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

COLLEGE OF SCIENCE

# ASSESSMENT OF THE PHYSICO-CHEMICAL AND MICROBIOLOGICAL LEVELS OF SACHET WATER IN THE ATWIMA NWABIAGYA DISTRICT OF THE ASHANTI REGION OF GHANA

A thesis submitted to the Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, in partial fulfillment of the requirements for the award of

MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

**BY**

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# DECLARATION

I do hereby declare that this thesis was written by me and that it is the record of my own research works. It has neither in part nor in whole being presented for any degree elsewhere. Works of other scientists and all assistances received are duly acknowledged.

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# DEDICATION

To Akosua Achiaa Boah and Kwame Amponsah Boah.

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# ABSTRACT

Increase in human population has exerted an enormous pressure on the provision of safe drinking water; hence its availability has therefore become a critical and urgent problem especially in developing countries. Sachet water production is therefore one major way of making quality drinking water readily available and accessible to people at an affordable price. The study was conducted in the Atwima Nwabiagya District of the Ashanti region of Ghana between February and April, 2013 to determine the quality of seven different brands of sachet water which are produced and sold within the district. Two different storage places (inside a shop and a metal cage which is left outside) as well as two vending places (a refrigerator or an ice chest and street hawking) were identified. Sachet water samples from all the selected brands were analyzed for the levels of physico-chemical parameters as well as microbiological indicators at the various stages (production, storage and vending). The results showed that all the physico-chemical parameters, with the exception of Phosphate ($6.22 \pm 0.01$ mg/l) for brand SW 4 were within permissible limits at the time of production. Consequently, the microbiological indicators in all the brands at the time of production were below detectable limits (0 CFU/100 ml). At the two storage places, the results showed that sachet water samples stored inside the metal cage recorded higher values in most of the physico-chemical parameters than those stored inside the shop, even though all were within the WHO's permissible limits. Moreover, the results indicated that the Alkalinity ($p = 0.00117$), Chloride ($p = 1.1019E-12$), Fluoride ($p = 0.03026$), Magnesium ($p = 4.9E-6$) and Phosphate ($p = 0.0044$) levels were significantly different at the two storage places. Similarly, sachet water vended through street hawking recorded higher values than those vended through the refrigerator, even though all were within the WHO's guideline limits. Levels of microbiological indicators at the time of production remained unchanged at the storage and vending places. The general conclusion is that the quality of the sachet water in the district is good for human consumption.

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| | | |
|---|---|---|
| AND | – | Atwima Nwabiagya District |
| APHA | – | American Public Health Association |
| CFU | – | Colony Forming Unit |
| EC | – | Electrical Conductivity |
| EDTA | – | Ethylenediaminetetraacetic acid |
| EPA | – | Environmental Protection Agency |
| FCDPH | – | Fresno County Department of Public Health |
| FDB | – | Food and Drugs Board |
| FDEP | – | Florida Department of Environmental Protection |
| GSB | – | Ghana Standards Board |
| GSS | – | Ghana Statistical Service |
| GWCL | – | Ghana Water Company Limited |
| HDPE | – | High-Density Polyethylene |
| LLDPE | – | Linear Low-Density Polyethylene |
| NTU | – | Nephelometric Turbidity Unit |
| SPSS | – | Statistical Package for the Social Sciences |
| TCR | – | Total Coliform Rule |
| TCU | – | True Colour Unit |
| TDS | – | Total Dissolved Solids |
| USDA | – | United States Department of Agriculture |
| USEPA | – | United States Environmental Protection Agency |
| UV | – | Ultra Violet |
| WHO | – | World Health Organisation |

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background of study

Water is essential for life. It is clearly the most important nutrient and most abundant substance in the human body. It comprises about three quarters of the human mass and is a major component in every cell. Almost all body fluids are present as water solutions (Chapman, 1992).

In as much as water is needed for the sustenance of mankind, the quality of water that is ingested into the human body should be of prime concern. The term water quality is used to describe the condition of the water, including its chemical, physical and biological characteristics, usually with respect to its suitability for a particular purpose (Diersing, 2009).

The Third World Forum on Water (2003) reported that about 1.2 billion people across the world do not have access to potable water. Availability of water has become a critical and urgent problem in many developing countries, and it is a matter of great concern to families and communities that depend on non-public water supply system (Okonko *et al*., 2008). Increase in the human population has exerted an enormous pressure on the provision of safe drinking water in developing countries (Umeh *et al*., 2005).

In view of the ever-rising human population and the apparent lack of institutional capacity on the part of the Ghana Water Company Limited (GWCL) to supply potable water to the populace, there was therefore the need to explore other avenues of making quality drinking water readily available to people. One of these avenues resulted in the advent of the sachet water industry in Ghana.

Sachet water production therefore started in the country with the view of helping to alleviate the water situation by making quality water readily available and accessible to people at an affordable price. The industry has been in Ghana for about two decades now and it is undoubtedly the most readily available source of drinking water to most people, especially those living in the urban areas. They can be found in super markets, shops, kiosks and by the road side. The industry directly employs hundreds of individuals across the country, and indirectly provides some form of employment to the hundreds of people who on daily basis go to the road side to sell the water, just to make earns meet.

Sachet water production in Ghana is predominantly by small scale industries and individuals who are able to harness the ground water with the aid of borehole drilling machines. The water which comes out are then treated and packaged into small polyethylene sachet which are electrically heated and sealed at both ends, each containing 0.5 litres of water and subsequently distributed to retailers or shop owners who sell them to the consuming public.

## 1.2 Problem Statement

Rising human population and urbanization have put a lot of pressure on water resources the world over, resulting in an increased demand on both ground and surface water sources so as to meet the needs of the ever-growing human population.

The GWCL is the main supplier of potable pipe borne water in Ghana, but most inhabitants within the Atwima Nwabiagya District do not have access to this pipe borne water partly due to lack of service lines in certain areas and poverty (GWCL, 2007). Consequently, provision of potable pipe borne water by GWCL in the district is woefully inadequate due to the irregular nature of supply.

In view of this situation, most people rely on other sources of water to meet their daily needs, and one of such sources is the use of sachet water.

Sachet water, popularly called ‘pure water’ can be found everywhere in Ghana. People use the water for drinking, cooking, and for other several domestic and industrial purposes, but the question that comes to mind is ‘how pure is the water we are consuming?’

The initial idea of sachet water production in Ghana was to make quality drinking water readily available and accessible to people at an affordable price. However, due to the lucrative nature of the industry, a lot of individuals have joined in the production of sachet water, thereby making it very difficult for the consuming public to distinguish between brands with high quality standards and those of inferior quality.

The proliferation of sachet water products raises the question as to whether they are produced under hygienic conditions, especially when the poor sanitary environment in urban Ghana, coupled with the irregular monitoring of sachet water producers by regulating agencies are taken into account (Adekunle *et al.*, 2004; Obiri-Danso *et al.*, 2003; Agada, 1998). Rutz (1996) reported that sachet water vending machine may not be free of microorganisms, because bacteria like *Streptococcus faecalis*, have been isolated from sachet water producing machines.

Nevertheless, the places where sachet water are stored or kept before they finally get to the consumer could also impact negatively on the quality of the water, thereby posing health threats to the consuming public. It is possible that contamination of sachet water may occur either during the processing, storage, transportation or improper handling by hawkers. Moreover, a greater proportion of the water that is used for the production of sachet water is obtained from boreholes that are exposed to microbial contamination through rainfall runoffs and the fact that they are usually constructed very close to pit toilets (Adegoke *et al*., 2012). Drinking of unwholesome water can result in a lot of diseases; notably cholera, typhoid, dysentery, diarrhoea, and many more.

Therefore, the aim of this research was to investigate whether the quality of the sachet water produced and sold within the Atwima Nwabiagya District meets the World Health Organization's guidelines for drinking water purposes in terms of the physico-chemical parameters and microbiological indicators.

## 1.3 Objective of Study

The main objective of this study was to assess the quality of the sachet water produced and sold within the Atwima Nwabiagya District of the Ashanti Region of Ghana.

### 1.3.1 Specific objectives:

The specific objectives were:

i. To assess the physico-chemical parameters as well as the microbiological indicators of the sachet water in the district at the time of production.
ii. To determine the quality of the sachet water at two different storage places (shop and metal cage).
iii. To determine the quality of the sachet water at two different vending places (refrigerator and street hawking).

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Background information on sachet water

During the 1970s and 1980s, it was very common to buy a cup of drinking water on the streets of Ghana. Here, the purchaser drank directly from a plastic or metal cup, which the vendor uses to scoop water out of a larger storage vessel. This form of water entrepreneurship was aimed at poor, transient population segments, but eventually demand grew beyond this demographic. Increased demand, coupled with the obvious sanitary shortcomings of such a system led to the packaging of water in small plastic bags in the 1990s. These small bags were hand-tied at the top and generally contained 250–500 ml of water (generally municipal water) (Hammond *et al*., 2004).

According to (Olayemi, 1999; Obiri-Danso *et al*., 2003), hygiene remained an issue, as bags were generally filled by women and children with suspect sanitary practices. During the late 1990s, new Chinese machinery that heat-sealed water in a plastic sleeve effectively created the modern sachet that is currently sold on the streets of several West African nations. Filtration and chemical treatment processes were eventually built into some of the high-end machines as well.

Figure 2.1(a) Sachet water purchased from a street vendor, and (b) typical Koyo sachet filling machine at a small production facility.

A water pump draws directly from a piped connection of municipally-treated water or from a storage tank or borehole. Sachet water produced in small-scale industries are mainly treated by aeration, double or single filtration using porcelain molecular candle filters or membrane filters and in rare instances, disinfection is applied. The level of treatment generally depends on the source of water. However, sometimes tap water is used without additional treatment and is sold in markets without clearance from the Food and Drugs Board of Ghana or other bodies concerned with water quality (Dodoo *et al*., 2006).

The water then goes into the sachet machine which fills a fixed volume (typically 500 ml) of a plastic roll, then heat-seals and slices the edge to create the individual sachet. Sachets typically drop into a basket on the floor and are quickly hand-packed into bags of thirty (i.e. 15 l by volume). These bags may be stored on pallets before being loaded onto trucks and delivered either to wholesalers or directly to market.

The sachet machines used in West Africa are generally made in China and marketed under several brands, the most common being the Koyo machine pictured in Figure 2.1(b). The filtration media, external to the sachet machine, are often bolted to the wall and usually comprise some combination of carbon and sand filters of different pore sizes for trapping different particles and organisms. Older machines are sometimes retrofitted with an ultraviolet filter to kill remaining bacteria and viruses; newer machines incorporate this feature internally (Wirka, 1998).

## 2.2 Agencies responsible for the regulation of sachet water production in Ghana

The Ghana Standards Board (GSB) and the Food and Drugs Board of Ghana (FDB), established in 1965 and 1993 respectively, are both responsible for ensuring that products being marketed in Ghana are of required quality. While the GSB generally develops and regulates standards for varying products that range from foods, drinks, and drugs to electrical and other engineered products, the FDB regulates and certifies only food, drinks, drugs, cosmetics, and other products which have health implications for the consuming public (GSB, 2004).

Both the FDB and the GSB regulate and certify sachet-water production and therefore there is some duplication of functions by the two authorities. However, while it is optional to have factory-produced sachet water registered with the GSB, it is mandatory to have the products approved and registered with the FDB. The main advantage of being registered by the GSB is to build product reputation.

Products that have been certified by the GSB, including factory-produced sachet water, bear the “Mark of Conformity”, also called the “Certification Mark” or the “Quality Mark”. The procedure for obtaining certification for sachet water factories includes submitting a complete application form together with a registration certificate for the factory. An inspection of the factory is then carried out to assess its Quality Management System and laboratory analyses of water samples taken. The sachet water is also inspected to assess the labeling requirements (GSB, 2004). According to the specifications given by the GSB (1998), all packaged drinking water are required to have the name of the product, the brand name or trade name if any, the net volume, name and address of manufacturer, the batch code and the expiry date indicated by the words “BEST BEFORE”.

Sachet-water factories that conform to all requirements are then issued with a license which authorizes them to use the Board’s “Mark of Conformity”. The license is valid for one year after which it can be renewed. The certified products are regularly audited by the GSB, both at the factory and market, to ensure that the quality is maintained. The certification mark therefore generally serves as an assurance of quality in locally produced goods in Ghana. Figure 2.2 shows the mark of conformity. The mark has a logo that bears a unique registration number for all products and a standard number that depends on the type of product.

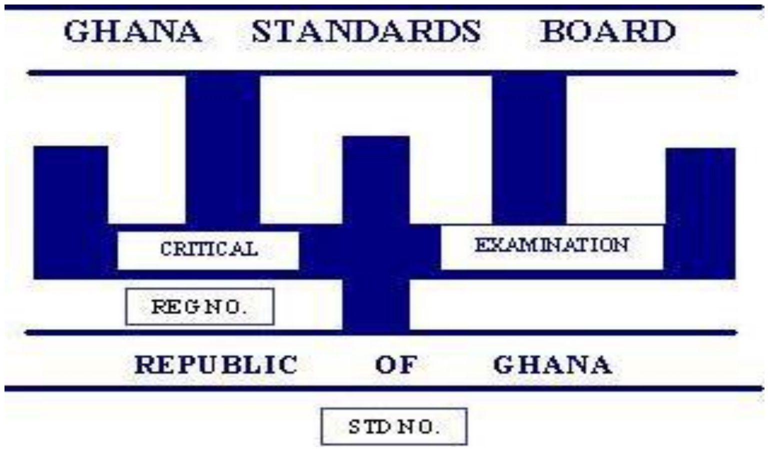


Figure 2.2: The GSB's Mark of Conformity.

The FDB enforces its own standards as well as those of the GSB. Although the FDB was established in 1993, it became fully operational in 1997 (FDB, 2005). The registration procedures for food products in Ghana, including sachet water, involve completing an application form and submitting it together with supporting documents that include a business registration certificate, certificate of analysis, a site master plan of the factory, and health certificates for all workers in the product line showing test results for tuberculosis, hepatitis A and E, typhoid and other communicable diseases (FDB, 2005).

Water samples are analyzed to assess the quality before registration is approved. Once the sachet water is registered with the FDB, the registration is valid for three years and is renewable by the end of the third year.

## 2.3 Guidelines set by the Food and Drugs Board (FDB)

The Food and Drugs Board of Ghana (FDB, 2005) specifies guidelines for the establishment of food industries, which also applies to factory-produced sachet water. Applications for the establishment of sachet water factories are submitted with supporting documents which include a site plan of the production premise and an environmental permit from the Environmental Protection Agency (EPA). Other requirements and relevant documentation required by the FDB are summarized below.

### 2.3.1 Minimum water treatment requirements

According to the FDB, the minimum water treatment requirements in sachet water production are filtration followed by UV disinfection. At least 5 filters and one UV disinfection unit are required for each sachet machine. The filter cartridges are required to be changed at least once every 3 months.

### 2.3.2 Water quality tests, licensing and certificates

Two categories of licenses are issued by the FDB and are described below:

Pre-licenses: Here, the FDB carries out water quality analysis on samples of sachet water produced by unregistered factories before they are allowed to produce and market sachet water. Here, the factory owners pay for all costs incurred in carrying out the tests. A certificate of analysis is then issued as one of the required documents for registration or renewal.

Post-licenses: This is carried out randomly on sachet-water samples produced by registered sachet-water factories to ensure that production of quality water is maintained. Post-licensing is carried out at the expense of the FDB. It is sometimes based on customer complaints. The FDB carries out punitive measures, such as license withdrawal, if samples tested are not of required quality. A product certificate is issued for factories that meet the water quality requirements.

According to the FDB, three certificates are therefore required for factory-produced sachet water: One certifying the product is of quality (certificate of analysis), one to certify the premises are up to standard and the third to certify that the factory workers handling sachet water are of good health. The premise certificate and certificate of analysis must always be displayed in the factories.

### 2.3.3 Plastic material used for sachet water production

The plastic bags used in hand-tied sachet water production are made of transparent, linear low-density polyethylene (LLDPE) film grade plastics. This type of plastic is very flexible and can elongate easily under stress, making it possible for hand-tied sachet water vendors to knot the bags. On the other hand, the bags used for packaging factory produced sachet water are made of high-density polyethylene (HDPE), which is slightly more opaque than the LLDPE used for hand-tied sachet water. It has a higher tensile strength (more difficult to elongate), and can withstand higher temperatures (Polyprint, 2007).

## 2.4 Water quality requirements for drinking water – Ghana standards

The Ghana Standards for drinking water (GSB, 1998) indicates the required physical, chemical, microbial and radiological properties of drinking water. The standards are adapted from the World Health Organization's Guidelines for Drinking Water Quality, Second Edition, Volume 1, 1993, but also incorporate national standards that are specific to the country's environment.

### 2.4.1 Physical Requirements

The Ghana Standards set the maximum turbidity of drinking water at 5 NTU. Other physical requirements pertain to temperature, odour, taste and colour. Temperature, odour and taste are generally not to be "objectionable", while the maximum threshold values for colour are given quantitatively as True Colour Units (TCU) or Hazen units. The Ghana Standards specify 15 TCU or 15 Hazen units for colour after filtration. The requirements for pH values set by the Ghana Standards Board for drinking water is 6.5 to 8.5 (GSB, 1998).

### 2.4.2 Microbial Requirements

The Ghana Standards specify that *E. coli* or thermotolerant bacteria and total coliform bacteria should not be detected in a 100 ml sample of drinking water (0 CFU/100 ml). The Ghana Standards also specify that drinking water should be free of human enteroviruses.

