THE AVAILABILITY AND QUALITY OF WATER SUPPLY SOURCES IN PERI-URBAN ADENTAN, GHANA.

By

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DECLARATION

I hereby declare that apart from the sources specifically acknowledged as contributions in the text, this work constitutes the results of my research and that it has not been admitted in part or in whole to any other university.

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DEDICATION

This work is dedicated to our Lord and Master Jesus Christ, Amen.

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My heartfelt gratitude goes to God almighty for his grace and mercy throughout this programme.

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ABSTRACT

Globally, urban growth has been increasing tremendously. This rapid growth has escalated the difficulties in water provision. The rate of urbanisation is also rampant in Sub-Saharan Africa and has led to peri-urban settlements. Access to water sources in such areas in developing countries has being a challenge. In Ghana, Adentan Municipality is one of the peri-urban communities where access to water supply has been a challenge over the years. This study therefore focused on determining the sources available, uses, access to these sources, physico-chemical and bacteriological quality and the source suitable for drinking. Household survey was done in 6 communities where 402 households were interviewed to access the necessary data such as sources mainly used for other purposes, drinking water source, access to water and cost. The results revealed a variety of water sources which included pipe borne, hand-dug well, rain harvesting, tanker service provision were used for cooking, washing, and other purposes. Pipe borne water was the most widely used source for other purposes while sachet water was used mainly (77.9% of all household) for drinking purposes. The financial analysis revealed that, household water expenditure was high due to expenditure on drinking water and water for other purposes. There were considerable variation in physico-chemical quality. With the exception of most boreholes and hand-dug wells across the communities, all other sources fluctuated within the expected limits. The sources were also identified to contain nutrients and bacteria not of faecal origin.

LIST OF ABBREVIATIONS

TSS	**Total Suspended Solids**
TDS	**Total Dissolved Solids**
EC	**Electrical Conductivity**
GWCL	**Ghana Water Company Limited**
DALYs	**Disability-Adjusted Life Years**
WHO	**World Health Organisation**
MDGs	**Millennium Development Goals**
GSS	**Ghana Statistical Service**
CFU	**Coliform Forming Unit**

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The boundaries of peri-urban areas are porous and transitory as urban development extends into rural and industrial land, thus in terms of growth dynamics, the urban areas expand into and replace parts of the peri-urban areas (Fertner, 2012). 8

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CHAPTER ONE

INTRODUCTION

1.1 Background

Water in its pure state is said to be a key to good health, thus water is more basic to survival than all other things (Wilk, 2006). Water also forms a major component of the human cells protoplasm (Heilbrunn,2013) and it is also needed for vital physiological and biochemical processes (Muyi, 2007). The importance of water to humans cannot be overemphasized hence the need for its availability in the right quantity and quality. In addition to human consumption and health requirements, water is also needed in agriculture, industrial, recreational industry and for other purposes (De Groot et al, 2002). Water is also considered a purifier of people and places in most religions (Baboo, 2009). Though all these needs are important, water for human consumption and sanitation is considered to be of greater social, health and economic importance (WHO, 2004). According to Odiette (1999), environmental water usage includes artificial wet lands, artificial lakes intended to create wildlife habitat, fish ladders around dams and water releases from reservoirs to help fish spawn.

In developing countries, access to safe drinking water can be a daily struggle and water-related problems persist due to microbiological contamination of water sources (Thomas *et al*, 2015; WHO 2006). For example diarrhoea disease alone accounts for an estimated 4.1 % of the total Disability-Adjusted Life Years (DALYs) global burden of disease and is responsible for the deaths of 1.8 million people every year. It was estimated that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene and is mostly concentrated on children in developing countries (WHO, 2004a). Ukpong, and Okon, (2013) asserts that most developing countries like Ghana has dangerous and highly toxic industrial and domestic wastes disregard for aquatic lives and rural dwellers (medium for the transmission of enteric diseases in most communities). Poisonous chemicals are known to percolate the layers of the earth and terminate in ground waters thereby constituting public health hazards (Itah and Akpan,2005).

With rapid urbanization and increasing land values in Ghana as a result of high population growth in urban areas due to rural urban migration (www.statsghana.gov.gh) which occurs as a result of wrongly perceived opportunities in urban areas, there are widespread trends for the growing numbers of residents causing the urban poor to move from the central city to the outskirts or peri-urban areas (Thomas *et al*., 2015).

Peri- urban areas are areas that are difficult to define due to their location in between the urban and rural settings. Such areas serves as transitional zones where urban and rural activities are juxtaposed (Simon, 2008) and sometimes a zone of chaotic urbanization that spread irregularly. Consequently, households in these areas experience a change in availability of accessible water sources particularly access to piped water, and after relocation, often have to rely on a variety of poorer quality water sources (Thomas *et al*, 2015; Truelove, 2011). In most cases, they have to trek long distances to access clean water. In the event of acute shortage in supplies they end up paying high prices to water vendors for this special commodity. The clear need for basic water and sanitation services for the poor assumes even greater significance when the linkages with other dimensions of poverty are considered.

Water and sanitation related sicknesses put severe burdens on health services and keep children out of school (Ahmed *et al*., 2012).

This study therefore intends to look at the various sources of water available to such communities for household usage, the purity of the water, how readily available the various sources are and which source(s) is/are good for drinking.

1.2 Problem Statement

Clean water is not merely a human need but a human right. Access to safe and adequate water supply is essential to man and all living things, and these form part of Ghana‘s Growth and Poverty Reduction Strategy and also linked to the Sustainable Development Goal number 6 (sdgs.un.org).

According to Benton-Short (2013), most developing countries such as Ghana, has their peri –urban areas characterized by the impact of high demands for land resulting from urban growth leading to congestion, high pollution rate and inaccessible supply to good and wholesome drinkable water. Hence most inhabitants of peri-urban areas make their own inadequate arrangements or pay excessively high prices to water vendors for meagre water supplies (Hofmann, 2011). For instance, in Accra, the provision of clean and safe drinking water is one of the major infrastructural problems. In urban Accra, it is estimated that 95% of households have access to treated piped water, which is received directly in their homes or at community standpipes (Ghana Water Company, 1998). However, this is not the case in the peri-urban communities. According to Hutton and Chase(2016), Ghana has currently exceeded its 2015 target of 78% coverage for use of improved drinking water by 6%. This was achieved by the construction of the Accra sea water

Desalination plant at Nungua and the expansion of the Kpong water works. The Desalination plant was estimated to produce 13 million gallons of water per day to serve about 500,000 people whiles the Kpong expansion project produced extra 40 million gallons of water per day (80 million gallons of water at its speak when the second phase of the project is completed) to inhabitants of Accra and some communities in the Eastern region of Ghana (Citi News, 2015).

However, with this significant step in improving drinking water facilities in the country, some communities still do not have access to improved sources of water. This was affirmed by The Chief Manager of Accra Production of treated water at Ghana Water Company Limited (GWCL), Mr Charles Brobbey, who said even with the company's operation at the highest capacity, the company still had a deficit of about 30 million gallons per day, which had compelled it to manage water supply in the national capital (www.lorlornyofm.com). And as such, communities with access to improved water source will even have their water supply curtailed or disrupted in case of any treatment shortfall in any of the treatment plants because of power challenges (www.lorlornyofm.com; Daily Graphic, 2018). Also, the shut down of Desalination plant in January, 2018 has led to rationing of water supply in the catchment area (acadamicjournals.org).

The situation of inadequate supply of water to some communities within the capital region not to talk about its peri-urban area has risen as a result of government's inability to supply enough water to keep pace with the growing population. It was noted that the main water supplier in Ghana, Ghana Water Company Limited (GWCL), lacked the necessary funds to ensure sustainable water supply in peri urban communities (Nyarko, 2007).

Moreover, the operational cost incurred by the company, including payment for electricity is very high. This coupled with revenue leakages in the system as a result of illegal connections, inefficient transmission system resulting from leakage from broken pipeline and price regulation by Public Utilities Regulatory Commission (PURC) affects the company's operations and reduces its capacity to expand supplies to peri-urban areas. For example, concerning Teshie Desalination plant, a consolidation of all the costs of the plants culminates in GWCL buying the water from the plant at about GH¢ 6.5 per cubic meter, and selling at the PURC regulated rate of about GH¢ 1.5 per cubic meter (mobile.ghanaweb.com), thus a loss of GH¢ 5.0 per cubic meter (Citi News, 2018). This has compelled individuals living in such areas to resort to their own means of water supply including construction of boreholes, hand-dug wells, pipe borne water and dependence on tanker supply services, which is characterizes by the payment of excessively high prices.

Furthermore, according to WHO chronicle (2011), one of the priorities in selecting a water source is its quality. The quality and protection of the source is important regardless of whether the water will be treated or not. Good quality water needs less, or no, treatment; and if treatment fails there will be fewer health risks (Fewtrell *et al*., 2005). A domestic water supply can take different forms such as a stream, a spring, a hand-dug well, a borehole with hand pump, a rainwater collection system, a piped water supply with tap-stand or house connection, sachet water or water vendors (Reed *et al*, 2013). With all these sources of water and the various uses of it, drinking water is valued to have the highest quality since it acts as an important vehicle for the transmission of a large variety of infectious diseases (Leclerc et al.,2002). This leads the WHO to estimate that 70 per cent of disease episodes in developing countries are deeply related to polluted water and inappropriate excreta treatment (UN-Water/Africa, 2006). Good drinking water and sanitation are therefore used as socio-economic development indicators of nations. Sustainable access to safe drinking water and basic sanitation has become essential in many developmental programs and consequently a cross cutting theme in the Sustainable Development Goals (SDGs).

