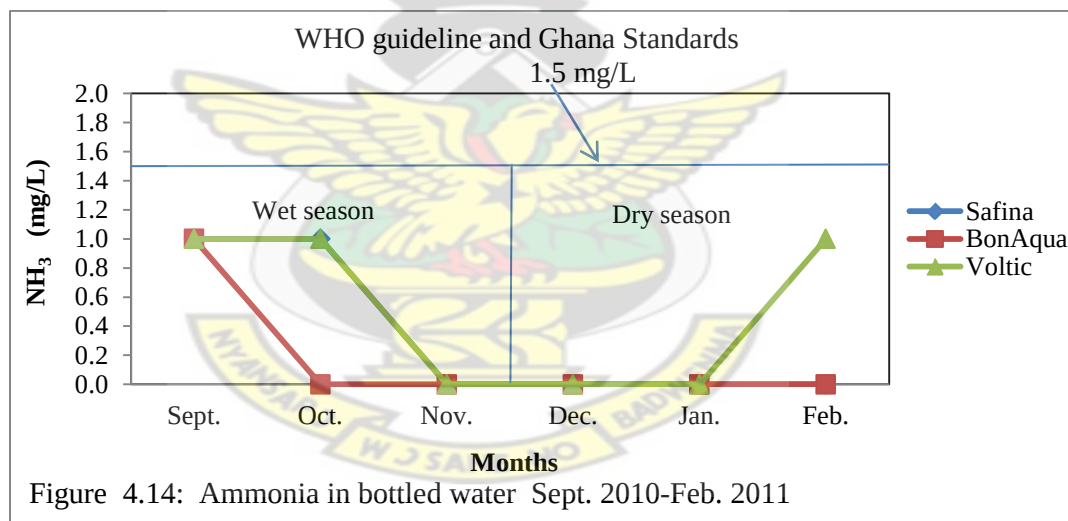
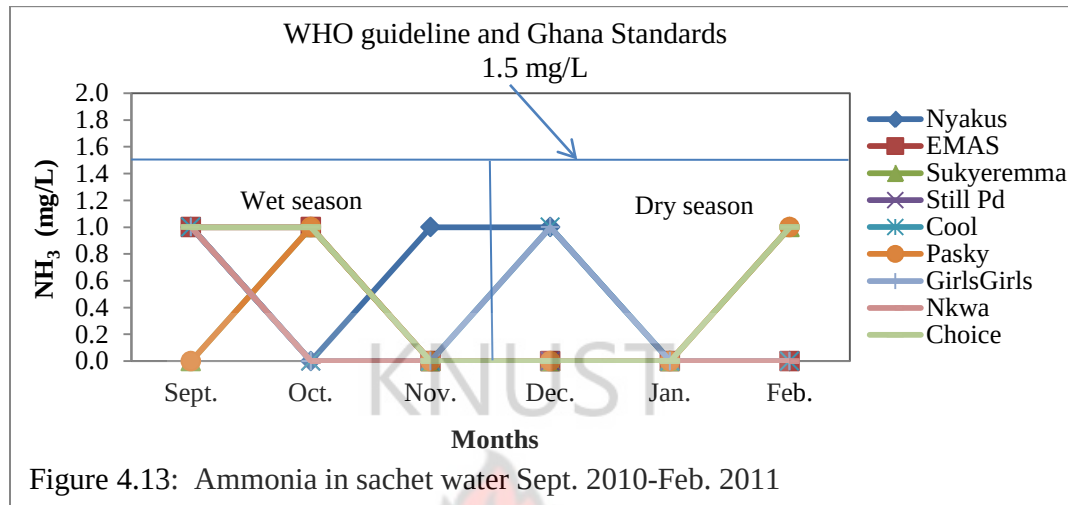




In addition, the oxidation of constituent minerals in the packaged waters could also have contributed to the low concentration of dissolved oxygen recorded during the dry season (World Health Organisation, 1984). There was significant difference in concentration of dissolved oxygen in brands of bottled water between the wet and dry seasons ($p \leq 0.001$) but not for sachet water.

The values of ammonia recorded for the packaged waters were low ranging from 0.0 mg/L to 1.0 mg/L (Fig. 4.13 and 4.14). Even though some chemicals in water are essential for the health of man, higher concentrations can cause morphological abnormalities. Some could reduce human growth and increase mortality and mutagenic effects (Nkono and Asubiojo, 1998). The concentrations of ammonia in most of the brands of packaged water were below the Ghana Standards Board (1998) and World Health Organisation (2007) permissible limit of 1.5 mg/L. The presence of the ammonium cation in water may result in drinking-water containing nitrite as the result of catalytic action or the accidental colonization of filters by ammonium-oxidizing bacteria (World Health Organisation, 2003). According to the World Health Organisation

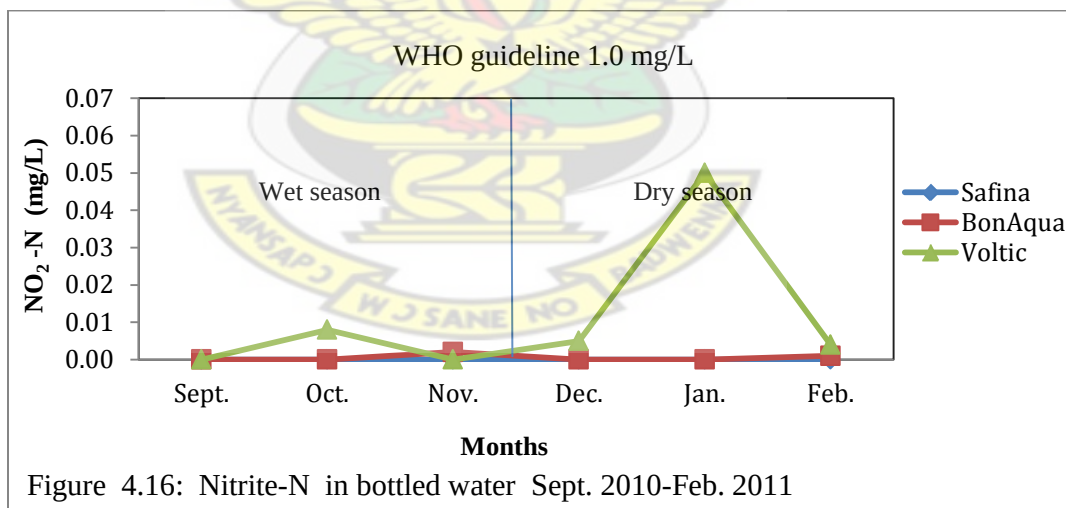
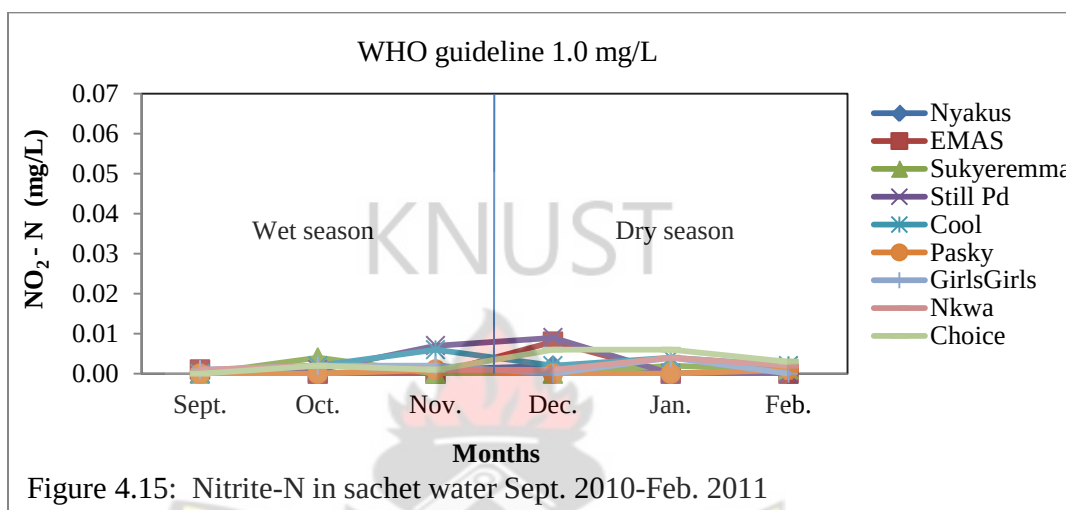
(2007), taste and odour problems as well as decreased disinfection efficiency are to be anticipated if drinking water contains more than 0.2 mg/L of ammonia.



On few occasions, some packaged water brands recorded ammonia concentrations as high as 1.0 mg/L. Significant difference in ammonia concentration between the wet and dry seasons was higher for bottled water ($p \leq 0.02$) than for sachet water ($p \leq 0.04$).

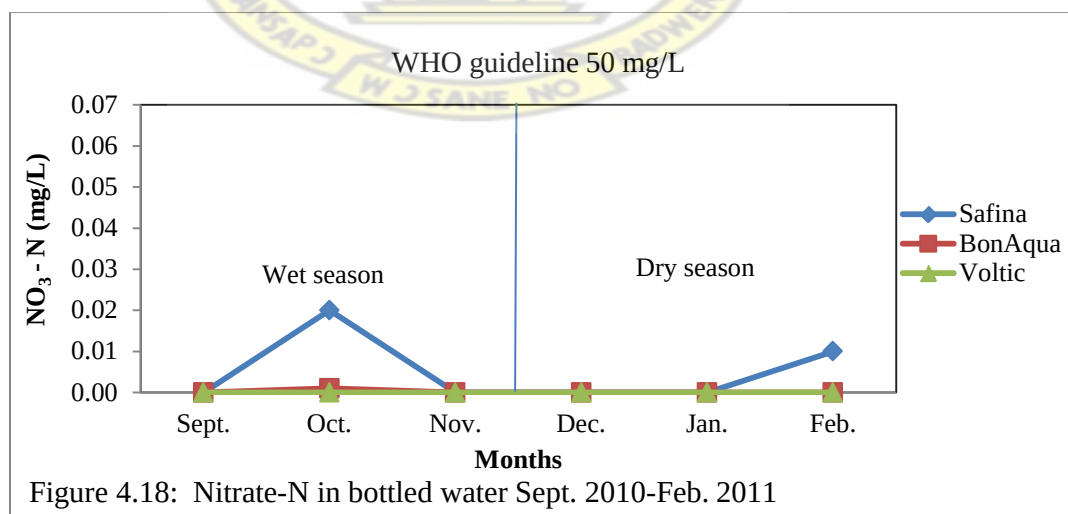
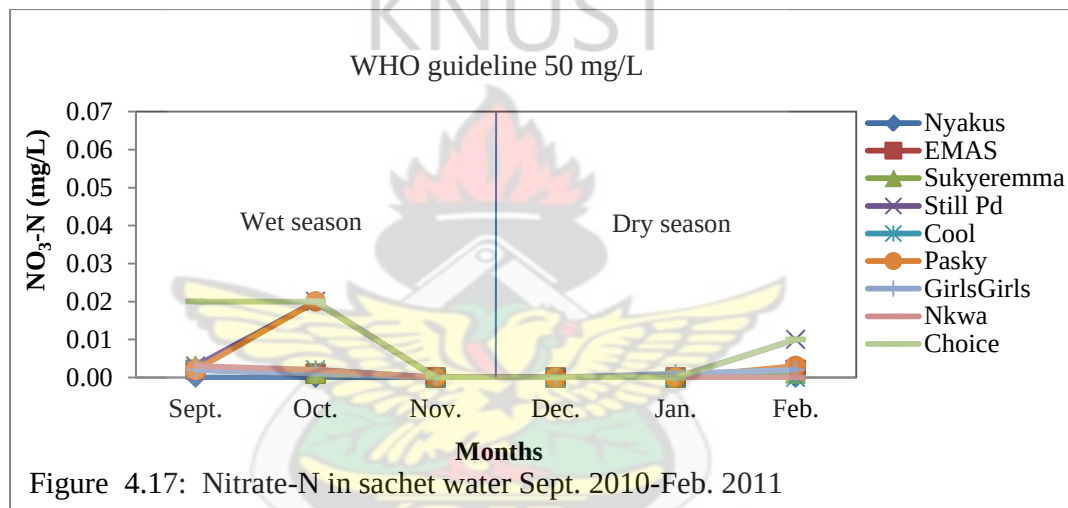
Lower concentrations were recorded for the conversion products of ammonia, explicitly nitrite-nitrogen and nitrate-nitrogen. The nitrate-nitrogen and nitrite-nitrogen contained in the packaged

waters ranged from 0.0 mg/L to 0.05 mg/L (Fig. 4.15 to 4.18). High nitrite or nitrate concentrations in drinking water may cause methaemoglobinaemia (NHMRC– ARMCANZ, 1996). This is especially a predicament for newly born infants with other complicating conditions.