## 2.5 Some physico-chemical parameters of water

### 2.5.1 pH

pH is a measure of the activity of the solvated hydrogen ion or the measure of the hydrogen ion concentration (Bates, 1973). It could also be referred to as the negative common logarithm of hydrogen ion activity: pH = -log ($H^+$). Pure water has a pH very close to 7 at 25°C. Solutions with pH less than 7 are said to be acidic whiles those with pH greater than 7 are basic or alkaline. In dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration (WHO, 2011). The pH of water is a measure of the acid-base equilibrium and in most natural waters, it's controlled by the carbon dioxide-bicarbonate-carbonate equilibrium system. An increased carbon dioxide concentration will lower the pH whereas a decrease will cause it to rise (APHA, 1989). The pH of most raw water lies within the range 6.5 – 8.5 (APHA, 1989). Temperature also affects the equilibrium and pH of water. pH is also an important factor in determining the corrosivity of water. In general, the lower the pH, the higher the level of corrosion. The pH of water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Failure to do so can result in the contamination of drinking water and will have adverse effect on its taste, odour and colour (APHA, 1989).

### 2.5.2 Total Dissolved Solids (TDS)

Total dissolved solid is a measure of the combined content of all inorganic and organic substances contained in liquid; molecular, ionized or micro-granular (colloidal) in suspended form. Generally the solids must be small enough to survive filtration through a sieve, the size of two micrometers. The presence of dissolved solids in water may affect its taste.

Although TDS is not generally considered a primary pollutant (i.e. it is not deemed to be associated with health effects), it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants. Primary sources for TDS in receiving waters are agricultural and point source water pollution discharge from industrial or sewage treatment plants. More exotic and harmful elements of TDS are pesticides arising from surface runoff. Certain naturally occurring TDS arise from the weathering and dissolution of rocks and soils (DeZuane, 1997).

### 2.5.3 Electrical conductivity (EC)

The electrical conductivity of water is a measure of the ability of water to conduct an electric current. EC in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate and phosphate anions (ions which carry a negative charge) or sodium, magnesium, calcium, iron and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. EC is also affected by temperature; the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 $^{o}$C (APHA, 1992). Conductivity is useful as a general measure of stream water quality. Significant changes in conductivity could be an indication that a discharge or some other sources of pollution have entered the stream.

### 2.5.4 Total hardness

Hard water is water that has high mineral content. Hard drinking water is generally not harmful to one's health, but can pose serious problems in industrial settings, where water hardness is monitored to avoid costly breakdowns in boilers, cooling towers, and other equipment that handle water. In domestic settings, hard water is often indicated by a lack of suds formation when soap is agitated in water (WHO, 2011). Water hardness is determined by the concentration of multivalent cations in the water. Multivalent cations are cations (positively charged metal complexes) with a charge greater than 1+. Usually, the cations have the charge of 2+. Common cations found in hard water include $Ca^{2+}$ and $Mg^{2+}$. These ions enter a water supply by leaching from minerals within an aquifer. Common calcium-containing minerals are calcite and gypsum. A common magnesium mineral is dolomite (which also contains calcium). Rainwater and distilled water are soft because they also contain few ions (Weingärtner, 2006).

### 2.5.5 Turbidity

Turbidity is a measure of the clarity of water. It is also a measure of light transmission and indicates the presence of suspended material such as clay, silt, finely dissolved organic material, plankton and other inorganic material. Turbidity caused by high levels of organic matter can protect microorganisms from the effect of drinking water disinfection. Excessive turbidity or cloudiness in drinking water is aesthetically unappealing, and may also represent a health concern. High turbidity can provide food and shelter for pathogens and it can promote re-growth of pathogens in the distribution system which can lead to the outbreak of waterborne disease. It can even stimulate bacterial growth. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacterium. These organisms can cause nausea, cramps, diarrhoea and headaches (USEPA, 2007).

### 2.5.6 Nitrate and Nitrite

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. The nitrate ion ($NO_3^-$) is the stable form of combined nitrogen for oxygenated systems. Although chemically unreactive, it can be reduced by microbial action. The nitrite ion ($NO_2^-$) contains nitrogen in a relatively unstable oxidation state. Chemical and biological processes can further reduce nitrite to various compounds or oxidize it to nitrate (ICAIR Life Systems, Inc., 1987).

The major health risk from nitrate/nitrite is to infants under six months of age. At this early stage of development, nitrate in the body is transformed to nitrite, which reacts with haemoglobin (the oxygen carrier in the blood) and prevents transport of oxygen. The result is a decreased oxygen supply to the body, often called blue baby syndrome (or methemoglobinemia). It gets this name because the skin often turns a blue or grayish colour, especially around the mouth. Adults are at low risk from this syndrome; however adults with chronic health problems such as heart or lung disease or enzyme deficiencies may be at higher risk form elevated nitrate/nitrite levels. Pregnant and nursing mothers should also avoid drinking water high in nitrate/nitrite because of potential effects passed on to the foetus or infants (Masarik, 2008).

### 2.5.7 Iron

Iron is the second most abundant metal in the earth's crust, of which it accounts for about 5%. Elemental iron is rarely found in nature as the iron ions ($Fe^{2+}$ and $Fe^{3+}$) readily combine with oxygen and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides. In drinking-water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide, which settles out as a rust-coloured silt (Elinder *et al*., 1986). Iron in drinking water can provide a health benefit. Small concentrations are essential to human health, because iron helps transport oxygen in the blood. High concentrations of dissolved iron can result in poor tasting, unattractive water that stains both plumbing fixtures and clothing (DeZuane, 1997).

When iron-rich waters mix with tea, coffee or alcoholic beverages, they assume a black, inky appearance with an unpleasant taste. Vegetables cooked in iron-rich waters tend to become dark and unappetizing. Ferric iron deposits within corroded pipes can break free and generate rusty tap water. Iron bacteria gives water a disagreeable taste and causes yellow stains on laundry. The bacteria can also clog water systems, plug filters or envelop pump screens resulting in expensive repairs (WHO, 2011). Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50 mg/day (Asklund and Eldvall, 2005).

### 2.5.8 Chloride

Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). Water with high chloride may also have elevated sodium content. Higher concentrations of chloride in water usually indicate contamination from septic systems, road salt, fertilizer, animal waste or industrial waste (Masarik, 2008). Chloride is not toxic, but higher concentrations of Chloride ions may result in an objectionable salty taste to water and corrosion of plumbing in the hot water system. High chloride waters may also produce a laxative effect (Adams, 2001). Levels less than 10 mg/l are desirable but an upper limit of 250 mg/l has been set for the chloride ions, although at this limit, few people will notice the taste (WHO, 2011).

### 2.5.9 Temperature

Temperature has both direct and indirect effects on aquatic ecosystems. Variations in water temperature occur both seasonally and daily. Maximum daily temperatures usually occur in the afternoon whereas minimum temperatures are recorded in the early morning hours. Variations in daily temperature are attributed to radiation into and out of the water. Temperature is a critical water quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms. As the temperature of water changes, chemical and physical properties of water are affected. Specific conductivity and pH are dependent on temperature. Increase in temperature of water also increases the velocity of salt ions and in turn, the conductivity of the water. Changes in chemical nature of streams can have significant impacts on biological processes. Temperature of water for drinking and domestic use should not exceed 30 $^0$C (EPA, 1997).

### 2.5.10 Alkalinity

Alkalinity is a measure of the presence of bicarbonate, carbonate or hydroxide constituents. The recommended range for drinking water is 300 to 400 mg$CaCO_3$/l (Anonymous, 2006). A minimum level of alkalinity is desirable because it is considered a “buffer” that prevents large variations in pH. Water with low alkalinity (less than 75 mg$CaCO_3$/l), especially some surface waters and rainfall, is subject to changes in pH due to dissolved gasses that may be corrosive to metallic fittings. Moderately alkaline water (between 75 – 350 mg$CaCO_3$/l); in combination with hardness, forms a layer of calcium or magnesium carbonate that tends to inhibit corrosion of metal piping. Many public water utilities employ this practice to reduce pipe corrosion and to increase the useful life of the water distribution (Anonymous, 2006). High alkalinity (above 500 mg$CaCO_3$/l) is usually associated with high pH values, hardness and high dissolved solids and has adverse effects on plumbing systems, especially on hot water systems (water heaters, boilers, heat exchangers, etc.). Total alkalinity is an important test in determining the aggressiveness or scale forming tendency of water. If the total alkalinity is low the water may be aggressive and cause corrosion to pipe work and structures; if the total alkalinity is high the water may more readily promote scale formation (Masarik, 2008).

### 2.5.11 Fluoride

Fluorine is the 13th most common element in the earth's crust. In the form of fluoride, it is found in varying amounts in all natural waters. High fluoride concentrations are usually found in surface waters such as lakes and streams. However, they can occur in groundwater supplies. Fluoride is a normal part of the human diet and an optimum concentration of 1.0 mg/l in drinking water produces no ill effects. Children who have received optimally fluoridated water from birth have shown as much as 65% reduction in the occurrence of cavities when compared to areas with little or no fluoride. Children exposed to excessive amounts of fluoride while teeth are developing can develop dental fluorosis. Dental fluorosis appears as whitish or brown spots on the teeth (WHO, 2011).

## 2.6 Microbiological indicators of water

### 2.6.1 Faecal coliform

Faecal coliform is a facultative gram-negative anaerobic, rod-shaped non-sporulating bacterium (Doyle *et al*., 2006). *Escherichia coli* (*E. coli*) is a specific type of faecal coliform that lives in the intestines of humans and other warm-blooded animals and in their wastes. The presence of faecal coliform in drinking water or at swimming sites is an indication that human or animal waste is present and this may be cause for concern because many diseases can be spread through faecal transmission. In general, increased levels of faecal coliforms provide a warning of failure in water treatment, a break in the integrity of the distribution system, and a possible contamination with pathogens. Large quantities of faecal coliform bacteria in water are not necessarily harmful, but may indicate a high risk of pathogens in the water. Some water borne pathogenic diseases that may coincide with faecal contamination include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis and hepatitis A (FCDPH, 2009).

Faecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from human sewage. Failing home septic systems can allow coliforms in the effluent to flow into the water table, aquifers, drainage ditches and nearby surface waters. Sewage connections that are connected to storm drain pipes can also allow human sewage into surface waters. They also kill bacteria essential to the proper balance of the aquatic environment, endangering the survival of species dependent on those bacteria.

### 2.6.2 Total coliform

Total coliform group includes faecal coliform bacteria such as *Escherichia coli* (*E. coli*) as well as other types of coliform bacteria that are naturally found in the soil, most of which are not dangerous to human health. However, these bacteria are not naturally present in groundwater and are an indication that more harmful organisms might be present. Faecal coliform and *E. coli* are subgroups within the total coliform group which primarily come from the faeces of warm blooded animals. Presence of *E. coli* indicates that the water has been exposed to faeces and an immediate risk to human health exists (EPA, 2009).

# CHAPTER THREE

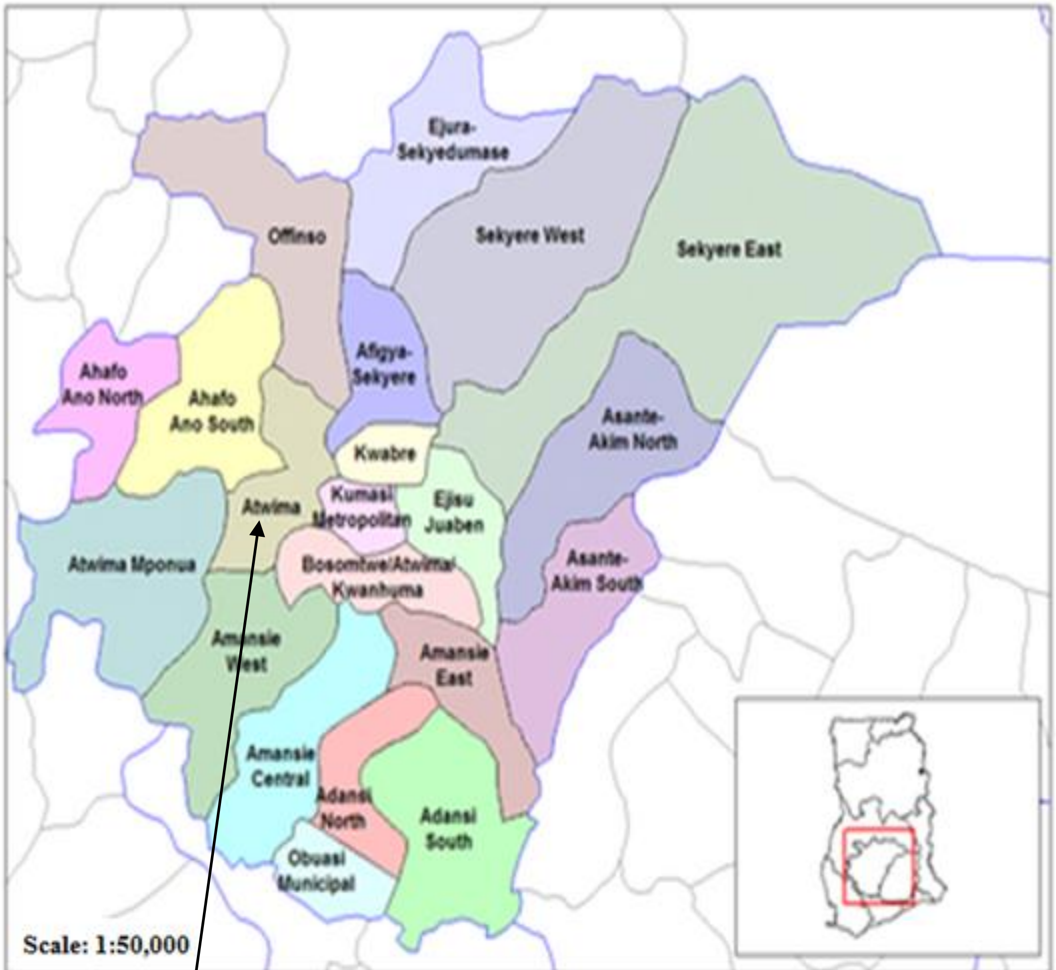
## 3.0 MATERIALS AND METHODS

### 3.1 Study area

The study was conducted in the Atwima Nwabiagya District of the Ashanti region of Ghana (figures 3.1). The region is the largest in the country with a population of 4,780,380 people, representing 19.4% of the total population of Ghana. The district has 149,025 people, representing 3.1% of the total population in the Ashanti region (GSS, 2012).

The district lies approximately between latitude $6^0$ 32'N and $6^0$ 75'N and between longitude $1^0$ 45' and $2^0$ 00' West. It is situated in the western part of the region and shares common boundaries with Ahafo-Ano South and Atwima Mponua districts to the west, Offinso Municipal to the north, Amansie-West and Bosomtwe-Atwima Kwanwoman districts to the south, Kumasi Metropolis and Kwabre districts to the east. It covers an estimated area of 294.84 sq. km. The district's capital is Nkawie.

The main highway corridor from the Ashanti Region to the Western Region goes through the district.




Source: Ministry of Local Government and Rural Development - Kumasi, Ghana

Atwima Nwabiagya District (Study area)

**Figure 3.1: A map of Ashanti region showing the various districts.**

### 3.2 Sampling Procedure

Preliminary studies were conducted to identify all the sachet water producers within the district from the FDB. Personal observations and interviews with shop owners also formed part of the preliminary studies which sought to find out the different storage and vending places for the sachet water and the length of time the water stays in each of these places. At the end of this preliminary exercise, seven sachet water producers were identified in the district. Two different storage places (inside a shop and a metal cage which is being left outside at the mercy of the weather) as well as two different vending places (a refrigerator or an ice chest and street hawking) were identified.

Three (3) bags each of sachet water were bought directly from all the seven production centres in the district on the same day that the water were produced and packaged. For ethical reasons, the seven sachet water (SW) production houses were coded as SW 1, SW 2, SW 3, SW 4, SW 5, SW 6 and SW 7. Each of the bags contained thirty (30) pieces of sachet water with each sachet containing 500 ml of water.

One bag from each of the seven brands was kept in a metal cage which was placed outside a shop. The water in the metal cage was exposed to the weather for a period of two weeks after which three sachet water were randomly selected from all the seven brands and taken to the laboratory for physico-chemical and microbiological analyses. The purpose of keeping the water in the metal cage was to determine whether the exposure to direct sunlight and even rains could have an effect on the quality of the water.

Another set of one bag each from the seven brands were kept inside a kiosk or shop under normal room temperature for one week. After the one week elapsed, three sachet water samples were randomly selected from each of the seven brands and taken to the laboratory for analyses. The purpose here was to determine whether or not there were changes in the initial quality of the water after it had been stored inside a shop for a week.

The third set of bags of sachet water from the seven brands was divided into three equal parts, each part including ten pieces of sachet water. The first part was put inside a refrigerator for three days on the same day that the water was produced and packaged. At the end of the third day, three samples were taken from each of the seven different brands to the laboratory and analyzed to determine the levels of their physico-chemical parameters as well as their microbiological contents.

The second set of sachet water from all the seven brands were given to a particular vendor who sells sachet water by the road side. The vendor was made to bulk all the sachet water from the seven brands and put all of them together inside the head pan in which she sells her water from. The vendor was made to sell the water by the roadside under conditions of direct sunshine, and the purpose of this was to examine whether extreme weather conditions could have an impact on the water. At the end of the day, three sachet water samples from each of the seven brands were randomly selected from the few remaining pieces of sachet water. These samples were subsequently sent to the laboratory the following morning for analyses.