In Ghana, almost all citizens seems to perceive sachet water as best for drinking purposes. In the 2010 Ghana census, 28% of households across the Accra metropolitan area reported using sachet water (GSS, 2013), a rare product just a decade prior, as the primary drinking water source. This is because, sachets have gained public affinity due to low price, convenience, ubiquity, and the perception of higher quality (Stoler *et al*., 2012) compared to tap water and other sources of water.

Considering the Adentan municipality, which has been known for their disadvantage in accessing pipe borne water and the struggle for water over the decades, it is not certain whether this improvement in water supply in Ghana has been able to solve this difficulty and even if water is currently available to inhabitants, it is still important to find out how widespread the various water sources are and how the quality of their drinking water has improved in the study area.

It is therefore imperative to undertake a full assessment of the water supply sources available, what the various sources are used for, their availability considering time,cost and distance, which source is suitable for drinking, the physico-chemical and biological quality of the sources in six peri-urban communities in the Adentan Municipality of the Greater Accra Region.

1.3. Hypothesis

For this study, the following hypotheses are generated;

1. There is no difference in the sources and uses of water within the communities.
2. There is no significant difference in the availability of water to inhabitants.
3. The average levels of physico-chemical and microbiological quality of the various sources of water from the study communities are not significantly different from permissible limits.
4. There is no significant difference in the suitability of the various sources of water for drinking.

1.4. Objectives

The main objective of the study is to determine access to water supply and to assess the quality and assess the the quality of their drinking water in the study area. Specific objective include;

1. To identify the sources of water and its use in the study area.

2. To determine the availability of the water sources to inhabitants based on distances, cost in accessing a particular source and time within a day that the water can be accessed.

3. To compare the levels of physico-chemical and microbiological parameters of all the drinking water sources and their health implications.

4. To determine the best source suitable for drinking.

CHARPTER TWO

LITERATURE REVIEW

2.1 Peri-urban Areas

Peri-urban areas are zones of transition from rural to urban land uses located between the outer limits of urban and regional centres and the rural environment (Simon, 2008) or areas on the urban periphery into which cities expand or which cities influence and thus embody some characteristics of both areas (Aguilar, 2008).

The boundaries of peri-urban areas are porous and transitory as urban development extends into rural and industrial land, thus in terms of growth dynamics, the urban areas expand into and replace parts of the peri-urban areas (Fertner, 2012).

In terms of demographics, peri-urban areas tend to attract newcomers, who are likely to belong to diverse ethnic groups (backgrounds) (Hirts, 2007). Unsurprisingly, according to Ward and Peters (2007), squatters usually settle in peri-urban area, and as a result slums develop in these area but peri-urban areas are not synonymous with slums. Housing in peri-urban areas is usually of mixed types, with quality and value that are generally inferior to those in urban areas (Douglas, 2006). The population density is likely to be lower than in the urban areas, whereas house occupancy is likely to be higher (McMillen and Smith, 2003). The quality of community facilities in general (schools, hospitals, etc.) is commonly inferior in these areas than in urban areas (Douglas, 2006). Naturally, income levels in peri-urban areas are lower than those in urban areas.

The planning status of peri-urban areas is usually 'unplanned' because of the former rural status of these areas. However, the status may change later through land regularization (Kombe, 2005). Accessibility of their different parts and circulation within peri-urban areas is generally difficult. This is because roads and other infrastructure services are deficient in terms of service level and standard (Aguilar et al., 2003).

Owing to the lower service level and standards of infrastructure services, environmental health conditions in peri-urban areas are impacted more drastically. This is mainly as a result of peri-urban areas having higher population and housing densities, use more resources, and generate considerably more wastes. Poor environmental health conditions in peri-urban areas in developing countries are manifested in higher cases of such diseases as malaria, diarrhoea, worm infections, and upper respiratory track infections (Allen et al., 1999).

2.2 Domestic Water Sources in Peri-urban Areas

In its Guidelines for Drinking-Water Quality, WHO (Ghana Standard Authority; WHO, 1993) defines domestic water as being 'that which is used for all usual domestic purposes including drinking, cooking, washing hands and body, washing clothes, cleaning cooking utensils, cleaning the house, watering animals and irrigating the garden', thus the adequacy of water used in our homes encompasses all including, but not limited to:

i. water used for human consumption and public water supply;

ii. water used in agriculture and aquaculture;

iii. water used in industry;

iv. water used for recreation; and

v. water used for electrical power generation (Howard et al., 2003).

According to International Fact-finding Mission, (2000) access to treated water is available to 62-70 per cent in urban areas and 35-40 percent in rural areas. However, in urban areas, only 40 per cent of the population have access to tap water (Agarwal, 2011). According to the 2000 Population and housing census of Ghana, 42.1 % have access to pipe borne water and tanker services, 33.0 % to wells and boreholes and 4.9 % to rivers, streams, rainwater etc. (Ghana Statistical Service (GSS), 2002). Thus most peri-urban areas do not have access to pipe borne water .

Water supply sources used domestically can take different forms: a stream, ground water (a spring, a hand-dug well, and a borehole with hand pump), a rainwater collection system, a piped water supply with tap-stand or house connection, sachet water or water vendors (Reed *et al*, 2013).

2.2.1 Groundwater

Groundwater may be defined as that portion of the total precipitation which has percolated downward into the porous space in the soil and rock where it remains, or from which it finds its way out to the surface (Bear, 2012). It also refers to all the water occupying the voids, pores and fissures within geological formations (Otieno *et al*., 2012). Examples of groundwater are wells, boreholes and springs (Calow *et al*, 2010).

According to National Ground Water Association of the United States of America, approximately 25% of the earth's total fresh water supply is stored as ground water, while less than 1% is stored in surface water resources, such as rivers and lakes .

Godfrey et al. (2010) indicated that, as many as two billion people depend on it directly with 40% of the world's food (William *et al*., 2006) produced by irrigating agricultural lands with groundwater. Groundwater constitutes about 95% of the freshwater on our planet making it fundamental to human life and economic development. In Ghana for example, borehole and well water remains the number one source of water for many rural and peri-urban poor households in Ghana, making up 41% of available water sources (GSS, 2008). About 16.0% of the urban population resort to wells as their major sources of water whiles 59.4% of the rural inhabitants use well water as their main source of water (GSS, 2008). The recent census (2010) also listed boreholes as the most common primary source of drinking water (42.5% on average), with rivers and streams being second (Alexandra *et al.,* 2017; GSS, 2013). In rural Ghana, over 95% of improved water supplies intended for domestic purposes are groundwater supplies, primarily communal boreholes or wells (Alexandra *et al.,* 2017). With the above assertions, then Ackah *et al*. (2011) was right to say groundwater resources are under increasing pressure in response to threats of rapid population growth, coupled with the establishment of human settlements lacking proper water supply and sanitation services in Ghana.

Groundwater was the most practical and safe in nature based on the fact that groundwater excluded from the atmosphere would be less susceptible to pollution (Rahman, 2008). However, groundwater in hard-rock aquifers is vulnerable to quality problems that may have serious impact on human health. The rocks are often carbonate-deficient and has been given rise to poorly buffered water (Kortatsi *et al.*, 2008), thus, some ground water pollutants occur naturally. Ground water can also be polluted through anthropogenic activities. For example, the increasing mining operations in the Pra Basin and its environs has led to chemical pollution of groundwater and streams, siltation through increased sediment load, increased faecal matter and de-watering effects. Thus, the publication by Project underground (2000) that lack of access to clean water in small scale gold mining communities has a relationship with the reduced health status of these communities is a true fact.

The quality of groundwater is constantly changing in response to seasonal and climatic factors (Moris *et al.*, 2003). These changes occur by reducing precipitation and increasing evapo-transpiration (Bjorn *et al.*, 2014), leading to reduction in recharge and possibly increase groundwater withdrawal rates. Groundwaters are generally acidic to alkaline with pH ranging from 6.0 to 8.2 pH units. Though the health impacts of such non-compliance are not clear, the possibility of causing health problems such as acidosis cannot be overlooked and also values of very low pH would make the water corrosive and hence place further strain on equipment (Bowen and Benison, 2009). Groundwater with unpleasant taste or excess hardness, even when readily available, can drive consumers to continue using micro biologically contaminated unimproved sources (Alexandra *et al.*, 2017). For example, drilling records in the Eastern Region of Ghana, indicated that 20–30% of rural boreholes have iron and manganese concentrations in excess of the Ghana water quality standards and WHO water quality(WQ) guidelines (0.3 mg/L and 0.1 mg/L, respectively), causing them to be abandoned or marginally used (Alexandra *et al.*, 2017).

Despite the assertion above, physico-chemical parameters, such as pH, total dissolved solids (TDS), hardness, and levels of non-toxic compounds, such as iron, manganese, sulphate, and phosphate ions of groundwater, do not necessarily pose a health threat at minimal levels. However, these parameters define the organoleptic and aesthetic quality of water, which affects its acceptability for drinking and domestic uses (Alexandra *et al*., 2017).

2.2.2 Rainwater

Most often, in rainy season, people collect and store rainwater in buckets and tanks. This commonly referred to as rainwater harvesting and has been practised for centuries (Worm, 2006) since it is a simple low - cost technique that requires minimum specific expertise or knowledge and offers many benefits. Rainwater can be used for multiple purpose, ranging from irrigating crops to washing, cooking and drinking hence can supplement other water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season (Marks *et al.*, 2006).