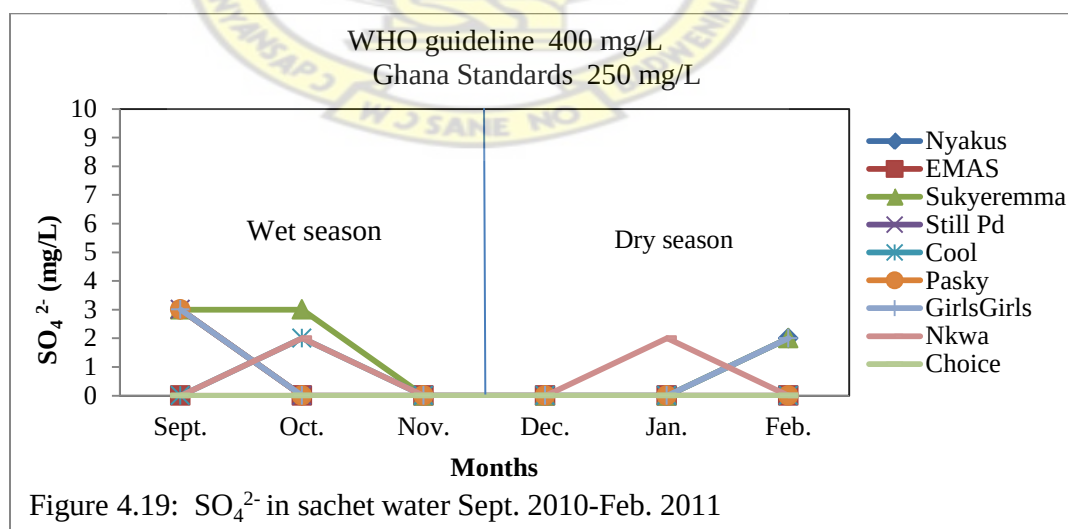
Nitrite-nitrogen and nitrate-nitrogen concentration in all the water samples were far below the World Health Organisation permissible limit of 1.0 mg/L and 50 mg/L respectively. The highest concentration of nitrite-nitrogen recorded (0.05 mg/L) was noted for ‘Voltic’ mineral water.

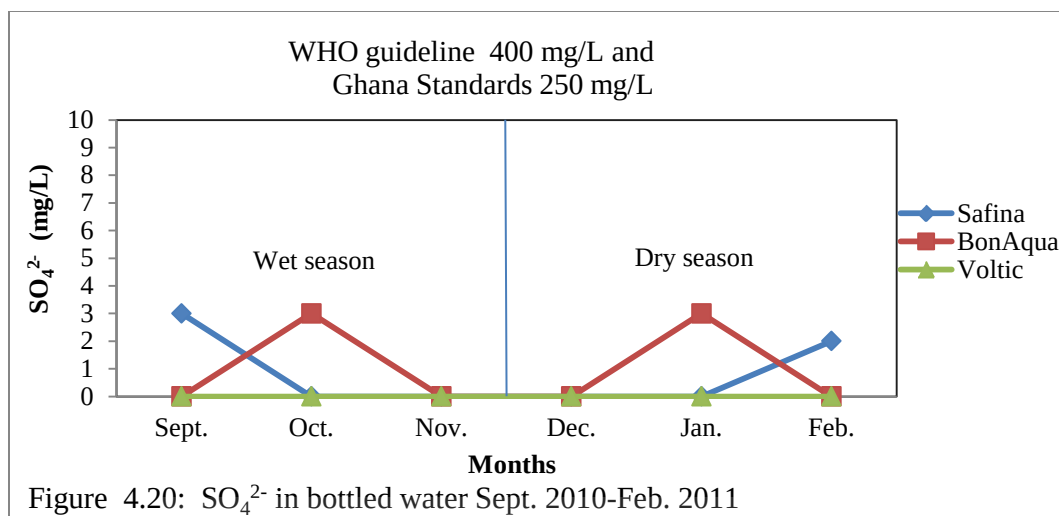
Among the brands of sachet water, ‘Still-Pd’ and ‘Choice’ had relatively higher nitrite-nitrogen concentration (Table 4.18). Brands of sachet and bottled drinking waters did not record any significant difference in nitrite-nitrogen concentration between the wet and dry season. Brands of sachet water recorded relatively higher concentrations of nitrate-nitrogen than brands of bottled water. According to the World Health Organisation (2004), nitrate and its conversion products may enter drinking water sources from the excessive application of fertilizers, leaching of wastewater and other organic wastes.



Generally, most brands of packaged water recorded slightly higher concentrations of nitrate-nitrogen during the wet season than in the dry season. The presence of nitrogen in the form of nitrates indicates older events of pollution and does not represent an immediate threat (World Health Organisation, 1984). The concentration of nitrate-nitrogen in 'Nyakus' and 'Voltic' water were below detection limit. Significant difference in nitrate-nitrogen concentration between the wet and dry seasons was recorded for brands of sachet water ($p \leq 0.015$) but not in brands of bottled water.

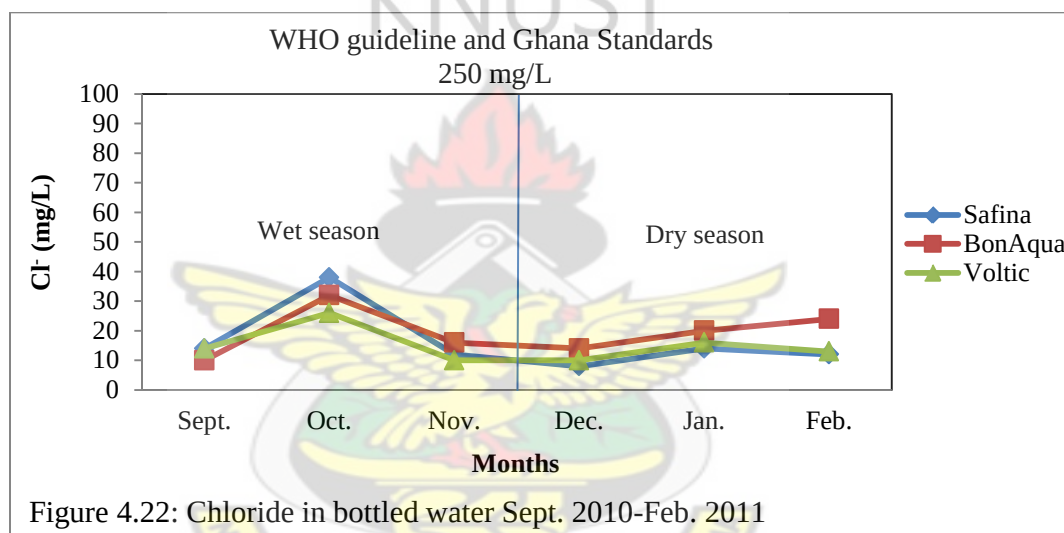
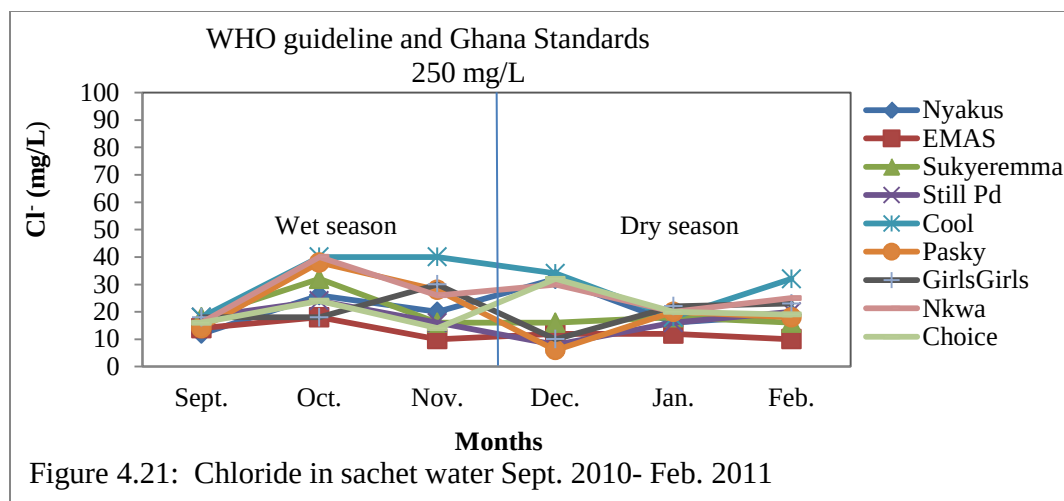
The concentration of sulphate ranged from 0 mg/L to 3.0 mg/L in all brands of packaged water as shown below (Fig. 4.19 and 4.20). Many drinking waters have sulphate because of the addition of calcium and magnesium sulphate to drinking water to improve the taste of drinking waters (World Health Organisation, 2004). According to the World Health Organisation (2004), sulphates occur naturally in numerous minerals, including barite (BaSO_4), epsomite ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). These dissolved minerals contribute to the mineral content of many drinking waters.





Health concerns regarding sulphate in drinking water have been raised due to reports claiming that diarrhea may be associated with the consumption of water rich in sulphates (Beamonte *et al.*, 2007). Sulphate concentration in two brands of sachet water ('EMAS' and 'Choice') and one brand of bottled water ('Voltic') were below detection limit. Generally, sulphate concentrations were far below the Ghana Standards value of 250 mg/L and World Health Organisation permissible limit of 400 mg/L. Significant difference in sulphate concentration between the wet and dry season for only sachet water ($p \leq 0.04$) was recorded.