Three samples of sachet water from the remaining third set were randomly selected from each of the seven brands and sent to the laboratory the following morning for analyses. The results obtained at this stage gave a clear indication of the initial quality of the various brands of sachet water at the time of production.

## 3.3 Laboratory Analyses

### 3.3.1 Physico-chemical Parameters

**pH**

The pH meter (HANNA instrument) was used to measure the pH of all the water samples. The electrode was put into a glass tube containing 250 ml of the water sample for about a minute. A stable figure then appeared on the screen of the meter and this value was read and recorded as the pH of that particular sample.

**Turbidity**

2100P turbidimeter (HACH Company) was used in measuring the turbidity values of the samples. A cell of 25 ml was taken from each of the samples and placed inside the turbidimeter and allowed to stand for about a minute. A stable figure appeared on the screen and the turbidity value was then read and recorded in Nephelometric Turbidity Units (NTU).

**Conductivity**

The Conductivity was determined by using 4510 conductivity meter (Jenway product). The conductivity cells and beaker were rinsed with a portion of the sample. Then the beaker was filled completely. The probe was then inserted into the water sample, a stable figure appeared on the screen and the conductance was read.

### Total Dissolved Solids and Temperature

The same instrument which was used in determining the conductivity of the samples was used for the determination of the total dissolved solids as well as the temperature of the various samples. For the TDS values of the samples, the mode of the meter was changed to mg/l. The electrode was rinsed in deionised water and placed in the sample to record TDS values. The results were displayed digitally on the screen of the meter and the TDS and temperature values were recorded.

### Total Hardness

1 ml of a buffer solution was added to a conical flask containing 100 ml of sample. One gram of Eriochrome Black T indicator was added to the sample in the conical flask, mixed gently and later titrated against 0.01N EDTA. The colour changed from an initial violet to sea blue, giving an indication that the end point had been reached. The reading was taken and then multiplied by 10 to change it to mg/l.

### Calcium Hardness

100 ml of sample was taken and 1 ml of 1N NaOH (buffer solution) was added to it. One gram of Mureoxide indicator was added to the sample and the colour changed to pink. This was then titrated against 0.01N EDTA until an end point was reached where

the colour changed to violet. The reading was taken and multiplied by 10 to obtain the total calcium.

**Magnesium Hardness**

Calcium and total hardness were determined by EDTA titration method. Magnesium hardness was calculated from the difference between the total hardness and the calcium hardness which is expressed in mg/l. The magnesium concentration was obtained by multiplying magnesium hardness by 0.243.

**Total Alkalinity**

100 ml of sample was taken and 1ml of methyl orange indicator was added to it and immediately titrated against HCl. When the end point was reached, the colour changed from yellow to orange and the reading was then taken.

**Chloride**

0.5 ml of potassium chromate ($K_2CrO_4$) indicator solution was added to 100 ml of the sample and titrated against a standard $AgNO_3$. When the end point was reached, the colour then changed from yellow to rust (brick red). The reading was then taken and multiplied by 10 to get the chloride value.

**Nitrite**

50 ml of the sample was taken. 2 ml each of ILOSVAY'S number 1 and 2 were added to the sample and left to stand for 15 minutes. At the end of the 15 minutes, a pinkish

development appeared to indicate nitrite. The nitrite was then measured using a Lovibond Comparator and a nitrite disc (which has different colours). The colour was then matched against the colours on the disc and the nitrite value was read on the comparator. The figure was then multiplied by 0.02 to change it to mg/l.

**Total Iron**

A test tube was filled with the sample to the 10 ml mark and one iron Low Range (LR) tablet was added to the sample in the test tube. The iron LR tablet was crushed in the test tube and then mixed to dissolve. The test tube was then made to stand for a period of one minute to allow for full colour development. A wavelength of 520 nm on the transmittance-display photometer was selected.

A blank test tube was placed in the test chamber. The ON button was pressed and kept depressed until the display read 100 (100%T) after which the button was released. The blank tube was then removed and placed in tube holder and the sample tube was then placed in the test chamber. A reading was displayed when steady then the instrument turned off automatically after 6-8 seconds. The displayed reading (%) was compared against the appropriate iron LR calibration chart to obtain the iron value.

**Sulphate**

A test tube was filled with the sample to the 10 ml mark. One sulphate turb tablet was added to the sample in the test tube. The sulphate turb tablet was crushed inside the test tube and then mixed to dissolve. A cloudy solution appeared and that indicated the presence of sulphate. The sample was then made to stand for five minutes after which it was mixed again to ensure uniformity. A wavelength of 520 nm on the transmittance-display photometer was selected by moving the slide control left or right.

A blank test tube was placed in the test chamber. The ON button was pressed and kept depressed until the display read 100 (100%T) after which the button was released. The blank tube was then removed and placed in tube holder and the sample tube was then placed in the test chamber. A reading was displayed when steady then the instrument turned off automatically after 6-8 seconds. The displayed reading (%) was compared against the appropriate sulphate calibration chart to obtain the sulphate value.

**Nitrate**

The Nitratest Tube was filled with sample to the 20 ml mark. One level spoonful of Nitratest powder and one Nitratest tablet were added. The screw cap was replaced and the tube was shaken well for one minute. The tube was then allowed to stand for about one minute and inverted gently three or four times to aid flocculation. The tube was then allowed to stand for two minutes or longer in order to ensure complete settlement. The screw cap was removed and a clean tissue was used to wipe around the top of the tube. The clear solution was carefully decanted into a round test tube, filling to the 10 ml mark. One Nitricol tablet was added, crushed and mixed to dissolve. The sample was then made to stand for 10 minutes to allow for full colour development, after which a wavelength of 570 nm was selected on the transmittance-display photometer. The same procedure used in determining the iron and sulphate values were repeated and the displayed readings (%) were compared against the appropriate nitrate calibration chart to obtain the nitrate values.

**Phosphate**

The cap of the Tubetests Phosphate/12P Tube was removed and 2.0 ml of the sample was added. One Tubetest Phosphate No 1 tablet was added, and this was then crushed and mixed to dissolve. After the tablet was completely dissolved, one Tubetests Phosphate No 2 tablet was also added, crushed and mixed to dissolve. The cap of the tube was replaced and the tube was gently inverted several times to mix after which it was allowed to stand for colour development.

A wavelength of 640 nm on Photometer was selected and the phosphate value was determined on the phosphate calibration chart using the same procedure as in the iron and sulphate.

**Fluoride**

The test tube was filled with sample to the 10 ml mark. One fluoride No1 tablet was added to the sample, crushed and mixed to dissolve. One fluoride No 2 tablet was then added, crushed and mixed to dissolve. The solution was allowed to stand for five minutes to allow for full colour development. The photometer reading was taken in usual manner using the appropriate fluoride calibration chart.

### 3.3.2 Microbiological indicators

The membrane filtration method was used in the determination of microbiological indicators; Faecal coliform (*E. coli*) and Total coliform. 100 ml of each sachet water sample was passed through a membrane filter with pore size 0.45 µm. After the filtration, the membrane filter was then placed on 10 ml of an already sterilized agar (M-Endo agar) in a petri dish and subsequently incubated.

**Faecal Coliform (*E. coli*)**

The petri dish was inverted or turned upside down and placed in an incubator for a period of 24 hours and under a temperature of 44 $^{0}$C. The petri dish was then removed from the incubator after the 24 hours elapsed and was observed to see if there were colonies on the agar. *E. coli* colonies will be dark coloured, but will also appear to have a metallic green sheen.

**Total Coliform**

For total coliform determination, the petri dish was as well inverted and incubated for a period of 24 hours but at a temperature of 37 $^{0}$C. At the end of the 24 hours, the petri dish was removed from the incubator and was observed to see if there were colonies on the agar.

## 3.4 Data analysis

Mean and Standard deviations of the water data were determined using SPSS (version 16) software. T-test was carried out to determine the level of significance between the various storage and vending places. The graphical representations (bar charts) were also generated using SPSS software.

# CHAPTER FOUR

## 4.0 RESULTS

## 4.1 Production

A summary of results recorded for both the physico-chemical parameters as well as the microbiological indicators of all the seven brands of sachet water at the time of production is presented in table 4.1.

**Table 4.1: Mean (±) Standard Deviation levels of parameter at production**

| Parameter | SW 1 | SW 2 | SW 3 | SW 4 | SW 5 | SW 6 | SW 7 | WHO Limits (WHO, 2011) |
|---|---|---|---|---|---|---|---|---|
| | BRAND | | | | | | | |
| | Mean ± Standard deviation | | | | | | | |
| Alkalinity ($mgCaCO_3/l$) | 40.00 ± 1.00 | 36.00 ± 1.00 | 20.00 ± 1.00 | 56.00 ± 1.00 | 60.00 ± 1.00 | 86.00 ± 1.00 | 38.00 ± 1.00 | 300 - 400[#] |
| Calcium (mg/l) | 6.00 ± 1.00 | 4.00 ± 1.00 | 4.00 ± 1.00 | 24.00 ± 1.00 | 18.00 ± 1.00 | 30.00 ± 1.00 | 8.00 ± 1.00 | 200 |
| Chloride (mg/l) | 26.00 ± 1.00 | 24.00 ± 1.00 | 33.00 ± 1.00 | 41.00 ± 1.00 | 29.00 ± 1.00 | 30.00 ± 1.00 | 31.00 ± 1.00 | 250 |
| EC (µS/cm ) | 89.00 ± 1.00 | 63.60 ± 0.10 | 116.70 ± 0.10 | 41.60 ± 0.10 | 164.90 ± 0.10 | 307.00 ± 1.00 | 93.30 ± 0.10 | 1000 |
| Fluoride (mg/l) | 0.30 ± 0.10 | 0.05 ± 0.02 | 0.35 ± 0.01 | 1.00 ± 0.01 | 0.65 ± 0.01 | 1.35 ± 0.01 | 0.35 ± 0.01 | 1.5 |
| Iron (mg/l) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.3 |
| Magnesium (mg/l) | 6.00 ± 1.00 | 4.00 ± 1.00 | 2.00 ± 1.00 | 6.00 ± 1.00 | 4.00 ± 1.00 | 34.00 ± 1.00 | 10.00 ± 1.00 | 150 |
| Nitrate (mg/l) | 0.84 ± 0.01 | 1.89 ± 0.01 | 1.14 ± 0.01 | 4.62 ± 0.01 | 0.92 ± 0.01 | 0.97 ± 0.01 | 4.84 ± 0.01 | 10 |
| Nitrite (mg/l) | 0.001 ± 0.000 | 0.001 ± 0.001 | 0.001 ± 0.000 | 0.001 ± 0.000 | 0.002 ± 0.001 | 0.002 ± 0.001 | 0.004 ± 0.001 | 1 |
| pH | 7.56 ± 0.02 | 7.55 ± 0.02 | 7.86 ± 0.01 | 8.20 ± 0.02 | 7.49 ± 0.01 | 8.25 ± 0.01 | 7.90 ± 0.02 | 6.5 - 8.5 |
| Phosphate (mg/l) | 0.34 ± 0.01 | 0.88 ± 0.01 | 0.94 ± 0.01 | **6.22 ± 0.01*** | 0.82 ± 0.01 | 0.72 ± 0.01 | 2.44 ± 0.02 | 5[a] |
| Sulphate (mg/l) | 5.00 ± 1.00 | 3.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 5.00 ± 1.00 | 12.00 ± 1.00 | 5.00 ± 1.00 | 250 |
| TDS (mg/l) | 60.61 ± 3.61 | 38.90 ± 0.10 | 69.40 ± 0.10 | 24.90 ± 0.00 | 100.10 ± 0.10 | 182.60 ± 0.10 | 56.10 ± 0.10 | 1000 |
| Hardness ($mgCaCO_3/l$) | 12.00 ± 1.73 | 8.00 ± 1.00 | 6.00 ± 1.00 | 30.00 ± 1.00 | 22.00 ± 1.00 | 64.00 ± 1.00 | 18.00 ± 1.00 | 120 |
| Turbidity (NTU) | 0.17 ± 0.02 | 0.29 ± 0.02 | 0.24 ± 0.01 | 0.23 ± 0.01 | 0.42 ± 0.01 | 0.32 ± 0.01 | 0.35 ± 0.02 | 5 |
| Faecal coliform (count/100 ml) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0 |
| Total coliform (count/100 ml) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0 |
| | *Values that exceed WHO Limit | | | [a](FDEP, 2008) | | [#](Masarik, 2008) | | |

As seen in table 4.1, the total Alkalinity levels in all the brands at production ranged from 20.00 ± 1.00 mg$CaCO_3$/l (G-Life) to 86.00 ± 1.00 mg$CaCO_3$/l (SW 6). SW 2 and SW 3 recorded the lowest Calcium levels whiles SW 6 recorded the highest, representing 4.00 ± 1.00 mg/l and 30.00 ± 0.00 mg/l respectively. For Chloride, the results showed that SW 1 and SW 4 recorded the lowest and highest levels of 26.00 ± 1.00 mg/l and 41.00 ± 1.00 mg/l respectively. From table 4.1, it was observed that the Electrical Conductivity (EC) levels in the sachet water ranged from 41.60 ± 0.10 µS/cm (SW 4) to 307.00 ± 1.00 µS/cm (SW 6). The highest Fluoride level of 1.35 ± 0.01 mg/l was recorded in brand SW 6, whereas the lowest level of 0.05 ± 0.02 mg/l was recorded in SW 2. The concentrations of iron in all the brands at production were below detectable limits (0.00 ± 0.00 mg/l). Magnesium levels ranged between 34.00 ± 1.00 mg/l in SW 6 to 2.00 ± 1.00 mg/l (SW 3). Nitrate levels in the sachet water at production ranged from 4.84 ± 0.01 mg/l (SW 7) to 0.84 ± 0.01 mg/l (SW 1). SW 1, SW 2, SW 3 and SW 4 all recorded mean nitrite values of 0.001 ± 0.001 mg/l. The rest of the brands recorded nitrite values ranging from 0.002 ± 0.001 mg/l to 0.004 ± 0.001 mg/l (SW 7). pH values for all the brands ranged from 7.49 ± 0.01 to 8.25 ± 0.01, with SW 5 and SW 6 recording the lowest and highest values respectively. The highest Phosphate value was recorded at SW 4 (6.22 ± 0.01 mg/l) whiles SW 1 recorded the least (0.34 ± 0.01mg/l). The sulphate levels of SW 3 and SW 4 at production were below detectable limits (0.0 ± 0.0 mg/l); with SW 6 recording the highest sulphate value of 12.0 ± 1.0 mg/l. Total Dissolved Solids (TDS) recorded values which ranged from 24.90 ± 0.00 mg/l (SW 4) to 182.60 ± 0.1 mg/l (SW 6).

Total hardness also recorded values ranging from 6.00 ± 1.00 $mgCaCO_3/l$ to 64.00 ± 1.00 $mgCaCO_3/l$ for SW 3 and SW 6 respectively. The turbidity levels of the sachet water also ranged from 0.17 ± 0.02 NTU (SW 1) to 0.42 ± 0.01 NTU (SW 5).

The microbiological indicators (faecal coliform and total coliform) of all the sachet water were below detectable limits (0.00 ± 0.00 CFU/100 ml).

## 4.2 Storage

Some sachet water samples were stored inside a shop whereas others were stored inside a metal cage which was being left outside for specified periods of time (one and two weeks respectively). The results obtained in the two storage places (shop and metal cage) for the seven brands of sachet water samples in relation to the various parameters are presented in figures 4.1 to 4.14. The WHO's guideline limits have been indicated in the graphs where possible.

### 4.2.1 Alkalinity

The mean Alkalinity ($mgCaCO_3/l$) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.1 below.

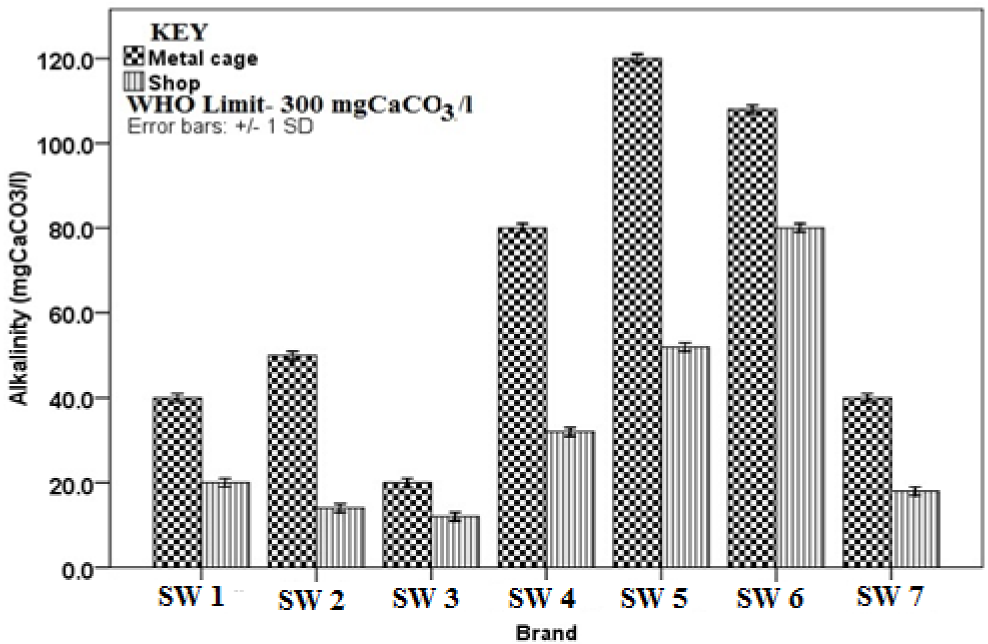



**Figure 4.1: Mean Alkalinity levels at the two storage places**

The results showed that the mean Alkalinity levels for water stored inside the metal cage were higher in all the brands as compared to water stored inside the shop (figure 4.1). Alkalinity levels for water stored inside the metal cage ranged from 20.00 ± 1.00 $mgCaCO_3/l$ (SW 3) to 120.00 ± 1.00 $mgCaCO_3/l$ (SW 5), whereas water stored inside the shop ranged from 12.00 ± 1.00 $mgCaCO_3/l$ (SW 3) to 80.00 ±1.00 $mgCaCO_3/l$ (SW 6). The results also showed that the mean alkalinity values for all the water samples stored inside the metal cage were significantly different ($p = 0.00117$) from those stored inside the shop.