Effective rainwater harvesting strategies are essential to meet the escalating demand for good quality water in sufficient quantities in urban areas that experience urban stream depletion and water shortages. However, several studies have reported that rainwater harvesting may pose a public health risk because of its potential to carry microbial pathogens (Lee and Han, 2012). For example, in five districts of the Northern region of Ghana, fourteen dugouts in which rainwater are stored were all found to contained coliform bacteria, thus making them unwholesome for human consumption unless treated (Cobbina et al., 2013).

Other studies have suggested that harvested rainwater used for drinking water should be assessed by monitoring the presence of faecal indicators and bacterial pathogens (Lee, 2012). It should be noted that the presence of micro-organisms in a rainwater tank does not always necessitate their removal. Some earlier studies concluded that the probability of illness caused by drinking microbial-contaminated rainwater is very low, and no link was made between untreated rainwater consumption and illness (Minju *et al*., 2017; Australian Government Department of Health, 2011). Minju *et al.*(2017) further reported that the chance of contracting an illness from drinking rainwater is significantly lower compared with drinking piped water, even though most of the rainwater was not treated. Nonetheless, the presence of possible illness suggests that caution is needed to minimise microbial contamination.

The quality of harvested rainwater has also been found to be dependent both on the roof type and environmental conditions, i.e., the local climate and atmospheric pollution (Lee *et al*., 2012). Representative potential sources of non point pollution on a rooftop are classified according to whether they are external or internal. External sources include airborne pollutants and organic substances from human activity, leaves and birds waste. Pathogens are found primarily in the faeces of birds and mammals that have access to the rooftop. Internal sources of non point pollution originate in the roofing materials themselves. Rainwater reacts physico-chemically with roof materials, and the presence of lichens and mosses on the roof also influences water quality over the long term (Lee, 2012). With this, Sazakli *et al.,* (2007) is right to say the quality of harvested rainwater is contradictious. For example, the pH of the samples taken from the wooden shingle, concrete tile and clay tile roofs was higher than that from the galvanized steel roof (Lee, 2012).

Rainwater has nearly neutral pH and no hardness, disinfection by-products, or man-made contaminants (Texas Water Development Board, 2005; Lee, 2012).

2.2.3. Sachet Water

Sachet water is popularly known as “pure water”. This product is 500ml of water in clear nylon square sachets which have been electrically heated and sealed at both ends and widely patronized by both low and middle income earners (Addo et al., 2009). The production of sachet water has increased tremendously in Ghana. According to the Food and Drugs Authority of Ghana, majority of sachet water are produced under questionable hygienic environmental conditions and they have had cause to impose a ban on some producers (Owusu Ansah, 2016).

Besides, some products do not bear the stamp of approval of the Food and Drugs Authority. Even those who have registered do not always meet the standard required of them (Accra Daily Mail, Ghana News Agency (GNA), 2005) hence sachet water is not completely sterile and may not be entirely free of all infectious micro organisms. The potential danger associated with sachet water contamination can be the source of the water itself, treatment, packaging materials, dispensing into packaging materials and closure (Akinde *et al.*, 2011). Under prolonged storage of packaged water at favourable environmental conditions, total heterotrophic bacteria can grow to levels that may be harmful to humans since they are practical indicators of water treatment efficiency as well as after-growth and biofilm formation (Marsh and Bugusu, 2007). Regardless of all these problems, the production of sachet water enjoys a high patronage because apart from affordability, it is considered wholesome for drinking purposes as compared to tap or well water (Ernest *et al.*, 2007).

Although a recent review of this literature through 2010 found that most sachet quality studies have suffered design flaws such as tiny samples sizes or egregiously non random sampling (Stoler *et al.*, 2014). The sachet water industry has also undergone significant transformation since the late 2000s because many cottage-industry players have been replaced by large corporate-type producers who are importing heavy industrial machinery to filter and process sachet and bottled water (Ernest *et al.*, 2016). Consistent quality control of sachet water has so far been unattainable in Nigeria, but in Ghana, the comparatively smaller and more concentrated urban market has enabled the Ghana Standards Authority to register most sachet producers and enforce standards over the past few years (Jideonwo, 2014). Our field work now suggests that brand awareness among consumers is on the increase and that the conscious patronage of brands exhibiting better taste and no particles constitutes substantial market-based pressures for quality control by producers. Low-quality sachet brands may only persist in poor neighbourhoods with severe drinking water shortages (Stoler *et al.*, 2014).

2.3 Domestic Uses Of Water

In relation to normal domestic supply, water is used for so many things. Such uses include;

2.3.1 Water for Consumption

Water is a basic nutrient of the human body and is critical to human life. It supports the digestion of food, adsorption, transportation and use of nutrients and the elimination of toxins and wastes from the body. Water is also essential for the preparation of foodstuffs and requirement for food preparation (Falkenmark, 1997).

The human body requires a minimum intake of water in order to be able to sustain life and prevent mild (a loss of 3-5% of body weight) and then severe dehydration (a loss of 9-15% of body weight) since Wilmore (2012), suggested that 2.6 litres of water per day is lost through respiratory loss, insensible perspiration, urination and defecation. In addition, a significant quantity of water is lost through sensible perspiration if hard work is performed (Howard *et al*., 2003). These led to the suggestion that a daily minimum of water required in tropical climates would be around 3 litres per person, although the volume of water loss suggests that this should be at the upper end of the scale (Grandjean, 2005). However, under extreme conditions of hard work at high temperatures in the sun this figure could rise to as much as 25 litres per day (Howard *et al*., 2003).

The quality of water that is consumed is well-recognised as an important transmission route for infectious diarrhoeal and other diseases causing organisms (Bosch *et al*., 2008). Disease may also result from consumption of water containing toxic levels of chemicals. The health burden is most significant for two chemicals: arsenic and fluoride. Arsenic contamination of drinking water sources is being found in increasing numbers of water supplies world-wide although the total disease burden is as yet unknown (Goldhaber, 2003). Fluoride is also a significant global problem and WHO (1999) suggest that over 60 million people are affected by fluorosis in India and China. Nitrate is also of concern since it leads to methemaglobinaemia.

Water provided for direct consumption and ingestion via food should be of a quality that does not represent a significant risk to human health. A 'zero-risk' scenario for public supplies is however not achievable and evidence points to the need to define tolerable risks which are commonly based on estimates of numbers of excess cases per defined population size. This approach underpins much risk assessment thinking within the water sector for both microbial and chemical contaminants (Fewtrell and Bartram, 2001).

2.3.2 Water for Hygiene

The need for domestic water supplies for basic health protection exceeds the minimum required for consumption (drinking and cooking). Additional volumes are required for maintaining food and personal hygiene through hand and food washing, bathing and laundry (Bartram et al, 2003).

Poor hygiene may in part be caused by a lack of sufficient quantity of domestic water supply. The diseases linked to poor hygiene include diarrhoea and other diseases transmitted through the faecal-oral route; skin and eye diseases, in particular trachoma and diseases related to infestations, for instance louse and tick-borne typhus (Fewtrell et al, 2005).

More so, several pathogens can be transmitted through infectious skin or contaminated clothes. Certain vectors of disease live on clothes, or prefer people with a poor personal hygiene. All infections that spread by direct contact can be transmitted via direct person-to-person contact through contaminated skin or clothes (Pittet et al, 2006).

Washing hands after every contact that could potentially pick up the pathogen, and before doing anything that could transmit the pathogen onward, can prevent transmission (Bloomfield *et al*, 2006). Faecal-oral infections can largely be prevented if hands are washed after defecation, after coming in contact with animals, and after contact with anything that could be contaminated with faeces. In addition, hands should be washed before preparing or handling food, and before eating. The transmission of trachoma and conjunctivitis can also be prevented by washing hands after touching a person's face or after handling material used to wipe somebody's eyes or face, and before coming into contact with another person's face or eyes. Also keeping body and clothes clean will reduce the transmission risk of all these infections (Neira and Prüss-Üstün, 2016).

The effectiveness of hand washing, body washing and clothes washing depends mainly on how thoroughly they are washed, and for how long. Hence, water alone is not as effective as water with a washing agent such as soap or ash, which are both effective in removing pathogens from hands, body and clothes (Bloomfield and Nath, 2009).

The evidence from the literature consistently points that there is no definition for a minimum quantity of water recommended for use to ensure effective hygiene practices and while benefits are accrued from increased availability of water, this is not solely related to quantities of water used, although increased availability is likely to increase quantities used. The evidence further suggests that it is the effective use of both water and cleansing agents and the timing of hygiene practices that are more important than volumes of water used. Furthermore, as some hygiene behaviour is protective of health, for example laundry and bathing, may be carried out off-plot, the quantity of water required to sustain good hygiene may vary significantly with water collection behaviour.

2.4 Water Availability

Water is only available if it is at hand when needed. The amount of water that people need, or use, will depend on its availability and what it is used for. Factors that influence water use include the socio-economic status of the users, whether and how people have to pay for the water, whether water is easy to get, and whether water is used for special activities (Kundzewicz and Stakhiv, 2010).

Whether water is available or accessible to people depends on the time, energy, and money they have to invest to obtain it. The collection time of water is a good indicator of water availability as it takes into account distance, waiting times, and to a certain extent the effort needed to obtain water. Studies have shown that people will not really restrict their water use if collection times are less than three minutes, or a distance of about 100m in easy terrain with no waiting times. Longer collection times will result in a restriction on the use of water (Bartram et al, 2003). For example, water from a hand pump that is 25m from the home but always has a long queue may be as inaccessible as water from a river that is 1.5km away or water that has to be bought. In addition, safety problems, such as mines or a hostile population near the water may also limit accessibility.