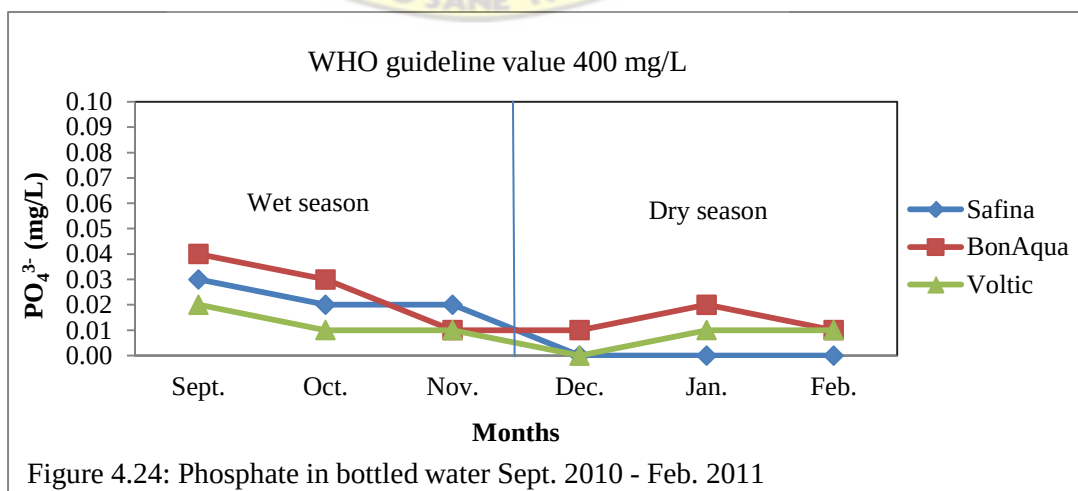
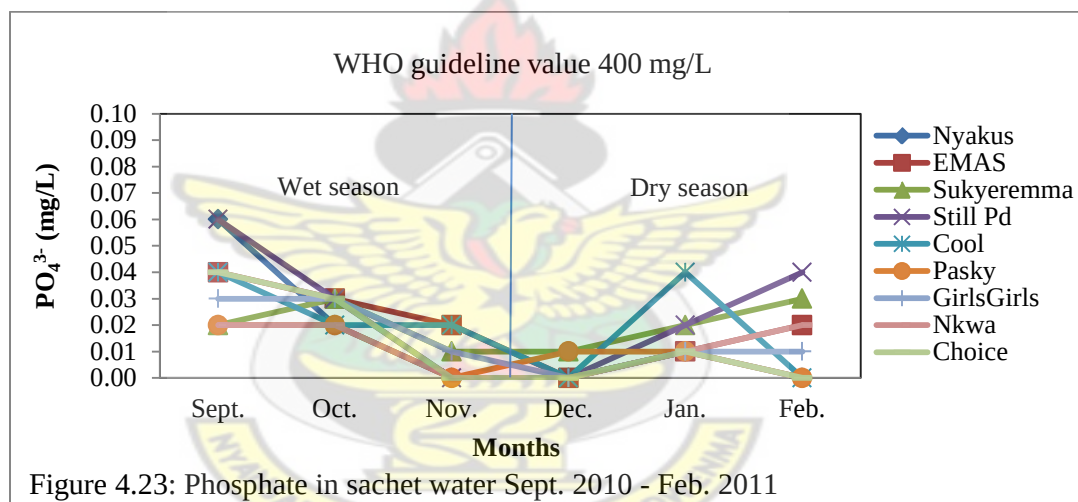
Chloride concentrations ranged from 6.0 mg/L to 40.0 mg/L for sachet water and 10.0 mg/L to 38.0 mg/L for bottled water (Fig. 4.21 and 4.22). These concentrations were also lower than the World Health Organisation and the Ghana Standards Board (1998) permissible limit of 250 mg/L. According to the World Health Organisation (2004), the main operational issue for chloride is its ability to increase the corrosiveness of water, particularly in low alkalinity waters. High concentrations of chloride may result in a detectable taste in water, but consumer acceptability varies widely depending on the form of chloride (Putz, 2003).



The toxicity of chloride salts depends on the cation present and that of chloride itself is unknown. Although excessive intake of drinking water containing sodium chloride at concentrations above 2.5 g/L has been reported to produce hypertension and this effect is believed to be related to the sodium ion concentration (World Health Organisation, 1996). High chloride dose is lethal to pathogens hence the distasteful aesthetic effects of chloride in water may be compromised when there is a suspected contamination of drinking water with harmful bacteria. 'Nkwa' and 'Cool' recorded relatively higher chloride concentration hence no faecal indicator bacteria were detected in them. Those brands with relatively lower chloride

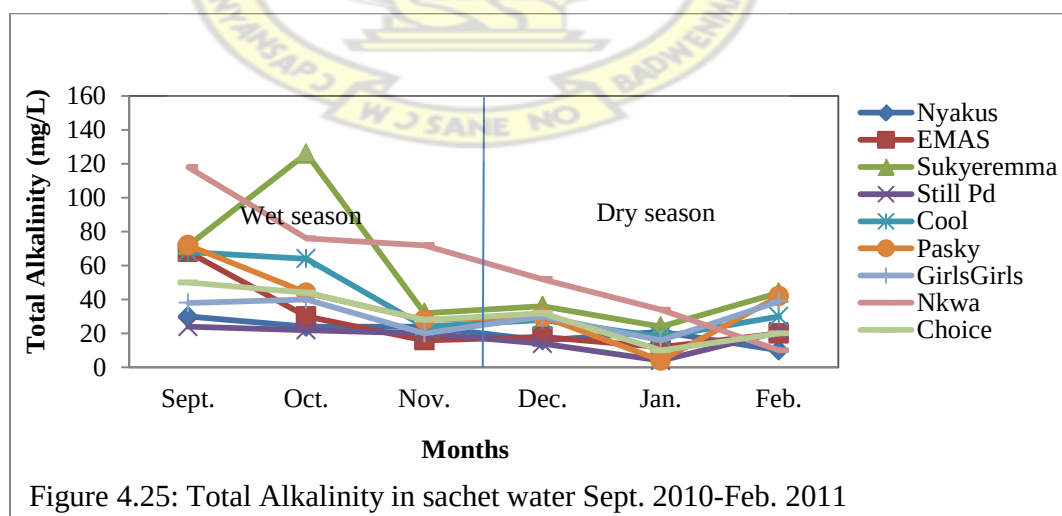
concentrations were highly contaminated with bacteria, namely ‘Choice’, ‘Still-Pd’ and ‘Sukyeremma’ (Table 4.42 and 4.44). Statistically, there was no significant difference in chloride concentration in any brand of packaged water between the wet and dry season.

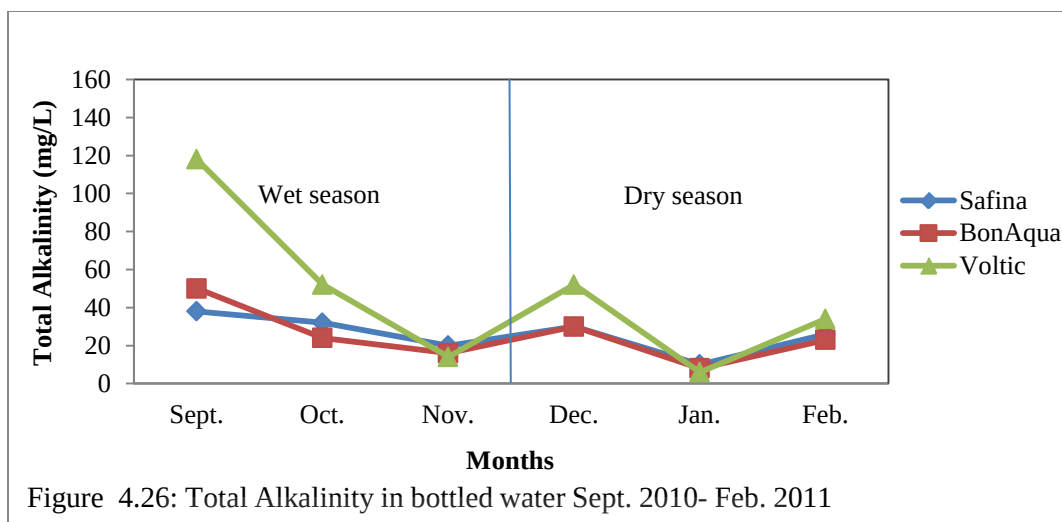
The phosphate values recorded were very negligible and ranged from 0.0 mg/L to 0.06 mg/L for brands of sachet water and 0.0 mg/L to 0.04 mg/L for brands of bottled water (Fig 4.23 and 4.24). Sachet water recorded slightly higher phosphate concentration than bottled water. Often, the phosphorus concentration in drinking water is below the detection limit (2 µg/L) of the standard methods for phosphorus measurement (Noble *et al.*, 1996).



In a study by Wetzel (1975), it was stated that the concentration of phosphorus needed to stimulate microbial growth in water was exceptionally low. Even the addition of 1.0 µg/L of PO₄-P increased microbial growth significantly both in fresh drinking water and in water from distribution networks. Most of the total phosphorus is associated with particulate matter, and only a minor part exists dissolved hence directly usable for microbes (Wetzel, 1975). Significant difference in phosphate concentration was recorded between the wet and dry season in brands of sachet water ($p \leq 0.001$) and bottled water ($p \leq 0.002$). Nevertheless, all the packaged water brands had phosphate concentrations far below the World Health Organisation permissible limit of 400 mg/L.

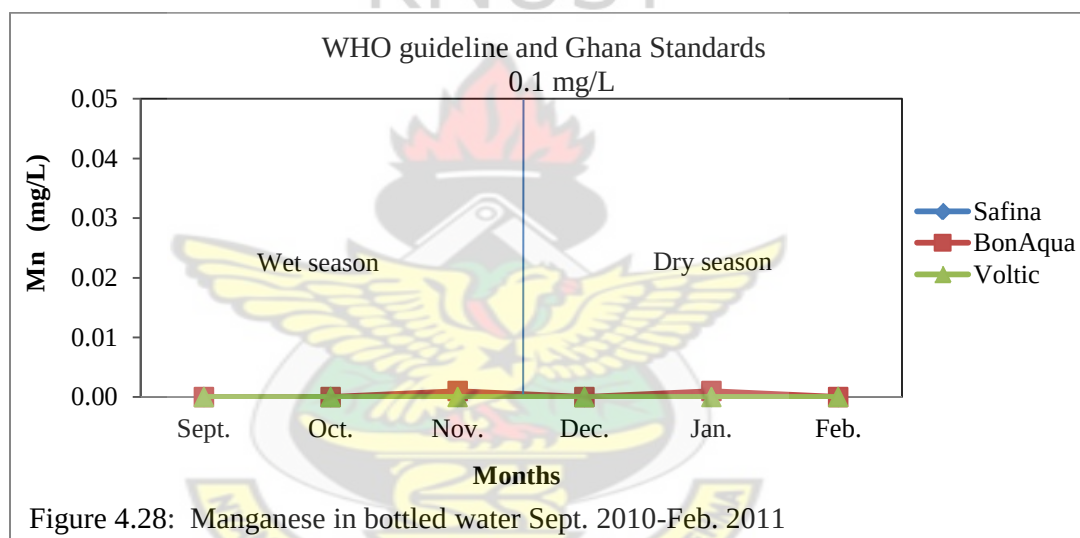
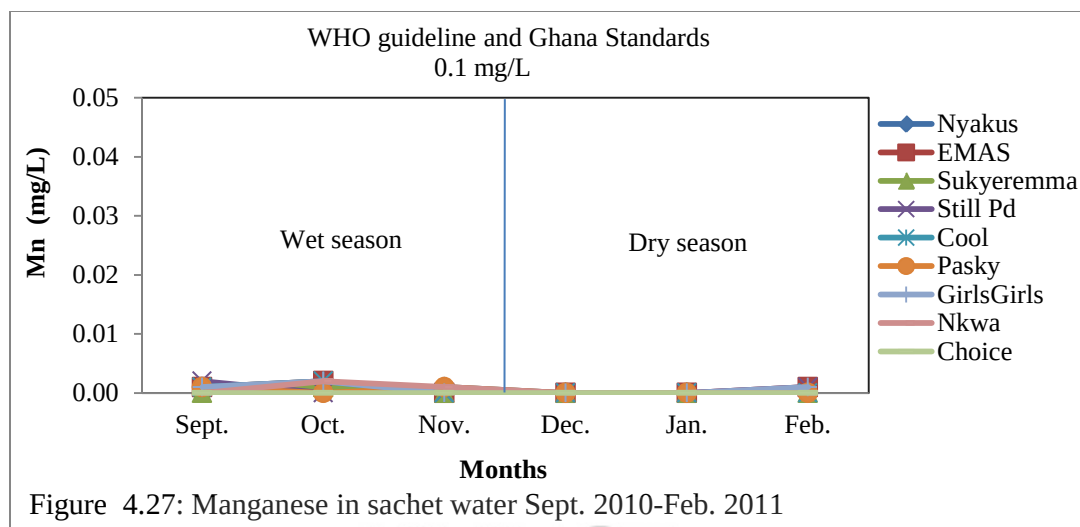
Total Alkalinity values ranged from 4.0 mg/L to 126 mg/L for brands of sachet water and 6.0 mg/L to 118.0 mg/L for brands of bottled water (Fig. 4.25 and 4.26). The constituents of alkalinity in natural systems include mainly carbonate, bicarbonate and hydroxide (Manivasakam, 1996). Higher alkalinity was recorded during the wet season than in the dry season (Table 4.28).