### 4.2.2 Calcium

The mean Calcium (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.2 below.

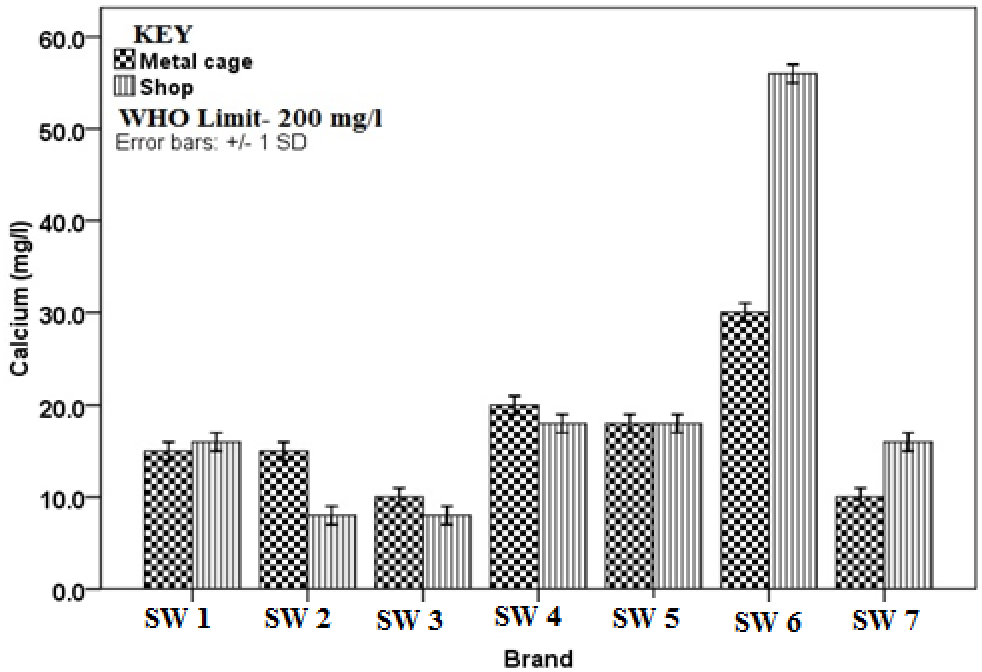



**Figure 4.2: Mean Calcium levels at the two storage places**

Water stored inside the metal cage witnessed SW 3 and SW 7 recording the lowest calcium levels whereas SW 6 recorded the highest, representing 10.00 ± 1.00 mg/l and 30.00 ± 1.00 mg/l respectively. For water stored inside the shop, SW 2 and SW 3 recorded the least calcium levels whiles SW 6 recorded the highest with 8.00 ± 1.00 mg/l and 56.00 ± 1.00 mg/l respectively. For brands SW 2, SW 6 and SW 7, the results indicated that there was a significant difference between the two storage places. However, the mean values of all the brands stored inside the metal cage as against those stored inside the shop, the results showed that there was no significant difference ($p = 0.4009$) between the two storage places.

### 4.2.3 Chloride

The mean Chloride (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.3 below.

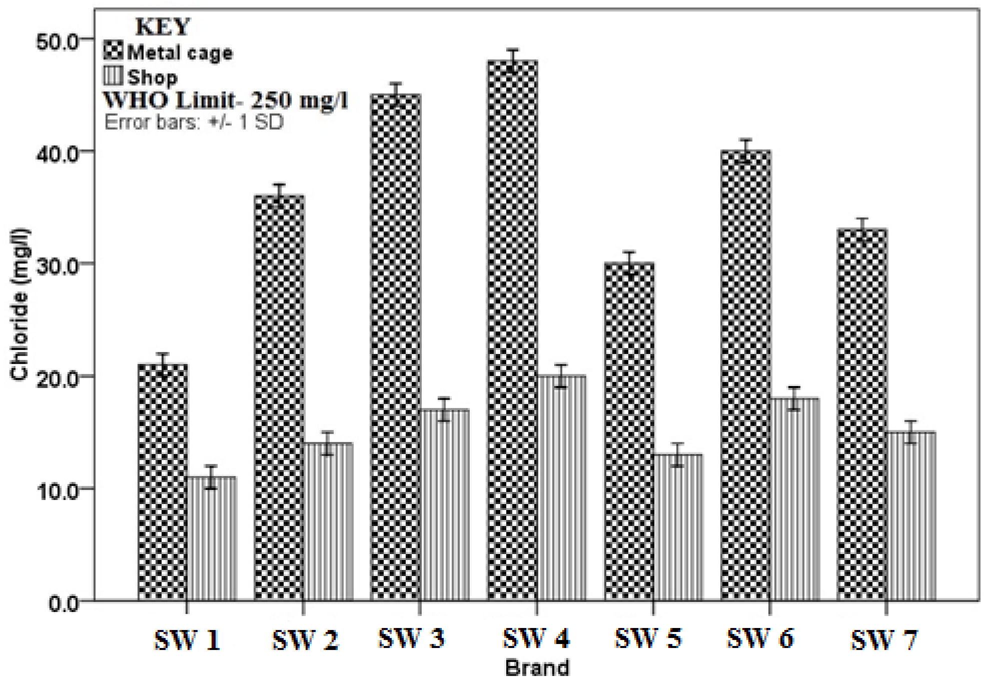



**Figure 4.3: Mean Chloride levels at the two storage places**

Mean chloride levels in all the brands recorded higher values for water stored inside the metal cage than those stored inside the shop (figure 4.3). SW 4 and SW 1 recorded the highest and lowest chloride levels representing 48. 00 ± 1.00 mg/l and 21.00 ± 1.00 mg/l respectively for water stored inside the metal cage. Similarly, the two brands recorded the highest and lowest chloride levels representing 20.00 ± 1.00 mg/l and 11.00 ± 1.00 mg/l for water stored inside the shop respectively. The results revealed that there was a significant difference (p = 1.1019E-12) between the mean values of all the water stored inside the metal cage and those stored inside the shop.

### 4.2.4 Electrical Conductivity (EC)

The mean Electrical Conductivity (µS/cm) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.4 below.

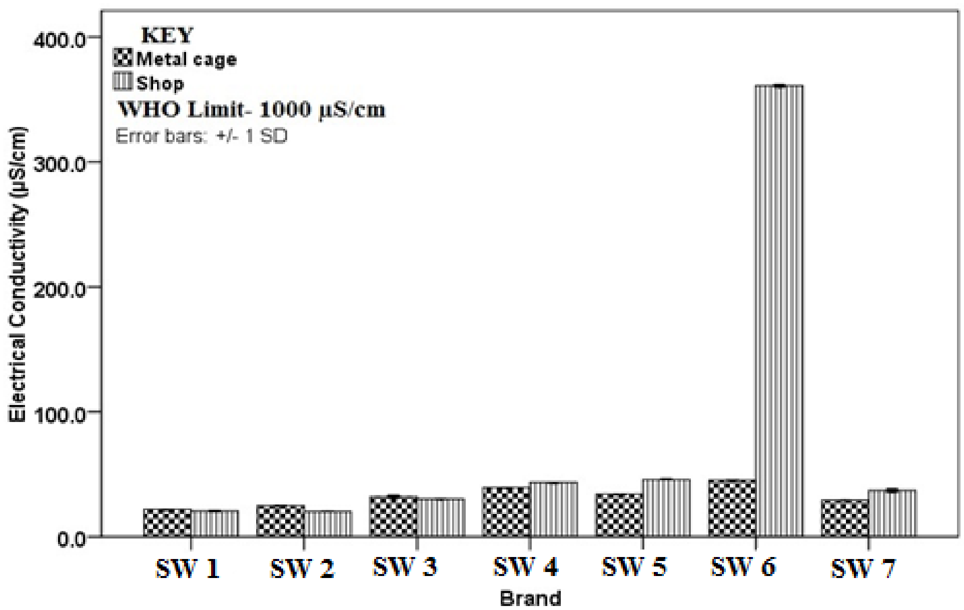



**Figure 4.4: Mean EC levels at the two storage places**

For water stored inside the metal cage, the highest EC level was recorded at brand SW 6 (45.20 ± 1.00 µS/cm) with SW 1 recording the lowest (21.90 ± 1.00 µS/cm). Similarly, SW 6 recorded the highest EC value of 361.00 ± 1.00 µS/cm for water stored inside the shop whiles SW 2 recorded the least with 20.10 ± 1.00 µS/cm (figure 4.4). For brand SW 6, the results indicated that there was a significant difference between the mean values of the two storage places. However, when the mean values for all the water stored inside the metal cage as against those stored inside the shop was taken into account, the results showed that there was no significant difference ($p = 0.07386$) between the two storage places.

### 4.2.5 Fluoride

The mean Fluoride (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.5 below.

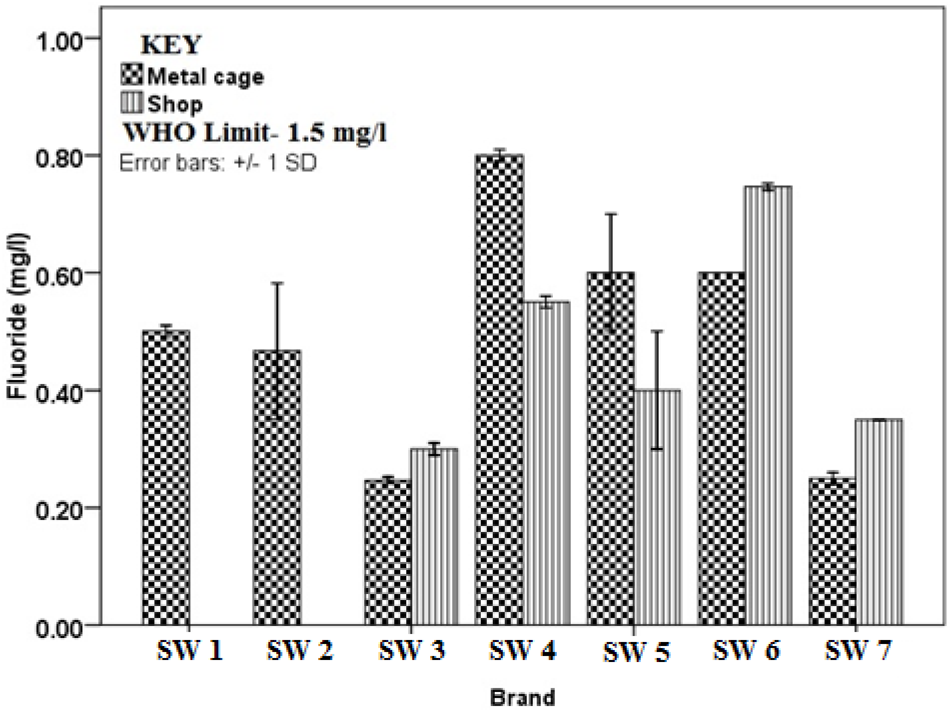



**Figure 4.5: Mean Fluoride levels at the two storage places**

Fluoride levels for water stored inside the metal cage recorded values ranging from 0.25 ± 0.01 mg/l (SW 3) to 0.80 ± 0.01 mg/l (SW 4). For water stored inside the shop, fluoride levels for SW 1 and SW 2 were below detectable limits (0.00 ± 0.00 mg/l); with SW 6 recording the highest value of 0.75 ± 0.01 mg/l (figure 4.5). For all the water stored inside the metal cage, the results showed that their mean fluoride levels were significantly different (p = 0.03026) from those stored inside the shop.

### 4.2.6 Hardness

The mean Hardness ($mgCaCO_3/l$) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.6 below.

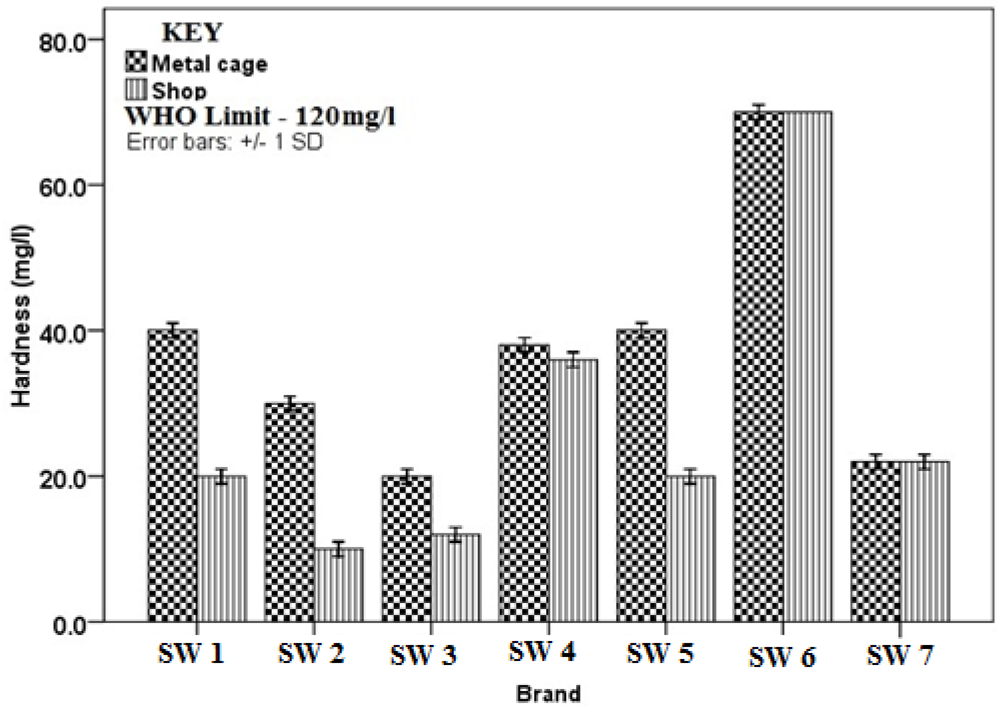



**Figure 4.6: Mean Hardness levels at the two storage places**

Hardness levels for the sachet water ranged from 70.00 ± 1.00 $mgCaCO_3/l$ (SW 6) to 20.00 ± 1.00 $mgCaCO_3/l$ (SW 3) for water stored inside the metal cage. For water stored inside the shop, SW 6 recorded the highest value whereas SW 2 recorded the lowest value representing 70.00 ± 1.00 $mgCaCO_3/l$ and 10.00 ± 1.00 $mgCaCO_3/l$ respectively (figure 4.6). Even though SW 1, SW 2, SW 3 and SW 5 witnessed significant differences between the two storage places, the results did indicate that mean hardness levels for all the brands stored inside the metal cage, as against those stored inside the shop was not significantly different ($p = 0.07691$).

### 4.2.7 Magnesium

The mean Magnesium (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.7 below.

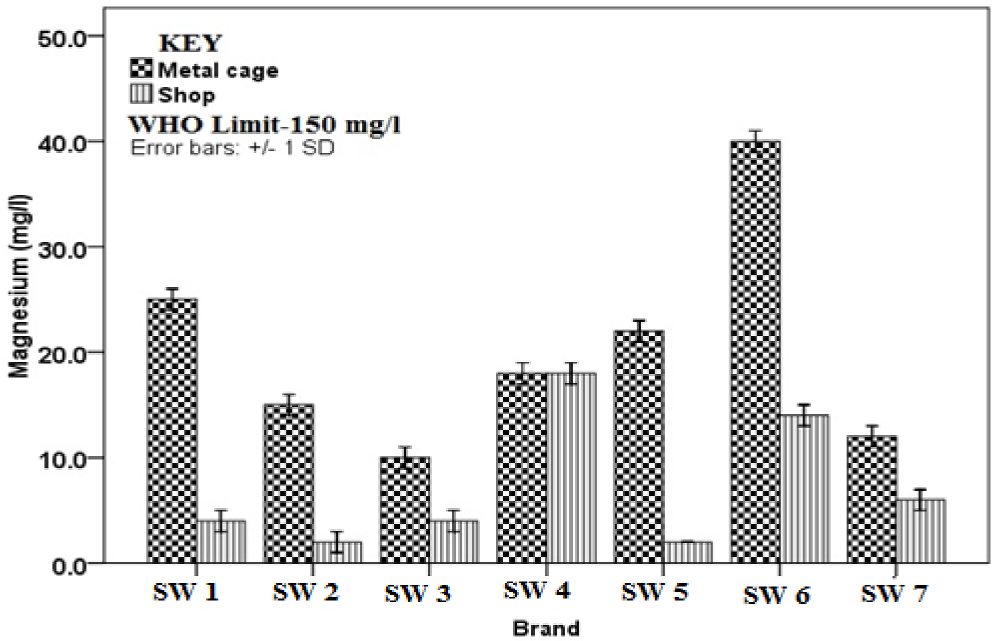



**Figure 4.7: Mean Magnesium levels at the two storage places**

Water stored inside the metal cage recorded higher magnesium values than those stored inside the shop in all the brands except SW 4 where both storage places recorded the same value of 18.00 ± 1.00 mg/l (fig. 4.7). For water stored inside the metal cage, SW 6 and SW 3 recorded the highest and lowest magnesium levels of 40.00 ± 1.00 mg/l and 10.00 ± 1.00 mg/l respectively. For water stored inside the shop, SW 2 and SW 5 recorded the lowest magnesium level of 2.00 ± 1.00 mg/l whereas SW 4 recorded the highest level of 18.00 ± 1.00 mg/l. Even though there wasn't any significant difference between the mean values of SW 4 at the two storage places, the results indicated that the overall mean values for all the water stored inside the metal cage was significantly different (p = 4.9E-6) from those stored inside the shop.

