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PHYSICO-CHEMICAL ANALYSIS OF THE QUALITY OF DIFFERENT BRANDS OF SACHET WATER IN THE SUNYANI MUNICIPALITY

BY

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DECLARATION

I hereby do declare that except for reference to other people's work which have been duly acknowledged, this piece of work is my own composition and neither in whole nor in part has this work been presented for the award of a degree in this university or elsewhere.

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DEDICATION

This thesis is dedicated to my family for their support and guidance during the research project.

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LIST OF ABBREVIATIONS AND ACRONYMS

APHA	American Public Health Association
BOD	Bio-chemical Oxygen Demand
CAMON	Consumers Affairs Movement of Nigeria
CCMEWQI	Canadian Council of Minister, Environment Water Quality Index
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FDA	Food Drugs Authority
GNA	Ghana News Agency
GSB	Ghana Standard Board
MoH	Ministry of Health
NAFDAC	National Agency for Food, Drug Administration and Control
NGOs	Non-Governmental Organizations
NIS	Nigeria Industrial Standard
NSFWQI	National Sanitation Foundation Water Quality Index
OWQI	Oregon Water Quality Index
SON	Standard Organization of Nigeria
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
UNICEF	United Nation Child Emergency Fund
UV	Ultra-Violet
WAWQI	Weighted Arithmetic Water Quality Index
WHO	World Health Organization
WQI	Water Quality Index

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ABSTRACT

Good quality water is necessary for the sustenance of growth and development. Several scientific studies has proven that there is a direct relationship between the quality of drinking water and human health, and argue that the quality of drinking water is a powerful determinant of health. Therefore, good quality drinking water gives a firm assurance and foundation for the prevention and control of water-borne diseases. Water is an indispensable element to the wellbeing of man. Water pollution is, therefore, a major global public health problem, and accounts for more than 14, 000 deaths daily. This study sought to analyze the physio-chemical quality of different brands of sachet water in the Sunyani municipality. The study adopted a cross-sectional design with questionnaires used to elicit data on selected brands of sachet water. A total of four brands of sachet water were randomly selected by first conducting a market survey on all sachet water companies and most preferred sachet water brands that people preferred to consume within the municipality Sunyani. Data collected was cleaned and samples collected were stored in an ice chest to prevent contamination. Physical and chemical laboratory analyses were performed on the selected samples. Characteristics of the selected factories and the differences among samples for the various parameters were determined using STATA version 14. Three (75%) of the factories selected were located in the premises of a rented apartment and all (100%) the factories were certified by Ghana Standard Authority, (GSA) Food and Drugs Authority (FDA) and Environmental Protection Agency (EPA) of Ghana. Half

(50%) of the factories managed their solid and liquid waste by disposal in a hole. Similarly, fifty percent (50%) of the factories disposed of solid waste in an itinerant waste van. All factories disinfected their production rooms. However, only one (25%) had a schedule for disinfection. All factories were found to have not replaced the Ultra Violet (UV) sterilization since the start of production of close to seven years for the youngest factory, and none of the factories had disinfected the trucks used in distributing water to retailers. All factories were operating using just four (4) out of the eleven (11) standard operating procedures and practices set by Ghana Standard Authority and Food Drugs Authority. However, for all factories, while variations existed, all the physico-chemical properties of the sachet water produced were within the normal limits prescribed by World Health Organisation. (WHO) Microbial content analysis of sachet water from each factory indicated that 3 out of the 4 factories had no faecal coliforms while one factory was found to contain high level of faecal coliforms. In conclusion, all factories were operating below average (4 out of 11) of the standard operating procedures and practices set by Ghana Standard Authority and Food Drugs Authority, even though the physico-chemical properties of sachet water from all the factories were within the normal limits prescribed by World Health Organisation.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

According to Asonye *et al*. (2007), good quality water is necessary for the sustenance of development. Several studies have proven that there is a direct relationship between the quality of drinking water and human health. Onojah, Odin and Ochala (2013) supported that the quality of drinking water is a powerful determinant of health. Therefore, good quality drinking water which is safe gives a firm assurance and foundation for the prevention and control of water-borne diseases. Water is, therefore, an indispensable element to the wellbeing of man (Ugwu *et al*., 2016).

According to Okonko *et al*. (2007), water pollution is a major global problem and it is the leading worldwide cause of deaths and diseases and accounts for the deaths of more than 14,000 people daily. The major cause of water problem in the world has been identified as resulting from rapid urbanization, industrialization and growing population. Many industries, in their production efforts to meet the physical and chemical demands of the urban population, have resulted in massive pollutions which are not properly discharged into the environment and usually affect water bodies, in particular. This situation has been the major cause of the acute water problems in many developing as well as developed countries.

A report by the WHO/UNICEF JMP (2015) indicates that in 2015, about 663 million people worldwide did not have access to adequate and improved water supplies, adding that 319 million (49%) of this number lived in sub-Saharan Africa.

This supports an earlier finding by Uwah *et al.* (2014), who reiterated that in Nigeria, about 80% of all illnesses, as well as over 30% of deaths, are water-related. According to Ugwu and

Wakawa (2012), poor water quality is often as a result of physical and chemical contamination from several sources such as sewage, excreta and domestic wastes, and pollutants from direct defecation and urination into water bodies**.** Again, poor water quality has features of poor clarity, high colour, extreme pH, odour and taste affect. The palatability and general acceptability of sachet water have often resulted in consumer complaints (Akorli, 2012). This situation led to revolution of sachet water production across several African countries.

In Africa, Adeyemi *et al*. (2015) opined that before the introduction of sachet water into the Nigerian market, there were other kinds of drinking water which were packaged in hand-filled polythene bags. However, it became necessary to introduce sachet water because it was less expensive and improved form of drinking water. Again, Ugwu *et al*. (2016) retreated that the rationale behind the popularity of sachet water is its affordability. The affordability aspect of the sachet water business has resulted in an influx of sachet water producers where several of these producers are not able to produce good quality water for the populace. These unhygienic practices have led to griefs and deaths resulting from many water-related diseases in some tropical developing countries, including Ghana. Moreover, concerns have been raised regarding the reliability of the hygienic conditions under which majority of sachet waters are produced.

In Ghana, the need to provide the populace with safe, hygienic and inexpensive drinking water, and to prevent water-related diseases led to the introduction of sachet water in the country (Kwakye-Nuako & Borketey, 2007; Stoler *et al*., 2012). Several years after the introduction of sachet water, the consumption of sachet water has increased massively because concerns have been raised about the safety of pipe borne water. Also, the increased inflow of people into the major shopping areas in the country comes with the need for good drinking water (ObiriDanso *et al*., 2003).

However, in Ghana, there have been grave concerns about the quality of most locally produced sachet water since water for the production of sachet water is mainly from boreholes and hand-dug wells which mostly contain hazardous microbes and anions and, if not properly treated, can cause serious health disorders such as methemoglobinemia, a blood disorder in which an abnormal amount of methemoglobin is produced in the blood of infants (Nkansah *et al*., 2010; Obiri-Danso *et al*., 2003, Orisakwe *et al*., 2007).

To affirm this assertion, Abdul *et al*. (2014) conducted a survey of selected sachet water samples in the Kumasi metropolises and observed that majority of sachet water produced in Kumasi fall within the Ghana and WHO standards for drinking water. Nonetheless, a few selected sachet water samples were identified to have failed bacteriological tests. This implies that some of the sachet water producing companies adopt poor water treatment practices and, therefore, make them unwholesome and harmful to consumers.

1.2 Statement of the Problem

Over the years, the production, marketing and consumption of sachet water have increased in Ghana. Sachet water, popularly known as pure water, is available in several brands and marketed across various cities, towns and villages in Ghana at affordable prices. Nevertheless, there are grave concerns over the purity, hygienics, as well as the health and safety process involved in the production of sachet water.

According to Akorli (2012), there are numerous concerns over the hygienic conditions of places majority of water sachets are produced in Ghana. For instance, in Accra, a study conducted by Kwakye-Nuako *et al*. (2007) on the quality of some selected brands of sachet water observed the presence of faecal and zoonotic contaminants in some of the sachet water examined. They noticed a few causes of the low quality of the sachet water, for example, inappropriate preparing and sanitization methods, unhygienic handling of water after filtration, the little size of the pathogens which empowers them to escape filtration and the resistance of these pathogens to physical water treatment agents and disinfectants. This affirms that both physical and chemical contaminants have the propensity of affecting the quality of sachet water and their subsequent detrimental effects on the health of consumers (Kwakye-Nuako *et al*., 2007).

Similarly, the Food and Drugs Authority (FDA) which is the mandatory body established to ensure that sachet water is produced under specified standard operating procedures detected flaws in the operations of some sachet producing companies in the Sekondi-Takoradi Metropolis. The FDA, during an inspection of sachet water producing companies in the metropolis, observed a situation where a frog was found dead in one of the polytanks used in storing water for manufacturing sachet water (GNA, 2015).

This evidence as well as some other anecdotal evidence suggests that majority of sachet water produced in Ghana are of poor quality and are possible carriers of protozoan parasites, although the FDA has stated severally that sachet water produced in many cities in Ghana are of good quality (GNA, 2015).

This situation raises eyebrows over the quality of sachet water and gives alarming concerns over the standards and hygienic conditions under which sachet water is produced. It is in the light of this that this research seeks to determine the nature of sachet water by doing a physico-chemical investigation to find out whether distinctive brands of sachet water conform to the recommended standards for consumable water properties set by the WHO and the FDA in Ghana.

1.3 Significance of the Study

The outcome of this study will be of immense benefits in the following ways. Firstly, the outcome of the study will be of enormous benefit to many sachet water producers to know the quality of sachet water produced in the Sunyani Municipality and if need be improve on the quality. Secondly, the findings of this research will help consumers of sachet water and the community as a whole to know how the quality of sachet water affects their health. Also, the outcome of the study will serve as a benchmark and springboard to the research community such as the universities, research and laboratory centers to conduct further in-depth physico-chemical and bacteriological analyses of sachet water and other bottle water produced in Ghana.

Finally, the findings of the study would help policy makers such as the Ghana Standard Board (GSB), Environmental Protection Agency (EPA), the Food and Drugs Authority (FDA), Ministry of Works and Water Resources, the Ministry of Health (MoH) and other Non-Governmental Organizations (NGOs) to develop and implement policies and measures to regulate and monitor the activities of manufacturers of sachet water to ensure that they produce under hygienic conditions that are in line with the FDA and WHO standards.

1.4 Conceptual Framework

In order to make a consistent investigation of the impacts of quality of sachet water on consumer wellbeing, it is very essential to develop a clear analytical framework that can help draw the relationship between the various components involved in the production and quality of sachet water. This conceptual framework was developed to evaluate the effects of physico-chemical properties of different brands of sachet water on the quality and effects of sachet water on consumer health in the Sunyani municipality. This framework links the independent variables (physical and chemical properties, factory location and hygiene conditions) to the dependent variable (quality of sachet water).

In this conceptual framework, the physical properties of sachet water include the appearance, colour, odour, temperature, pH, turbidity, electrical conductivity, and major ions (sodium, potassium and total iron). The chemical properties of sachet water also include the pH, hardness, and other chemical elements such as carbon (IV) oxide, nitrate, nitrite, total dissolved solid and ammonium. The factory location assesses the various sources where the companies obtained their water for the manufacturing of sachet water such as springs, rivers, ground water, reservoirs, boreholes and natural lakes. The hygienic conditions include the various packaging, storage and handling processes. Therefore, to investigate the effects of the quality of sachet water on the health of consumers, the various independent variables must be critically analysed.