Alkalinity is not considered detrimental to humans but is generally associated with high pH values, water hardness and excess dissolved solids (World Health Organisation, 2006). High alkalinity waters may also have a distinctly flat, unpleasant taste (World Health Organisation, 2006). Total alkalinity measurements indicated that 'Nkwa', 'Sukyeremma' and 'Cool' had higher total alkalinity values hence may be considered hard drinking waters. The lowest total alkalinity readings were recorded in 'Still-Pd', 'EMAS', 'Girls-Girls' and 'Nyakus', indicating that they were soft waters. The brands of bottled water recorded relatively lower concentrations for total alkalinity indicating their softness. There was significant difference in total alkalinity between the wet and dry seasons, in brands of sachet water ($p \leq 0.0002$) but not in the bottled water.

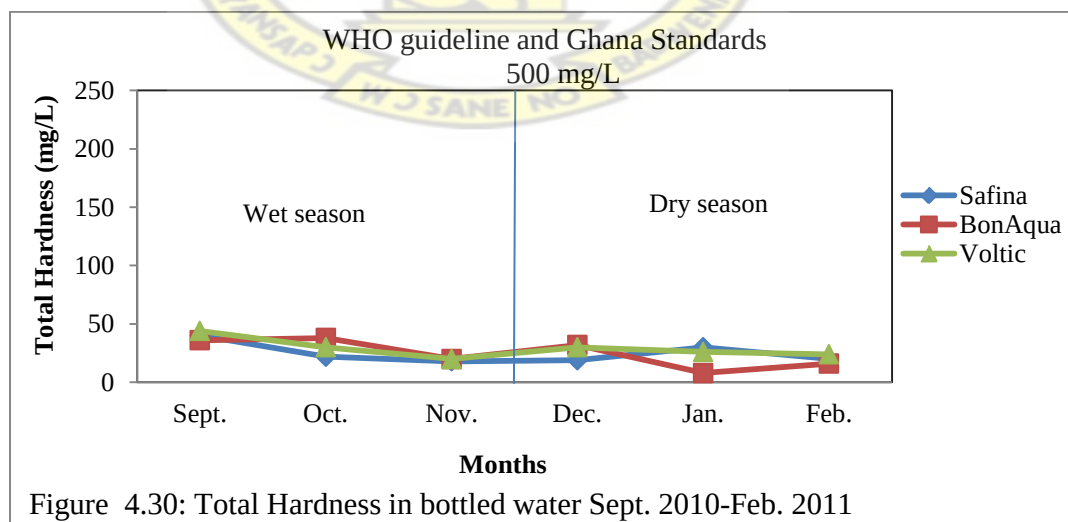
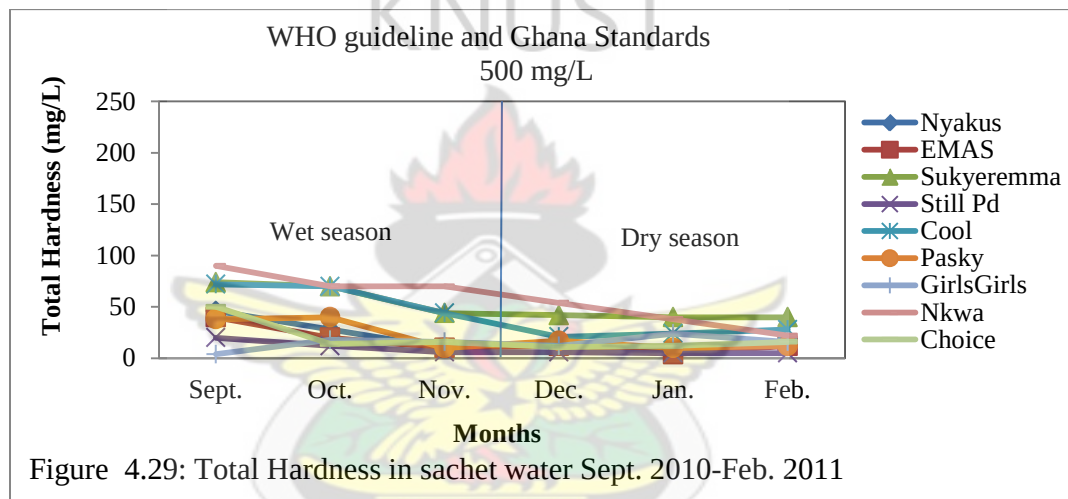
All the brands of packaged water recorded very low concentrations of manganese in the range of 0.001 mg/L and 0.002 mg/L (Fig. 4.27 and 4.28). Brands of sachet water recorded relatively higher concentrations of manganese than bottled water. The intake of manganese can be as high as 20 mg/day without apparent ill effects (Durlach *et al.*, 1985). Manganese may be objectionable to consumers if it is deposited in water and cause water discolouration.



Manganese concentration in 'Choice', 'Safina' and 'Voltic' was below the detection limit. Significant difference of manganese concentration in brands of sachet water between the wet and dry seasons was noted ($p \leq 0.003$).

The total hardness concentration were quite low ranging between 4.0 mg/L to 90.0 mg/L for sachet water and from 8.0 mg/L to 44.0 mg/L for brands of bottled water (Fig. 4.29 and 4.30). Hardness of packaged water were below the set guideline value of 500 mg/L and relatively higher water hardness was recorded in the wet season than in the dry season. The utilization of

these ions by microorganisms must have caused the decrease in the concentration of the total hardness in the dry season (Mustapha, 2008) and to pH changes. The total hardness concentrations obtained established that most packaged water brands offered for sale in the Kumasi metropolis were soft drinking waters. Waters with their hardness less than 100 mg/L have a little buffering capacity and may cause corrosion of metallic receptacles (World Health Organisation, 2006), hence some of these brands of packaged water have a great potential to contain higher concentrations of toxic metals.



The least total hardness concentrations recorded and hence the softest brands of sachet waters were noted for 'Still-Pd', 'Girls-Girls', 'EMAS' and 'Nyakus'. Depending on the content of alkalinity, hardness more than 200 mg/L can create precipitation, especially when the water is being heated (World Health Organisation, 2006). Total hardness concentrations differed significantly only in the brands of sachet water ($p \leq 0.001$) between the wet and dry season.

Calcium and magnesium salts play an important role in bone structure, muscle contraction, nerve impulse transmission, blood clotting and cell signaling (Institute of Medicine, 1997).