Ideally, all users should have a convenient, culturally acceptable source that provides an unlimited amount of water at an affordable price and without degrading the environment (Turner, 2004). In practice, it will rarely be possible to provide this, and a compromise will have to be made which takes into account the local, social, cultural, physical, financial, and environmental constraints.

According to studies organized by Geels (2005), the quantities of water used for bathing, washing of clothes and dishes is sensitive to service level. For houses using water sources outside the home, an average of 6.6 litres per capita are used for washing dishes and clothes and 7.3 litres per capita for bathing. By contrast for houses with a household connection to piped water supply use on average of 16.3

litres per capita for washing dishes and clothes and 17.4 litres per capita for bathing. This suggest that for the households using a water source outside the home, the lesser volume collected has a negative impact on hygiene although this is not quantified.

The importance of water availability has been shown above to influence health in the preceding discussion. As noted above, the benefit from increased quantity of water is only felt in relation to the gross differences of service level. It is therefore useful to review the evidence of the interaction between accessibility and quantity in order to assess how health may be influenced by these factors.

2.5. Accessibility And Cost of Water Supply to the Urban Poor

In Sub-Saharan Africa, access to water and its cost has been a major challenge to the urban poor. Kosoe and Osumanu (2015) observed and rated the challenges of accessing potable water in the Wa Municipality (an urban centre in northern Ghana) as follows: “long queues” rate 35.7%, follow by “high cost” which rated 24%. The next challenge was time of repair of broken down water facilities (15.6%), followed by “irregular flow” rating 10.4%, then the challenge of distance (7.8%) and finally, “high chemical input” (6.5%).

Whilst government believes that the subsidies reach the people who deserve it, the question remains whether a non-targeted subvention like lower water price does reach the right people (the poor including peri-urban habitant)), under the present conditions of inadequate water supply (poor reliability and accessibility) (Van Rooijen et al., 2008).

In the city of Accra (Ghana), only 45% of the population has direct access to tap water (i.e household connection) and these mainly in the higher income classes. Other household are completely dependent on water vendors (Van Rooijen et al, 2008).

Furthermore, Peloso and Morinville (2014) observed in a study that when consumers were asked whether the price charged by vendors was good or fair, respondents generally said it was manageable but were also clear that they had to accept whatever price it was since there was nothing they could do about it; the price of water was up to the discretion of the vendor.

Access to domestic water and reliability is much worse in peri-urban areas and consumers generally spend between 4 and 18 times the normal tariff that is charged to consumers with direct access to piped water. The social and physical constraints to planning are affecting the poor more than the rich in terms of access and affordability (Van Rooijen et al, 2008).

Zuin et al, (2011) asserted that in Maputo (Mozambique), households with water connections in their premises have better service across virtually all indicators measured. These households express greater satisfaction with their service as compared with those using other water sources. However households purchasing water from their neighbours pay lower time and money costs per litre of water, on average, as compared with those using standpipes.

On the other hand, where the poor are enabled to access household connections, they benefit significantly from the convenience and cost savings of piped water. The benefits can also be significant in terms of economics and health (Franceys, 2005).

2.6 Water Quality

The incidents of water borne disease and epidemics nationwide arising from drinking water of doubtful quality have become of great concern. The primary purpose of the guideline for drinking water quality is the protection of public health (WHO, 2006).

Considering the quality of drinking water in general, certain requirements must be met for water to be fit for human consumption. If these requirements are met, the water can be described as „wholesome‟, „potable‟ or simply „water supply‟. According to Eja (2002), the requirements are:

i. Freedom from organism and chemical substances which might be injurious to health. This is the most important requirement.

ii. Drinking water should be of such composition that consumers do not question the safety of the water. This requirement implies that turbidity, colour, taste and odour should be low. Macro organisms (e.g. warms, aquatic and fly nymphs) should be absent.

iii. Drinking water should be suitable for house-keeping and for this reason, iron and manganese content should be low, because these substances colour laundry (like shirt) during washing. Iron causes a brown colour, while manganese causes a black colour. Hardness should be low, because water with a high hardness causes scale formation in water heaters by precipitation of calcium carbonates. Moreover, a high hardness implies that a high dosage of detergents is required for washing.

iv. Drinking water should not be aggressive to materials such as lead, copper, asbestos, cement and concrete, cast iron, galvanized steel, PVC (Polyvinylchloride) and PE (Polyethylene). This is because pipes, tubes and apparatus used in distribution systems and plumbing installations may consist of these materials. Pipes, tubes and apparatus affected by water cause many problems.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The area where this study was conducted is within Adentan Municipality. The municipal consists of thirteen (13) peri-urban communities and it lies 10 kilometres to the North east of Accra, in the Greater Accra region of Ghana, West Africa. It is geographically located within latitude 5′ 43″ north and longitude 0′ 09″ West.

The municipal has a total population of about 78,215(Ghana Statistical Service, 2010) with an average household size of 3.7 and household population of 76,601 with a total number of 20,478 households (Ghana Statistical Service, 2010). About 62.5 percent of the population resides in urban and 37.5 percent in rural areas. The type of settlement in the municipality is the dispersed form.

About 74.1 percent of the population aged 15 years and older are economically active while 25.9 per cent are economically not active. Of the economically active population, 91.2 percent is employed while 8.8 percent is unemployed. For those who are economically not active, about half of them are students (50.9%), 23.9 percent perform household duties and 2.4 percent are disabled or too sick to work. The major occupation for the inhabitants can be categorized as skilled self-employed which include people who offer services with a particular skill they have acquired to earn an income in return. Examples include sowing, carpentry, driving, hair dressing etc. However, there are also others who own their private enterprises and a few government employees.

Generally the main water supply for drinking in the Municipality are sachet water (53.4%), pipe-borne outside dwelling (15.4%) and tanker supply/Vendor provided (13.4%).

Figure 3.1: Map of study area

3.2. Sources of Data

Data for this study was obtained from both primary and secondary sources. With the primary source, questionnaires were administered to inhabitants within the study area in exploring the reactions of the communities in response to some commonly experienced aspects of accessing water (Tsiboe, 2004). Water samples were also taken and analyse at the laboratory using standard methods. The secondary source of information included literature from books, papers from peer-reviewed journals as well as the review of both published and unpublished articles.

3.3 Social Survey

A household survey was conducted using questionnaires for inhabitants Adenta, Adjinkano, Amanfrom, Ashiyie, Ashaley Botwe and Ogbojo communities (within the municipality) to identify access to water, sanitation, water quality, and their knowledge on the possible link between poor water quality and health. The social survey was conducted within the months of May and June, 2018.

3.3.1 Sample Size

In order to get a representation of the inhabitants within the area, the study used a sample size of 402 respondents which was obtained using the formula below.

Sample Size =

$$\frac{\frac{z^2 \times p(1-p)}{e^2}}{1+\left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

(www.surveymonkey.com)

(*Where; Population Size = N Margin of error = e z-score = z e is percentage, put into decimal form (for example, 5% = 0.05).*

Z=1.96 N=78,215 e= 0.05

$\cong$ *383*

3.4 Water Sampling Methods

A representation of the water sources (5 samples for each source) were selected randomly from each of the community under study. A total of 160 samples were collected which was made up of 80 samples for dry season and 80 samples for the wet or rainy season. The samples were put on ice and conveyed to the Ecological Laboratory of the University of Ghana for analysis.

3.4.1 Sample Collection

For physico-chemical analysis, water samples were collected using clean containers, labelled and transported on ice immediately to the Ecological laboratory of the University of Ghana .

Samples for physico-chemical analysis were collected into one litre plastic bottles previously washed and rinsed several times with distilled water. Bacteriological samples were collected into narrow-mouthed pre-sterilized 500 ml glass bottles. In taking samples for bacteriological analysis, the taps were sterilized by cleaning the inside and outside of the nozzles with 70% alcohol. Cotton soaked in the alcohol was then set ablaze and used to strongly heat the nozzles. The taps were then turn on and allowed to run waste for about a minute before samples were taken.

3.5 Laboratory Analysis

3.5.1 Physico-chemical Analysis of Samples

i) Temperature, pH, electrical conductivity (EC), and total dissolved solids were measured on the field using HORIBA U-50 series.

ii) Sulphate (SO_4^{2-}) analysis

The level of the sulphate in the sample was determined using Sulpha Ver 4 powder pillows in a direct reading by means of Hach spectrophotometer Model DR. 2000. Twenty five (25) millilitres of the sample was measured into sample cell. One Sulpha 4 Reagent powder pillow was added to the sample and swirl to dissolve. A 5-minutes reaction period was allowed. Another sample cell (the blank) was filled with 25ml of sample and placed into the cell holder to calibrate it. After the reaction period the prepared sample was placed into the cell holder and the concentration of the phosphorus was determined at 450 nm. The Sulphate ions in the sample react with barium in the Sulfa Ver 4 Sulphate Reagent and form insoluble barium sulphate turbidity. The amount of turbidity form is proportional to the sulphate concentration. (APHA, 1996).