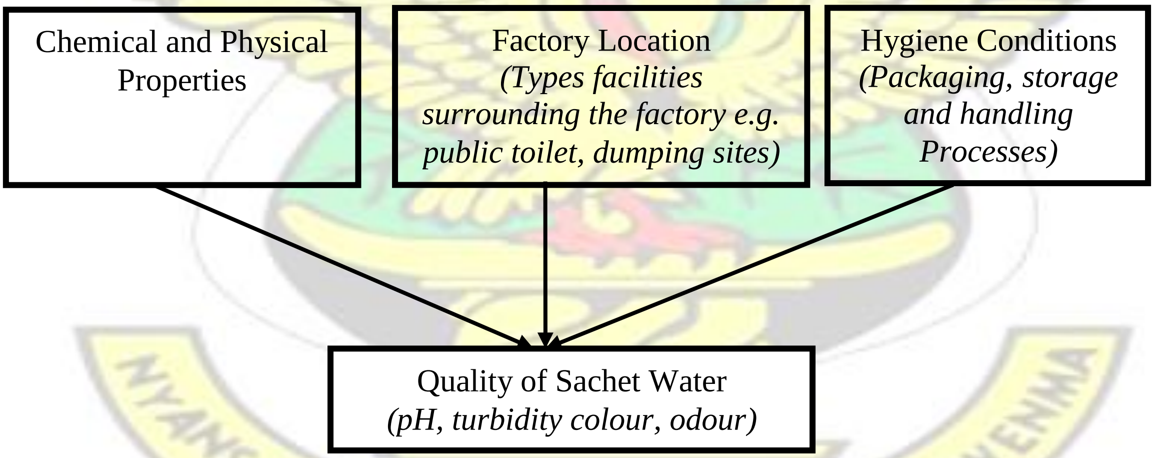

Figure 1: Conceptual Framework

Source: Authors’ construct (2018)

1.5 Research Questions

1. What are the physico-chemical properties at the factory of various brands of sache t water in the Sunyani Municipality?

2. What is the relationship between factory location of sachet water and the physicochemical properties in the Sunyani Municipality?
3. What are the hygiene conditions under which sachet water is packaged and handle d in the Sunyani Municipality?

1.6 General Objective of the Study

The general objective of this study was to analyse the physico-chemical quality of different brands of sachet water in the Sunyani Municipality.

1.7 Specific Objectives

The study is guided by these specific objectives:

1. To determine the physico-chemical properties of various brands of sachet water;
2. To examine the relationship between various sachet water factory location variabl es and physico-chemical properties;
3. To assess the hygiene of sachet water packaging and handling.

1.8 Scope of the Study

Geographically, this study has focus on sachet water producers within the Sunyani Municipality. In terms of content, the study has focus on the subject matter of sachet water, quality of water, and others related to the objective of the study.

1.9 Organisation of the Study

The study has been organized into six (6) chapters. Chapter One gives a general introduction of the study. Chapter Two will deal with aspects of the study relating to the literature review concerning the study. This chapter will discuss key conceptual and theoretical aspects of the subject matter. Chapter Three is the research methodology which includes the study area, types and source of data, method of data collection, sampling method, sampling size justification and data analysis. Chapter Four will involve presentation of data results. Chapter Five will form the discussions of the results obtained. Chapter Six looks at the summary of findings, conclusion and policy recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter represents the review of relevant secondary information related to the subject matter. It makes an in-depth discussion of the theoretical and conceptual framework on the subject matter. It also highlights the empirical evidence of researches and developments related to the subject.

2.2 Conceptual Framework

2.2.1 Concept of Drinking Water and Sachet Water

According to Gore (1993), the composition of water in the universe is almost equal to the same composition of water in human beings. Water, therefore, constitutes a significant percentage of our daily food intake, since human bodies do not have reserve supply, and because it is naturally abundant, it is considered a universal solvent (Nwosu & Ogueke, 2004). Water covers about 75% of the earth surface and is abundant in nature, making it an important part of the earthly environment (Ikeme *et al*., 2012). Drinking water quality has often been adulterated owing to several anthropogenic factors which render it unfit for drinking. Asonye *et al.* (2007) emphasized that good quality water is necessary for the sustenance of human and animal development.

In view of this, Ezeugwunne *et al.* (2009) expressed that for water to have good quality, it must be odourless, colourless, tasteless, and free from faecal pollution. Several scientific studies have proved that there is a direct relationship between the quality of drinking water and human health. Onojah *et al*. (2013) supported that the quality of drinking water is a powerful guarantee of health.

Therefore, good quality drinking water which is safe is needed for the avoidance and control of water-related infections. Water is, therefore, an indispensable element to the health of man (Ugwu *et al*., 2016) and the most important and valuable natural resource which constitutes the major component of the ecosystem (Olowe *et al*., 2016).

2.2.2 Importance of Quality Drinking Water

According to Lamikanra (1999), good quality water is critical to the physiology of man, whose life is contingent on the availability of water. Good quality water is, therefore, indispensable for the sustenance of growth in every part of human society (UNCSD, 2000). Additionally, Erah *et al*. (2002) opined that water is an essential natural resource since it is unthinkable for life to exist without it and most manufacturing industries cannot work in its nonexistence. A basic pre-requisite for the formation of a stable community is the availability of safe and reliable sources of water.

This means that good quality water helps to maintain life and is necessary for the sustenance of the human development (Asonye *et al*., 2007).

Similarly, Tyagi *et al*. (2013) discovered that water is essential to the existence of life and various sectors of the economy (for example, agriculture, livestock production, forestry, industrial power generation, fisheries and other creative activities). The use of water for drinking purposes is perhaps the most essential usage that should be given adequate attention because this may directly affect the health and well-being of human beings (Odiongenyi1 & Enengedi, 2015). Ugwu *et al*. (2016), therefore, concluded that water has been found indispensable to the wellbeing of man and that explains the saying that water is life.

On the other hand, Mansour *et al.* (2002) argued that globally, many people, especially those living in developing countries, have challenges with the accessibility of safe drinking water. In many developing countries, access to quality drinking water is challenged by the affordability and reliability of quality standard water (Dada, 2009).

The WHO/UNICEF JMP (2015) identified that there are around six hundred and sixty-three million people living without access to adequate water supplies. Three hundred and nineteen million (49%) of this people live in sub-Saharan Africa. As a result of this inability to access and afford quality drinking water, sachet water was introduced to give safe drinking water to the general public and to control the magnitude of water-related diseases in the communities (Fajobi & Shittu, 2008).

2.2.3 Sources of Drinking Water

Flusche *et al*. (2005) identify sources from which water can be obtained, for example, streams, lakes, rivers, ponds, springs and wells. Generally, water can be sourced from rain and surface or ground water (Balan *et al*., 2012). Compared to surface water, ground water is widely used for domestic, industrial and agricultural purposes since it is available and is of better chemical and microbial quality (Grönwall *et al.,* 2010).

Again, Taiwo *et al*. (2012) also mentioned that water can be sourced from natural lakes, rivers, springs, boreholes and reservoirs. Balan *et al*. (2012) also mentioned that water that is sourced from ground water is of higher quality, compared to surface water due to the effective filtration. However, Taiwo *et al*. (2012) argued that as water passes through the ground, it dissolves some minerals in rocks, suspended particles, and pathogenic microorganisms from faecal matters rendering it unsafe for drinking.

Substantiating this argument, Hudson-Edward *et al*. (2003) supported that the purity of water can contaminate through a number of human activities (resulting in industrial and atmospheric pollution) and agricultural run-offs and leaching. Also, Boah *et al*. (2015), through a study on water quality determination, supported that water from most ground sources, without some sort of treatment, is unsafe for human consumption. This affirms that most sachet water that is produced from ground water as is the case in Ghana is deemed not healthy for consumption. For example, Dodoo *et al*. (2006), through a study on the quality of sachet water produced in the Cape Coast Metropolis found and concluded that most sachet water quality in Ghana is poor. However, this is not the case, as some producers of sachet water have argued that they adequately treat water from ground water sources (boles) before packaging them for public consumption.

Additionally, Singh (2015) observed through a study that the quality of water sources deteriorates as a result of point source and non-point source pollution. Point source pollution comprises industrial wastes and discharges from municipal waste water treatment plant while non-point source pollution includes agricultural run-off, seepage of septic tank effluents into ground water, indiscriminate dumping of wastes into streams and rivers, among others.

2.2.4 Sachet Water Production

According to Nwaka *et al.* (2017), sachet water is commercially treated and packaged water which is distributed for sale, usually in 60 centiliter (cl) sachet or in plastic containers of 60 cl, 75 cl and 1.5 Litre (L) respectively, intended for human consumption. Sachet water was actually introduced to provide to the public water that is hygienic for consumption, and to prevent water-related diseases in communities (Fajobi & Shittu, 2008).

The sale and consumption of bottled and sachet drinking water continue to grow rapidly in most African countries, including Nigeria, because most urban areas do not have adequate reliable and safe municipal water (Oyedeji *et al*., 2010). There is tremendous growth in the production of sachet water, especially among the poor and middle social classes in Nigeria (Omalu *et al*., 2012).

In Nigeria, Adeyemi *et al*. (2015) opined that sachet water was brought into the market as a more affordable means of accessing drinking water and improvement over the former types of drinking water packaged for sale in hand-filled and hand-tied polythene bags. Again, Ugwu *et al*. (2016) retreated that the rationale behind the popularity of sachet water is its affordability. The affordability aspect of the sachet water business has resulted in an influx of sachet water producers, where several of these producers are not able to produce good quality water for the populace.

In Ghana, the introduction of sachet water in the country was to provide safe, clean and affordable instant drinking water to the people, in general, and to check the magnitude of water-related diseases in the nation (Kwakye-Nuako & Borketey, 2007;

Stoler *et al*., 2012). Quite a while after the introduction of sachet water**,** there have been enormous increase in the utilization of sachet water, because of factors such as increased concerns about the safety of piped water supply, and an increased influx of individuals into the significant shopping areas with a prerequisite for good drinking water (Obiri-Danso *et al*., 2003).

2.2.5 Manufacturing Location and Hygiene Conditions of Sachet Water Production

Sachet water production in Africa is usually done from borehole water which are purified (and treated before bottling) and sealed. These manufacturing processes have raised a lot of concerns about the quality of most sachet water produced in Africa.

According to the Consumer Affairs Movement of Nigeria (CAMON), concerns have been raised regarding the purity of sachet water production, with emphasis on the integrity of the hygienic conditions of environments where the majority of sachet water are produced (CAMON, 2007). In Nigeria, for instance, Adeyemi *et al*. (2012) observed that generally, most sachet and bottled water are manufactured from local municipal pipe borne water and that several manufacturers use questionable hygiene conditions in various stages of production. In most cases, the major source of water for the production of sachet water is borehole water connected to tap (Nwaka *et al*., 2017).

In Ghana, sachet water is usually produced using water obtained from boreholes and hand-dug wells which mostly contain hazardous microbes and anions and, if not properly treated, can cause serious health disorders such as methemoglobinemia, a blood disorder in which an abnormal amount of methemoglobin produced in the blood of infants (Nkansah *et al*., 2010; Obiri-Danso *et al*., 2003; Orisakwe *et al*., 2007). Additionally, a study conducted by Abdul *et al.* (2014) on selected sachet water samples in the Kumasi Metropolis indicates that majority of sachet water produced in Kumasi fall within the Ghana and WHO standards for drinking water. Nonetheless, a few selected sachet water samples were identified to have failed bacteriological tests.