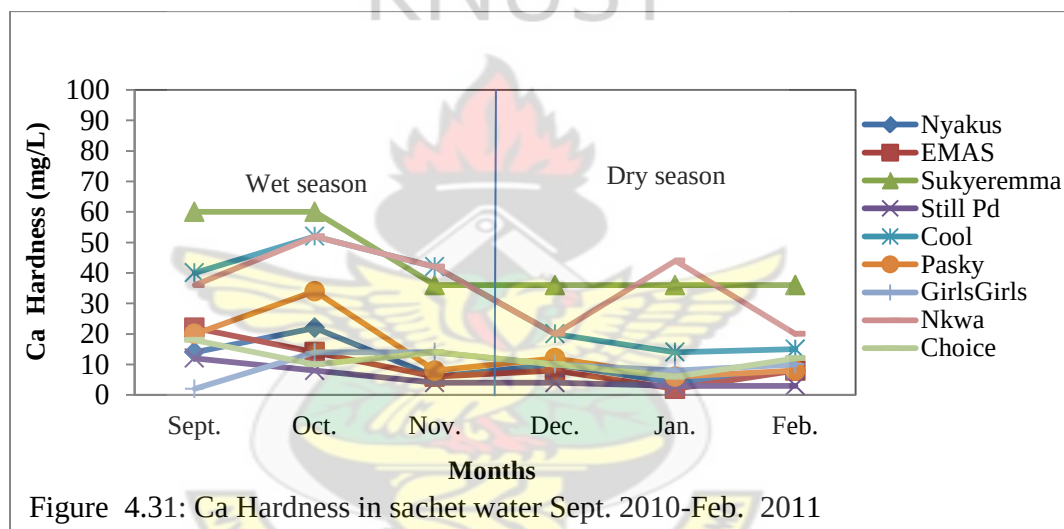


Figure 4.31: Ca Hardness in sachet water Sept. 2010-Feb. 2011

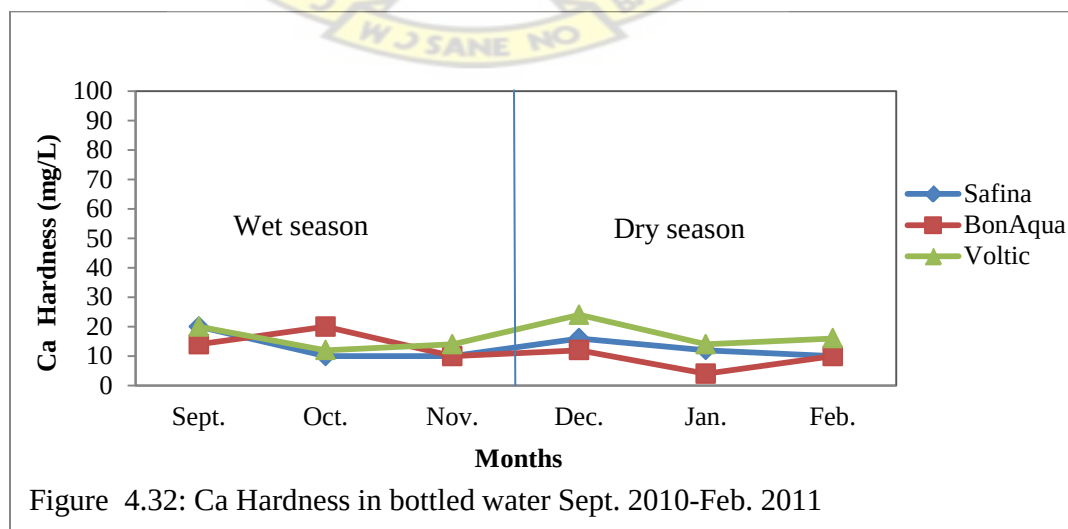
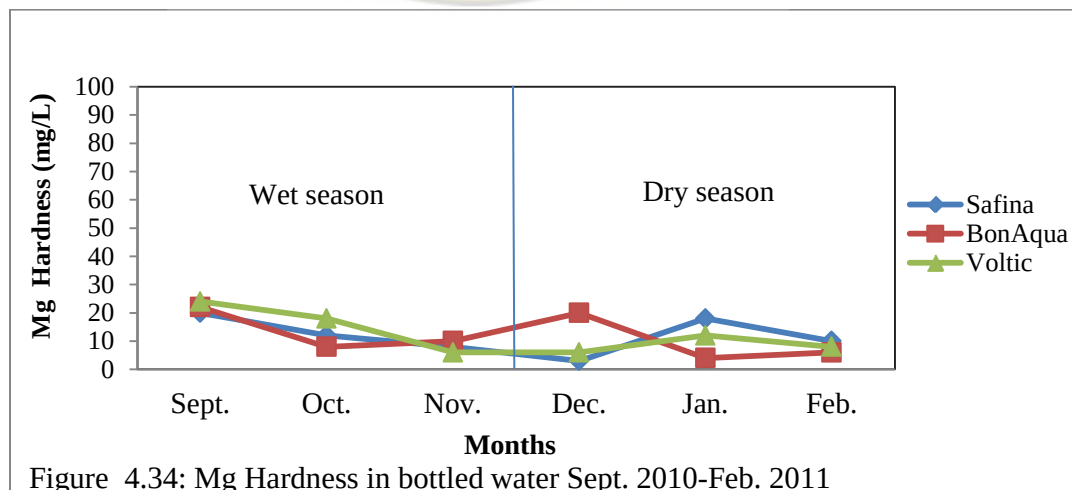
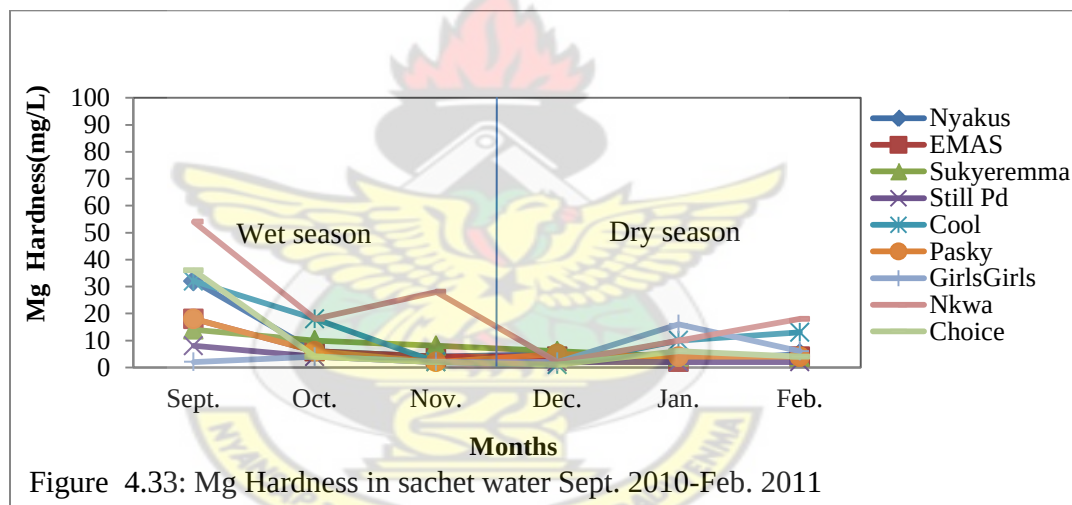
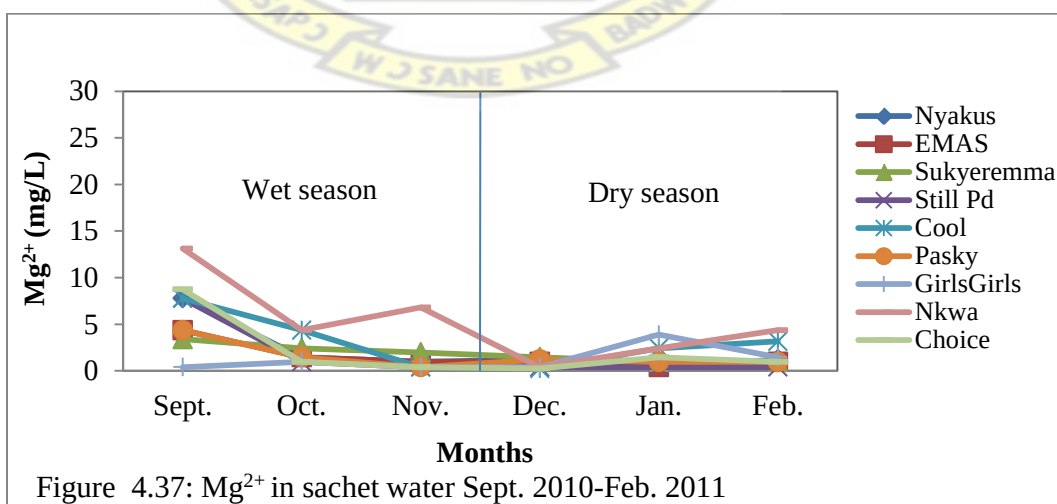
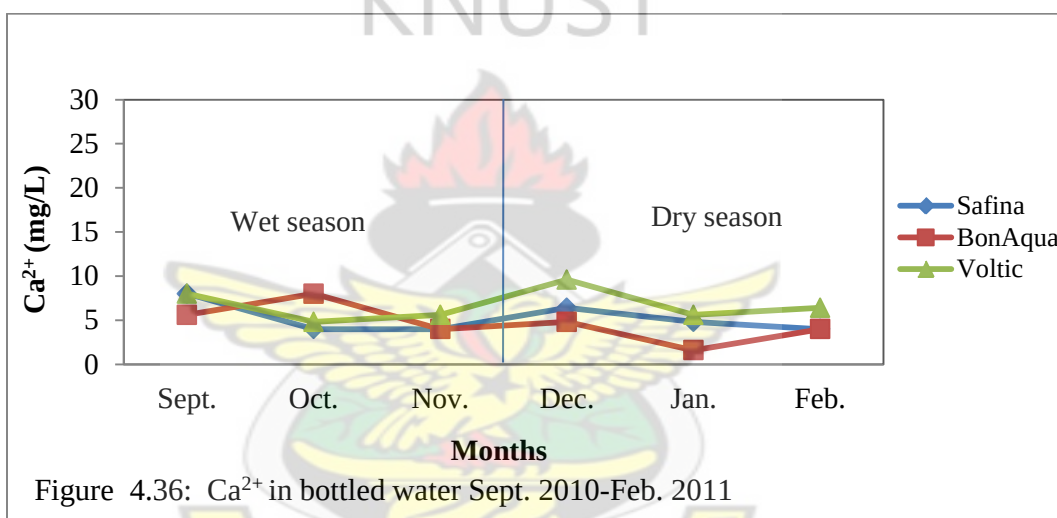
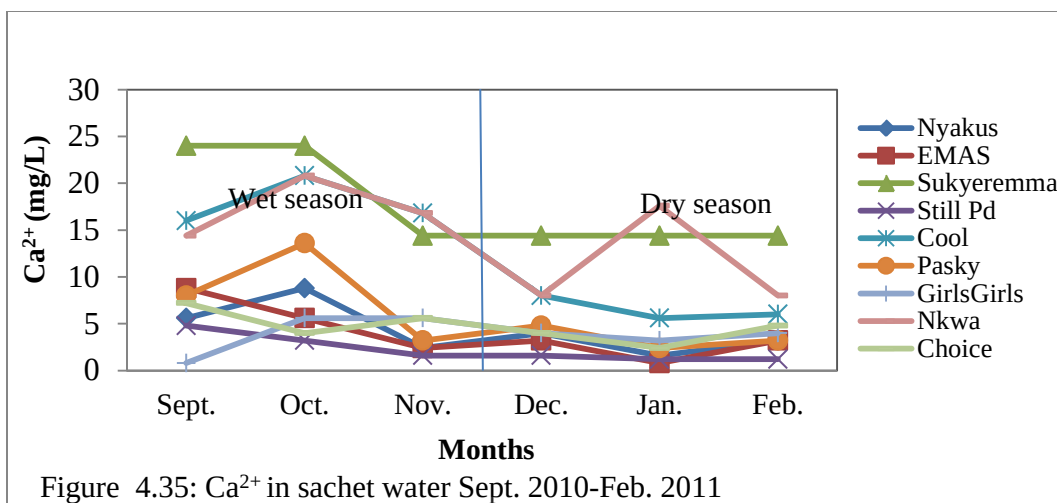
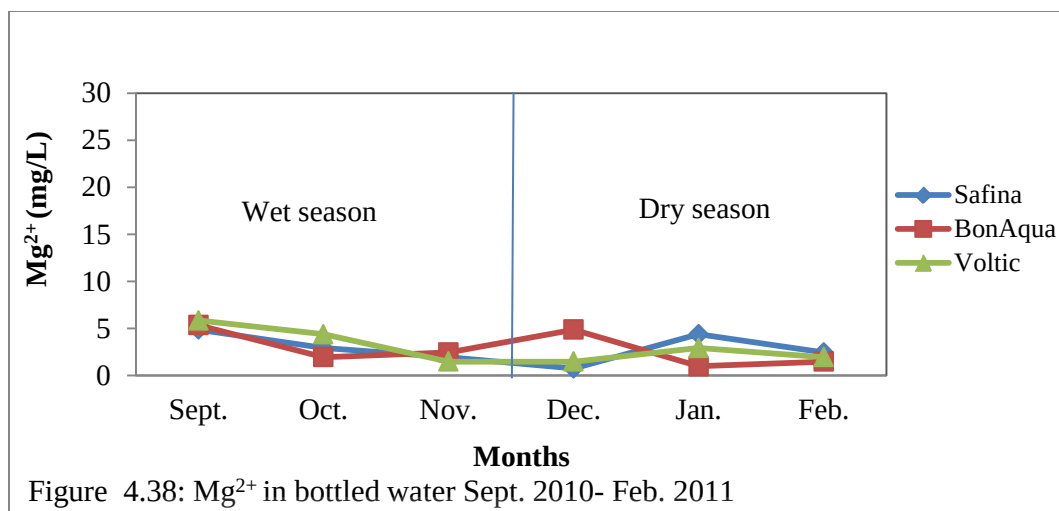


Figure 4.32: Ca Hardness in bottled water Sept. 2010-Feb. 2011

Calcium-deficient children show rickets, the condition of under-mineralized bone, resulting in structural deformities of growing bones, while bone under-mineralization in adults is involved in osteoporosis with associated increases in fracture risk. Calcium hardness in sachet water ranged from 2.0 mg/L to 60.0 mg/L and 4.0 mg/L to 20 mg/L for bottled water. Magnesium hardness also ranged from 1.0 mg/L to 54 mg/L for sachet water and 3.0 mg/L to 24 mg/L for bottled water. Significant difference in the concentration of calcium hardness ($p \leq 0.0059$) and magnesium hardness ($p \leq 0.0041$) were recorded between the wet and dry season in brands of sachet water only.