### 4.2.8 Nitrate

The mean Nitrate (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.8 below.

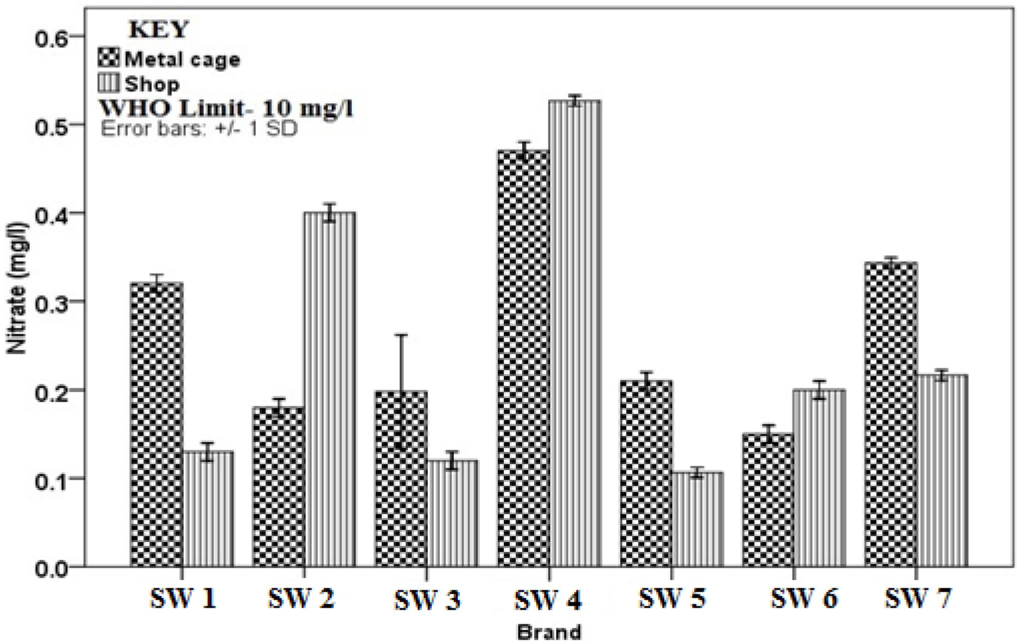



**Figure 4.8: Mean Nitrate levels at the two storage places**

The highest nitrate level for water stored inside the metal cage was recorded in SW 4 (0.47 ± 0.01 mg/l) whereas SW 6 recorded the lowest representing 0.15 ± 0.01 mg/l. For water stored inside a shop, SW 4 and SW 5 recorded the highest and lowest levels; representing 0.53 ± 0.01 mg/l and 0.11 ± 0.01 mg/l respectively (figure 4.8). From the results obtained, it was observed that there was a significant difference between the mean values of all the individual brands at the two storage places. However, when the mean values of all the brands stored inside the metal cage was compared to the mean values of all the brands stored inside the shop, the results showed that there wasn't any significant difference ($p = 0.55502$) between the two storage places.

### 4.2.9 Nitrite

The mean Nitrite (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.9 below.

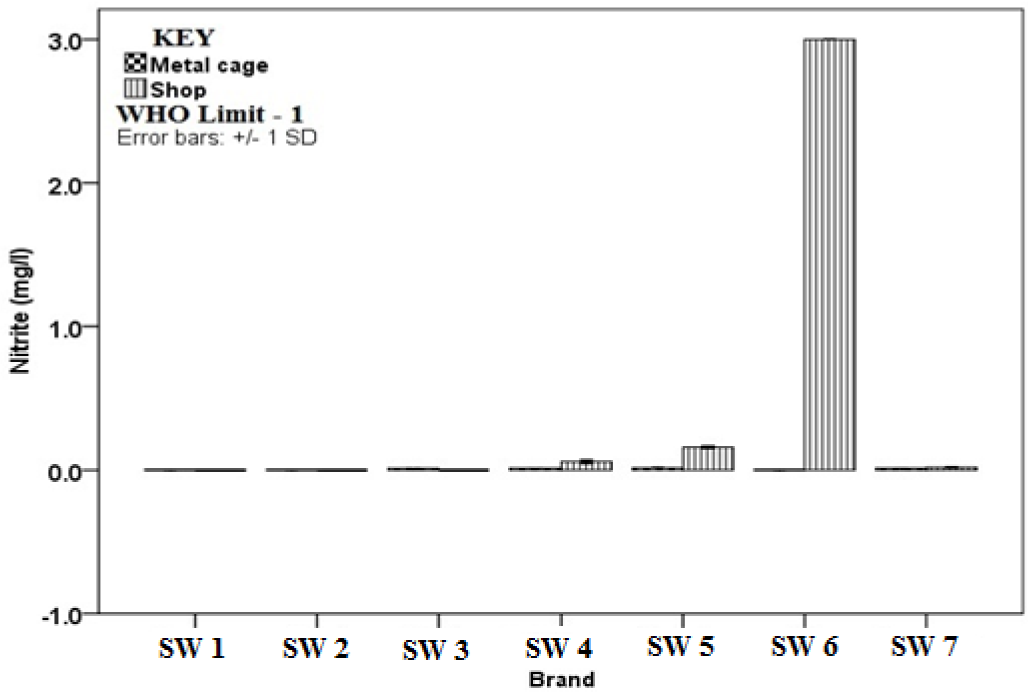



**Figure 4.9: Mean Nitrite levels at the two storage places**

Nitrite levels ranged from 0.004 ± 0.001 mg/l to 0.016 ± 0.001 mg/l for water stored inside the metal cage. For water stored inside the shop, the nitrite levels in SW 1, SW 2 and SW 3 were all below detectable limits. SW 6 however recorded the highest nitrite level of 3.00 ± 0.000 mg/l. The results however indicated that there was no significant difference (p = 0.05770) between the mean values of water stored inside the metal cage and those stored inside the shop.

### 4.2.10 pH

The mean pH levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.10 below.

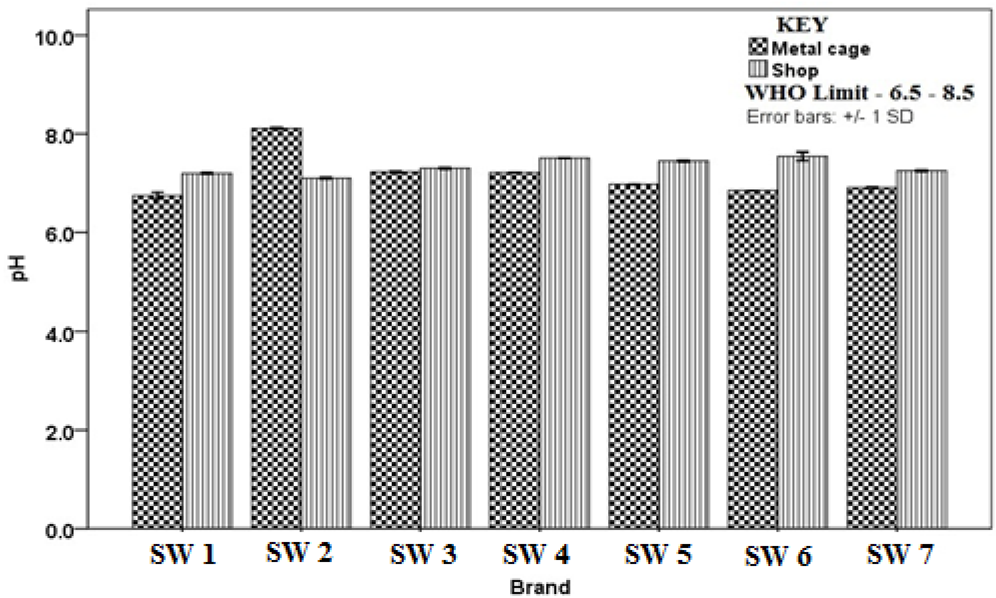



**Figure 4.10: Mean pH levels at the two storage places**

pH values were higher in water stored inside the shop than those stored inside the metal cage in all the brands except SW 2 (figure 4.10). Water stored inside the metal cage recorded pH values ranging from 6.78 ± 0.02 (SW 1) to 8.11 ± 0.02 (SW 2), whiles water stored inside the shop also recorded pH values ranging from 7.10 ± 0.02 (SW 2) to 7.55 ± 0.10 (SW 6). The results indicated that the mean pH values for water stored inside the metal cage was not significantly different ($p = 0.07220$) from water stored inside the shop.

### 4.2.11 Phosphate

The mean Phosphate (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.11 below.

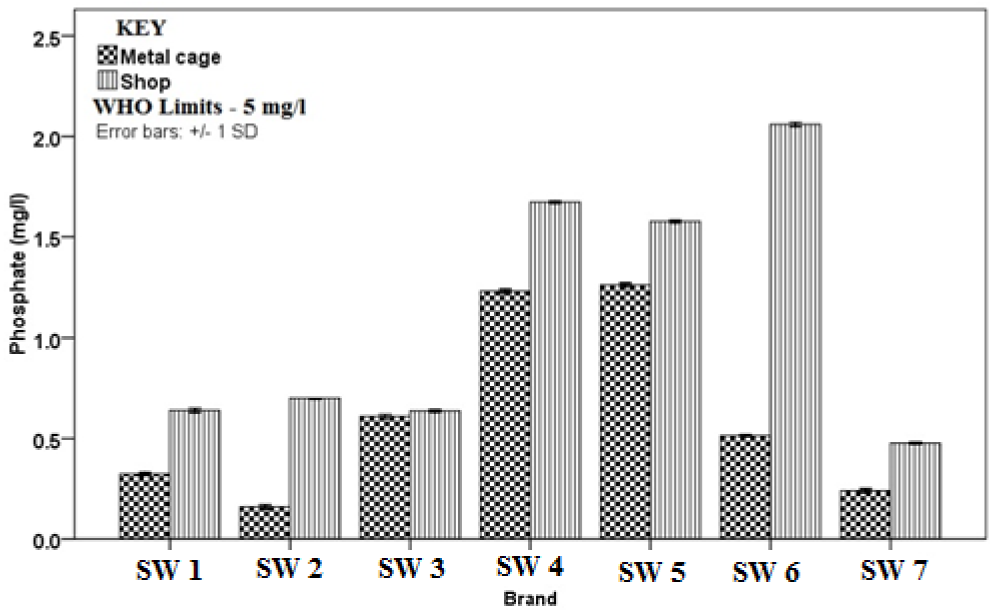



**Figure 4.11: Mean Phosphate levels at the two storage places**

Phosphate levels were higher in water stored inside the shop than those stored inside the metal cage in all the brands (figure 4.11). SW 2 and SW 5 recorded the lowest and highest phosphate levels of 0.16 ± 0.01 mg/l and 1.26 ± 0.01 mg/l respectively for water stored inside the metal cage. On the other hand, SW 7 recorded the lowest phosphate level of 0.48 ± 0.01 mg/l whiles SW 6 recorded the highest with 2.06 ± 0.01 mg/l for water stored inside the shop. Even though the mean values for SW 3 at the two storage places was not significant, the results showed that the mean phosphate values for all the water stored inside the metal cage was significantly different ($p = 0.00444$) from the mean values of all the water stored inside the shop.

### 4.2.12 Sulphate

The mean Sulphate (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.12 below.

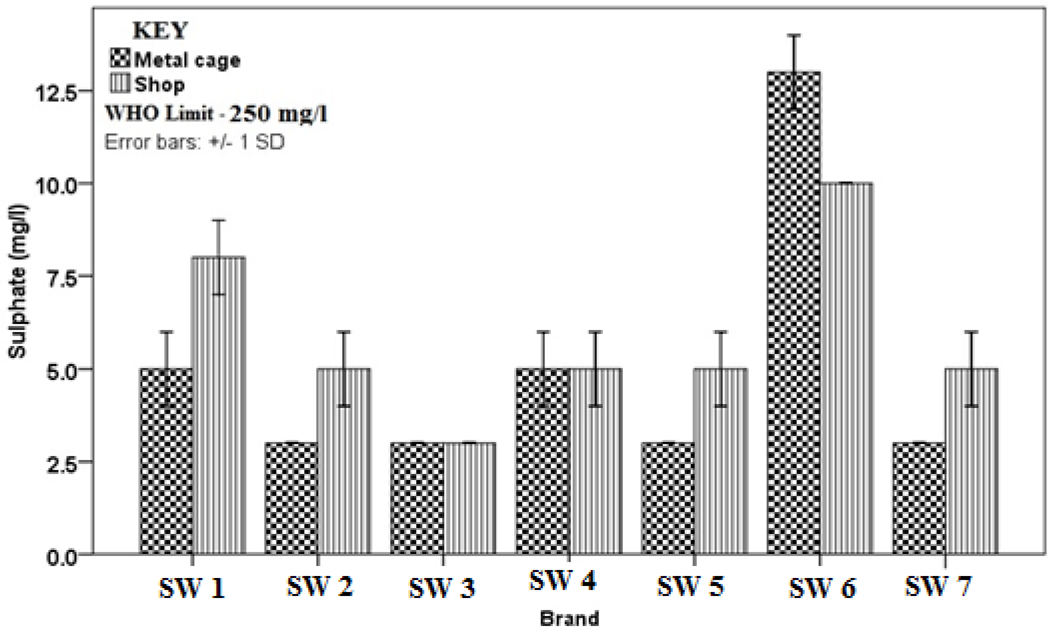



**Figure 4.12: Mean Sulphate levels at the two storage places**

Sulphate levels for water stored in the metal cage ranged from 3.00 ± 1.0 mg/l to 13.00 ± 0.01 mg/l with SW 2, SW 3, SW 5 and SW 7 recording the lowest whiles SW 6 recorded the highest respectively. Water stored inside the shop also recorded sulphate levels ranging from 3.00 ± 0.01 mg/l (SW 3) to 10.00 ± 0.01 mg/l (SW 6) (figure 4.12). With the exception of brands SW 3 and SW 4, the results showed that there were significant differences between the two storage places for all the brands. However, when the mean values for all the brands stored inside the metal cage was compared to the mean values of those stored inside the shop, the results showed that there was no significant difference ($p = 0.35648$) between the two storage places.

#### 4.2.13 Total Dissolved Solids (TDS)

The mean TDS (mg/l) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.13 below.

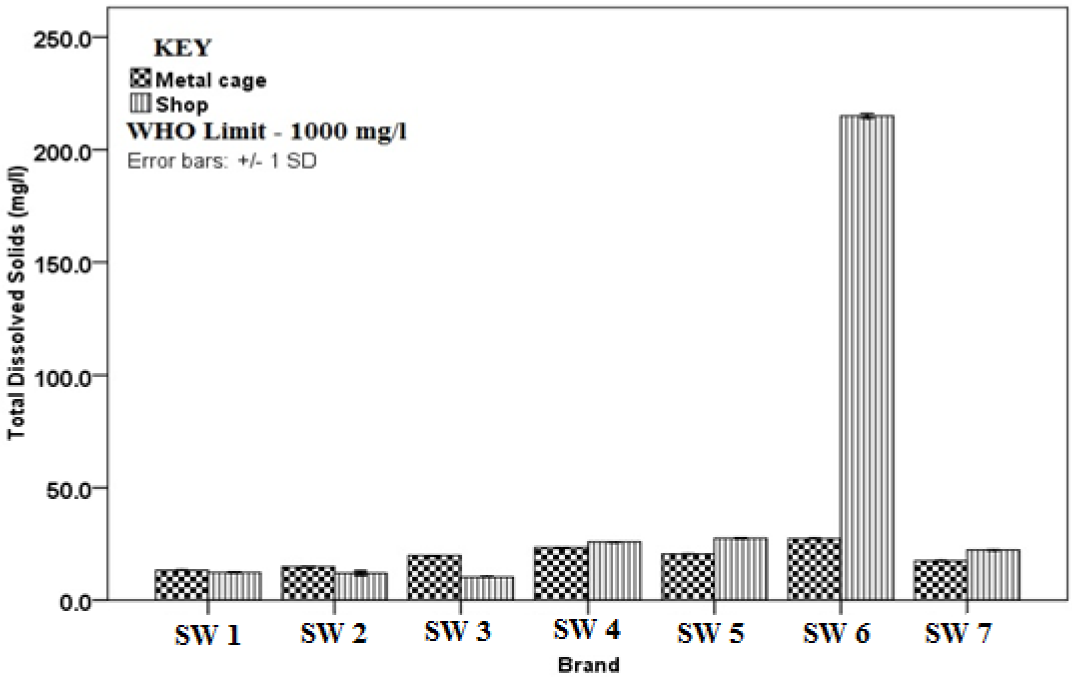



**Figure 4.13: Mean TDS levels at the two storage places**

TDS levels ranged from 13.30 ± 0.10 mg/l (SW 1) to 27.30 ± 0.10 mg/l (SW 6) for water stored inside the metal cage. For water stored inside the shop, SW 3 recorded the lowest TDS value of 10.30 ± 0.10 mg/l whereas SW 6 recorded the highest with 215.00 ± 1.0 mg/l (figure 4.13). For SW 6, the results showed a significant difference between the storage places. However, the results indicated that the mean values for all the water stored inside the metal cage and those stored inside the shop wasn't significant different ($p = 0.08943$).