Again, the FDA, during an inspection of sachet water producing companies in the Sekondi-Takoradi Metropolis, observed a situation where a frog was found dead in one of the polytanks used in storing water for manufacturing sachet water (GNA, 2015). This evidence as well as some other undocumented ones indicates and suggests that majority of sachet water produced in Ghana is produced under poor manufacturing processes, although the FDA has stated severally that sachet water produced in many cities in Ghana are of good quality. This situation raises eyebrows over the quality of sachet water and gives alarming concerns over the standards and hygienic conditions under which sachet water is produced.

Again, concerns have been raised with regards to the appropriateness or the otherwise of the hygienic conditions under which majority of sachet water are produced. The hygienic conditions involve all the manufacturing and distribution processes of handling sachet water, such as packaging, storage, retailing and selling or vendor to the final consumer. According to Omalu *et al*., (2012), improper vendor handling is another factor that poses threats to the health of the ignorant consumers. In many tropical developing countries, including Ghana, these unhygienic practices have led to a number of griefs and deaths resulting from infections and water-related diseases. These findings imply that some of the sachet water producing companies do not adopt appropriate water treatment practices and mechanisms and, therefore, make sachet water unsafe, unwholesome and harmful to consumers.

2.3 Assessment of Water Quality

According to Chapman (1996), water quality is the chemical, physical or biological characteristics by which the user evaluates the acceptability of water. One can assess water quality by examining its physiochemical parameters, organoleptic properties, gross organic parameters, radionuclides, heavy metals and bacteriological parameters (Ademoroti, 1993; Eddy, 2004; Leton & Nkwueke, 2005).

Similarly, Ubalua and Ezeronye (2005) observed that water quality can be assessed generally by examining the physico-chemical parameters, and organic and inorganic compounds that are dissolved or suspended in it. For instance, in most cases, the solubility of trace and heavy metals is determined by the pH value of water.
In this regard, at low pH, trace metals are likely to dissolve more (Muhammad *et al.*, 2007). Water assessment, therefore, come in three categories: physical, chemical and microbiological. Heavy metals, trace organic compounds, total suspended solids (TSS), and turbidity come under physical and chemical parameters (Krishnan, 2008).

Additionally, Tyagi *et al*. (2013) explained that using physical, chemical and microbiological parameters, one can assess the quality of water in any specific area or source. According to Odiongenyi *et al*. (2015), most studies have mentioned that water quality is assessed in terms of its physicochemical parameters and heavy metal content. In attempt to assess the quality of water, various methods and techniques have been adopted by different authors. Singh (2015) indicates that the term Water Quality Index (WQI) is one of the means used to effectively communicate information on water quality. This is a globally accepted index used to assess the physical and chemical quality of water to determine whether a particular water and its source are safe for drinking.

Ramakrishnaiah *et al*. (2009) defined WQI as a rating reflecting the composite influence of different water quality parameters. Based on several quality parameters, WQI gives a single number expressing the overall water quality at a certain location and time. This method which employs a mathematical method in calculating the quality of water in a single value from numerous test results was first developed in 1965 by Horton (Tyagi *et al*., 2013). Years after, several researchers such as Rao *et al*. (2010), Balan *et al.* (2012) and Chowdhury *et al*. (2012) have used the WQI method in assessing and classifying the quality and purity of water.

Moreover, Chaturvedi and Bassin (2010) assert that several national and international organisations have formulated a huge number of WQIs which have been used to evaluate water quality in a particular area. These WQIs include National Sanitation Foundation Water Quality Index (NSFWQI), Weighted Arithmetic Water Quality Index (WAWQI), Oregon Water Quality Index (OWQI), and Canadian Council of Minister of the Environment Water Quality Index (CCMEWQI).

2.4 Physical and Chemical Properties of Sachet Water

Brass (2000) argued that potable water must conform to certain physical, chemical and microbiological standards designed to guarantee that water is pleasant and safe for consumption. The World Health Organisation (WHO) has standardized parameters which are used in assessing the quality of water. These physio-chemical parameters include pH, Temperature, Electrical conductivity (EC), Turbidity, Colour, Total dissolved solid (TDS), Dissolved oxygen (DO), Biochemical Oxygen demand (BOD), Total suspended solid (TSS), Chlorine, Sodium (Na), Iron (Fe), Magnesium (Mg), Calcium (Ca) and Potassium.

Balan *et al*. (2012) assert that these parameters selection are considered to have a significant effect on the quality of water, taking into consideration the five characteristics of water: oxygen level, eutrophication, physical characteristics, health aspects and dissolved substances. This study has adopted these parameters to assess the various variables that affect the physical and chemical characteristics of the quality of sachet water in the Sunyani Municpality.

2. 4. 1 Assessing the Physical Properties of Sachet Water

The physical properties of sachet water include electrical conductivity, turbidity, taste, odour, solids (both dissolved and suspended solid), colour and temperature. Anduang *et al.* (2015) identified physical parameters as including appearance, colour, odour, temperature, pH, turbidity and electrical conductivity, as well as major ions (sodium, potassium and total iron).

Electrical Conductivity**:** According to Lind (1959), measured quantitatively, electrical conductivity refers to the ability of water to conduct electricity. It is also a measure of the total dissolved solid (TDS) or salinity. In the same vein, Anduang *et al.* (2015) defined electrical conductivity of water as a measure of its capacity to conduct electric current which is determined by the concentration of dissolved organic salts or ions. Electrical conductivity is subjected to influence by dissolved salts such as potassium chloride and sodium chloride which produce ions that migrate in solution to generate electric current. It also indicates whether water is saline or fresh.

Turbidity**:** Turbidity, on the other hand, refers to the loss of transparency of a solution. According to Putz (2003), turbidity is the reduction of transparency resulting from the presence of substances like clay or silt, plankton or other microscopic organisms or finely divided organic matter. Turbidity in water refers to the degree of its cloudiness which is caused by the presence of suspended particles (Anduang *et al*., 2015). Water becomes cloudy as a result of the presence of colloidal solid which reduces the transparency of water.

Odour: Another physical characteristic of water is taste and odour, which are usually affected when impurities are dissolved in water.

Total Dissolved and Suspended Solids: According to APHA (as cited in Taiwo *et al*., 2012), Total Dissolved Solids (TDS) are as a result of soluble materials. Again, solids include total dissolved and suspended solids and are discrete particles that can be measured by filtering the sample appropriately. According to ASTM (2004), hardness, turbidity, odour, taste, colour and alkalinity of water result from high concentration of dissolved solid in water. When there is an increase in suspended solids in water, the likelihood of the water being polluted also increases. It also accounts for odour and colour of water (Golterman, 1978). Water with high dissolved solid is generally of inferior quality and may induce an unfavorable physiological reaction in the transient consumer (Ikeme *et al*., 2014).

The maximum permissible concentration of TDS in drinkable water is 500mg/L. The amount of these solids is influenced by factors, for example, the type of filter (paper or sintered glass used), the pore size, the physical nature and the size of the particles (APHA, 1985; ASTM, 2004). The materials deposited on the filter are the main factors affecting separation of suspended solid from dissolved solid. TDS is another variable that affects the physical quality of water. Normally expressed in Mg/L, TDS is the portion of total dissolved solids that pass through the filter (APHA, 1985). Last but not least is colour, which is assessed by how transparent and clear water should be and this is expressed in Hazen units corresponding to the colouration of a series of platinum/cobalt. Finally, the temperature of water is impact temperature of temperature on the other properties of water such as the changing solubility of gases. The aesthetic value of the drinking water is affected by physical parameters, which might complicate the removal of microbial pathogens.

2.4.2 Assessing the Chemical Properties of Sachet Water

The chemical properties of sachet water include pH, hardness, and other chemical elements such as carbon (IV) oxide, nitrate, nitrite, total dissolved solid and ammonium. Anduang *et al*. (2015) identified the chemical parameters of water to include total alkalinity, phenolphthalein alkalinity, methyl orange alkalinity, chloride, total hardness, dissolved oxygen, carbon (IV) oxide, nitrate, nitrite, total dissolved solid and ammonium.

pH: According to Edward (as cited in Olowe *et al.*, 2015), the pH refers to the concentration of hydrogen ion present. pH measures the degree of acidity or alkalinity of the sample of water. It is normally expressed on a scale of 0-14 where 7 is neutral, below 7 is acidic and above 7 is basic.

Practically, every stage of water treatment (for example, softening, precipitation, coagulation, disinfection and corrosion) is depends on pH. The pH value of natural water ranges from 4 to 9 and most natural water are slightly basic as a result of the presence of bicarbonate and carbonates of alkali and alkaline earth metals (ALPHA, 1985). For instance, the solubility of trace and heavy metals are determined by pH value of water, such trace metals tend to dissolve more in water with low pH (Muhammad *et al.*, 2007). Therefore, it is very important to assess the pH of sachet water because pH significantly affects the chemical features of sachet water, including its ability in softening. Sachet water without the required pH will have low quality and this has detrimental effects on the health of consumers.

Hardness: The next chemical property of water is hardness. This phenomenon is seen in the inability of soap to easily lather with water, leading to the production of scales in pipes and boilers/kettles. With this, scales are produced in pipes and boilers/kettles. According to ALPHA (1999), hardness of water results from the presence of metallic salt (ion) of Calcium, Magnesium and, sometimes, Fe. Usually, these salts come in the form of bicarbonates, sulphates and chlorides. Water hardness could be temporary or permanent, with temporary hardness resulting from the presence of dissolved calcium and magnesium bicarbonates. Temporary hardness can be removed by boiling. On the other hand, permanent hardness is caused by sulphate and chloride of calcium and magnesium. Though permanent hardness of water cannot be removed by boing, it can be removed by the addition of sodium carbonate or by ion exchange methods. Water hardness is usually expressed as mgl-1CaCO3.

Other Chemical Elements: These elements include Dissolved Oxygen, Biological oxygen demand, Chemical oxygen demand (COD), and Alkalinity. According to Ikeme *et al.* (2014) Dissolved Oxygen (DO) refers to a measure of the oxygen content in water. Oxygen is needed by different life forms in water to survive. While waters with low dissolved oxygen content have an unpleasant smell, waters that are high in dissolved oxygen are good for consumption. Biological oxygen demand (BOD) and Chemical oxygen demand (COD) are other major elements that have an impact on the quality of water. BOD is the amount of oxygen used by microorganism per unit volume of water at a given time whilst Chemical oxygen demand (COD) is the amount of oxygen needed to oxidize the oxidizable compound of waste water. The elements nitrogen and chlorine, when present in water, also affect its quality. Nitrogen is a very important element and its presence is required before all biological reactions could begin. Thus, the quality of water samples can be determined using the concentration of nitrogen. The chloride content in water is also necessary for water quality analysis. Alkalinity is one of the major elements assessed for water quality in the chemical assessment procedure. Alkalinity is the presence of hydroxides, carbonate and bicarbonate in natural water. Alkalinity is defined by Ademorati (1996) as a measure of the ability of water samples to neutralize strong acids to an arbitrary pH or an indicator end-point.

2.5 Effects of Physical and Chemical Properties of Sachet Water on Consumers Health

Good quality water which is accessible is required for the wellbeing of humans. The primary purpose of good quality water is to avoid the potential health hazards associated with contaminated drinking water, such as water-borne diseases cholera, diarrhoea, hepatitis, dysentery. Researchers have shown that the intake of water obtained from polluted water sources is likely to cause water or chemical related diseases. For instance, the chemical parameters of drinking water tend to pose chronic health risks such as liver and kidney damage, cancer, damage to the immune system, disorders of the nervous system, and birth defects (Zaslow & Glenda, 1996).