iii) Nitrate Nitrogen (NO_3^- -N) analysis

The method used for the Nitrate analysis was Cadmium Reduction Method. The nitrate level in each sample was measured using Nitrate Powder Pillows in a direct reading HACH spectrophotometer Model DR. 2010. Ten (10) ml of the sample was measured into sample cell of the Spectrophotometer. One Nitraver 5 Nitrate Reagent Powder Pillow was added to the sample. The mixture was then shaken vigorously for 1 minute. Five minutes was be allowed for the solution to react. An orange colour of the mixture indicates the presence of Nitrate. After five minutes, another cell was filled with 10ml of only the sample (blank). The blank sample will be placed in the spectrophotometer for calibration. Then the prepared sample will be placed into the cell holder to determine the Nitrate concentration at 500nm in mg/l (HACH, 1992)

iv) Total Suspended Solids

About 500ml of sample was blended for exactly 2 minutes. The blended sample was poured into a 1 litre beaker, stirred and 25ml aliquots immediately poured into a sample cell. The prepared sample was swirled to remove any bubbles and the reading recorded with a spectrophotometer set at 810 nm which has previously been calibrated using 25ml of de-mineralized water (blank) to zero reading. (APHA, 1995).

v) Turbidity

Turbidity of the water was determined using Turbidimeter Model 2100P. The water Sample was vigorously shaken and Twenty five (25) millilitres measured into the cell holder. The cell was closed and the read button of the instrument pressed. The reading was taken from a screen after the figure had stabilized. Turbidity was recorded in Nephelometric Turbidity Unit (NTU). Each measurement was preceded by a calibration (APHA, 1995).

vi) Phosphate (PO_4^{3-}) analysis

A 10ml of water sample (the prepared sample) was placed in the sample cell. Phos Ver 3 Phosphate Powder pillow was added to the cell content and swirled immediately to mix. A two-minute reaction period was allowed. A blue colouration of the mixture indicates the presence of phosphate. Another sample cell (the blank) was filled with 10ml of sample and placed into the cell holder to calibrate it. After reaction period the prepared sample was placed into the cell holder and the level of phosphorus was determined at 890 nm. The Spectrophotometer displayed the results in mg/l PO_4^{3-} (HACH, 1992).

viii) Fluoride and Chloride

Fluoride and chloride were measured by using Aquaprobes (AP - 2000).

ix) Alkalinity

25 ml of the sample was diluted to 50ml with distilled water in a flask and 1 ml of ammonia buffer solution was added. Two drops of Eriochrome black T-indicator was added. A standard EDTA titrant (0.01M) was added slowly with continuous stirring the colour changed. The volume of EDTA titrant added is noted and used to calculate alkalinity in milligram per litre as calcium bicarbonate.

3.5.2 Bacteriological Analysis of Samples

i) Sterilization of Glassware: All glassware used for this study were sterilized in a hot box oven at 160°C for one hour.

ii) Serial Dilution of Samples: Nine millilitres of sterile water was transferred into 5 sterile tubes labelled 10^{-1} to $10^{-5.}$ One millilitre of the sample aseptically transferred into the first test tube (10^{-1}) with a sterile pipette and mixed. From the first test tube, one millimetre was equally transferred to the test tube labelled 10^{-2} and mixed using fresh pipette. This was repeated until the test tube labelled 10^{-5}.

iii) Total Plate Count (Total Viable Bacteria): The Pour Plate Technique was used and the culture medium was Plate Count Agar (PCA). The Plate Count Agar was prepared according to the manufacturer"s instruction (20.5g of the agar was put into one litre deionised water and allowed to soak for 10 minutes and then swirled to mix. It was then autoclaved at 121°C for 15 minutes) and allowed to cool to 47°C. One millilitre of the sample from each of the test tube was aseptically transferred into sterile petri dishes using sterile pipette. Twenty millilitres of the culture medium was poured into the petri dish and properly mixed with the sample by swirling. This was done in triplicates. A control was equally prepared, but without adding the sample. The plates were labelled, allowed to solidify and finally incubated at 37°C for 24-48 hours. The plates were observed for development of bacterial colonies.

iv) Total Coliform: The Pour Plate Technique was used and the culture medium was Violet Red Bile. One millilitre of the sample from each of the test tube was aseptically transferred into sterile Petri dishes using sterile pipette. The Violet Red Bile was prepared according to the manufacturer‟s instruction (thus, 38.5g of the Violet Red Bile was suspended in 1 litre of distilled water and boiled to completely dissolve the agar) and allowed to cool to 45°C. Twenty millilitres of the culture medium was poured into the Petri dish and properly mixed with the sample. This was done in triplicates. A control was equally prepared, but without adding the sample. The plates were labelled, allowed to solidify, inverted and finally incubated at 37°C for 24-48 hours. The plates were observed for development of bacterial colonies.

v) Faecal Coliform: The Pour Plate Technique was used and the culture medium was Eosin methylene blue agar (EMB agar). One millimetre of the sample from each of the test tube was aseptically transferred into sterile Petri dishes using sterile pipette. The EMB agar was prepared according to the manufacturers instruction (thus, 35.9g of the EMB agar was suspended in 1 litre of distilled water and boiled to completely dissolve the agar. It was then autoclaved at 121°C for 15 minutes) and allowed to cool to 45°C. Twenty millilitres of the culture medium was poured into the Petri dish and properly mixed with the sample. This was done in triplicates. A control was equally prepared, but without adding the sample. The plates were labelled, allowed to solidify, inverted and finally incubated at 37°C for 24-48 hours. The plates were observed for development of bacterial colonies.

3.6 Data Analysis

3.6.1 Frequency of water sources

Chi-square test was used to test how likely the distribution of water sources in the various communities is due to chance.

3.6.2 Water Quality

Paired T-test was used to determine whether there is significant difference between data collected in the wet and dry seasons and the One-way analysis of variance (ANOVA) was used to determine whether there were any statistically significant difference between the means of the physico-chemical and bacteriological parameters.

3.6.3 Household survey

Descriptive analysis was used to measure the frequency of sources in the communities, counts of the sachet water used in each household and the amount spent to access the sources.

CHARPTER FOUR

RESULTS

4.0. Introduction

The chapter begins by a presentation on the demographic background of respondents followed by the findings of the study.

4.1 Demographic Characteristics of Respondents

4.1.1. Gender of Respondents

The results show that generally, more of male respondents participated in the questionnaire survey compared to their female counterparts. According to the results, out of the 402 total number of respondents, 210, representing 52.2% were males while 192 representing 47.8% were females. Fig. 4.1.1 shows the breakdown of males as against the female respondents in all the five communities selected for the survey. From the figure, whereas there was almost equal representation of gender in Adjringano, Amanfrom and Ashiyie, more males were represented in Ashaley-Botwe and Ogbojo The results further revealed that less males participated in Adenta (Fig. 4.1.1).

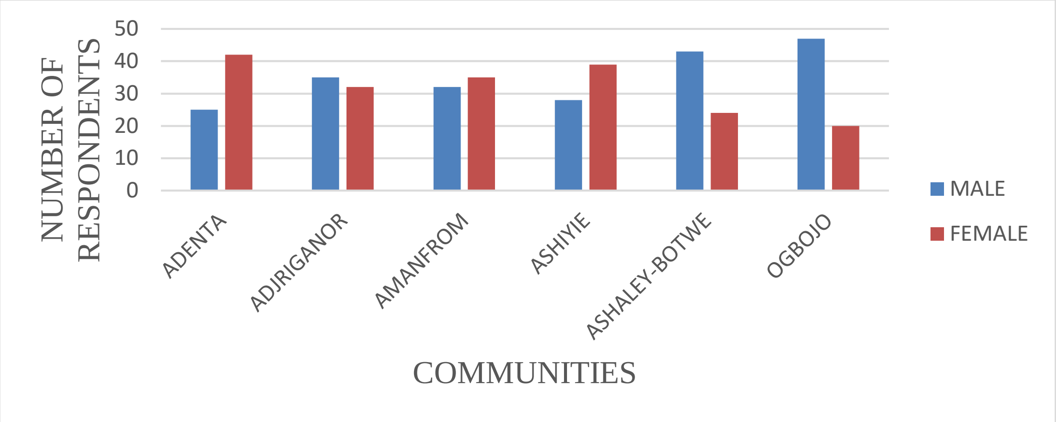

Figure 4.1.1: Gender of respondents.

4.1.2 Age of Respondents

Fig. 4.1.2 shows that the maximum number of respondents have the age 15 to 24 years. This depicts a broad base population pyramid which tapers off with a small number of elderly persons. Majority of the number of respondents in Amanfrom, Ashiyie, and Ashaley-Botwe ranged in age between 25 and 34 years; those from Adjringano and Ogbojo were between the age range of 15 to 24 years and while majority of those from Adenta were between the 25 to 44 years (Fig. 4.1.2).