### 4.2.14 Turbidity

The mean Turbidity (NTU) levels for all the seven brands of sachet water at the two storage places (metal cage and shop) are presented in figure 4.14 below.

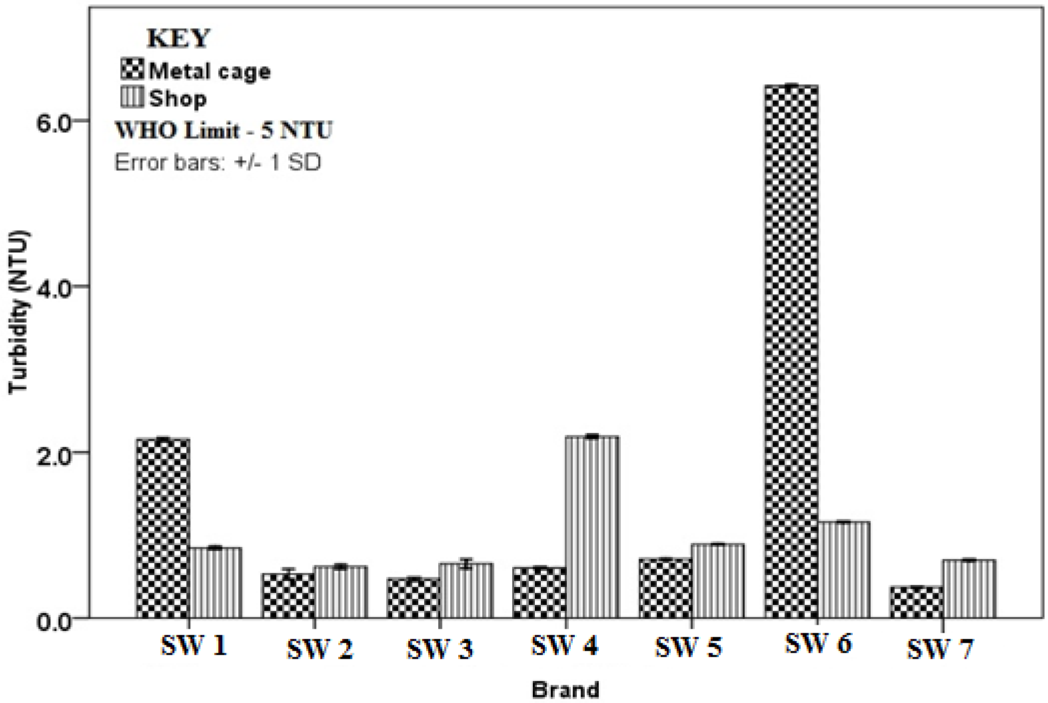



**Figure 4.14: Mean Turbidity levels at the two storage places**

SW 6 recorded the highest turbidity value of 6.42 ± 0.02 NTU whiles SW 7 recorded the least with 0.37 ± 0.01 NTU for water stored inside the metal cage. For water stored inside the shop, SW 2 and SW 4 recorded the lowest and highest turbidity values of 0.62 ± 0.03 NTU and 2.19 ± 0.02 NTU respectively (figure 4.14). For SW 1, SW 4 and SW 6, the results showed that there were significant differences between the two storage places. However, the results also did indicate that the mean values of all the water stored inside the metal cage did not differ significantly ($p = 0.20947$) from the water stored inside the shop.

### 4.2.15 Iron, faecal and total coliforms

The iron, faecal and total coliform levels in all the brands at the two storage places were below detectable limits as indicated in appendices A7, A16, and A17 respectively.

## 4.3 Vending

Two vending places (a refrigerator and street hawking) were identified and sachet water samples were vended in these two places for specified periods of time (three days and one day respectively). The results obtained for the seven brands of sachet water samples in relation to the various parameters are presented in table 4.2.

## Table 4.2: Mean (±) Standard Deviation levels of parameter at the vending stage

| | | BRAND | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Vending Place | SW 1 | SW 2 | SW 3 | SW 4 | SW 5 | SW 6 | SW 7 | WHO Limits |
| | | Mean ± Standard deviation | | | | | | | (WHO, 2011) |
| Alkalinity ($mgCaCO_3/l$) | Refrigerator | 30.00 ± 1.00 | 28.00 ± 1.00 | 10.00 ± 1.00 | 36.00 ± 1.00 | 52.00 ± 1.00 | 100.00 ± 1.00 | 32.00 ± 1.00 | 300 - 400[#] |
| | Hawking | 20.00 ± 1.00 | 16.00 ± 1.00 | 22.00 ± 1.00 | 38.00 ± 1.00 | 40.00 ± 1.00 | 84.00 ± 1.00 | 28.00 ± 1.00 | |
| Calcium (mg/l) | Refrigerator | 18.00 ± 1.00 | 4.00 ± 1.00 | 2.00 ± 1.00 | 3.00 ± 1.00 | 14.00 ± 1.00 | 1.00 ± 1.00 | 10.00 ± 1.00 | 200 |
| | Hawking | 20.00 ± 1.00 | 32.00 ± 1.00 | 8.00 ± 1.00 | 26.00 ± 1.00 | 24.00 ± 1.00 | 40.00 ± 1.00 | 20.00 ± 1.00 | |
| Chloride (mg/l) | Refrigerator | 10.00 ± 1.00 | 12.00 ± 1.00 | 18.00 ± 1.00 | 15.00 ± 1.00 | 13.00 ± 1.00 | 30.00 ± 1.00 | 31.00 ± 1.00 | 250 |
| | Hawking | 13.00 ± 1.00 | 16.00 ± 1.00 | 21.00 ± 1.00 | 18.00 ± 1.00 | 14.00 ± 1.00 | 16.00 ± 1.00 | 13.00 ± 1.00 | |
| EC (µS/cm ) | Refrigerator | 48.00 ± 0.00 | 41.10 ± 0.10 | 34.50 ± 0.10 | 36.80 ± 0.10 | 35.00 ± 0.10 | 55.60 ± 0.20 | 22.00 ± 1.00 | 1000 |
| | Hawking | 38.70 ± 0.00 | 37.37 ± 1.07 | 49.80 ± 0.00 | 62.70 ± 0.10 | 60.80 ± 0.10 | 597.00 ± 0.00 | 119.50 ± 0.10 | |
| Fluoride (mg/l) | Refrigerator | 0.33 ± 0.06 | 0.03 ± 0.03 | 0.35 ± 0.01 | 0.80 ± 0.01 | 0.55 ± 0.01 | 0.70 ± 0.01 | 0.35 ± 0.01 | 1.5 |
| | Hawking | 0.50 ± 0.01 | 0.40 ± 0.10 | 0.60 ± 0.01 | 0.94 ± 0.01 | 0.75 ± 0.01 | 0.85 ± 0.01 | 0.55 ± 0.01 | |
| Iron (mg/l) | Refrigerator | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.3 |
| | Hawking | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | |
| Magnesium (mg/l) | Refrigerator | 4.00 ± 1.00 | 4.00 ± 1.00 | 2.00 ± 1.00 | 3.00 ± 1.00 | 4.00 ± 1.00 | 30.00 ± 1.00 | 0.00 ± 1.00 | 150 |
| | Hawking | 2.00 ± 1.00 | 4.00 ± 1.00 | 14.00 ± 1.00 | 6.00 ± 1.00 | 8.00 ± 1.00 | 34.00 ± 1.00 | 4.00 ± 1.00 | |
| Nitrate (mg/l) | Refrigerator | 0.44 ± 0.01 | 0.44 ± 0.01 | 0.48 ± 0.01 | 5.63 ± 0.01 | 0.62 ± 0.01 | 0.62 ± 0.01 | 5.06 ± 0.01 | 10 |
| | Hawking | 0.03 ± 0.01 | 0.05 ± 0.01 | 0.07 ± 0.01 | 0.18 ± 0.01 | 0.11 ± 0.01 | 0.22 ± 0.01 | 0.22 ± 0.01 | |
| Nitrite (mg/l) | Refrigerator | 0.001 ± 0.000 | 0.001 ± 0.001 | 0.001 ± 0.000 | 0.001 ± 0.001 | 0.002 ± 0.001 | 0.002 ± 0.001 | 0.003 ± 0.001 | 1 |
| | Hawking | 0.003 ± 0.000 | 0.003 ± 0.001 | 0.002 ± 0.001 | 0.007 ± 0.001 | 0.009 ± 0.001 | 0.050 ± 0.010 | 0.008 ± 0.001 | |
| pH | Refrigerator | 6.36 ± 0.02* | 6.43 ± 0.02* | 6.55 ± 0.01 | 6.68 ± 0.02 | 6.48 ± 0.01 | 7.32 ± 0.01 | 6.81 ± 0.02 | 6.5 - 8.5 |
| | Hawking | 5.54 ± 0.02* | 5.38 ± 0.02* | 5.63 ± 0.02* | 5.71 ± 0.01* | 5.65 ± 0.03* | 5.95 ± 0.01* | 5.76 ± 0.01* | |
| Phosphate (mg/l) | Refrigerator | 0.46 ± 0.01 | 0.54 ± 0.01 | 0.36 ± 0.01 | 1.94 ± 0.01 | 1.30 ± 0.10 | 1.06 ± 0.01 | 0.36 ± 0.02 | 5[a] |
| | Hawking | 0.75 ± 0.01 | 0.78 ± 0.01 | 0.72 ± 0.01 | 1.88 ± 0.01 | 1.23 ± 0.01 | 1.46 ± 0.01 | 0.40 ± 0.03 | |
| Sulphate (mg/l) | Refrigerator | 8.00 ± 1.00 | 3.00 ± 1.00 | 5.00 ± 1.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 10.00 ± 1.00 | 3.00 ± 0.00 | 250 |
| | Hawking | 5.00 ± 0.00 | 3.00 ± 1.00 | 3.00 ± 1.00 | 5.00 ± 1.00 | 0.00 ± 0.00 | 7.00 ± 1.00 | 0.00 ± 1.00 | |
| TDS (mg/l) | Refrigerator | 29.00 ± 1.00 | 24.70 ± 0.10 | 21.00 ± 0.10 | 21.90 ± 0.10 | 20.90 ± 0.10 | 33.20 ± 0.10 | 13.00 ± 1.00 | 1000 |
| | Hawking | 22.30 ± 0.10 | 22.10 ± 0.10 | 29.70 ± 0.10 | 38.70 ± 0.10 | 36.40 ± 0.10 | 361.00 ± 1.00 | 70.90 ± 0.10 | |
| Hardness ($mgCaCO_3/l$) | Refrigerator | 22.00 ± 1.00 | 8.00 ± 1.00 | 4.00 ± 1.00 | 6.00 ± 1.00 | 18.00 ± 1.00 | 60.00 ± 1.00 | 10.00 ± 1.00 | 120 |
| | Hawking | 22.00 ± 1.00 | 36.00 ± 1.00 | 22.00 ± 1.00 | 32.00 ± 1.00 | 32.00 ± 1.00 | 74.00 ± 1.00 | 24.00 ± 1.00 | |
| Turbidity (NTU) | Refrigerator | 0.21 ± 0.02 | 0.37 ± 0.03 | 0.21 ± 0.02 | 0.30 ± 0.10 | 0.46 ± 0.01 | 0.33 ± 0.02 | 0.24 ± 0.01 | 5 |
| | Hawking | 0.83 ± 0.02 | 0.86 ± 0.04 | 0.36 ± 0.04 | 2.06 ± 0.02 | 1.28 ± 0.01 | 0.71 ± 0.04 | 0.43 ± 0.01 | |
| Faecal coliform (count/100 ml) | Refrigerator | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0 |
| | Hawking | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | |
| Total coliform (count/100 ml) | Refrigerator | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0 |
| | Hawking | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | |
| | *Values that exceed WHO Limit | | | | [a](FDEP, 2008) | | [#](Masarik, 2008) | | |

### 4.3.1 Alkalinity

At the refrigerator stage, mean alkalinity levels ranged from 10.00 ± 1.00 $mgCaCO_3/l$ (SW 3) to 100.00 ± 1.00 $mgCaCO_3/l$ (SW 6). Similarly, SW 2 and SW 6 recorded the lowest and highest alkalinity levels representing 16.00 ± 1.00 $mgCaCO_3/l$ and 84.00 ± 1.00 $mgCaCO_3/l$ respectively at the hawking stage (table 4.2). The mean difference between the two vending places was however not significantly different ($p = 0.45979$).

### 4.3.2 Calcium

Calcium levels recorded for all the water at the hawking stage were higher than those at the refrigerator stage (table 4.2). SW 3 recorded the lowest calcium level of 2.00 ± 1.00 mg/l whiles SW 1 recorded the highest with 18.00 ± 1.00 mg/l for water vended through the refrigerator. Those at the hawking stage witnessed SW 3 and SW 6 recording the lowest and highest calcium level of 8.00 ± 1.00 mg/l and 40.00 ± 1.00 mg/l respectively (table 4.2). The mean calcium levels at the two vending places was significantly different ($p = 0.00011$) from each other.

### 4.3.3 Chloride

Mean chloride levels ranged from 10.00 ± 1.00 mg/l (SW 1) to 31.00 ± 1.00 mg/l (SW 7) for water at the refrigerator stage. At the hawking stage, chloride levels ranged from 13.00 ± 1.00 (SW 1 and SW 7) to 21.00 ± 1.00 mg/l (SW 3) (table 4.2). There was however no significant difference ($p = 0.18374$) between the two vending places.

### 4.3.4 Electrical Conductivity (EC)

At the refrigerator stage, SW 7 recorded the lowest EC level of 22.00 ± 1.00 µS/cm whiles SW 6 recorded the highest with 55.60 ± 0.20 µS/cm. At the hawking stage, mean EC levels ranged from 37.37 ± 1.07 µS/cm (SW 2) to 597.00 ± 0.00 µS/cm (SW 6) (table 4.2). The results showed that the mean difference between the two vending places was significant ($p = 0.02452$).

### 4.3.5 Fluoride

SW 2 and SW 4 recorded the lowest and highest fluoride levels at the two vending places respectively. The mean fluoride levels ranged from 0.03 ± 0.03 mg/l to 0.80 ± 0.01 mg/l for water at the refrigerator stage, whereas that of the hawking stage recorded levels ranging from 0.40 ± 0.10 mg/l to 0.94 ± 0.01 mg/l (table 4.2). The results also showed a significant difference ($p = 0.00609$) between the means at the two vending places.

### 4.3.6 Hardness

With the exception of SW 1, all the other brands recorded mean hardness levels higher at the hawking stage than the refrigerator stage. Hardness levels in the sachet water at the refrigerator stage ranged from 4.00 ± 1.00 mg$CaCO_3$/l (SW 3) to 22.00 ± 1.00 mg$CaCO_3$/l (SW 1). At the hawking stage, SW 1 and SW 3 recorded the lowest hardness values of 22.00 ± 1.00 mg$CaCO_3$/l whereas SW 6 recorded the highest with 74.00 ± 1.00 mg$CaCO_3$/l (table 4.2). The two vending places however recorded mean values which were significantly different ($p = 0.00540$).

### 4.3.7 Magnesium

Magnesium level for SW 7 at the refrigerator stage was below detectable limit (0.00 ± 0.00 mg/l). The other brands however recorded values ranging from 2.00 ± 1.00 mg/l (SW 3) to 30.00 ± 1.00 mg/l (SW 6). Water at the hawking stage however recorded higher magnesium levels than those at refrigerator stage with the highest being 34.00 ± 1.00 mg/l (SW 6) and the lowest being 2.00 ± 1.00 mg/l (SW 1) (table 4.2). The mean difference between the two vending places was however not significant (p = 0.26571).

### 4.3.8 Nitrate

All the water at the refrigerator stage recorded mean nitrate levels which were higher than those at the hawking stage. SW 4 recorded the highest nitrate level of 5. 63 ± 0.01 mg/l whiles SW 1 and SW 2 both recorded the lowest with 0.44 ± 0.01 mg/l for water at the refrigerator stage. At the hawking stage, SW 1 recorded the lowest nitrate level of 0.03 ± 0.01 mg/l whiles SW 6 and SW 7 both recorded the highest with 0.22 ± 0.0 mg/l (table 4.2). The results also showed that there was a significant difference (p = 0.00080) between the means of the two vending places.

### 4.3.9 Nitrite

The nitrite levels in all the sachet water samples recorded higher values in all the brands at the hawking stage as compared to those at the refrigerator stage (table 4.2). At the refrigerator stage, nitrite levels ranged from 0.001 ± 0.000 mg/l (SW 1) to 0.003 ± 0.001 mg/l (SW 7), whereas those at the hawking stage witnessed SW 3 and SW 6 recording the lowest and highest levels representing 0.002 ± 0.001 mg/l and 0.50 ±

0.10 mg/l respectively (table 4.2). The results also indicated a significant difference (p = 0.00841) between the two vending places.