Again, Hutton (as cited in Ikeme, 2014) mentioned that some ions, when introduced into water bodies, may combine with other compounds to form insoluble compounds which can cause serious harm when introduced into the body system. Proving this assertion, Anduang *et al.* (2015) stated that there are numerous reported cases of different types of sicknesses associated with the consumption of polluted water that have led to the outbreak of cholera, typhoid, diarrhoea, hepatitis, dysentery, etc. (Levin, 1977; Mitchell, 1972; Sykes & Skinner, 1971).

In Ghana, researchers such as Nkansah *et al*. (2010), Obiri-Danso *et al.* (2003) and Orisakwe *et al.* (2007) have all noticed that water obtained from boreholes and hand-dug wells mostly contain hazardous microbes and anions have caused serious health disorders such as methemoglobinemia. Anduang *et al*. (2015), therefore, concluded that water is essentially for drinking purposes and that inadequate attention to the treatment of water can directly affect the health and wellbeing of human beings.

2.6 Regulatory Bodies of Quality of Sachet Water

According to Anunobi *et al*. (2006), so as to safeguard public health, it is very important to ensure, through comprehensive regulatory programs at both federal and state levels, that accessible water (such as lagoon, borehole, bottled and sachet water) is of highest quality standards. In view of this, the WHO is the global regulatory body of water quality. In Africa, most nations have bodies or institutions that regulate and control the quality of water including sachet water. Sachet water production is mainly done in the sub-Sahara regions of Africa, with Nigeria and Ghana being the leading producers of sachet water. In Nigeria, the Nigerian Industrial Standard (NIS) and the Nigerian regulatory agency called the National Agency for Food, Drug Administration and Control (NAFDAC) are the key institutions that have the responsibility to assess the quality of drinking water.

In Ghana, the Standard Board Authority (SB) and the Food and Drugs Authority (FDA), are the mandatory bodies established to ensure that sachet water is produced under specified standard operating procedures. Despite the tedious efforts of the FDA in ensuring that sachet water are produced under hygienic conditions that meet WHO standards, there are still evidences of poor water quality among some sachet water produced in Ghana. For instance, the FDA, during an inspection of sachet water producing companies in the Takoradi Metropolis, observed a situation where a frog was found dead in one of the polytanks used in storing water for manufacturing sachet water (GNA, 2015). This evidence as well as some other undocumented ones indicates and suggests that majority of sachet water produced in Ghana are of poor quality and are possible carriers of protozoan parasites, although the FDA has stated severally that sachet water produced in many cities in Ghana are of good quality. This situation raises eyebrows over the quality of sachet water and gives alarming concerns over the standards and hygienic conditions under which sachet water is produced.

2.7 Empirical Evidence

First of all, Taiwo *et al*. (2012), using twenty-six (26) sachet water samples bought from different wholesale depots, conducted a research to analyse the physicochemical and bacterialogical characteristics of sachet water samples in Abeokuta Metropolis. The purpose of the study was to ascertain the wholesomeness of the water samples studied. The results indicated a pH range of 6.00-7.87 for all samples, Total Solids (TS) of 25.00mg/L -187.5mg/L, Total Dissolved Solids (TDS) between 26.20mg/L- 122.20mg/L, Acidity between 0.10-0.80mg/L, Total hardness of 2.00mg/L-43.00mg/L and Conductivity of 35.00µS/cm -257.00µS/cm. Majority (96.15%) of the samples had acceptable World Health Organisation values of less than 10CFU/ml while all of the samples had acceptable Coliform or Escharichia coli values of less than 10CFU/ml (WHO, 1999). The findings suggested the existence of an effective quality control system and a high level of sanitation in all the production depots studied.

Secondly, Omalu *et al*. (2012) conducted a research to analyse the bacteriological and physico-chemical properties of sachet water in North Central Nigeria. The data for the study comprised fifteen water samples of five brands of sachet water labelled A, B, C, D and E obtained in Minna Metropolis. The physicochemical parameters were determined using standard methods. The values of physicochemical properties fell below WHO standards for drinking water except manganese whose values exceed the maximum permitted limit for water quality of the standard organization of Nigeria (SON). However, the study discovered that bacteria was present in some of the selected sachet water. The presence of such bacteria in the water was attributed to the fact that processing, purification and handling procedures in such water producing companies were inappropriate and unhygienic.

In Ghana, Kwakye-Nuako *et al.* (2007) investigates the quality of some selected brands of sachet water in Accra. Their findings indicated that there were contaminants of faecal and zoonotic origin present in some of the sachet water. The study also revealed that several factors (for example, improper processing and purification procedures, unhygienic handling after production, the small size of the pathogens which helps them to escape filtration and the resistance of these pathogens to physical water treatment agents) account for the poor quality of the sachet water.

Similarly, Abdul *et al.* (2014) conducted a survey of selected sachet water samples in the Kumasi Metropolises and noticed that majority of sachet water produced in Kumasi fall within the Ghana and WHO standards for drinking water. However, a few selected sachet water samples were identified to have failed bacteriological tests. This implies that some of the sachet water producing companies adopt poor water treatment practices and, therefore, make them unwholesome and harmful to consumers. These outcomes affirm that the water quality of some sachet water brands in Ghana is questionable and this can have detrimental effects on the health of consumers.

CHAPTER THREE
MATERIALS AND METHODS

3.0 Introduction

This section of the research presents the various methods, techniques, tools and procedures used in gathering both primary and secondary data for analysis. The chapter also explains the background of study area, research design, population, research variables, sampling technique and sample size of the study, data collection instruments, and data analysis method. The ethical considerations and institutional framework concerning the study are also discussed in this chapter.

3.1 Research Design

The study was a cross-sectional design with quantitative method approach to data collection in Sunyani Municipality in the Brong-Ahafo Region. The study employed different methods, including observing the environment of the factory site, how drivers and "driver mate" of water trucks offload packs of sachet water to retailers and how retailers also handle them during sales to individuals in order to validate data collection to ensure accuracy. The main data that were collected were the demographic characteristics and the knowledge of respondents on handling of sachet water.

3.2 Study Area

The study was conducted at four different manufacturing sites, four different moving trucks that offload packs of sachet water at retail vender points and four different single sachets from a head potter selling to the general public at Sunyani Municipality of the Brong Ahafo Region. The region is located between Latitudes 70 20'N and 70 05'N and Longitudes 20 30'W and 2010'W. It also shares boundaries with Sunyani West District to the North, Dormaa District to the West, Asutifi District to the South and Tano North District to the East (SMA, 2010).

The area falls inside the wet Semi-Equatorial Climatic Zone of Ghana. The mean monthly temperatures fluctuate somewhere in the range of 23ºC and 33ºC, with the most reduced around August and the most elevated being seen around March and April. The relative humidity is high, averaging somewhere in the range of 75 and 80 percent amid the stormy seasons and 70 and 80 percent amid the dry seasons of the year, which is perfect for luxurious vegetative growth. Sunyani experiences twofold maximum rainfall patterns. The main rainy season is between March and September while the minor one is between October to December.

Sunyani is located in the middle belt of Ghana, with Heights from 750 feet (229 meters) to 1235 feet (376 meters) above sea level. The area has a fairly flat landscape, and this makes it suitable for large scale agricultural activities. The drainage is fundamentally dendritic, with a few streams and waterways, notably Tano, Amoma, Kankam, Benu, Yaya and Bisi.

Generally, Sunyani falls inside the Moist-Semi Deciduous Forest Vegetation Zone. The vast majority of the primary vegetation, including the Yaya and the Amoma backwoods reserves, can be found in patches around the north-west, east and southern parts of the area.

3.3 Population Size and Growth Rate

As indicated by 2010 Population and Housing Census, the number of inhabitants in the Sunyani Municipality is 123,224, representing 5.3% of the regions entire population. Males represent 49.9% of the entire population and females constitute 50.1%. Over 80% of the population is urban, with the sex ratio being 100.0.

The total age dependency ratio for the municipality is 54.0, with that of males being higher (54.4) than that of females (53.62). Of the population aged 11 years and above, 81,118 (representing 85.9%) are literate and 13,417 representing 14.1% are nonliterate. Seven out of ten individuals (72.3 %) noted that they could read and write both English and Ghanaian languages. 53,269 of the population aged 3 years and older are currently attending school while 46,559 have attended school in the past.

About 62.0% of the population aged 15 years and older are economically active while 38.1% are not. Of the economically active population, employed and unemployed people constitute 93.2 percent and 6.8 percent respectively. While majority (75.4%) of those who are not economically active are students, 10.7% perform household duties and 2.1% are disabled or too sick to work. Six out of ten unemployed are seeking work for the first time. About 25.5% of the employed population are engaged as skilled agricultural, forestry and fishery workers, 28.1% in service and sales, 15.0% in craft and related trade, and 16.2% are engaged as managers, professionals, and technicians (Ghana Statistical Service, 2010).

As high as 34.3% of households in the municipality are into agriculture. Eight out of ten households (72.2 %) in the rural areas are agricultural households while 28.0% of households in the urban localities are engaged in agriculture. Majority of households in the municipal (93.7%) are involved in crop farming. Poultry (chicken) is the dominant animal reared in the area. A number of financial institutions are found in the municipality (Ghana Statistical Service, 2014).

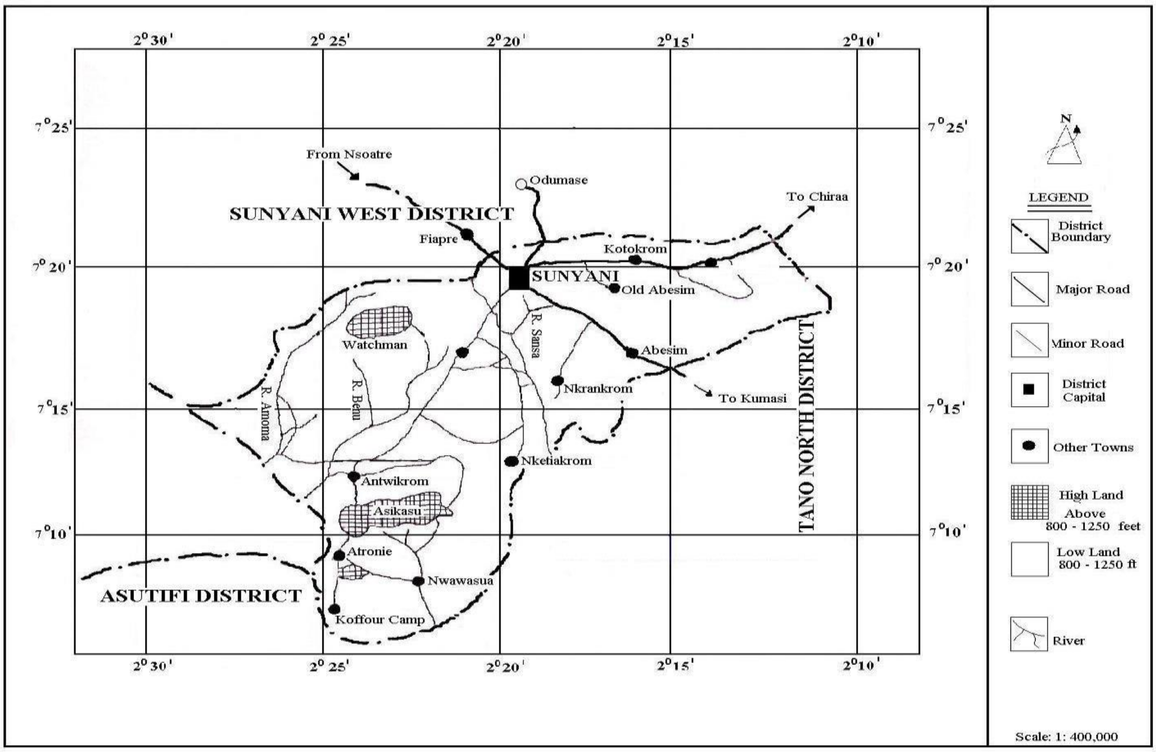

Figure 2: Map of the Sunyani Municipality

Source: Sunyani Municipal Assembly (2010)

3.4 Study Population

The population for this study comprised a total of seven (7) brands of sachet water produced and marketed in the Sunyani Municipality. However, four (4) of these brands were selected based on their weekly volume of production, consumer's perspective and volume of consumption of the various brands within Sunyani Municipality. Meanwhile, any sachet water brand that is not produced but marketed in Sunyani Municipality were not added to the sampling process.