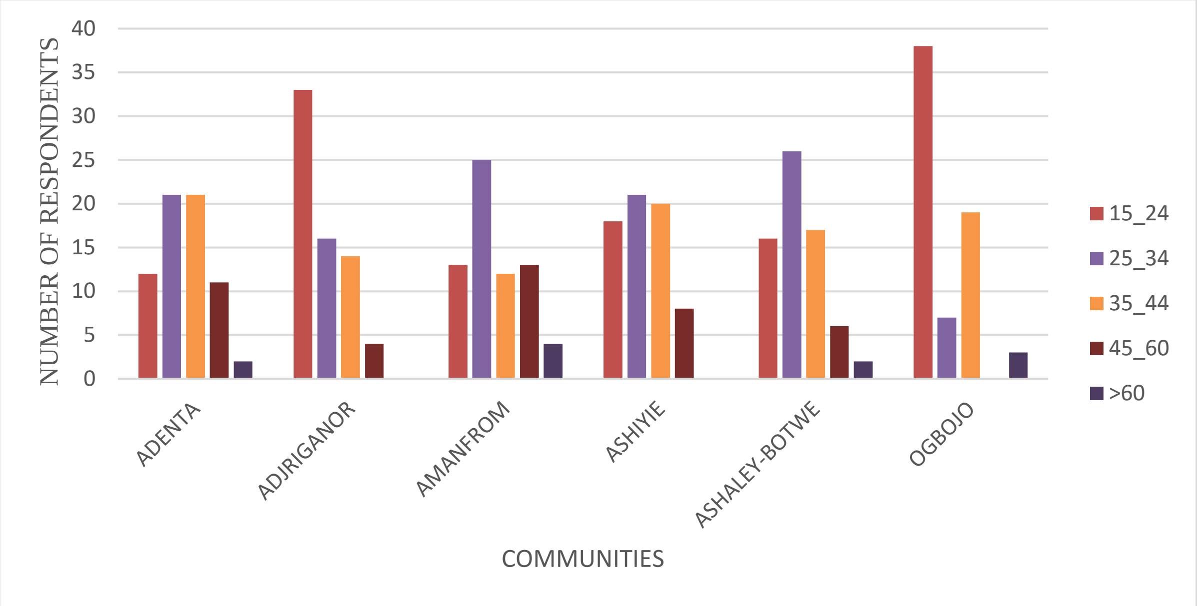

Figure 4.1.2: Age of Respondents

4.1.3. Educational Level of Respondents

Fig. 4.1.3 shows the breakdown of educational level in all the five communities selected for the survey.According to the results, out of the 402 total number of respondents, 38, representing 8.5% had no formal education while 364 representing 90.5% had formal education. Whiles those in Adenta, Adjringano, Ashiyie, Ashaley-Botwe and Ogbojo had majority of the respondent with secondary education, those in Amanfrom had more respondent with basic education.

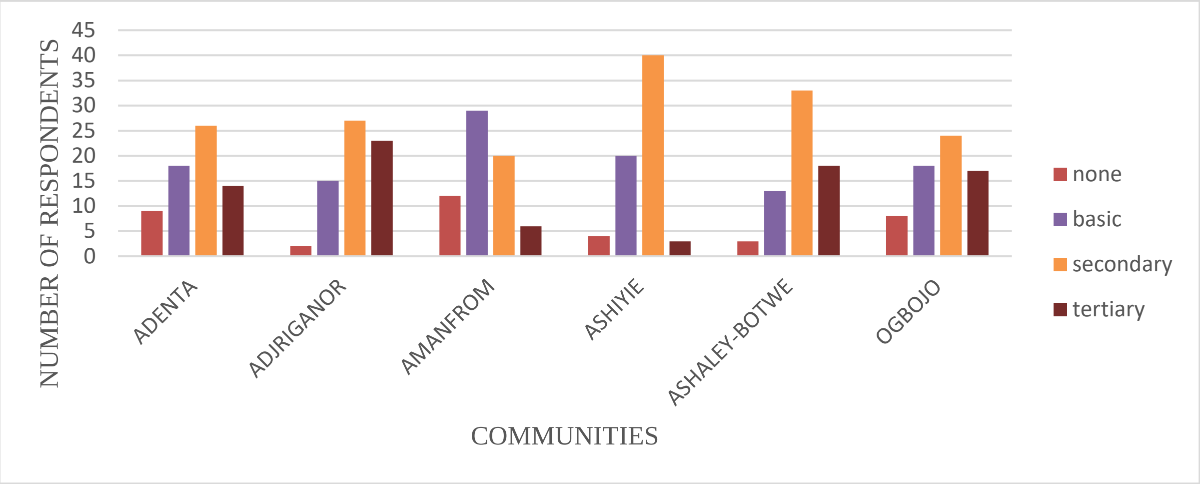

Figure 4.1.3: Educational level of respondents

4.1.4 Number of Years lived in the Community

Whiles Adenta, Adjringano, Amanfrom and Ashiyie had majority of the respondents lived in the community less than five years, those from Ashaley-Botwe and Ogbojo had the majority of the respondent lived in the community between 5 to 10 years (Fig 4.1.4). Per each community, only a few respondents had lived beyond 10 years.

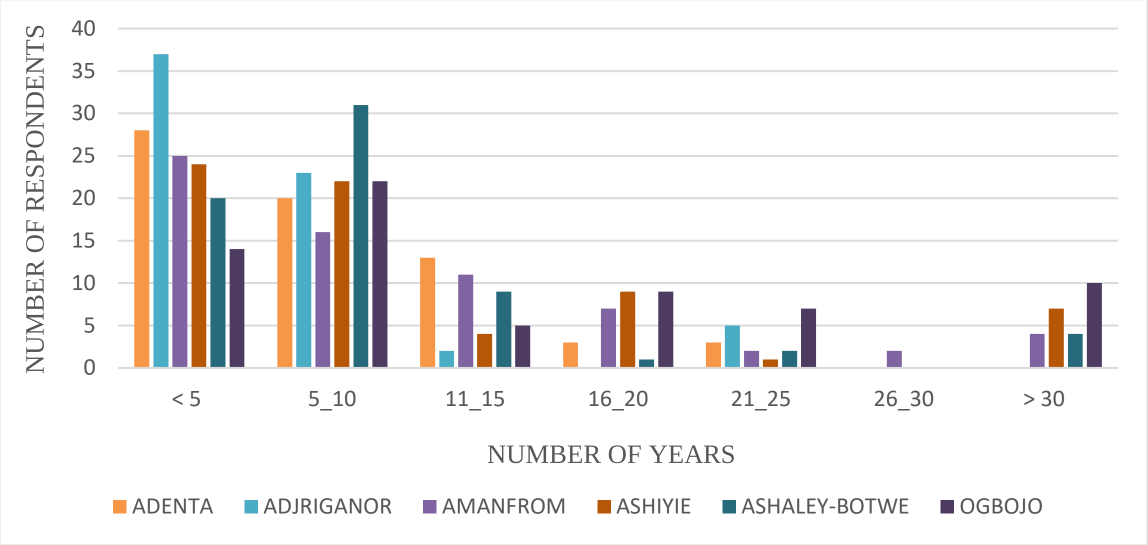

Figure 4.1.4: Number of years lived in the community

4.1.5 Household size

Where as most of the respondent from Adjringano, Ashiyie, Ashaley-Botwe and Ogbojo were in a household size of 2 to 4 persons, those in Adenta were in a size of 4 to 6 persons (Fig 4.1.5).

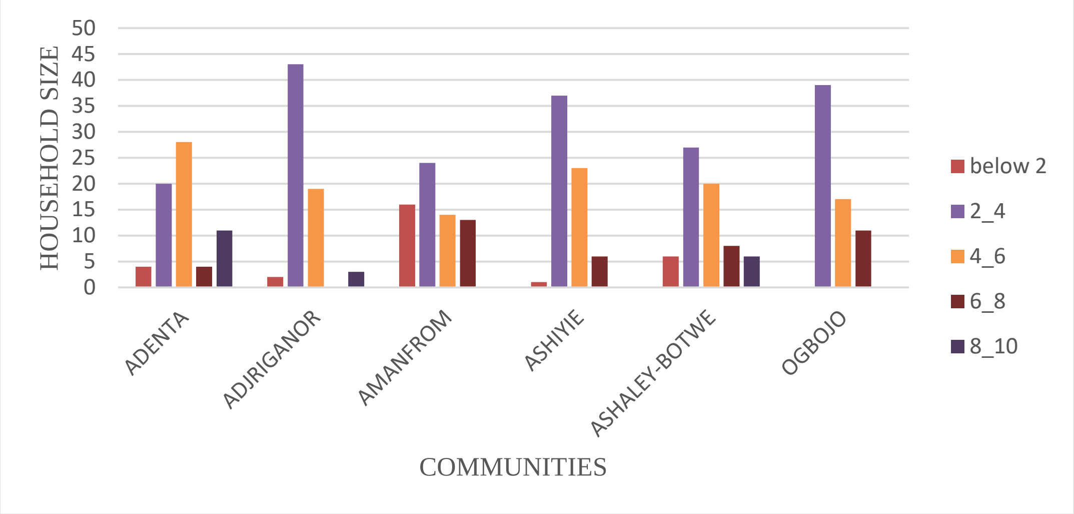

Figure 4.1.5: Household size.

4.2 Available Sources of Water

The results of this study shows that there are five sources of water available to the residents in the municipality. These are vendor supplied sources involving mainly treated water for drinking, hand-dug wells, boreholes, rain water harvesting and water from tanker service providers.

From Table 4.2a below, unlike other communities, Adjringano and Ogbojo have two and three sources of water respectively. These are rain water harvesting and pipe-borne water for Adjringano and hand-dug well, rainwater harvesting and water from tanker service providers for Ogbojo. Adenta, Adjringano and Ashaley-Botwe have high access to pipe-borne water, representing about 79.1%, 97% and 67.2%

respectively. In all the communities, households that harvest rain water are few, ranging from 1.5% to 4.0%.

Communities like Adenta, Amanfrom, Ashiyie, Ashaley-Botwe and Ogbojo also use other sources such as hand-dug well and borehole.

The chi-square test for the for the distribution of water sources in the communities (Table 4.2b), indicates that there is a relationship between communities and the water sources available.