Calcium and magnesium ion concentration in sachet water ranged from 1.2 mg/L to 24 mg/L and 0.4 mg/L to 13.12 mg/L respectively. Calcium and magnesium ion concentration in bottled water ranged from 1.6 mg/L to 9.6 mg/L and 0.72 mg/L to 5.83 mg/L respectively. Magnesium deficiency affects neurological and neuromuscular function, resulting in anorexia, muscular weakness, lethargy and unsteady gait (Combs *et al.*, 2005). Significant difference was recorded for calcium ion ($p \leq 0.0059$) and magnesium ion ($p \leq 0.0041$) between the wet and dry seasons for brands of sachet water only.

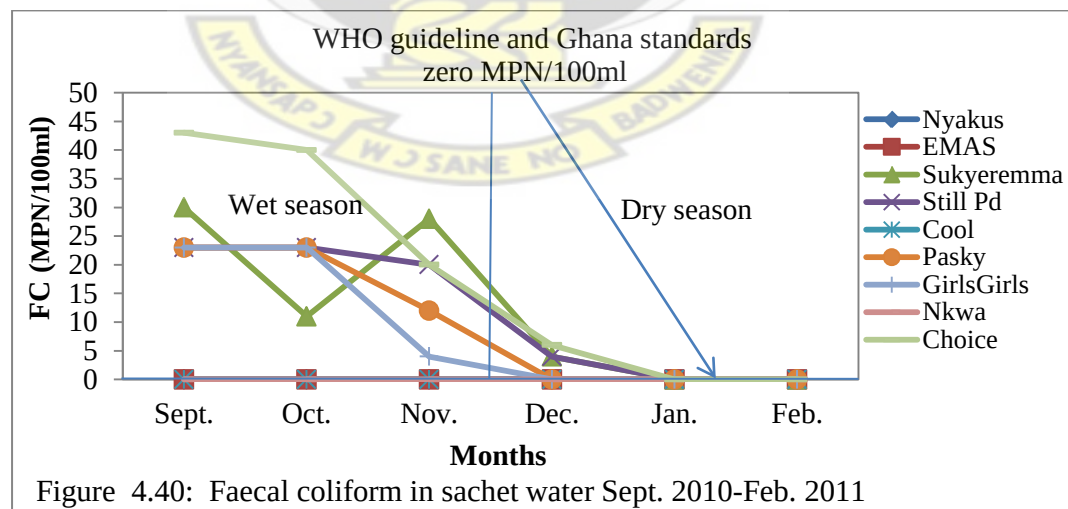
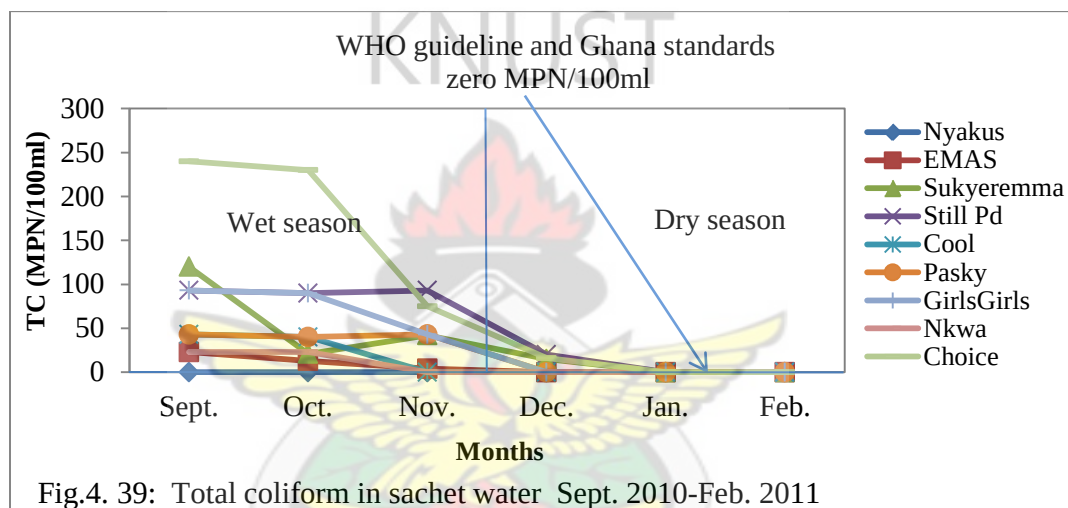
4.2. Bacteriological Characteristics of Packaged Water

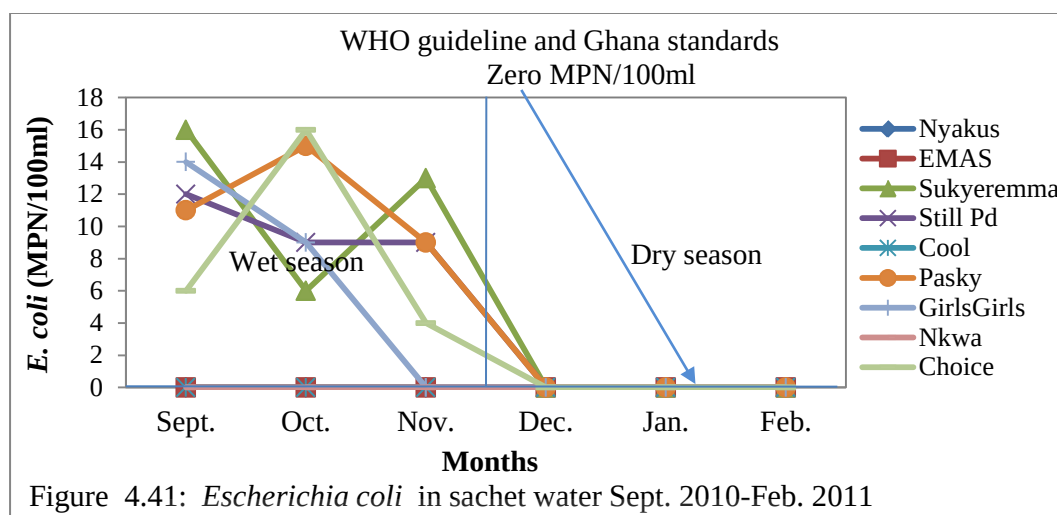
Bacteriological water quality analysis is a process of analysing water to estimate the number of bacteria present and if needed, to find out the consortium of bacteria (Mead *et al.*, 1999). It is subsequently possible to draw inferences as regards to the suitability of the drinking water for use from these concentrations. Drinking water regulations require that potable water for human consumption be free from human disease-causing bacteria and specific indicator bacteria that are

indicative of the presence of these pathogens (Lisle, 1993). Contamination of brands of sachet water with total coliforms bacteria ranged between 4 to 240 MPN per 100ml with the highest contamination occurring during the early periods of the wet season. The early part of the wet season recorded 88% of the brands of sachet water being contaminated with total coliform bacteria which later declined to 44% in during the early part of the dry season. In addition, 55.6% of the brands of sachet water were contaminated with faecal coliforms and *Escherichia coli* bacteria in a range of 4 to 43 MPN per 100ml and 4 to 16 MPN per 100ml respectively (Fig 4.39 and 4.40).

Total and faecal coliform bacteria were not detected in any brands of bottled water, namely 'Safina', 'BonAqua' and 'Voltic'. In confirmation with the observations made in this study, no microbial indicators of faecal contamination were found in bottled water in a similar study conducted by Obiri-Danso *et al.*, (2003). 'Choice' had the highest total coliforms than any other sachet water. It was found that some sachet waters offered for sale in the Kumasi metropolis were highly contaminated during the wet season than in the dry season. The high bacteriological contamination of sachet water during the wet season could be attributed to inadequate treatment of water samples by the producers, improper use of filters, poor sanitary conditions and post-production contamination (Addo *et al.*, 2009). Brands of sachet water, namely 'Choice', 'Still-Pd', 'Sukyeremma', 'Girls-Girls' and 'Pasky' were contaminated with various levels of total coliform, faecal coliform and *Escherichia coli* bacteria which indicated the presence of pathogens hence are unsafe for human consumption (World Health Organisation, 2004). Many producers in the Kumasi metropolis use pipe water in the production of sachet water. According to Anim *et al.*, (2010) higher microbial counts in pipe water were recorded during the wet season compared to the dry season.

Studies conducted by Quist (1999), on the pipe water in the Kumasi metropolis also reported contamination with faecal coliforms at concentration of between 10 and 28 per 100ml. Contaminations with total and faecal coliforms was not detected in 'Nyakus' hence rated excellent. Although 'EMAS', 'Cool' and 'Nkwa' were contaminated with total coliform bacteria, faecal coliform bacteria was not detected in them hence could also be classified as acceptable (World Health Organisation, 2004).





When water supplies contain coliform bacteria in levels greater than one per 100ml of water, the water may also contain pathogens that cause acute intestinal illness. While normally regarded as discomfort to health, these infections may be lethal to infants, the elderly and the infirm (Olowe *et al.*, 2005). The presence of *Escherichia coli*, a faecal coliform in drinking water is a strong indicator of recent sewage or animal waste contamination. Treated water should therefore not contain this organism because it is also an indicator microorganism in drinking water (USEPA, 2003). The detection of *Escherichia coli* in the brands of sachet water, namely 'Still-Pd', 'Pasky', 'Sukyeremma', 'Choice' and 'Girls-Girls', indicated strongly that they contained inhabitant pathogens which also confirmed a similar study by Obiri-Danso *et al.* (2003) who reported that sachet water had high bacterial loads, indicative of poor water quality on sale in the Kumasi metropolis. Most Ghanaian sachet water producers use beds or columns of ion exchange resins or activated carbon but these can also support similar bacterial growth unless properly maintained and serviced (Obiri-Danso *et al.*, 2003). However, according to the National Defence Research Council of the United States of America (1999), 25% of bottled waters sold in developed countries such as the United States are obtained from municipal tap water and as such

are generally of high quality by being placed under strict regulatory standard of the United States Environmental Protection Agency. The same is not the case in developing or underdeveloped countries.

No contaminations from total and faecal coliform bacteria was detected in any brands of bottled water, namely 'Safina', 'BonAqua' and 'Voltic' which agreed with Obiri-Danso *et al.* (2003), who also reported that bottled waters sold in Kumasi metropolis were safe for consumption since they were devoid of coliform bacteria. The absence of faecal indicator bacteria in all brands of bottled drinking water could be attributed to effective treatment processes employed in addition to the remoteness of sewage facilities from factories compared to the sachet water producing factories. Others include the use of personal protective equipments (PPE), protective sealed caps on bottles, improved and hygienic filling system and the use of non-returnable plastic containers (Oyedeji *et al.*, 2009).

It was reported that the Food and Drugs Board and the Ghana Standard Board, who are the main regulators of drinking water quality, have intensified their inspections, which should have put recalcitrant producers on the alert, but improvement is not forthcoming. Lack of information has made it difficult for consumers to identify the contaminated brands of sachet water to avoid patronising them.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

This study has revealed that the brands of bottled drinking water offered for sale in the Kumasi metropolis met the Ghana Standards Board (1998) and World Health Organisation guideline for the bacteriological, physical and the chemical characteristics of drinking water. The brands of sachet water generally met the physical and chemical quality standards of the Ghana Standards Board (1998) and World Health Organisation (2007), though 55.6% failed to meet the requirements in terms of the bacteriological quality.

5.2. RECOMMENDATIONS

It is recommended that the Food and Drugs Board and the Ghana Standards Board embark upon routine unannounced monitoring of the production process of the drinking water producers, especially sachet water. The random testing of market samples will be a good way of detecting whether or not the water quality is meeting the required standards. There should be information on the quality of brands of sachet water on sale in the Kumasi metropolis and this should be made available to the consumer population.