3.5 Inclusion and Exclusion Criteria

All sachet water production companies within the Sunyani East Municipality were included in the study, whereas sachet water producing company outside Sunyani East Municipality were excluded. Also, various companies that have lower production and lower participation of consumers were excluded.

3.6 Sample Collection

Four brands of sachet water were sampled from the total of the seven manufacturing sites. The brands of selected sachet water were the most consumed and coded 1-4. Each of the samples were taken at the site of production, from a transportation medium, and from a retail point. The samples were kept in a sterilized ice chest within a temperature range of 10°C to 15°C (50°F to 59°F) to prevent contamination by any physical, chemical or microbial material. The samples were kept in a sterilized ice chest to aid transportation to the laboratory for analysis.

The pH of various sachet brands was measured on-sit with a Suntex SP-707 portable pH meter. On the same day of sampling, the determination of the physicochemical properties such as anions and other elements component of the sachet water samples was performed. Also, within 24 hours of sampling, test on samples for bacteria was conducted to determine the microbial content of the selected brands of sachet water. In each factory, two caretakers and managers were selected to respond to the questionnaire.

3.7 Data Handling and Analysis

The study performed laboratory analysis on the selected sachet water samples. The four brands of selected sachet water were analyzed for physico-chemical quality. Physical parameters tested were colour, taste, odour, temperature and pH in conformity to the recommended limits by WHO and GSB. Chemical analyses carried out include: conductivity, Total Dissolved Solids (TDS), total hardness, nitrite, nitrate, fluoride, chlorides contents and residual free chlorine. Heavy metals tested include arsenic, zinc, cyanide, copper and manganese to the requirements of WHO and GSB standards. Microbial content analyses include E-coli and faecal coliforms of the four brands of selected sachet water. Socio-demographic characteristics of sachet water production companies, solid and liquid waste management and disposal as well as hygiene practices were analyzed using STATA version 14. The results were then presented in tables into proportions and percentages based on the characteristics of the four selected brands of sachet water in the selected companies.

3.8 Pre-Testing

The questionnaire was pre-tested in Sunyani Municipality with seven respondents so as to test for the validity of the data collection instrument. This enabled the researcher to re-phrase and re-structure unclear and ambiguous questions. The researcher later re-arranged some of the questions to ensure logical ordering and repeated ones were deleted.

3.9 Ethical Considerations

I sought ethical clearance from the committee on human research, publication and ethics. Before the beginning of data collection, permission was sought from the Sunyani Municipal Director and head of facilities. Throughout the study, the policy of voluntary participation was strictly observed. In this regard, using the information sheet, I informed all the participants well about the purpose of the research. Also, the data collected were handled with high confidentiality, and no individual information was kept after data collation. In the same way, as participants decide to participate, all participants were allowed to withdraw from the study anytime if they so desire, and this was clearly indicated on the consent forms that were signed/thumb printed by the respondents. By using pseudo names in the analysis of the data, anonymity of informants was ensured.

CHAPTER FOUR

RESULTS

4.0 Introduction

The purpose of this study was to assess the characteristics of four sachet water production factories, their solid and liquid waste management and disposal, hygiene practices in the factories, physico-chemical and microbiological characteristics of water samples in the factories as well as the standard operating procedure and practices in factories as set by GSB. To achieve these objectives, data were collected from four factories in the Sunyani Municipality and the results of the analysis and interpretation of the data collected are presented below.

4.1 Characteristics of the sachet water production companies

Table 1 presents the characteristics of the sachet water companies. Three (75.0%) of the four factories were located in premises. Boreholes were their main source of water. All the four (100%) factories were operating under the certification of the Ghana Standard Board (GSB), Food and Drugs Authority (FDA), and the Environmental Protection Agency (EPA). Two of the companies have been in operation for at most four years, and the other two companies (50.0%) have operated for four years and above.

All companies were found to use cartridge filtration in the treatment of water and two (50%) said they treat the water used for production at least once every six months and the other two (50.0%) factories only treat water when it is necessary. Two of the factories changed their cartridge used in water filtration at least once in every three months, and the other two companies only change their filtration cartridges only when it is found dirty.

Table 1: Characteristics of sachet water production companies in this study

Variable	Frequency (N = 4)	Percent (%)
Position of respondent caretaker		
	2	50.00
Manager	2	50.00
Original purpose of premises Dwelling apartment for rent	3	75.00
Dwelling apartment turn to factory	1	25.00
Main source of water for production		
Borehole	3	75.00
Pipe borne water	1	25.00
Are you certified by regulatory bodies in Ghana		
Yes	4	100.00
No	0	0.00
How long have you been in business 0-2years		
	1	25.00
3-4years	1	25.00
4years and above	2	50.00
Water treatment process Physical water purification	3	15.79
Sand filtration	3	15.79
Cross flow filtration	2	10.53
Microfiltration	2	10.53
Cartridge filtration	4	21.05
Reverse osmosis	3	15.79
Chemical addition	1	5.26
Disinfection	1	5.26
Frequency of water treatment		
At least once in 6 months	2	50.00
When we think it's necessary	2	50.00
How often do you change the cartridge in water filtration		
At least once in more than 3 months	2	50.00
when it is dirty	2	50.00

Source: Field work, 2018

4.2 Processes Involved in Solid and Liquid Waste Management and Disposal

Table 2 presents the solid and liquid waste management and disposal processes of the four factories. The results show that two (50.0%) of the factories collected their solid waste such as polythene and spoiled sachet into old buckets. All, the factories were found to have disposed their solid waste once in a week.

Two (50.0%) of the factories in this study disposed off solid waste in an itinerant waste van while the other two (50.0%) disposed off solid waste in a hole in the production compound. For three (75.0%) of the factories, the location for solid waste disposal was 5 meters away from the source of water for production while 2(50.0%) of them disposed water from human off about 5 to 25 meters away from the main source of water. Half of the factories disposed water waste on the open ground while the other half did so in a hole near the premises.

Table 2: Solid and liquid waste management and disposal of four sachet water factories.

Variable	Frequency (N = 4)	Percent (%)
In what type of container do you collect solid waste Wastebasket	1	25.00
Old bucket	2	50.00
Plastic bag	1	25.00
How often is the waste container emptied Once a week	4	100.00
Where do you usually dispose of solid waste In the itinerant waste van	2	50.00
In a hole in the production compound	2	50.00
Distance from the water source to the location of waste disposal 5m	3	75.00
Table 2, continued 5m to 25m	1	25.00
Where do you usually dispose of human waste/excreta		
In a hole near the premises	3	75.00
I don't know	1	25.00
Distance from the water source to the location for human waste/excreta disposal		
5 to 25m	2	50.00
25 to 50m	2	50.00
Where do you usually dispose of waste water		
On the ground/free range near the premises	2	50.00
In a hole near the premises	2	50.00

Distance from the water source to the location for human wastewater disposal		
<5m	1	25.00
5 to 25m	2	50.00
25 to 50m	1	25.00

Source: Field work, 2018

4.3 Hygiene Practices in Handling Sachet Water at Factories

Table 3 presents the hygiene practices of the four factories in the handling of sachet water. All the factories indicated that they disinfect the production room in the factories. However, two of the factories only disinfect the production rooms when it is dirty or when it has signs of filthiness. Only one (25.0%) factory had a schedule of disinfecting the floor every three months. All the four factories used protective clothing when treating water (n=4, 100.0%), used an apron as the protective clothing (n=4, 100.0%), and disinfected the protective clothing after use (n=4, 100.0%). Two (50.0%) of the factories used a disinfectant in the disinfection of protective clothing while the other two (50.0%) companies used soap and water. Two (50.0%) of the factories disinfected protective clothing every three months. All the factories stored water in polytanks before production (n=4, 100.0%), send samples of water to laboratories for testing (n=4, 100.0%), and are inspected by regulatory bodies in Ghana (n=4, 100.0%). However, none (n=4, 100.0%) of the factories were found to have not taken samples of water to the laboratories for testing since it was done at the start of production. Two (50.0%) of the factories could not remember how frequent the inspection is done while the other two (50.0%) factories said it is done once in more than six months.

Table 3: Hygiene practices in handling sachet water at four factories in Sunyani

Variable	**Frequency (N = 4)**	**Percent (%)**
Do you disinfect your production floor or room		
Yes	4	100.00
No	0	0.00
How many times do you disinfect the floor or room When it is dirty	2	50.00

Once in three months	1	25.00
I don't know	1	25.00
Do you use protective clothing when treating the water		
Yes	4	100.00
No	0	0.00
What type of protective clothing do you use		
Apron	4	100.00
nose mask	0	0.00
wellington boots	0	0.00
Do you disinfect protective clothing after use		
Yes	4	100.00
No	0	0.00
How is disinfection of use protective clothing done		
Use of disinfectant	2	50.00
Soap and water	2	50.00
How often is disinfection performed		
Table 3, continued		
Ant time it's dirty	1	25.00
Every three months	2	50.00
I don't know	1	25.00
How is water stored before production		
In a polytank	4	100.00
Do you send samples of your water to a laboratory for testing		
Yes	4	100.00
No	0	0.00
How often do you do the laboratory testing		
When we started production	4	0.00
Which laboratory do you send your samples for testing		
Ghana water company	4	100.00
Do regulatory bodies come to your factory for inspection		
Yes	4	100.00
No	0	0.00
How often do they inspect your factory		
Once in more than 6 months	2	50.00
I don't remember	2	50.00

Source: Field work, 2018

4.4 Hygiene Practices in the Packaging of Sachet Water

The hygiene practices of the factories in the packaging of sachet water were assessed and the results are presented in Table 4. Two (50.0%) of the companies reported that four personnel are engaged in the packaging of sachet water while the other two (50.0%) factories engage six people. All the factories had not replaced their

UV sterilization since the start of production (n=4, 100.0%), none of the factories disinfects the trucks that carry the sachet water (n=4, 100.0%), and only one factory covered the packs of sachet water before distribution (n=1, 25.0%). However, the covering of the packs before distribution was done occasionally.

Table 4: Hygiene practices in the packaging of sachet water at four factories

Variable	Frequency (N = 4	Percent (%)
How many people are engaged in water packaging		
Four	2	50
Six	2	50
How often do you replace UV sterilization		
We have not changed since we started production	4	100
Do you disinfect trucks before loading sachet water		
Yes	0	0
No	4	100
Do you cover packs of sachet water before distribution Yes	1	25
No	3	75
How often do you cover the packed water Occasionally	1	100

Source: Field work, 2018

4.5 Retail Point Handling of Sachet Water

Table 5 shows that the retail point of handling sachet water and the production factories directly delivered sachet water packs to all (n=4, 100.0%) the retailers at their shops. Most (n=2, 50.0%) of the retailers stored the sachet water packs in open metal cages and all (n=4, 100.0%) of them used their bare hands when serving sachet water to customers.