Table 4.2a: Sources of Water

COMMUNITY	SOURCE OF WATER USED				
	WELL	BOREHOLE	RAIN	TANKER	PIPE
ADENTA	7.50%	4.50%	3.0%	6.0%	79.10%
ADJINGANO	0	0	3.0%	0	97%
AMANFROM	11.90%	16.40%	3.0%	32.30%	36.30%
ASHIYIE	28.90%	14.90%	2.0%	6.0%	46.80%
ASHALEY-BOTWE	10.40%	6.0%	1.50%	16.40%	67.20%
OGBOJO	5.50%	0	4.0%	90.50%	0

Table 4.2b: Distribution of water sources by Chi-squre test (at confidence level of 0.05)

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-S . 9quare	342.434[a]	20	.000
Likelihood Ratio	347.007	20	.000
Linear-by-Linear Association	21.055	1	.000
N of Valid Cases	402		

4.3 Uses of Available Water Sources

4.3.1 Drinking Water Sources

Fig. 4.3.1 indicates that the households of study area use sachet water as the main drinking source than other sources. The percentage of sachet water users range from 68.7%, to 88.1%, pipe borne water from 20.9% to 22.4%, bottled water from 3.0% to 9.0%, hand-dug well from 1.5.0% to 9.0%, borehole from 1.50% to 4.5% and rain water about 4.4%. Also, among the communities, households in Ogbojo are the majority in sachet water usage represented by 88.1% .

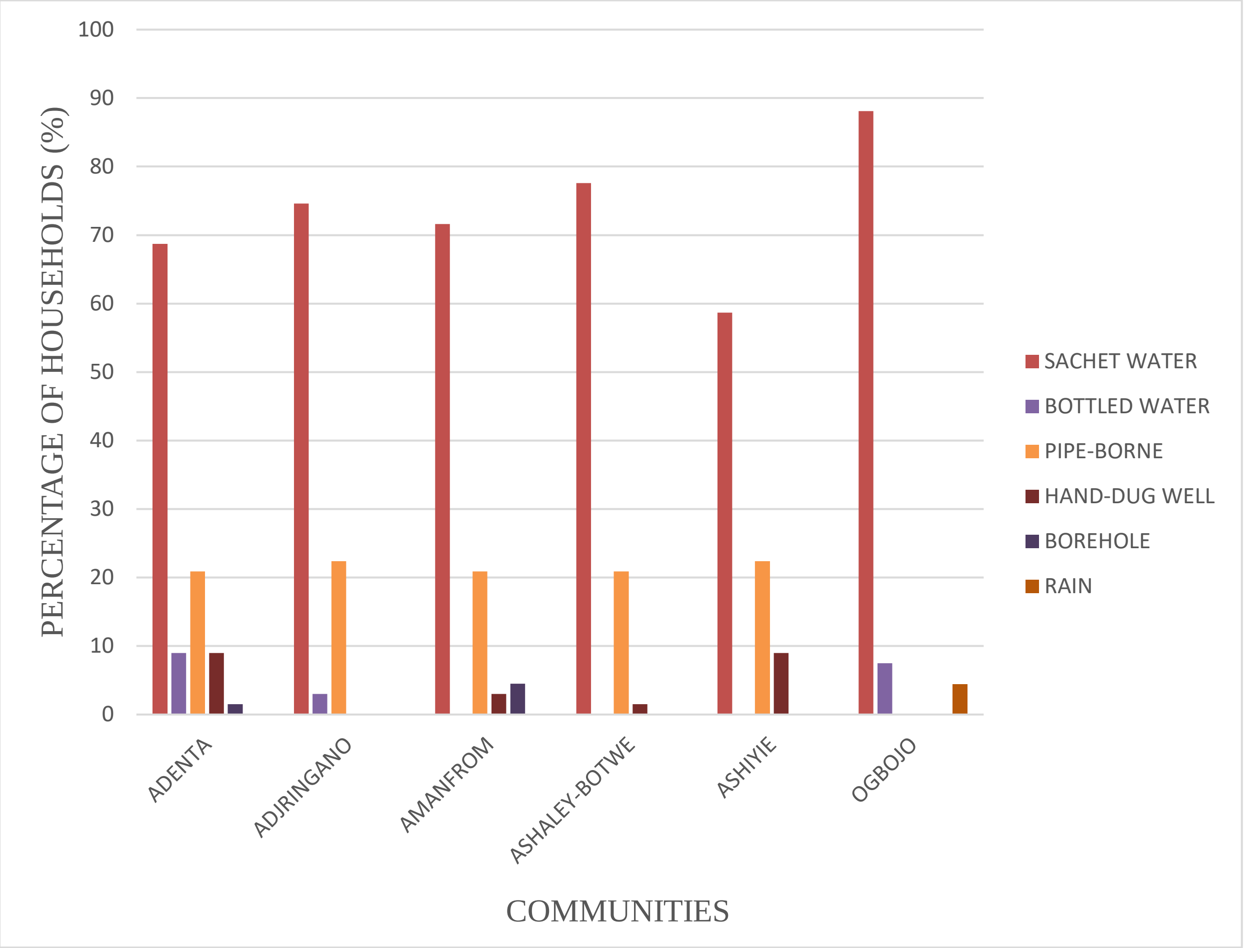

Figure 4.3.1: Drinking Water Sources

4.3.1.1 Number of Bags of Sachet Water use Weekly

Table 4.3.1.1a indicates that, households in the communities studied used one to five bags of sachet water weekly depending on the size of the household. Out of 402 households, 89 of them representing 22.1% do not use sachet water at all whiles 77.9% use sachet water. Out of those that use sachet water, a maximum of 141 households representing 35.1% use two bags of sachet water, 56 households representing 17.9% use one bag, 87 households representing 27.8% use 3 bags, 25 households representing 7.99% use 4 bags and the least 4 households representing 1.3% use five bags of sachet water weekly across the communities studied.

Table 4.3.1.1a: Number of Sachet Water Bags use Weekly per household size

	NUMBER OF SACHET WATER BAGS USE WEEKLY						**Total**
HOUSEHOLD SIZE	none	1	2	3	4	5	
below 2	7	20	0	1	0	0	**29**
2_4	47	32	99	11	1	0	**190**
4_6	28	2	40	47	4	0	**121**
6_8	3	2	2	22	14	0	**42**
8_10	4	0	0	6	6	4	**20**
Total	**89**	**56**	**141**	**87**	**25**	**4**	**402**

4.3.2 Water for Cooking

Considering Fig. 4.3.1 below, it shows that the households in Adenta, Adjringano, Amanfrom and Ashaley-Botwe use pipe-borne water for cooking representing a range within 29.9% to 97.0% whilst 47.8% of Ashiyie and 92.5% of Ogbojo use hand-dug well and water from the tanker service providers for cooking respectively. About 1.5% to 4.0% use harvested rain.

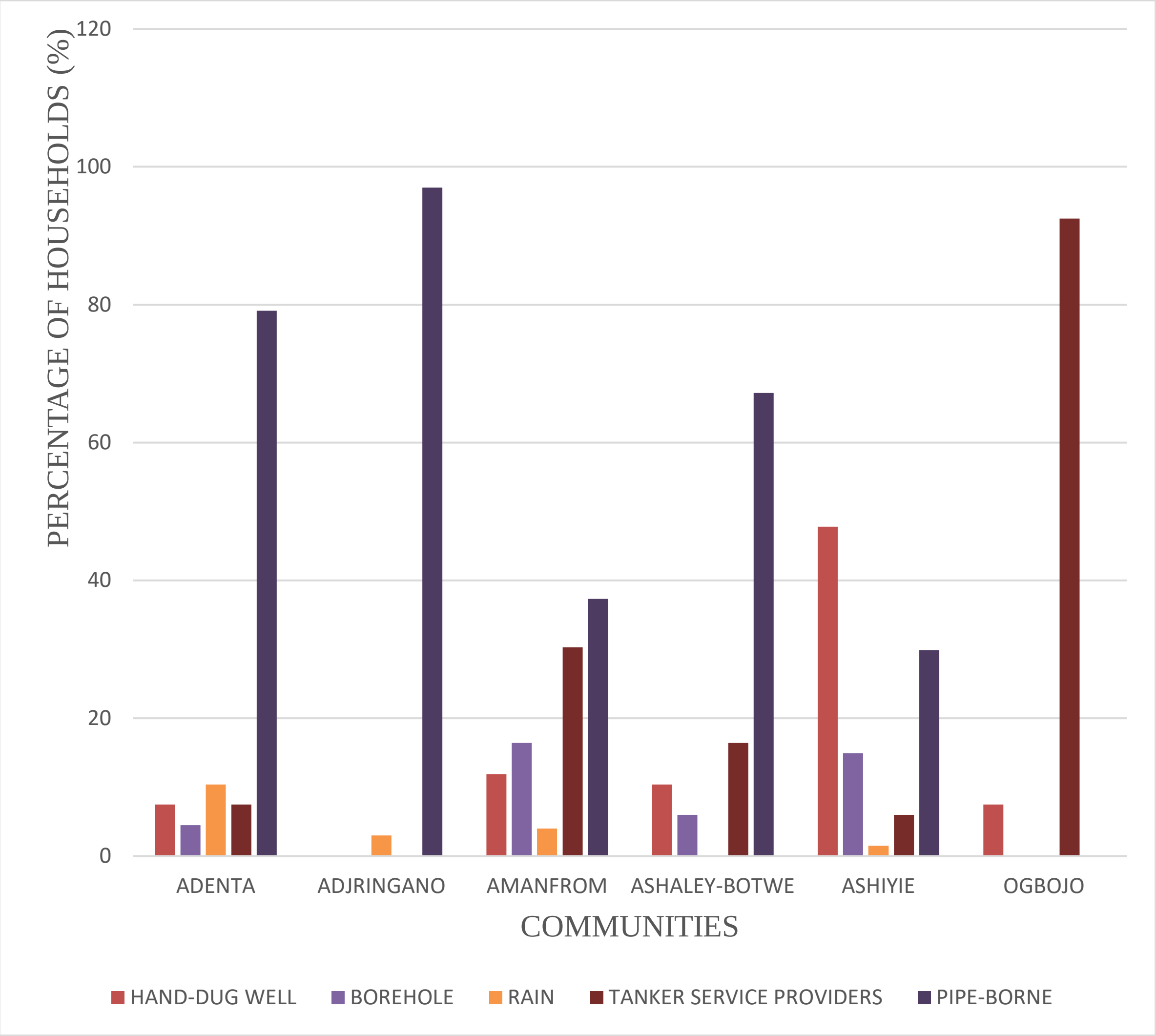

Figure 4.3.2: Water for Cooking

4.3.3 Water for Bathing

From Figure 4.3.2, about 100% to 68.7% of households in Adjringano, Adenta and Botwe use pipe borne water for bathing, whilst 49.3% and 92.5% households of Ashyie and Ogbojo use hand-dug well and water from tanker service providers for bathing respectively. Few households in the various communities use boreholes and water harvested from rains.