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APPENDIX I

Table 4.1: Student t –Test results		
	Sachet Water	Bottled Water
Temperature (°C)	0.0001	0.0080
pH	0.0008	0.0415
Turbidity (mg/L)	0.4540	0.2477
Conductivity (µs/cm)	0.1051	0.3332
Apparent Colour (Hz)	0.0038	0.1661
Suspended Solids (mg/L)	0.2116	0.0030
Total Dissolved Solids (mg/L)	0.1420	0.0702
Dissolved Oxygen (mg/L)	0.0770	0.0070
Ammonia (mg/L)	0.0431	0.0241
Nitrite-Nitrogen (mg/L)	0.1337	0.1649
Nitrate-Nitrogen (mg/L)	0.0148	0.1535
Sulphate (mg/L)	0.0382	0.4252
Chloride (mg/L)	0.0997	0.1244
Phosphate (mg/L)	0.0007	0.0018
Total Alkalinity (mg/L)	0.0002	0.0957
Manganese (mg/L)	0.0003	0.5000
Total Hardness (mg/L)	0.0011	0.0589
Calcium Hardness (mg/L)	0.0059	0.2895
Magnesium Hardness (mg/L)	0.0041	0.0759
Calcium Ion (mg/L)	0.0059	0.4671
Magnesium Ion (mg/L)	0.0041	0.0759

Raw Data of Physical and Chemical Water Quality

Table 4.2: pH of Sachet Water						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	6.84	7.02	7.69	6.91	6.84	6.72
EMAS	6.89	6.80	7.57	6.10	6.10	6.90
Sukyeremma	7.80	6.78	8.04	8.00	7.36	6.89
Still-Pd	6.25	7.53	6.61	6.42	7.09	7.00
Cool	7.74	8.01	8.03	6.63	6.94	6.78
Pasky	6.95	7.74	7.29	6.99	7.33	7.00
Girls Girls	6.69	7.45	7.53	6.36	7.39	7.20
Nkwa	7.82	7.55	7.69	7.23	7.62	7.30
Choice	7.69	6.86	8.11	6.71	6.78	6.68

APPENDIX II

Table 4.3: pH of Brands of Bottled Water						
Brands	Wet season			Dry season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	6.56	6.80	7.49	6.09	6.98	6.70
BonAqua	7.15	7.44	7.84	7.04	7.31	7.14
Voltic	7.18	6.84	7.07	6.34	6.90	6.80

Table 4.4: Turbidity in Sachet Water (NTU)						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	0.35	0.34	0.54	0.42	0.59	0.43
EMAS	0.35	0.70	0.49	0.54	0.33	0.45
Sukyeremma	0.44	0.70	0.46	0.46	0.54	0.43
Still Pd	0.21	0.54	0.31	0.84	0.54	0.42
Cool	0.42	0.60	0.39	0.55	0.47	0.43
Pasky	0.38	0.31	0.60	0.47	0.55	0.50
Girls Girls	0.44	0.70	0.60	0.22	0.85	0.32
Nkwa	0.65	0.40	0.37	0.47	1.06	0.65
Choice	0.46	0.50	0.61	1.30	0.80	0.63

Table 4.5: Turbidity in Brands of Bottled Water (NTU)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	0.17	0.30	0.19	0.61	0.15	0.24
BonAqua	1.00	0.17	0.31	0.21	0.30	0.28
Voltic	0.28	0.30	0.28	0.17	0.24	0.19

APPENDIX III

Table 4.6: Conductivity in Brands of Sachet Water ($\mu\text{S}/\text{cm}$)						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	95.00	55.00	54.70	50.40	46.70	45.70
EMAS	45.00	40.00	38.90	37.00	36.40	36.00
Sukyeremma	168.10	142.20	139.00	136.00	125.00	120.00
Still Pd	27.10	31.00	24.60	20.40	26.40	25.50
Cool	201.00	181.00	177.40	139.00	133.50	130.00
Pasky	50.80	77.00	65.30	48.40	60.60	58.70
Girls Girls	71.40	87.00	90.20	73.90	82.40	80.70
Nkwa	190.00	175.00	172.00	165.00	158.00	139.50
Choice	110.90	68.00	67.00	64.20	61.30	58.90

Table 4.7: Conductivity in Brands of Bottled Water ($\mu\text{S}/\text{cm}$)						
Brands	Wet season			Dry season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	24.70	41.70	40.00	41.00	28.70	30.00
BonAqua	16.40	54.00	195.80	63.20	95.70	83.20
Voltic	51.10	80.70	49.00	83.40	115.30	94.70

Table 4.8: Apparent Colour in Brands of Sachet Water (Hz)						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	0.0	0.0	3.0	3.0	0.0	0.0
EMAS	0.0	0.0	0.0	3.0	0.0	0.0
Sukyeremma	2.0	0.0	0.0	5.0	0.0	1.0
Still Pd	0.0	0.0	0.0	4.0	0.0	0.0
Cool	0.0	0.0	0.0	3.0	0.0	0.0
Pasky	0.0	0.0	0.0	1.0	0.0	0.0
Girls Girls	0.0	0.0	0.0	5.0	6.0	0.0
Nkwa	0.0	0.0	0.0	2.0	0.0	1.0
Choice	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX IV

Table 4.9: Apparent Colour in Brands of Bottled Water (Hz)						
Brands	Wet season			Dry season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	0.0	0.0	0.0	0.0	0.0	0.0
BonAqua	0.0	0.0	0.0	0.0	0.0	0.0
Voltic	0.0	0.0	0.0	0.0	3.0	0.0

Table 4.10: Total Dissolved Solids in Brands of Sachet Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	45.0	28.1	25.4	23.0	22.6	20.4
EMAS	21.3	19.0	16.3	18.4	18.0	17.8
Sukyeremma	84.1	78.0	67.0	62.5	60.3	56.0
Still Pd	13.2	15.2	12.0	10.2	12.0	11.6
Cool	95.0	88.7	86.0	84.5	78.0	73.0
Pasky	25.6	36.0	36.0	24.0	29.0	26.0
Girls Girls	35.6	46.2	45.1	35.4	39.0	40.0
Nkwa	89.0	84.0	83.2	82.0	82.0	69.0
Choice	52.0	34.0	32.4	29.2	30.0	28.9

Table 4.11: Total Dissolved Solids in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	16.0	22.0	20.0	19.0	18.0	12.0
BonAqua	37.0	45.0	98.4	30.0	24.0	8.4
Voltic	45.0	54.0	23.0	39.0	40.0	28.0

APPENDIX I V

Table 4.12: Dissolved Oxygen in brands of Sachet Water (mg/L)

Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	3.83	3.83	6.11	6.11	3.28	4.34
EMAS	4.13	4.56	4.69	4.21	3.78	4.40
Sukyeremma	4.39	4.55	4.75	3.88	5.20	4.53
Still Pd	4.17	4.59	8.26	4.11	4.09	4.60
Cool	4.19	4.47	4.39	3.21	3.74	4.20
Pasky	3.78	4.79	5.72	3.96	3.49	5.30
Girls Girls	3.57	4.49	6.27	4.06	5.26	4.76
Nkwa	3.41	3.74	6.67	3.11	5.52	3.95
Choice	3.66	4.45	4.65	5.81	3.24	3.80

Table 4.13: Dissolved Oxygen in Brands of Bottled Water (mg/L)

Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	3.90	4.75	4.75	3.33	3.63	4.12
BonAqua	3.92	4.79	5.18	3.71	3.23	4.32
Voltic	4.22	4.82	4.69	3.26	3.41	4.50

Table 4.14: Ammonia in Brands of Sachet Water (mg/L)

Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	1.0	0.0	1.0	1.0	0.0	0.0
EMAS	1.0	1.0	0.0	0.0	0.0	0.0
Sukyeremma	0.0	1.0	0.0	0.0	0.0	1.0
Still Pd	1.0	0.0	0.0	0.0	0.0	0.0
Cool	1.0	0.0	0.0	1.0	0.0	0.0
Pasky	0.0	1.0	0.0	0.0	0.0	1.0
Girls Girls	1.0	0.0	0.0	1.0	0.0	0.0
Nkwa	1.0	0.0	0.0	0.0	0.0	0.0
Choice	1.0	1.0	0.0	0.0	0.0	1.0

APPENDIX VI

Table 4.15: Ammonia in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	1.0	1.0	0.0	0.0	0.0	0.0
BonAqua	1.0	0.0	0.0	0.0	0.0	0.0
Voltic	1.0	1.0	0.0	0.0	0.0	1.0

Table 4.16: Nitrite-Nitrogen in Brands of Sachet Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	0.000	0.000	0.001	0.002	0.000	0.001
EMAS	0.001	0.000	0.000	0.002	0.000	0.000
Sukyeremma	0.000	0.004	0.000	0.000	0.002	0.001
Still Pd	0.000	0.001	0.007	0.009	0.000	0.000
Cool	0.000	0.002	0.006	0.002	0.004	0.002
Pasky	0.000	0.000	0.001	0.000	0.000	0.001
Girls Girls	0.001	0.002	0.002	0.000	0.004	0.000
Nkwa	0.001	0.002	0.001	0.001	0.004	0.002
Choice	0.000	0.002	0.001	0.006	0.006	0.003

Table 4.17: Nitrite -Nitrogen in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	0.000	0.000	0.000	0.000	0.000	0.000
BonAqua	0.000	0.000	0.002	0.000	0.000	0.001
Voltic	0.000	0.008	0.000	0.005	0.050	0.004

APPENDIX VII

Table 4.18: Nitrate-Nitrogen in Brands of Sachet Water (mg/L)

Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	0.000	0.000	0.000	0.000	0.000	0.000
EMAS	0.002	0.001	0.000	0.000	0.000	0.002
Sukyeremma	0.003	0.001	0.000	0.000	0.000	0.001
Still Pd	0.003	0.020	0.000	0.000	0.000	0.001
Cool	0.002	0.002	0.000	0.000	0.000	0.000
Pasky	0.002	0.020	0.000	0.000	0.000	0.003
Girls Girls	0.002	0.001	0.000	0.000	0.001	0.002
Nkwa	0.003	0.002	0.000	0.000	0.000	0.000
Choice	0.020	0.020	0.000	0.000	0.000	0.010

Table 4.19: Nitrate -Nitrogen in Brands of Bottled Water (mg/L)

Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	0.000	0.020	0.000	0.000	0.000	0.000
BonAqua	0.000	0.010	0.000	0.000	0.000	0.000
Voltic	0.000	0.000	0.000	0.000	0.000	0.000

Table 4.20: Sulphate in Brands of Sachet Water (mg/L)

Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	3.0	0.0	0.0	0.0	0.0	2.0
EMAS	0.0	0.0	0.0	0.0	0.0	0.0
Sukyeremma	3.0	3.0	0.0	0.0	0.0	2.0
Still Pd	3.0	0.0	0.0	0.0	0.0	0.0
Cool	0.0	2.0	0.0	0.0	0.0	0.0
Pasky	3.0	0.0	0.0	0.0	0.0	0.0
Girls Girls	3.0	0.0	0.0	0.0	0.0	2.0
Nkwa	0.0	2.0	0.0	0.0	2.0	0.0
Choice	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX VIII