Table 5: Retail point handling of sachet water in Sunyani

Variable	Frequency (N = 4)	Percent (%)
Where do you get your sachet water from		
It is delivered by the company	4	100.00
Where do you store sachet water		
On the bare floor	1	25.00

Table 5, continued

On a rack	1	25.00
In an open metal cage	2	50.00
How do handle sachet water when selling		
I use my bare hands to deliver to them	4	100.00

Source: Field work, 2018

4.6 Standard Operation Procedure and Practices in the Four Sachet Water Factories

The standard operating procedure and practices at the sachet water production factories are presented in Table 6. All the factories received water for production from stainless steel pipes (n=4, 100.0%), human inspection and modern equipment were used in all (n=4, 100.0%) the factories to ensure packaging quality assurance and automated cleaning equipment were used in all (n=4, 100.0%) the factories to ensure maximum cleanliness, effectiveness and control. As shown in Table 6, none of the factories was engaged in the other standard operating procedures and practices assessed in this study.

Table 6: Standard operating procedures and practices at sachet water production factories set by GSB and FDA

Variable	**Yes** **N (%)**	**No** **N (%)**
Water received through stainless steel pipes and quality testing of the original source is conducted	4(100.0)	0(0.00)
A water softener is used to reduce water hardness.	0(0.00)	4(100.00)
Demineralisation removes unwanted minerals (through reverse osmosis or distillation).	4(100.00)	0(0.00)
Water received in storage tanks is monitored on a daily basis.	0(0.00)	4(100.00)
Selected minerals are added to cater for consumer taste preferences.	0(0.00)	4(100.00)
Table 6, continued		
Pharmaceutical grade micro-filtration removes particles as small as 0.2 microns and microbiological contaminants.	0(0.00)	4(100.00)
Ultra-violet filtration provides additional product disinfection. This is monitored on an hourly basis.	0(0.00)	4(100.00)
Ozone disinfection is the third disinfection step (steps 7-9), using a highly reactive form of oxygen. This is monitored on an hourly basis.	0(0.00)	4(100.00)

The filling room is highly sanitary to ensure bottling is conducted in a microbiologically controlled environment. It is continuously monitored and controlled.	0(0.00)	4(100.00)
Packaging quality assurance is conducted by human inspection and the latest in modern equipment designed to ensure the removal of any packaging defects.	4(100.0)	0(0.00)
Line sanitation includes automated cleaning equipment to ensure maximum cleanliness, effectiveness, and control.	4(100.0)	0(0.00)

Source: Field work, 2018

4. 7 Physico-chemical Properties of Sachet Water

Table 7 illustrates the physico-chemical parameters of sachet water at the level of the factory, in the truck for distribution and at vendor shops from four sachet water production factories. For comparison, standard values as recommended by the World Health Organization (WHO) are presented in Table 7. It was observed that the pH of sachet water from all the four factories at the various points ranged between 6.6 to 6.8, residual free chlorine was 0.0, colour ranged between 3.0-5.0 pt.co, and turbidity of the water at the various points ranged between 0.09 to 1.0 FTU. Although there were variations at the various points, the parameters were all within the normal limits prescribed by WHO. From the table, the lowest total dissolved solids, total hardness and calcium hardness were 36.0 mg/I, 28.0 mg/I, and 23.0 mg/I, respectively. These low values were recorded in factory C and D. However, Factory B recorded the highest values for total dissolved solids (138 mg/I), total hardness (146 mg /I), and calcium hardness (110 mg/I). Chloride in the sachet water reduced from 28.0 mg/I in factory A to 27.0 mg/I at the vendor shop, increased from 31.0 mg/I in factory B to 32.0 at the vendor shop, and reduced from 40.0 mg/I in factory C and D to 39.0 mg/I at their respective vendor shops. Nitrite and nitrate results from the various samples ranged from 0.006 to 0.08 and 1.60-4.48, respectively. These values were within the recommended range set by WHO. The levels of aluminium, cyanide, arsenic, zinc and lead in the water samples from the various factories were all 0.0 mg/I.

Table 7: Physico-chemical analysis of sachets water from four sachet water production factories

Parameters	Factory 1			Factory 2			Factory 3			Factory 4			WHO standard
	Factory	Truck	Vendor	Factory	Truck	Vendor	Factory	Truck	Vendor	Factory	Truck	Vendor	
Temperature	27.7	28.0	20.9	26.5	27.6	27.8	25.5	25.6	26.4	25.5	25.6	26.4	-
Ph	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5-8.5
Residual free	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Colour	5.0	5.0	6.0	5.0	5.0	5.0	4.0	4.0	3.0	4.0	4.0	3.0	0-15
Turbidity	1.0	1.0	1.0	1.1	1.0	1.0	0.14	0.14	0.09	0.14	0.14	0.09	5
Conductivity	244.0	244.0	240.0	271.0	272.0	273.0	72.0	72.0	73.0	72.0	72.0	73.0	-
TDS	122.0	122.0	126.0	136.0	137.0	138.0	36.0	37.0	38.0	36.0	37.0	38.0	1000
Total hardness	129.0	129.0	128.0	146.0	146.0	146.0	28.0	28.0	28.0	28.0	28.0	28.0	500
Calcium hardness	76.0	76.0	75.0	110.0	110.0	110.0	23.0	23.0	24.0	23.0	23.0	24.0	
Magnesium hardness	53.0	53.0	53.0	36.0	36.0	36.0	5.0	5.0	4.0	5.0	5.0	4.0	
Alkalinity	126.0	125.0	124.0	143.0	143.0	141.0	49.0	49.0	49.0	49.0	49.0	49.0	
Chloride	28.0	28.0	27.0	31.0	31.0	32.0	40.0	40.0	39.0	40.0	40.0	39.0	250
Nitrite	0.006	0.006	0.005	0.07	0.07	0.08	0.037	0.037	0.036	0.037	0.037	0.036	3.0
Nitrate	4.48	4.48	4.83	1.60	1.62	1.64	4.0	4.0	3.9	4.0	4.0	3.9	50
Ammonia (nitrogen)	0.36	0.36	0.36	1.0	1.0	1.0	0.6	0.5	0.5	0.6	0.5	0.5	1.5
Flouride	0.34	0.34	0.34	0.13	0.13	0.12	0.10	0.10	0.09	0.10	0.10	0.09	1.5
Iron	0.12	0.12	0.10	0.17	0.17	0.15	009	0.09	0.10	0.09	0.09	0.10	0.3
Sulphate	6.0	6.0	6.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0	5.0	5.0	250
Manganese	0.04	0.04	0.04	0.028	.028	0.026	0.04	0.04	0.04	0.04	0.02	0.04	0.5
Phosphate	0.03	0.03	0.03	0.05	0.05	0.05	0.026	0.026	0.027	0.026	6	0.027	0.3
Aluminium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Cyanide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07

Arsenic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
Copper	0.0	0.0	0.0	0.002	0.002	0.002	0.002	0.001	0.001	0.002	1	0.001	1.0
Zinc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Lead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01

Source: Field work, 2018

4.8 Microbiological Analysis of Sachet Water

Table 8 presents the results of microbiological analysis of sachet water from the factory premises, in trucks, and at vendor shops. E.coli level was 0.0 MPN index/100ml in all the water samples that were taken from sachet water in the factory premises, in the trucks, and at the various vendor shops. A higher normal level of faecal coliform was detected in samples from factory 1 distribution trucks (4.0 MPN index/100ml) and vendor shops (6.0 MPN index/100ml). The remaining factories recorded normal values (0.0 MPN index/100ml) of faecal coliform at the various points. For total viable count, abnormally high levels were detected in samples taken from factory 1 distribution truck (22.0 CFU), vendor shop (40.0 CFU), factory 2 distribution truck (50.0 CFU), vendor shop (80.0 CFU), factory 3 vendor shop (10.0 CFU), and factory 4 vendor shop (60 CFU). As shown in Table 8, a high level of total coliforms were observed in samples taken from factory 1 distribution truck (9.0 MPN index/100ml), vendor shop (18.0 MPN index/100ml), factory 2 distribution truck (6.0 MPN index/100ml), vendor shop (9.0 MPN index/100ml), factory 3 vendor shop (6.0 MPN index/100ml), and factory 4 vendor shop (4.0 MPN index/100ml)

Table 8: Microbiological analysis of sachet water from four sachet water production factories

Parameters	Factory 1			Factory 2			Factory 3			Factory 4			Detection Limit
	Factory	Truck	Vendor	Factory	Truck	Vendor	Factory	Truck	Vendor	Factory	Truck	Vendor	
E.coli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faecal coliform	0.0	4.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total viable count	0.0	22.0	40.0	0.0	50.0	80.0	0.0	0.0	10.0	0.0	0.0	60.0	0-3
Total coliforms	0.0	9.0	18.0	0.0	6.0	9.0	0.0	0.0	6.0	0.0	0.0	4.0	0.0

Source: Field work, 2018

CHAPTER FIVE

DISCUSSION

5.0 Introduction

This chapter discusses the results of the study by linking the findings with previous works that were done by other scholars. This will help the researcher to identify gaps and strengths of the study to help suggest key recommendations to stakeholders and policy makers.

5.1 Physico-chemical Properties of Various Brands of Sachet Water

Physico-chemical properties of sachet water measured the physical parameters, chemical constituents, and heavy metals of the brands of sachet water selected. These physico-chemical properties of sachet water were tested to the requirements of WHO and GSB/FDA standards. This is because these parameters have health implications on the consumer and a shared public health concern to the prevention of diseases. Again, these physico-chemical properties also have accumulative effects on water safety and how the water is wholesome for human consumption. Overload of microbial contents affect water taste, colour, and the overall quality of the water and thereby making it unsafe for human consumption.

According to the World Health Organisation (WHO), physico-chemical properties, among others, include pH, Temperature, Turbidity, Colour, Chlorine, Iron, Calcium, Sodium, Magnesium and Potassium which contribute to improve water quality and safety. From the current study, the ranges of physical parameters of the brands of sachet water selected indicate variations of some of the parameters with the requirements with WHO and GSB, even though some were still within the normal limits as prescribed by WHO and GSB.

These physico-chemical properties proposed by Balan *et al*. (2012), who cited these parameters to have significant impact on water quality and safety, were in agreement with the current study. Abiding to these standards and physico-chemical parameters, managers of the various brands of the selected sachet water were influenced by the roles played by the regulatory bodies such as GSB and FDA.

Also, the findings of the current study indicate a lower total dissolved solids, total hardness regarding calcium magnesium contents and these values were recorded in factory 3 and 4. However, Factory 2 recorded the highest values for total dissolved solids (138 mg/I), total hardness (146 mg /I), and calcium hardness (110 mg/I). These chemical properties defined the ability of the water to dissolve solutes and could either make the water hard or soft depending on the presence of calcium and other minerals. The ability of water to become hard or soft as influenced by elementary constituents have health implications on humans, depending on the contents of these elements, and could have effects in the transmission of electrical impulse in the human body within the cell membrane.

The low total dissolved solids in factory 3 and 4 could be attributed to negligence on the part of regulatory bodies during their monitoring and supervisory exercise. A study conducted by Anduang *et al.* (2015) equally cited similar physical parameters and said low content of these parameters could have effects on human health regarding electrical impulse conductivity within the nervous system which has positive relation to the findings of this current study.