### 4.3.10 pH

The results showed that the pH values for the street hawking were lower (slightly acidic) than those of the refrigerator (table 4.2). At the refrigerator stage, pH levels ranged from 6.36 ± 0.02 (SW 1) to 7.32 ± 0.01 (SW 6) whereas that of the hawking stage recorded mean pH values ranging from 5.38 ± 0.02 (SW 2) to 5.95 ± 0.01 (SW 6) (table 4.2). Consequently, the results showed that the mean difference between the two vending places was significant (p = 7.5E-16).

### 4.3.11 Phosphate

SW 4 and SW 7 recorded the highest and lowest phosphate levels at the two vending places respectively. Water at the refrigerator stage ranged between 0.36 ± 0.02 mg/l to 1.94 ± 0.01 mg/l whiles those at the hawking place recorded mean phosphate levels ranging from 0.40 ± 0.03 mg/l to 1.88 ± 0.01 (table 4.2). The results however showed that the mean difference between the two vending places was not significant (p = 0.29849).

### 4.3.12 Sulphate

The sulphate level for SW 4 and SW 5 were below detectable limits at the refrigerator stage. The rest of the water recorded mean sulphate values ranging from 3.03 ± 1.00 mg/l (SW 2 and SW 7) to 10.00 ± 1.00 mg/l (SW 6). Similarly, water at the hawking stage saw SW 5 and SW 7 recording mean sulphate values which were below detectable limits. The rest of the water recorded values ranging from 3.0 ± 1.0 mg/l (SW 2 and SW 3) to 7.0 ± 1.0 mg/l (SW 6). There was however no significant difference (p = 0.38552) between the means of the two vending places.

### 4.3.13 Total Dissolved Solids (TDS)

TDS at the refrigerator stage recorded mean values ranging between 13.00 ± 1.00 mg/l (SW 7) to 33.20 ± 0.10 mg/l (SW 6). At the hawking stage, SW 6 recorded the highest TDS value of 361.00 ± 1.00 mg/l whiles SW 1 recorded the lowest with 22.30 ± 0.10 mg/l (table 4.2). There was however no significant difference (p = 0.20002) between the mean values of the two vending places.

### 4.3.14 Turbidity

The results showed that the turbidity values for all the water at the hawking stage were higher than the samples at the refrigerator stage. Levels ranged from 0.21 ± 0.02 NTU (SW1 and SW 3) to 0.46 ± 0.01 NTU (SW 5) at the refrigerator stage. Water at the hawking place recorded mean turbidity values ranging from 0.36 ± 0.04 NTU (SW 3) to 2.06 ± 0.02 NTU (SW 4) (table 4.2). The results also showed that there was a significant difference (p = 1.13E-53) between the two vending places.

### 4.3.15 Iron, faecal and total coliforms

The iron, faecal and total coliform levels in all the brands at the two vending places were below detectable limits as indicated in appendices A7, A16, and A17 respectively.

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Production

From the results obtained in the research, it could be stated that, generally all the seven different brands of sachet water in the district are very good for human consumption, and that there cannot be adverse health implications on individuals who consume the water.

Alkalinity levels in all the brands of sachet water were very low, ranging between 20.00 ± 0.01 mg$CaCO_3$/l to 86.00 ± 0.01 mg$CaCO_3$/l. According to Masarik (2008), alkalinity levels less than 150 mg$CaCO_3$/l are more likely to be corrosive. This therefore implies that the ability of the sachet water in the district to buffer acidic solution is very minimal. The low alkalinity levels of sachet water in the district may be due to low concentrations of carbon-based mineral molecules such as calcium carbonate suspended in groundwater solutions within the district, and as such, the water is more likely to be corrosive.

Calcium and magnesium levels were all within the recommended WHO's limit. Dissolved calcium and magnesium are the two most common minerals that make water hard. The degree of hardness becomes greater as the calcium and magnesium content increases. Hard water is not a health hazard but it interferes with almost every cleaning task, from laundry and dishwashing to bathing and personal grooming (Skipton and Dvorak, 2009). The results therefore indicated that the sachet water in the district is soft due to the low levels of calcium and magnesium and may not cause any lime buildup (scaling) in pipes and water heaters as well as graying of white laundry over time and can easily form lather with soap.

Chloride levels were far below the WHO’s limit of 250 mg/l, and that there cannot be any objectionable salty taste to consumers. Adams (2001) indicated that chloride is not toxic, but high concentrations of chloride ions in water may produce a laxative effect and corrosion of plumbing in the hot water systems.

EC and TDS levels were also within the recommended guideline limits as none of the brands recorded a value higher than the acceptable limit, hence the sachet water in the district can be said to be palatable. The palatability of drinking water with a TDS level less than 600 mg/l is generally considered to be good, whereas water supplies with TDS levels greater than 1200 mg/l are unpalatable to most consumers (MacCutcheon *et al.,* 1983).

According to the results, the fluoride levels in most of the brands of sachet water being produced and sold in the district are very low. Optimally, fluoridated water helps to prevent tooth cavities in children. An optimum concentration of 1.0 mg/l in drinking water produces no adverse effect. The WHO (2011) gives a maximum limit of 1.5 mg/l of fluoride in drinking water and at concentrations over 1.5 mg/l, fluorosis (mottling) of the teeth may occur. The highest fluoride level ($1.35 \pm 0.01$ mg/l) was recorded in brand SW 6 and this therefore implies that the fluoride levels of the sachet water in the district are not above the WHO’s maximum limit of 1.5 mg/l, hence drinking of these water will not cause any fluorosis especially among children. However, there is a high possibility that the sachet water in the district may not be able to prevent the occurrence of tooth cavities especially in children due to the fact that their levels are very low. The WHO (2011) indicated that the beneficial effect of fluoride diminishes greatly as the fluoride concentrations decrease below 0.7 mg/l. With the exception of SW 4 and SW 6 which recorded mean fluoride values of 1.00 ± 0.01 mg/l and 1.35 ± 0.01 mg/l respectively, all the other brands recorded mean fluoride values which were lower than 0.7 mg/l, hence their ability to prevent the occurrence of tooth cavity is very minimal.

The results also showed that the iron concentrations in all the brands of sachet water samples were below detectable limits; hence the water may not cause any brown and black stains on laundry, plumbing fixtures and sinks. The WHO (2011) indicated that drinking water with iron concentrations higher than 0.3 mg/l will most likely result in a metallic taste and this may affect the taste of beverages made from the water as well as vegetables cooked in iron-rich waters will also become dark and unpleasant.

The nitrate and nitrite levels in all the sachet water samples from all the brands were within the recommended limits, and as such there could not be any adverse health effects with the consumption of any of the brands in relation to the these two parameters. High nitrate levels in water can be an indicator for other potential contaminants such as pesticides. Drinking water containing more than 10 mg/l of nitrate may cause methemoglobinemia (also called blue baby disease) in infants less than six months of age. This is a condition in infants which inhibits the blood's ability to carry oxygen and this can be very fatal if not detected and treated early (Masarik, 2008). Some studies have also suggested that drinking water containing high levels of nitrate may cause birth defects and miscarriages. Similarly, infants below six months of age who drink water containing nitrite in excess of 1 mg/l could become seriously ill and if untreated, may die. Symptoms include shortness of breath and blue baby syndrome (Masarik, 2008).

The pH of the water samples ranged between 7.49 ± 0.01 (SW 5) to 8.25 ± 0.01 (SW 6) and this was within the WHO's range of 6.5 – 8.5. Although pH usually has no direct impact on water to consumers, it is one of the most important operational water quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection (Covington *et al.*, 1985). Exposure to extreme pH values results in irritation to the eyes, skin and mucous membranes. In sensitive individuals, gastrointestinal irritation may also occur and in addition, solutions of pH 10 – 12.5 have been reported to cause hair fiber to swell (WHO, 2011).

The WHO does not have a guideline value for phosphate to compare the recorded values with, but works of other scientists have suggested that a permissible limit of 5 mg/l is desirable. The results from the research work showed that all the brands except SW 4 recorded mean phosphate levels lower than 5 mg/l; hence very conducive for human consumption. The mean phosphate level for SW 4 at production was 6.22 ± 0.01 mg/l, and this was higher than the recommended limit. This may be due to runoff resulting from human and animal waste, laundry, cleaning, phosphorus rich bedrock and fertilizer around the production house. There is therefore the tendency of the water to cause algal bloom. The FDEP (2008) also noted that algal bloom causes aesthetic degradation of surface water bodies and in some cases, it can be harmful to human health. A minute amount of phosphorus entering a water body can trigger a significant algal bloom, thereby lowering light penetration and dissolved oxygen levels in the water.

Sulphate levels were very low in all the sachet water samples and this could be attributed to the lack of industrial waste, oxidation of sulfite ores as well as unavailability of shales within the district. High sulphate content in drinking water affects the taste of water and also forms a hard scale in boilers and heat exchangers (Adams, 2001). According to Kempster *et al.* (1997), the intake of $SO_4^{2-}$ ions at elevated concentrations can cause diarrhoea problems to the users. The South African Bureau of Standards (SABS, 1984) regards the presence of Sulphate ($SO_4^{2-}$) ions in drinking water as non-toxic within the limit of 0.0 – 200.0 mg/l, however an upper limit of 250 mg/l is recommended by the WHO for drinking purposes. All the sachet water in the district can thus be considered as good since none of them recorded a mean sulphate value higher than the recommended limit.

Hardness is an important criterion for ascertaining the suitability of water for domestic, drinking and many industrial uses (Karanth, 1994). Hem (1970) and the British Columbia Groundwater Association (2007) classified water as soft (0 – 60mg$CaCO_3$/l), moderately hard (61 – 120 mg$CaCO_3$/l), hard (121 – 180 mg$CaCO_3$/l) and very hard (greater than 180 mg$CaCO_3$/l). Comparing the hardness values obtained in the research work to this classification, the hardness level of all the sachet water samples can thus be said as soft.

According to the turbidity index by Johnson *et al*. (1997), the turbidity of water can be classified as good (< 1 NTU), fair (1 – 5 NTU) or poor (> 5 NTU). The WHO gives a guideline limit of 5 NTU for drinking water purposes. Based on this index, all the sachet water in the district can be considered as very good in relation to their turbidity levels since all the brands were below 1 NTU. Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause nausea, cramps, diarrhoea and associated headache (USEPA, 2007).

Faecal and total coliforms were below detectable limits in all the brands of sachet water samples analysed. One possible reason for this observation is that, there are no direct discharge of wastes from mammals and birds in the district. Besides, the septic systems in the district do not allow effluents to flow into the water table, aquifers, drainage ditches and nearby surface waters. It could also mean that there is an effective disinfection and treatment of water by the sachet water producers in the district. The WHO (2011) stipulates that the faecal and total coliform counts/100 ml of water should be zero, hence the sachet water in the district is thus very conducive for human consumption.

## 5.2 Storage

The results from the research work indicated that, all the samples analysed in the two storage places (metal cage and shop) were within the recommended guideline limits by the WHO. Even though all the parameters were within the permissible range, the results showed that most of the parameters recorded higher levels when stored inside the metal cage. Total alkalinity levels in samples stored inside the metal cage was significantly different from those stored inside the shop ($p = 0.00117$). Similarly, the chloride ($p = 1.1E-12$), fluoride ($p = 0.03026$), magnesium ($p = 4.9E-6$) and phosphate ($p = 0.00444$) levels for samples stored inside the metal cage recorded mean values which were significantly different from those stored inside the shop. What may have accounted for this observation is that, water stored inside the metal cage were exposed to direct sunlight; therefore there is a possibility of some form of chemical reaction taking place between the direct sun rays and the water. It is also possible that some form of chemical reaction between the metal cage and the water may have resulted in the high levels in most of the parameters analysed.

The microbiological contents in all the brands at the two storage places remained unchanged from their initial levels at production. That is, levels were below detectable limits, hence the two storage places did not impact negatively on the microbiological contents of the sachet water.

## 5.3 Vending

The two vending places (a refrigerator and street hawking) recorded values which were all within the permissible range for drinking purposes. However, the results showed that the levels of physico-chemical parameters in most of the brands were higher for the street hawker than those vended through the refrigerator. Consequently, the mean values for most of the physico-chemical parameters were significantly different from those vended through the refrigerator. No clear explanation could be given to the high levels of parameters for the street hawking, but just like the water stored inside the metal cage, there is a possibility that the direct sunlight on the sachet water may have resulted in some form of chemical reaction leading to the high levels. The two vending places did not also show traces microbial contamination (faecal or total coliforms).

# CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATIONS

### 6.1 Conclusion

All the physico-chemical parameters as well as the microbiological indicators were far below the WHO's recommended guideline limits for drinking purposes, hence the sachet water in the Atwima Nwabiagya District could generally be considered as safe for human consumption.

The results also showed that, brand SW 6 recorded relatively higher values in most of the physico-chemical parameters analysed. Even though their levels were within the permissible limits, it raises concern which should be looked at closely. The quality of the water at the two storage places was good; however, samples stored inside the metal cage recorded significantly higher values in most of the brands as compared to those stored inside the shop. Similarly, the two vending places recorded values which were within permissible limits, even though water vended through street hawking recorded higher values as compared to those vended through the refrigerator.

The microbiological content of sachet water in the district is very good since none of the samples recorded any colony count for both faecal and total coliforms either at the production, storage or vending stages.

It can therefore be concluded that the sachet water which are being produced and sold within the Atwima Nwabiagya district are very good for human consumption.

## 6.2 RECOMMENDATION

From the study, it is recommended that;

- Further studies on sachet water in the district should look closely at why SW 6 recorded higher values in most of the physico-chemical parameters analysed as compared to the other brands.
- Moreover, further studies should be conducted to investigate the real reasons why water stored inside the metal cage and those vended through street hawking recorded high values.
- The regulatory institutions, especially the FDB should continue with its monitoring and supervisory activities on the production houses to ensure that the quality of water they produce unto the market are not compromised and that they continue to meet the recommended standards.

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# Appendices

## Appendix A: Mean (±) Standard Deviation values for all the brands at the various stages

Appendix A1: Mean (±) Standard Deviation values for Alkalinity (mgCaCO3/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| **Production** | 40.00 ± 1.00 | 36.00 ± 1.00 | 20.00 ± 1.00 | 56.00 ± 1.00 | 60.00 ± 1.00 | 86.00 ± 1.00 | 38.00 ± 1.00 |
| **Metal cage** | 40.00 ± 1.00 | 50.00 ± 1.00 | 20.00 ± 1.00 | 80.00 ± 1.00 | 120.00 ± 1.00 | 108.00 ± 1.00 | 40.00 ± 1.00 |
| **Shop** | 20.00 ± 1.00 | 14.00 ± 1.00 | 12.00 ± 1.00 | 32.00 ± 1.00 | 52.00 ± 1.00 | 80.00 ± 1.00 | 18.00 ± 1.00 |
| **Refrigerator** | 30.00 ± 1.00 | 28.00 ± 1.00 | 10.00 ± 1.00 | 36.00 ± 1.00 | 52.00 ± 1.00 | 100.00 ± 1.00 | 32.00 ± 1.00 |
| **Hawking** | 20.00 ± 1.00 | 16.00 ± 1.00 | 22.00 ± 1.00 | 38.00 ± 1.00 | 40.00 ± 1.00 | 84.00 ± 1.00 | 28.00 ± 1.00 |

Appendix A2: Mean (±) Standard Deviation values for Calcium (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| **Production** | 6.00 ± 1.00 | 4.00 ± 1.00 | 4.00 ± 1.00 | 24.00 ± 1.00 | 18.00 ± 1.00 | 30.00 ± 0.00 | 8.00 ± 1.00 |
| **Metal cage** | 15.00 ± 1.00 | 15.00 ± 1.00 | 10.00 ± 1.00 | 20.00 ± 1.00 | 18.00 ± 1.00 | 30.00 ± 1.00 | 10.00 ± 1.00 |
| **Shop** | 16.00 ± 1.00 | 8.00 ± 1.00 | 8.00 ± 1.00 | 18.00 ± 1.00 | 18.00 ± 1.00 | 56.00 ± 1.00 | 16.00 ± 1.00 |
| **Refrigerator** | 18.00 ± 1.00 | 4.00 ± 1.00 | 2.00 ± 1.00 | 3.00 ± 1.00 | 14.00 ± 1.00 | 1.00 ± 1.00 | 10.00 ± 1.00 |
| **Hawking** | 20.00 ± 1.00 | 32.00 ± 1.00 | 8.00 ± 1.00 | 26.00 ± 1.00 | 24.00 ± 1.00 | 40.00 ± 1.00 | 20.00 ± 1.00 |