Table 4.21: Sulphate in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	3.0	0.0	0.0	0.0	0.0	2.0
BonAqua	0.0	3.0	0.0	0.0	3.0	0.0
Voltic	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.22: Chloride in Brands of Sachet Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	12.0	26.0	20.0	32.0	16.0	19.0
EMAS	14.0	18.0	10.0	12.0	12.0	10.0
Sukyeremma	18.0	32.0	16.0	16.0	18.0	16.0
Still Pd	18.0	24.0	16.0	8.0	16.0	20.0
Cool	18.0	40.0	40.0	34.0	18.0	32.0
Pasky	14.0	38.0	28.0	6.0	20.0	18.0
Girls Girls	18.0	18.0	30.0	10.0	22.0	23.0
Nkwa	16.0	40.0	26.0	30.0	20.0	25.0
Choice	16.0	24.0	14.0	32.0	20.0	19.0

Table 4.23: Chloride in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	14.0	38.0	12.0	8.0	14.0	12.0
BonAqua	10.0	32.0	16.0	14.0	20.0	24.0
Voltic	14.0	26.0	10.0	10.0	16.0	13.0

APPENDIX IX

Table 4.24: Phosphate in Brands of Sachet Water (mg/L)						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	0.06	0.02	0.00	0.00	0.01	0.00
EMAS	0.04	0.03	0.02	0.00	0.01	0.02
Sukyeremma	0.02	0.03	0.01	0.01	0.02	0.02
Still Pd	0.06	0.03	0.00	0.00	0.02	0.04
Cool	0.04	0.02	0.02	0.00	0.04	0.00
Pasky	0.02	0.02	0.00	0.01	0.01	0.00
Girls Girls	0.03	0.03	0.01	0.00	0.01	0.01
Nkwa	0.02	0.02	0.00	0.00	0.01	0.02
Choice	0.04	0.03	0.00	0.00	0.01	0.00

Table 4.25: Phosphate in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	0.03	0.02	0.02	0.00	0.00	0.00
BonAqua	0.04	0.03	0.01	0.01	0.02	0.01
Voltic	0.02	0.01	0.01	0.00	0.01	0.01

Table 4.26: Total Alkalinity of Brands of Sachet Water (mg/L)						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	30.0	24.0	24.0	16.0	21.0	10.0
EMAS	68.0	30.0	16.0	18.0	12.0	20.0
Sukyeremma	72.0	126.0	32.0	36.0	24.0	44.0
Still Pd	24.0	22.0	20.0	14.0	4.0	21.0
Cool	68.0	64.0	24.0	28.0	18.0	30.0
Pasky	72.0	44.0	28.0	30.0	4.0	42.0
Girls Girls	38.0	40.0	20.0	30.0	16.0	39.0
Nkwa	118.0	76.0	72.0	52.0	34.0	10.0
Choice	50.0	44.0	28.0	32.0	10.0	20.0

APPENDIX X

Table 4.27: Total Alkalinity of Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	38.0	32.0	20.0	30.0	10.0	26.0
BonAqua	50.0	24.0	16.0	30.0	8.0	23.0
Voltic	118.0	52.0	14.0	52.0	6.0	34.0

Table 4.28: Manganese in Brands of Sachet Water (mg/L)						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	0.001	0.000	0.001	0.000	0.000	0.000
EMAS	0.001	0.002	0.000	0.000	0.000	0.001
Sukyeremma	0.000	0.001	0.000	0.000	0.000	0.000
Still Pd	0.002	0.000	0.000	0.000	0.000	0.001
Cool	0.001	0.002	0.000	0.000	0.000	0.000
Pasky	0.001	0.000	0.001	0.000	0.000	0.000
Girls Girls	0.001	0.002	0.000	0.000	0.000	0.001
Nkwa	0.000	0.002	0.001	0.000	0.000	0.000
Choice	0.000	0.000	0.000	0.000	0.000	0.000

Table 4.29: Manganese in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	0.000	0.000	0.001	0.000	0.001	0.000
BonAqua	0.000	0.000	0.000	0.000	0.000	0.000
Voltic	0.000	0.000	0.000	0.000	0.000	0.000

APPENDIX XI

Table 4.30: Total Hardness in Brands of Sachet Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	46.0	28.0	10.0	15.0	6.0	13.0
EMAS	40.0	20.0	10.0	12.0	4.0	12.0
Sukyeremma	74.0	70.0	44.0	42.0	40.0	40.0
Still Pd	20.0	12.0	6.0	6.0	5.0	5.0
Cool	72.0	70.0	44.0	21.0	24.0	28.0
Pasky	38.0	40.0	10.0	17.0	10.0	12.0
Girls Girls	4.0	18.0	16.0	12.0	24.0	16.0
Nkwa	90.0	70.0	70.0	54.0	38.0	22.0
Choice	50.0	14.0	16.0	11.0	12.0	16.0

Table 4.31: Total Hardness in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	40.0	22.0	18.0	19.0	30.0	20.0
BonAqua	36.0	38.0	20.0	32.0	8.0	16.0
Voltic	44.0	30.0	20.0	30.0	26.0	24.0

Table 4.32: Calcium Hardness in Brands of Sachet Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	14.0	22.0	6.0	10.0	4.0	8.0
EMAS	22.0	14.0	6.0	8.0	2.0	8.0
Sukyeremma	60.0	60.0	36.0	36.0	36.0	36.0
Still Pd	12.0	8.0	4.0	4.0	3.0	3.0
Cool	40.0	52.0	42.0	20.0	14.0	15.0
Pasky	20.0	34.0	8.0	12.0	6.0	8.0
Girls Girls	2.0	14.0	14.0	10.0	8.0	10.0
Nkwa	36.0	52.0	42.0	20.0	44.0	20.0
Choice	18.0	10.0	14.0	10.0	6.0	12.0

APPENDIX XII

Table 4.33: Calcium Hardness in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	20.0	10.0	10.0	16.0	12.0	10.0
BonAqua	14.0	20.0	10.0	12.0	4.0	10.0
Voltic	20.0	12.0	14.0	24.0	14.0	16.0

Table 4.34: Magnesium Hardness in Brands of Sachet Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	32.0	6.0	4.0	5.0	2.0	5.0
EMAS	18.0	6.0	4.0	4.0	2.0	4.0
Sukyeremma	14.0	10.0	8.0	6.0	4.0	4.0
Still Pd	8.0	4.0	2.0	2.0	2.0	2.0
Cool	32.0	18.0	2.0	1.0	10.0	13.0
Pasky	18.0	6.0	2.0	5.0	4.0	4.0
Girls Girls	2.0	4.0	2.0	2.0	16.0	6.0
Nkwa	54.0	18.0	28.0	2.0	10.0	18.0
Choice	36.0	4.0	2.0	1.0	6.0	4.0

Table 4.35: Magnesium Hardness in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	20.0	12.0	8.0	3.0	18.0	10.0
BonAqua	22.0	8.0	10.0	20.0	4.0	6.0
Voltic	24.0	18.0	6.0	6.0	12.0	8.0

APPENDIX XIII

Table 4.36: Calcium Ion in Brands of Sachet Water (mg/L)						
Brands	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	5.6	8.8	2.4	4.0	1.6	3.2
EMAS	8.8	5.6	2.4	3.2	0.8	3.2
Sukyeremma	24.0	24.0	14.4	14.4	14.4	14.4
Still Pd	4.8	3.2	1.6	1.6	1.2	1.2
Cool	16.0	20.8	16.8	8.0	5.6	6.0
Pasky	8.0	13.6	3.2	4.8	2.4	3.2
Girls Girls	0.8	5.6	5.6	4.0	3.2	4.0
Nkwa	14.4	20.8	16.8	8.0	17.6	8.0
Choice	7.2	4.0	5.6	4.0	2.4	4.8

Table 4.37: Calcium Ion in Brands of Bottled Water(mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	8.0	4.0	4.0	6.4	4.8	4.0
BonAqua	5.6	8.0	4.0	4.8	1.6	4.0
Voltic	8.0	4.8	5.6	9.6	9.6	6.4

Table 4.38: Magnesium Ion in Brands of Sachet Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	7.78	1.46	0.97	1.22	0.40	1.22
EMAS	4.37	1.46	0.97	0.97	0.40	0.97
Sukyeremma	3.40	2.43	1.97	1.46	0.97	0.97
Still Pd	7.78	0.97	0.40	0.40	0.40	0.40
Cool	7.78	4.37	0.40	0.24	2.43	3.16
Pasky	4.37	1.46	0.40	1.22	0.97	0.97
Girls Girls	0.40	0.97	0.40	0.40	3.89	1.46
Nkwa	13.12	4.37	6.80	0.40	2.43	4.37
Choice	8.75	0.97	0.40	0.24	1.46	0.97

APPENDIX XIV

Table 4.39: Magnesium Ion in Brands of Bottled Water (mg/L)						
Brands	Wet Season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	4.86	2.92	1.94	0.73	4.37	2.43
BonAqua	5.35	1.94	2.43	4.86	0.97	1.46
Voltic	5.83	4.37	1.46	1.46	2.92	1.94

Bacteriological Quality Results

Table 4.40: Total Coliforms in Sachet Water (MPN/100ml)						
Brands of sachet water	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	<0	<0	<0	<0	<0	<0
EMAS	23	13	4	<0	<0	<0
Sukyeremma	120	21	42	15	<0	<0
Still Pd	93	90	93	20	<0	<0
Cool	43	40	<0	<0	<0	<0
Pasky	43	40	43	<0	<0	<0
Girls Girls	93	90	43	6	<0	<0
Nkwa	23	23	<0	<0	<0	<0
Choice	240	230	75	16	<0	<0

Table 4.41: Total Coliforms in Bottled Water (MPN/100ml)						
Brands of Bottled water	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	<0	<0	<0	<0	<0	<0
BonAqua	<0	<0	<0	<0	<0	<0
Voltic	<0	<0	<0	<0	<0	<0

APPENDIX XV

Table 4.42: Faecal Coliforms in Sachet Water (MPN/100ml)						
Brands of Sachet water	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	< 0	< 0	< 0	< 0	< 0	< 0
EMAS	< 0	< 0	< 0	< 0	< 0	< 0
Sukyeremma	30	11	28	< 0	< 0	< 0
Still Pd	23	23	20	< 0	< 0	< 0
Cool	<0	<0	<0	< 0	< 0	< 0
Pasky	23	23	12	< 0	< 0	< 0
Girls Girls	23	23	4	< 0	< 0	< 0
Nkwa	<0	<0	< 0	< 0	< 0	< 0
Choice	43	40	20	6	< 0	< 0

Table 4.43: Faecal Coliforms in Bottled Water (MPN/100ml)						
Brands of Bottled water	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	<0	<0	<0	<0	<0	<0
BonAqua	<0	<0	<0	<0	<0	<0
Voltic	<0	<0	<0	<0	<0	<0

Table 4.44: <i>Escherichia coli</i> in Sachet Water (MPN/100ml)						
Brands of Sachet water	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Nyakus	< 0	< 0	< 0	< 0	< 0	< 0
EMAS	< 0	< 0	< 0	< 0	< 0	< 0
Sukyeremma	16	6	13	< 0	< 0	< 0
Still Pd	12	9	9	< 0	< 0	< 0
Cool	<0	<0	<0	< 0	< 0	< 0
Pasky	11	15	9	< 0	< 0	< 0
Girls Girls	14	9	<0	< 0	< 0	< 0
Nkwa	<0	<0	<0	< 0	< 0	< 0
Choice	6	16	4	< 0	< 0	< 0

APPENDIX XVI

Table 4.45: <i>Escherichia coli</i> in Bottled Water (MPN/100ml)						
Brands of Bottled water	Wet season			Dry Season		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Safina	<0	<0	<0	<0	<0	<0
BonAqua	<0	<0	<0	<0	<0	<0
Voltic	<0	<0	<0	<0	<0	<0

KNUST