Lind's (1959) study share similar understanding with Anduang *et al*. (2015) as well as Taiwo *et al.* (2012), ASTM (2004), APHA (1985), and Ikeme *et al.* (2014) on the total dissolved solid (TDS) or salinity of water.

Also, other minerals such as chloride in the selected brands of sachet water were found to have a reduced content at the vendor shop in Factory 1, 3 and 4, and an increased content in Factory 2 at the vendor shop. Also, nitrite and nitrate contents were within the recommended limits of WHO and GSB standards, and levels of heavy metals such as aluminum, cyanide, arsenic, zinc, and lead in the selected brands of sachet water were low. These were quiet okay as an increased level have negative health implications on the consumer as cited by Anduang *et al.* (2015), Edward (1980), Olowe *et al*. (2015), Muhammad *et al.* (2007) and Ikeme *et al.* (2014) which have positive relations with the current study.

5.1.1 Effects of Physico-chemical Properties on Consumer Health

Health, according to WHO (1986), is defined as a state of complete physical, mental and social wellbeing and not merely the absent of diseases and infirmities. The physical, mental and social wellbeing of an individual could have a dread consequence by the influence of the physico-chemical properties of sachet water if standard operating procedures and practices set by GSB and WHO are not adhered to.

Access to quality water promotes good health and prevents outbreak of diseases such as cholera, and could be affected if due processes are not followed at the site of production. This could result in microbial contamination and distortion of the physico-chemical properties of the water, thereby making it unwholesome for human consumption. From the current study, high faecal coliform level was detected in the sample of water from factory 1 through the distribution trucks. This could be attributed to poor hygiene practices and has the implication of affecting water quality and the health of the consumer.

In a related study conducted by Zaslow and Glenda (1996), it was found that the chemical parameters of drinking water have the propensity of posing threat to people.

These threats were found to include the risks of developing chronic diseases such as cancer, and other health complications with the liver and kidney as well as disorders of the nervous system, damage to the immune system, and birth defects. These were attributed to the fact that chemical parameters of drinking water did not meet the prescribed standards by WHO. Similar findings relating health complications due to poor water quality were found in studies conducted by Hutton (1981), Ikeme (2014), and Anduang *et al.* (2015). In Ghana, similar related studies were found to include Nkansah *et al*. (2010), Obiri-Danso *et al.* (2003) and Orisakwe *et al.* (2007). All these studies cited sachet water produced especially from boreholes and hand-dug wells to contain hazardous microbes and anions that can cause serious health disorders such as methemoglobinemia and nervous system disorders.

5.2 Factory Location and the Physico-chemical Properties

The locations of factories contribute to water safety and its contamination. From the current study, about three-quarters of the factories were located in the premises of apartments originally designed for rent. For these factories, water for the production of sachet water was obtained from boreholes, and all were found certified by the GSB, FDA and EPA which are the regulatory bodies in Ghana. These regulatory bodies, according to Anunobi *et al*. (2006), provide regulatory programs and ensure quality standard for the water that is produced to safeguard public health. Almost all the selected factories have been in operation for more than four years, and used cartridge filtration in the treatment of water. These, as part of regulatory measures, are meant to ensure and prevent water contamination to make the water wholesome for public consumption. About half of the factories were found to only treat the filtration cartridges when they found it necessary, and similar proportion reported to change the cartridges at least once in every three months. The change of cartridges contributes and helps to trap foreign particles and other impurities from contaminating the water, thereby making the water safe for consumption. Hence, cartridges should be regularly changed under supervision and monitored to ensure water safety, as the continuous use of cartridges without changing them could influence the physico-chemical properties of the water through debris and the resultant health complications through water-borne diseases.

Studies by Erah *et al.* (2002), Asonye *et al.* (2007), Tyagi *et al.* (2013), Odiongenyi and Enengedi (2015), and Ugwu *et al*. (2016) emphasized the need to give adequate attention to ensuring water safety, because when water is not safe, it has direct effects on the health of people. These studies further highlighted the importance of good quality water, and said quality water helps to maintain life and ensures the necessary life sustenance for growth and development.

5.3 Hygiene Practices at Sachet Water Production

Effective and efficient solid and liquid waste disposal and management at production site promote hygiene and safety of the drinking water that is produced. About half of the factories conveyed their solid waste such as polythene and other debris with a bucket and all factories disposed their solid waste once every week. Also, about half of the factories disposed off their solid waste in an itinerant waste van while similar proportion disposed off their solid waste in a hole in the production compound. Again, about three-quarters of the factories disposed off their liquid waste in a hole within the compound.

A study by Singh (2015) indicates that water quality could be deteriorated by pollutions emerging from solid and liquid wastes if they are not properly managed.

This is because, once the factories are operating a borehole, the water source from which water is obtained for production can get polluted when the waste water sinks into it.

In factory 1, as per the current study, faecal coliform was found in the distribution trucks of water to vendor shops and could be attributed to inefficient hygiene practices at the point of production and distribution. A study conducted in Cape Coast by Dodoo *et al.* (2006) cited water pollution to be attributed to the point source of production and equally found water quality to be poor due to water sources being contaminated by solid and liquid waste.

Also, about 50% of factories in this current study disposed their solid and liquid waste in a distance of about 5 meters, and similar proportion disposed off solid waste in a distance of about 5 to 25 meters. Nwaka *et al.* (2017) argue that, when point source of waste disposal is closer to water production, it paves way for microbes and other contaminants to have easy access to the drinking water and contaminate the sources. Related studies by Fajobi and Shittu (2008), Oyedeji *et al*. (2010) and Omalu *et al.* (2012) cited similar views and suggested that, to ensure water safety, the distance must be further away of more than 25cm and the environment should be clean.

5.4 Hygiene Practices of Sachet Water during Packaging and Handling

After the production of water, the processes involved in packaging and handling sachet water should conform to international standards and procedures set by recognised bodies like WHO, GSB, FDA and EPA. If such procedures and standards are not adhered to, the water could get contaminated, making it unsafe for public consumption.

From the current study, it was realized that almost all the factories reported to have always disinfected their production rooms. Regarding the frequency of disinfections, it was realized that only one factory disinfect the production room when it is dirty and one-quarter of the factories had a schedule of disinfecting the rooms floor every three months.

Regular disinfection of the production room of sachet water prevent microbes and other contaminants from causing infestation with the produced sachet water.

In Ghana, studies conducted by Kwakye-Nuako and Borketey (2007), and Stoler *et al.* (2012) noted the need to provide safe, hygienic and affordable drinking water to individuals, while emphasizing the need to control water-related diseases. These studies equally highlighted the need for regulatory bodies to make sure that water is safe for public consumption. Production managers should equally play their managerial roles by ensuring that water is safe throughout the production chain.

In addition, from the current study, all the four factories were found to have used protective clothing such as aprons when treating water. These protective clothing were cited to have been disinfected before use. More than half of the factories said they used disinfectants to disinfect the protective clothing and similar proportion said they used soap and water as disinfectants in every three months. Also, almost all the factories stored their water in polytanks before production and said to have send samples to laboratories for testing and regularly inspected by GSB, FDA and EPA.

Regular inspection of water production site and testing of water samples used in production contribute to ensure water safety and also put the managers in position to be more proactive. Kwakye-Nuako *et al.* (2007) indicate that it is important for water production companies to be regularly inspected to ensure water quality. Similar findings were equally cited by Akorli (2012), Abdul *et al.* (2014), and Obiri-Danso *et al.* (2003).

Safety packaging and handling of sachet water are equally vital to ensuring water is safe for public consumption. From the current study, all factories were found to have not replaced their UV sterilization since the start of production, and none of the factories disinfects the trucks that carry the sachet water. It was also realized that only one factory covered the packs of sachet water with polythene before distribution to vendors/retailers. Also, UV sterilization was not regularly done to ensure water safety and this could contribute to increased contact with pathogenic particles and hence affect water safety and quality. Adeyemi *et al.* (2015), Ugwu *et al.* (2016), Ugwu and Wakawa (2012), and Nkansah *et al*. (2010) indicated that unhygienic practices have a resultant effect of many deaths resulting from infections due to open water supplies, and noted the needs to cover water before distribution to vendors and retailers.

5.5 Limitations

The major limitation to the study is the fact that the chemicals used in carrying out the laboratory test were very expensive. Due to that, the sample size for the study was too small. This could affect the generalization of the study findings as this may not truly reflect the situation in the Sunyani Municipality.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter of the study summarizes the findings of the study to draw sound conclusions and recommendations.

6.1 Conclusions

Overall, four sachet water production factories were selected for the purpose of this study, of which 3(75%) were located in the premises of a rented apartment with borehole as the source of water for production. All the four factories were certified by Ghana Standard Board, Food and Drugs Authority, and the Environmental Protection

Agency to operate. All the four factories were found using cartridge filtration in the treatment of water.

Solid and liquid waste disposal and management was average, as 50% of the factories disposed solid waste in an itinerant waste van and similar proportion disposed solid waste in a hole in the production compound. Hygiene practices at production site were quiet okay, as all factories have indicated to have disinfected the production rooms, with only one (25%) factory to have had a schedule for disinfection.

In addition, hygiene practices during packaging of sachet water was satisfactorily inadequate as no factory was found to have replaced the UV sterilization since the start of production. Also, no factory was found to have disinfected the trucks used in distributing water to retailers. Almost all the factories were operating within four (4) out of eleven (11) of the standard operating procedures and practices set by GSB, FDA and EPA. All the factories' physico-chemical properties of the sachet water produced were within the normal limits recommended by WHO, even though there were variations with regards to individual factory. Microbial content analysis of sachet water from each factory indicates that 3(75%) of the factories had no faecal coliform, except factory 1 (25%) which was found to contain high level of faecal coliform.

6.2 Recommendations

Based on the findings of the study, the following recommendations are made to stakeholders.

6.2.1 Regulatory Bodies (GSB, FDB & EPA)

1. Regulatory bodies should intensify monitoring and supervision at the various factories in the Sunyani Municipality to ensure that managers adhere to regulatory standards and procedures.

2. Regulatory bodies should undertake evaluation of factories to ensure that they are truly certified and are following the regulatory standards and programs that are put in place to ensure water safety and quality.
3. They should also put in place punitive measures to sanction any production factory that violates and does not obey the standard operating procedures and measures laid down regarding sachet water production or strengthen the current once if there suffices any.
4. Regulatory bodies should intensify public education through the media and other public gatherings to educate the public and sachet water production factories on regulatory and quality measures to ensuring water is safe for the public.

6.2.2 Factory Managers/Owners

1. Factory managers/owners should ensure that standard procedures regarding hygiene practices such as cartridges and UV sterilization and proper waste disposal and management such as septic tanks, itinerant waste van and other modern waste management systems are adopted to ensure the safety and quality of the water.
2. Also, managers should ensure that the sources of water for production is pipe borne and should be regularly monitored to ensure that the pipes are not leaking to avoid contamination and safety of water.
3. Managers should also organize regular in-service training to caretakers on standard operating procedures and practices and the use of protective clothing such as aprons, head gears/cover, gloves, among others, to avoid crosscontamination and other infectious particles.

4. Again, managers should ensure that trucks and vans that are used in transporting sachet water to retailers are not the same trucks that are used in domestic/commercial transportation process, and if used, should be disinfected with disinfectants before they are used in conveying the produced water.