Appendix A3: Mean (±) Standard Deviation values for Chloride (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| **Production** | 26.00 ± 1.00 | 24.00 ± 1.00 | 33.00 ± 1.00 | 41.00 ± 1.00 | 29.00 ± 1.00 | 30.00 ± 1.00 | 31.00 ± 0.00 |
| **Metal cage** | 21.00 ± 1.00 | 36.00 ± 1.00 | 45.00 ± 1.00 | 48.00 ± 1.00 | 30.00 ± 1.00 | 40.00 ± 1.00 | 33.00 ± 1.00 |
| **Shop** | 11.00 ± 1.00 | 14.00 ± 1.00 | 17.00 ± 1.00 | 20.00 ± 1.00 | 13.00 ± 1.00 | 18.00 ± 1.00 | 15.00 ± 1.00 |
| **Refrigerator** | 10.00 ± 1.00 | 12.00 ± 1.00 | 18.00 ± 1.00 | 15.00 ± 1.00 | 13.00 ± 1.00 | 30.00 ± 1.00 | 31.00 ± 1.00 |
| **Hawking** | 13.00 ± 1.00 | 16.00 ± 1.00 | 21.00 ± 1.00 | 18.00 ± 1.00 | 14.00 ± 1.00 | 16.00 ± 1.00 | 13.00 ± 1.00 |

Appendix A4: Mean (±) Standard Deviation values for EC (µS/cm)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Samreg** | **Vidat** | **G-Life** | **Eddyrose** | **Baroko** | **3A** | **Pacmay** |
| **Production** | 89.00 ± 1.00 | 63.60 ± 0.10 | 116.70 ± 0.10 | 41.60 ± 0.10 | 164.9 ± 0.10 | 307.00 ± 1.00 | 93.30 ± 0.10 |
| **Metal cage** | 21.90 ± 0.10 | 24.80 ± 0.10 | 32.00 ± 1.00 | 39.40 ± 0.10 | 34.1 ± 0.10 | 45.20 ± 0.10 | 29.20 ± 0.17 |
| **Shop** | 20.50 ± 0.10 | 20.10 ± 0.10 | 30.30 ± 0.10 | 43.50 ± 0.10 | 45.9 ± 0.10 | 361.00 ± 1.00 | 37.00 ± 1.00 |
| **Refrigerator** | 48.00 ± 0.00 | 41.10 ± 0.10 | 34.50 ± 0.10 | 36.80 ± 0.10 | 35 ± 0.10 | 55.60 ± 0.20 | 22.00 ± 1.00 |
| **Hawking** | 38.70 ± 0.00 | 37.37 ± 1.07 | 49.80 ± 0.00 | 62.70 ± 0.10 | 60.8 ± 0.10 | 597.00 ± 0.00 | 119.50 ± 0.10 |

Appendix A5: Mean (±) Standard Deviation values for Fluoride (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Samreg** | **Vidat** | **G-Life** | **Eddyrose** | **Baroko** | **3A** | **Pacmay** |
| **Production** | 0.30 ± 0.10 | 0.05 ± 0.02 | 0.35 ± 0.01 | 1.00 ± 0.01 | 0.65 ± 0.01 | 1.35 ± 0.01 | 0.35 ± 0.01 |
| **Metal cage** | 0.50 ± 0.01 | 0.47 ± 0.12 | 0.25 ± 0.01 | 0.80 ± 0.01 | 0.6 ± 0.01 | 0.6 ± 0.01 | 0.25 ± 0.01 |
| **Shop** | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.3 ± 0.01 | 0.55 ± 0.01 | 0.4 ± 0.01 | 0.75 ± 0.01 | 0.35 ± 0.01 |
| **Refrigerator** | 0.33 ± 0.06 | 0.03 ± 0.03 | 0.35 ± 0.01 | 0.80 ± 0.01 | 0.55 ± 0.01 | 0.7 ± 0.01 | 0.35 ± 0.01 |
| **Hawking** | 0.50 ± 0.01 | 0.40 ± 0.10 | 0.6 ± 0.01 | 0.94 ± 0.01 | 0.75 ± 0.01 | 0.85 ± 0.01 | 0.55 ± 0.01 |

Appendix A6: Mean (±) Standard Deviation values for Hardness (mgCaCO3/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Samreg** | **Vidat** | **G-Life** | **Eddyrose** | **Baroko** | **3A** | **Pacmay** |
| **Production** | 12.00 ± 1.73 | 8.00 ± 1.00 | 6.00 ± 1.00 | 30.00 ± 1.00 | 22.00 ± 1.00 | 64.00 ± 1.00 | 18.00 ± 1.00 |
| **Metal cage** | 40.00 ± 1.00 | 30.00 ± 1.00 | 20.00 ± 1.00 | 38.00 ± 1.00 | 40.00 ± 1.00 | 70.00 ± 1.00 | 22.00 ± 1.00 |
| **Shop** | 20.00 ± 1.00 | 10.00 ± 1.00 | 12.00 ± 1.00 | 36.00 ± 1.00 | 20.00 ± 1.00 | 70.00 ± 0.00 | 22.00 ± 1.00 |
| **Refrigerator** | 22.00 ± 1.00 | 8.00 ± 1.00 | 4.00 ± 1.00 | 6.00 ± 1.00 | 18.00 ± 1.00 | 60.00 ± 1.00 | 10.00 ± 1.00 |
| **Hawking** | 22.00 ± 1.00 | 36.00 ± 1.00 | 22.00 ± 1.00 | 32.00 ± 1.00 | 32.00 ± 1.00 | 74.00 ± 1.00 | 24.00 ± 1.00 |

Appendix A7: Mean (±) Standard Deviation values for Iron (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Metal cage | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Shop | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Refrigerator | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Hawking | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |

Appendix A8: Mean (±) Standard Deviation values for Magnesium (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 6.00 ± 1.00 | 4.00 ± 1.00 | 2.00 ± 1.00 | 6.00 ± 1.00 | 4.00 ± 1.00 | 34.00 ± 1.00 | 10.00 ± 0.00 |
| Metal cage | 25.00 ± 1.00 | 15.00 ± 1.00 | 10.00 ± 1.00 | 18.00 ± 1.00 | 22.00 ± 1.00 | 40.00 ± 1.00 | 12.00 ± 1.00 |
| Shop | 4.00 ± 1.00 | 2.00 ± 1.00 | 4.00 ± 1.00 | 18.00 ± 1.00 | 2.00 ± 1.00 | 14.00 ± 1.00 | 6.00 ± 1.00 |
| Refrigerator | 4.00 ± 1.00 | 4.00 ± 1.00 | 2.00 ± 1.00 | 3.00 ± 1.00 | 4.00 ± 1.00 | 30.00 ± 1.00 | 0.00 ± 0.00 |
| Hawking | 2.00 ± 1.00 | 4.00 ± 1.00 | 14.00 ± 1.00 | 6.00 ± 1.00 | 8.00 ± 1.00 | 34.00 ± 1.00 | 4.00 ± 1.00 |

Appendix A9: Mean (±) Standard Deviation values for Nitrate (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 0.84 ± 0.01 | 1.89 ± 0.01 | 1.14 ± 0.01 | 4.62 ± 0.01 | 0.92 ± 0.01 | 0.97 ± 0.01 | 4.84 ± 0.01 |
| Metal cage | 0.32 ± 0.01 | 0.18 ± 0.01 | 0.24 ± 0.01 | 0.47 ± 0.01 | 0.21 ± 0.01 | 0.15 ± 0.01 | 0.34 ± 0.01 |
| Shop | 0.13 ± 0.01 | 0.4 ± 0.01 | 0.12 ± 0.01 | 0.53 ± 0.01 | 0.11 ± 0.01 | 0.20 ± 0.01 | 0.22 ± 0.01 |
| Refrigerator | 0.44 ± 0.01 | 0.44 ± 0.01 | 0.48 ± 0.01 | 5.63 ± 0.01 | 0.62 ± 0.01 | 0.62 ± 0.01 | 5.06 ± 0.01 |
| Hawking | 0.03 ± 0.01 | 0.05 ± 0.01 | 0.07 ± 0.01 | 0.18 ± 0.01 | 0.11 ± 0.01 | 0.22 ± 0.01 | 0.22 ± 0.01 |

Appendix A10: Mean (±) Standard Deviation values for Nitrite (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Samreg** | **Vidat** | **G-Life** | **Eddyrose** | **Baroko** | **3A** | **Pacmay** |
| **Production** | 0.001 ± 0.000 | 0.001 ± 0.001 | 0.001 ± 0.000 | 0.001 ± 0.000 | 0.002 ± 0.001 | 0.002 ± 0.001 | 0.004 ± 0.001 |
| **Metal cage** | 0.004 ± 0.000 | 0.004 ± 0.001 | 0.012 ± 0.001 | 0.014 ± 0.001 | 0.016 ± 0.001 | 0.004 ± 0.001 | 0.014 ± 0.001 |
| **Shop** | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.060 ± 0.010 | 0.160 ± 0.010 | 3.000 ± 0.000 | 0.020 ± 0.001 |
| **Refrigerator** | 0.001 ± 0.000 | 0.001 ± 0.001 | 0.001 ± 0.000 | 0.001 ± 0.001 | 0.002 ± 0.001 | 0.002 ± 0.001 | 0.003 ± 0.001 |
| **Hawking** | 0.003 ± 0.000 | 0.003 ± 0.001 | 0.002 ± 0.001 | 0.007 ± 0.001 | 0.009 ± 0.001 | 0.050 ± 0.010 | 0.008 ± 0.001 |

Appendix A11: Mean (±) Standard Deviation values for pH

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Samreg** | **Vidat** | **G-Life** | **Eddyrose** | **Baroko** | **3A** | **Pacmay** |
| **Production** | 7.56 ± 0.02 | 7.55 ± 0.02 | 7.86 ± 0.01 | 8.20 ± 0.02 | 7.49 ± 0.01 | 8.25 ± 0.01 | 7.90 ± 0.02 |
| **Metal cage** | 6.78 ± 0.02 | 8.11 ± 0.02 | 7.23 ± 0.02 | 7.21 ± 0.01 | 6.98 ± 0.01 | 6.85 ± 0.00 | 6.91 ± 0.01 |
| **Shop** | 7.20 ± 0.02 | 7.1 ± 0.02 | 7.30 ± 0.02 | 7.51 ± 0.00 | 7.45 ± 0.02 | 7.55 ± 0.10 | 7.25 ± 0.00 |
| **Refrigerator** | 6.36 ± 0.02 | 6.43 ± 0.02 | 6.55 ± 0.01 | 6.68 ± 0.02 | 6.48 ± 0.01 | 7.32 ± 0.01 | 6.81 ± 0.02 |
| **Hawking** | 5.54 ± 0.02 | 5.38 ± 0.02 | 5.63 ± 0.02 | 5.71 ± 0.01 | 5.65 ± 0.03 | 5.95 ± 0.01 | 5.76 ± 0.01 |

Appendix A12: Mean (±) Standard Deviation values for Phosphate (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Samreg** | **Vidat** | **G-Life** | **Eddyrose** | **Baroko** | **3A** | Pacmay |
| **Production** | 0.34 ± 0.01 | 0.88 ± 0.01 | 0.94 ± 0.01 | 6.22 ± 0.01 | 0.82 ± 0.01 | 0.72 ± 0.01 | 2.44 ± 0.02 |
| **Metal cage** | 0.32 ± 0.01 | 0.16 ± 0.01 | 0.61 ± 0.01 | 1.23 ± 0.01 | 1.26 ± 0.01 | 0.51 ± 0.01 | 0.24 ± 0.01 |
| **Shop** | 0.64 ± 0.01 | 0.70 ± 0.01 | 0.64 ± 0.01 | 1.67 ± 0.01 | 1.58 ± 0.01 | 2.06 ± 0.01 | 0.48 ± 0.01 |
| **Refrigerator** | 0.46 ± 0.01 | 0.54 ± 0.01 | 0.36 ± 0.01 | 1.94 ± 0.01 | 1.30 ± 0.10 | 1.06 ± 0.01 | 0.36 ± 0.02 |
| **Hawking** | 0.75 ± 0.01 | 0.78 ± 0.01 | 0.72 ± 0.01 | 1.88 ± 0.01 | 1.23 ± 0.01 | 1.46 ± 0.01 | 0.40 ± 0.03 |

Appendix A13: Mean (±) Standard Deviation values for Sulphate (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 5 ± 1.0 | 3.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 5.0 ± 1.0 | 12.0 ± 1.0 | 5.0 ± 1.0 |
| Metal cage | 5.0 ± 1.0 | 3.0 ± 0.0 | 3.0 ± 0.0 | 5.0 ± 1.0 | 3.0 ± 0.0 | 13.0 ± 1.0 | 3.0 ± 0.0 |
| Shop | 8.0 ± 1.0 | 5.0 ± 1.0 | 3.0 ± 0.0 | 5.0 ± 1.0 | 5.0 ± 1.0 | 10.0 ± 0.0 | 5.0 ± 1.0 |
| Refrigerator | 8.0 ± 1.0 | 3.0 ± 1.0 | 5.0 ± 1.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 10.0 ± 1.0 | 3.0 ± 0.0 |
| Hawking | 5.0 ± 0.0 | 3.0 ± 1.0 | 3.0 ± 1.0 | 5.0 ± 1.0 | 0.0 ± 0.0 | 7.0 ± 1.0 | 0.0 ± 0.0 |

Appendix A14: Mean (±) Standard Deviation values for TDS (mg/l)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 60.61 ± 3.61 | 38.90 ± 0.10 | 69.40 ± 0.10 | 24.90 ± 0.00 | 100.10 ± 0.10 | 182.60 ± 0.10 | 56.10 ± 0.10 |
| Metal cage | 13.30 ± 0.10 | 14.80 ± 0.10 | 19.80 ± 0.10 | 23.40 ± 0.10 | 20.50 ± 0.10 | 27.30 ± 0.10 | 17.50 ± 0.10 |
| Shop | 12.30 ± 0.10 | 12.00 ± 1.00 | 10.30 ± 1.00 | 25.90 ± 0.10 | 27.50 ± 0.10 | 215.00 ± 1.00 | 22.30 ± 0.10 |
| Refrigerator | 29.00 ± 1.00 | 24.70 ± 0.10 | 21.00 ± 0.10 | 21.90 ± 0.10 | 20.90 ± 0.10 | 33.20 ± 0.10 | 13.00 ± 1.00 |
| Hawking | 22.30 ± 0.10 | 22.10 ± 0.10 | 29.70 ± 0.10 | 38.70 ± 0.10 | 36.40 ± 0.10 | 361.00 ± 1.00 | 70.90 ± 0.10 |

Appendix A15: Mean (±) Standard Deviation values for Turbidity (NTU)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 0.17 ± 0.02 | 0.29 ± 0.02 | 0.24 ± 0.01 | 0.23 ± 0.01 | 0.42 ± 0.01 | 0.32 ± 0.01 | 0.35 ± 0.02 |
| Metal cage | 2.16 ± 0.02 | 0.53 ± 0.06 | 0.47 ± 0.02 | 0.61 ± 0.02 | 0.71 ± 0.01 | 6.42 ± 0.02 | 0.37 ± 0.01 |
| Shop | 0.85 ± 0.02 | 0.62 ± 0.03 | 0.66 ± 0.06 | 2.19 ± 0.02 | 0.89 ± 0.01 | 1.16 ± 0.06 | 0.70 ± 0.01 |
| Refrigerator | 0.21 ± 0.02 | 0.37 ± 0.03 | 0.21 ± 0.02 | 0.30 ± 0.10 | 0.46 ± 0.01 | 0.33 ± 0.02 | 0.24 ± 0.01 |
| Hawking | 0.83 ± 0.02 | 0.86 ± 0.04 | 0.36 ± 0.04 | 2.06 ± 0.02 | 1.28 ± 0.01 | 0.71 ± 0.04 | 0.43 ± 0.01 |

Appendix A16: Mean (±) Standard Deviation values for Faecal coliform (count/100ml)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Metal cage | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Shop | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Refrigerator | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Hawking | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |

Appendix A17: Mean (±) Standard Deviation values for Total coliform (count/100ml)

| STAGE | BRAND | | | | | | |
|---|---|---|---|---|---|---|---|
| | Samreg | Vidat | G-Life | Eddyrose | Baroko | 3A | Pacmay |
| Production | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Metal cage | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Shop | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Refrigerator | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Hawking | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |

**Appendix B: T-test for the parameters at the various storage and vending stages**

Appendix B1: T-test for parameters at storage places (Metal cage and Shop)

| Parameter | P-value for Metal cage and Shop |
|---|---|
| **Alkalinity** | 0.00117404372543153* |
| **Calcium** | 0.40090 |
| **Chloride** | 1.10191102145305E-12* |
| **EC** | 0.07386 |
| **Fluoride** | 0.0302693834266886* |
| **Magnesium** | 0.0000049047255692806* |
| **Nitrate** | 0.55502 |
| **Nitrite** | 0.05770 |
| **Ph** | 0.07220 |
| **Phosphate** | 0.00444278154403601* |
| **Sulphate** | 0.35648 |
| **TDS** | 0.08943 |
| **Hardness** | 0.07691 |
| **Turbidity** | 0.20947 |

$\alpha = 0.05$

Appendix B2: T-test for parameters at vending places (Refrigerator and Hawking)

| Parameter | P-value for Refrigerator and Hawking |
|---|---|
| **Alkalinity** | 0.459799559 |
| **Calcium** | 0.00011157196101122* |
| **Chloride** | 0.183746313 |
| **EC** | 0.0245251677824383* |
| **Fluoride** | 0.00609426165630996* |
| **Magnesium** | 0.265719061 |
| **Nitrate** | 0.000809620244625349* |
| **Nitrite** | 0.00841395268020429* |
| **pH** | 7.50630689268709E-16* |
| **Phosphate** | 0.298499094 |
| **Sulphate** | 0.38552481 |
| **TDS** | 0.2000232 |
| **Hardness** | 0.00540144980997591* |
| **Turbidity** | 1.13495561210439E-53* |

$\alpha = 0.05$ * Mean values significantly different