6.2.3 Retailers and Consumers

1. Retailers should ensure that sachet water is kept either in net container/cages to prevent contamination from the external environment or should be kept in a safe place to avoid direct UV light and other radiations because they might have effects on the physico-chemical properties of the water.
2. Consumers should be consciously alert by checking regulatory bodies tamps and other standard operating measures before purchasing the sachet water to guarantee their safety and health.

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APPENDIX I

Questionnaires

QUESTIONNAIRE PHYSICO-CHEMICAL ANALYSIS OF THE QUALITY OF DIFFERENT BRANDS OF SACHET WATER IN THE SUNYANI MUNICIPALITY- GHANA Name of Factory______ Area
Interviewer ID_____

I am a final year student of the School of Public Health (Department of Health Population and Reproductive Health) of the Kwame Nkrumah University of Science and Technology (KNUST) conducting research on Physico-Chemical Analysis of the Quality of Different Brands of Sachet Water in the Sunyani Municipality.

Participation in this study is voluntary. I will much appreciate your participation. I want to assure you that the information that would be obtained from this questionnaire is for the purpose of educational research, and no part of it would be used for any other purpose without your permission. For the purpose of confidentiality and anonymity, you do not have to write your name on any part of the questionnaire.

Key informant Interview on factory site

Please tick in the bracket where you deem appropriate

Name of factory/ institution……………..

Manager [ ] Caretaker [ ] Date………

Tell me about your involvement in the factory/institution.............................

Name of caretaker/manager…………………………………

Position/ Rank ………………………………………………

Volume of production per week/day………………..

Target population………………………………………………………………
PHYSICO-CHEMICAL PROPERTIES OF SACHET

1. What was the premises/house/building originally built for?
   A. Mainly as a factory for water production [ ]

B. Dwelling apartment for rent [ ]

C. Dwelling apartment turn to a factory [ ]

D. Other ………………………………………..

2. Which of the following is your main source of water for production?

A. Borehole [ ]

B. Hand dug well [ ] C. Pipe borne water [ ]

D. Others ……………………………….

3. Are you certified by Ghana Standard Board, Food and Drugs Board Environmental Protection Agency as a Certified Water Specialist, Certified Sales Representative, or Certified Installer?

Yes [ ] No [ ]

4. How long have you been in business?...

A. One year [ ]
B. Two years [ ]
C. Three years [ ]
D. Four years [ ]
E. Others……………………………………

5. What specific water treatment process do you carry out? Tick as many as apply

A. Physical water purification[ ] F. Microfiltration [ ] K. Chemical addition [ ]
B. Screen [ ] G. Cartridge filtration[ ] L. Disinfection [ ]
C. Sand filtration [ ] H. Ultrafiltration [ ] M. Distillation [ ]
D. Cross flow filtration [ ] I. Reversed Osmosis [ ] N. Electro dialysis [ ]
E. Nanofiltration [ ] J. Clarification [ ]

6. How often do you treat your water for production?

A. At least once in a week [ ]

B. At least once in a month [ ]

C. At least once in 3 months [ ]

D. At least once in 6 months [ ]

E. Other ………………………………………………

7. How many times do you change your cartridges in water filters

A. At least once in a week [ ]

B. At least once in a month [ ]

C. At least once in 3 months [ ] D. At least once in more than 3 months [ ]

E. Other ……………………………………………..

RELATIONSHIP BETWEEN FACTORY LOCATION AND PHYSICOCHEMICAL PROPERTIES OF SACHET WATER Solid waste Management and Disposal

8. In what type of container do you collect solid waste? (one or more answers)
    A. Carton [ ]
    B. Waste Basket [ ]
    C. Old bucket [ ]
    D. Plastic bag [ ] E. Tin/can [ ]
    F. Other ………………..
9. How often is the waste container emptied?
    A. Once a day [ ]
    B. Once in two days [ ]
    C. Once in three days [ ] D. Once in a week [ ]
    E. Other …………………….
10. Where do you usually dispose solid waste?
    A. In the Public dumping site [ ]
    B. In the itinerant waste van [ ]
    C. By the valley/lake side/river [ ]
    D. By the road side or street side [ ] E. In a hole in the production compound [ ]
    F. Others ……………………………….
11. How far from the main water supply of this factory as stated in question 2 is the location for disposal of solid waste of this premise as stated in question 10?
    A. 5m [ ]
    B. 5 to 25m [ ]
    C. 25 to 50m [ ]
    D. 50 to 100m [ ]
    E. 100 to 500m [ ]

F. 500M to 1,000m [ ]

G. Other……………………………

Liquid waste management/disposal

12. Where do you usually dispose human waste/excreta?

A. On the ground/free range near the premises that is back-/courtyard, private [ ]
B. On the ground/free range away from the premises in the community shared, public [ ]
C. In a hole near the premises that is back-/courtyard, private [ ]
D. In a hole away from the house in the community shared, public [ ]
E. Pour in surface water in the community that is lake, pond, river, stream, public, shared [ ]
F. Pour in the sewer in the community shared, public [ ]
G. Other, specify ________________________
H. Don't know [ ]

13. How far from the main water supply of this factory as stated in question 2 is the location for disposal of human waste/excreta of this premise as stated in question 12?

A. 5m [ ]

B. 5 to 25m [ ]

C. 25 to 50m [ ]

D. 50 to 100m [ ]

E. 100 to 500m [ ]

F. 500 to 1,000m [ ]

G. 1,000m [ ]

H. Don't know [ ]

14. Where do you usually dispose waste water from e.g. cooking/preparation of food/ meals, bathing and/or cleaning?
A. On the ground/free range near the premises that is back-/courtyard, private [ ]
B. On the ground/free range away from the premises in the community shared, public [ ]
C. In a hole near the premises that is back-/courtyard, private [ ]
D. In a hole away from the house in the community shared, public [ ]

E. Pour in surface water in the community that is lake, pond, river, stream, public, shared [ ]
F. Pour in surface water in the community that is canal, irrigation canal, public, shared. [ ]

G. Pour in spring water in the community public, shared. [ ]
H. Other, specify ………………………………………….
I. Don't know [ ]

15. How far from the main water supply of this factory as stated in question 2 is the location for disposal of human waste water of this premise as stated in question 14?
    A. <5m [ ]
    B. 5 to 25m [ ]
    C. 25 to 50m [ ]
    D. 50 to 100m [ ]
    E. 100 to 500m [ ]
    F. 500 [ ]
    G. Don't know [ ]

ASSESSMENT OF HYGIENIC OF SACHET WATER PACKAGING AND HANDLING

Handling of Sachet Water

16. Do you disinfect your production floor or room? Yes [ ] No [ ]
17. If yes, how many times do you disinfect your production floor or room?
    A. Everyday [ ]
    B. At least once a week [ ] C. At least once in two weeks [ ]
    D. Others …………………………….......
18. Do you use protective clothing's when treating the water? Yes [ ] No [ ]
19. If yes tick any of the following that you use during production?
    A. Hand gloves [ ]
    B. Apron [ ]
    C. Nose mask [ ]
    D. Wellington boots [ ]

20. Do you wash or disinfect protective clothing's if you use one?

Yes [ ] No [ ]

21. If yes, how is disinfection done/carried out?

A. Sterilization [ ]

B. Use of water at boiling point [ ] C. Use of disinfectant [ ]

D. Others……………………………………..

22. If yes, how often is disinfection performed?

A. Everyday [ ]
B. At least once a week [ ]
C. At least once in two weeks [ ]
D. Others …………………………........

23. How is water stored before production?

A. In a polytank [ ]

B. Direct from the well [ ]

C. Direct from the bore hole [ ] D. Direct from the pipe borne water [ ]

E. Other ……………………………..

24. Do you send sample of your water to the laboratory for testing? Yes [ ] No [ ]

25. If yes, how often do you do the laboratory testing?

A. Once in a month [ ]

B. Once in every three months [ ]

C. Once in every six months [ ]

D. Once in more than every 6 months [ ]

E. Other ……………………………

26. Which laboratory do you send your samples for testing?

A. Ghana water company [ ]

B. Private water laboratory [ ]

C. Factory's laboratory [ ]

D. Other …………………………………

27. Does Food and Drugs Authority, Ghana Standard Authority and other standards enforcement agencies come to your facility for inspection? Yes [ ] No [ ]

28. If yes, how often do they come?

A. Once in a month [ ]

B. Once in every three months [ ]

C. Once in every six months [ ] D. Once in more than every 6 months [ ]

E. Others ………………………………………..

Packaging of Sachet Water

29. On the average, how many people are involved in water packaging during production?

A. One [ ]

B. Two [ ]

C. Three [ ] D. Four [ ]

E. Others ………………………………..

30. How often do you replace UV sterilization light?

A. Once in every six month [ ]

B. Once every year [ ]

C. Once in every two years [ ]

D. Others ………………………………………………

31. Do you disinfect trucks before loading sachet water?

Yes [ ] No [ ]

32. If yes, how often do you disinfect the loading truck?

A. Everyday [ ]

B. At least once a week [ ] C. At least once in two weeks [ ]

D. Others ……………………………........

33. Do you cover packs of sachet water before distribution?

Yes [ ] No [ ]

34. If yes how often do you cover the packaged water?

A. Occasionally [ ]

B. Anytime we distribute [ ]

C. We don’t [ ]

D. Others ……………………………

Retailer

35. Name: …………………………

36. Address:……...

37. Where do you get your sachet water from?

A. I go to the factory myself to collect it [ ]

B. It is delivered to me by the company [ ] C. I get it from the wholesale [ ]

D. Others ………………………………………………..

38. Where do you store sachet water when you purchase them?

A. On the bare floor [ ]

B. On a rack [ ]

C. In the fridge [ ]

D. In an open metal cage [ ]

E. Others …………………………………………..

39. How do you handle sachet water when selling to individual customers?

A. I use my bare hands to deliver to them [ ]

B. Buyers personally pick the water [ ]

C. I wear a protective covering on my hands before selling [ ]

D. Other ……………………………………………………..

CHECKLIST OF STANDARD OPERATION PROCEDURES AT SACHET WATER PRODUCING FACTORY.

These steps are taken during sachet water production. It consists of removing chlorines and THMs (trihalomethanes) through a daily-monitored activated carbon filtration process.

1. Water is carefully collected and received through stainless steel pipes from either a local well or municipal water supply. Quality testing of the original source is conducted regularly to monitor for abnormalities.
Yes [ ] No [ ]

1. A water softener is used to reduce water hardness.

Yes [ ] No [ ]

2. Demineralisation removes unwanted minerals (through reverse osmosis or distillation).

   Yes [ ] No [ ]

3. Water received in storage tanks is monitored on a daily basis.

   Yes [ ] No [ ]

4. Selected minerals are added to cater for consumer taste preferences.

   Yes [ ] No [ ]

5. Pharmaceutical grade micro-filtration removes particles as small as 0.2 microns. It is also
   capable of removing potential microbiological contaminants. This is monitored on an hourly basis.

   Yes [ ] No [ ]

6. Ultra-violet filtration provides additional product disinfection. This is monitored on an hourly basis.

   Yes [ ] No [ ]

7. Ozone disinfection is the third disinfection step (steps 7-9), using a highly reactive form of oxygen. This is monitored on an hourly basis.

   Yes [ ] No [ ]

8. The filling room is highly sanitary to ensure bottling is conducted in a microbiologically controlled environment. It is continuously monitored and controlled.

   Yes [ ] No [ ]

9. Packaging quality assurance is conducted by human inspection and the latest in modern equipment designed to ensure the removal of any packaging defects.

   Yes [ ] No [ ]

10. Line sanitation includes automated cleaning equipment to ensure maximum cleanliness, effectiveness and control.

    Yes [ ] No [ ]