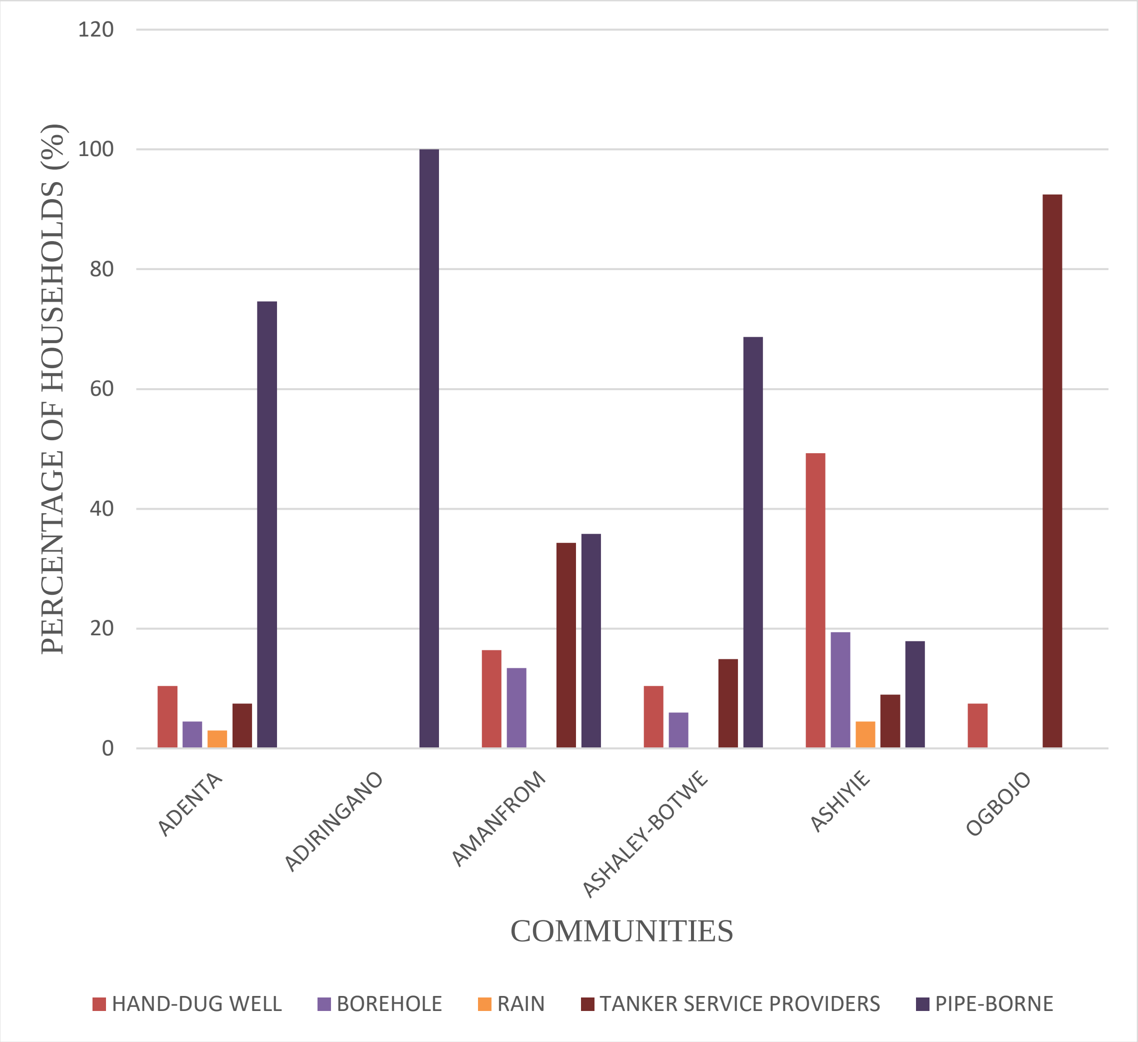

Figure 4.3.3: Water for Bathing

4.3.4 Water for Washing

Fig 4.3.4, shows that 35.8% to 100% of households in Adjringano, Adenta, Amanfrom and Ashaley-Botwe use pipe-borne water for washing, 49.3% and 92.5% households of Ashiyie and Ogbojo use hand-dug well and water from tanker service providers for washing. Few households of the various communities use boreholes and water harvested from rains.

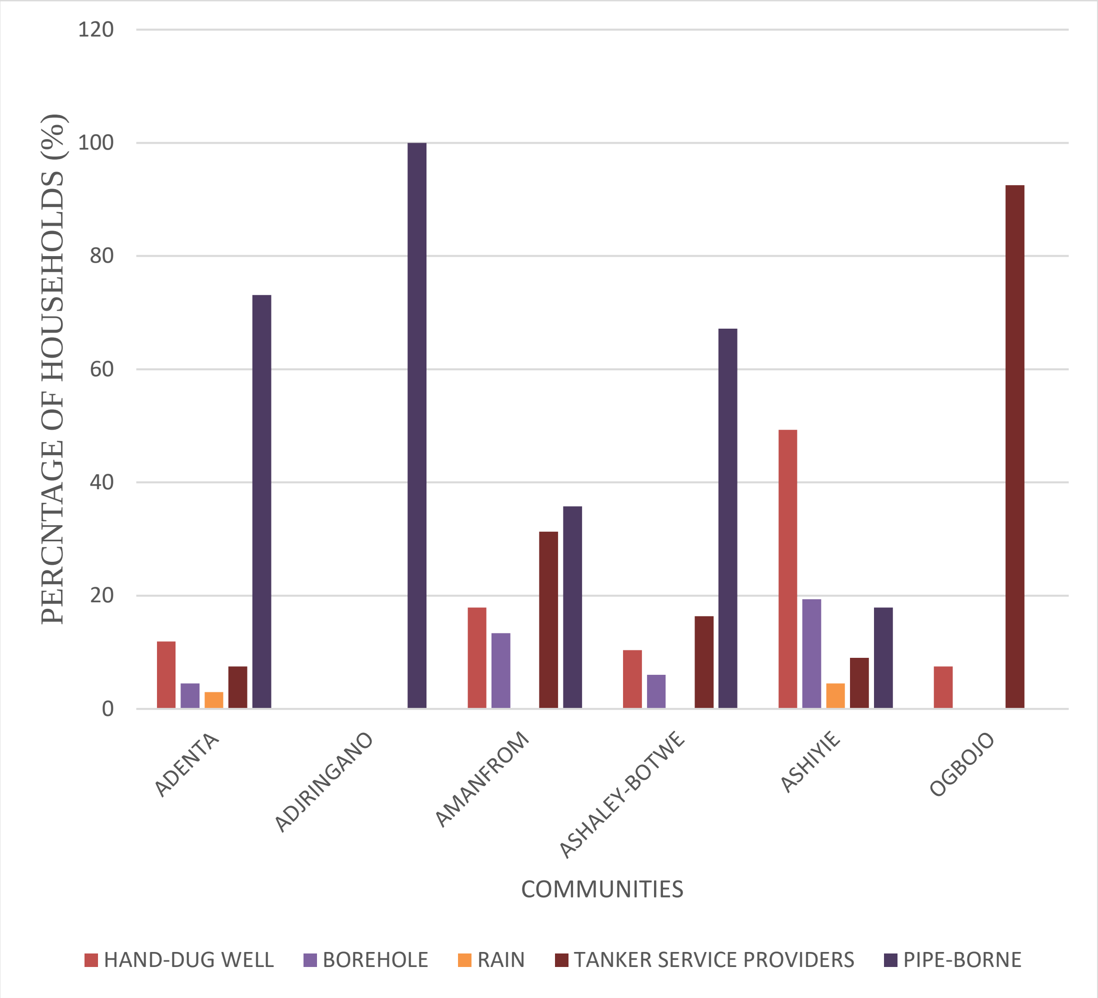

Figure 4.3.4 : Water for Washing

4.4 Availability of Water Sources to Households

4.4.1. Time within a Day that a Water Source can be accessed

Considering Fig 4.4.1, 55.20% to 82.10% of the households in Adenta, Adjringano, Amanfrom and Ashiyie communities have access to water throughout the day whilst 17.90% to 44.80% during day time. 44.80 to 46.30% households in Ashaley-Botwe and Ogbojo communities access water 24hours whiles 53.70% to 55.20% access water supply sources during day time. 4.5% of the households in Amanfrom access water 3 to 5 hours and 6 to 8 hours in a day.

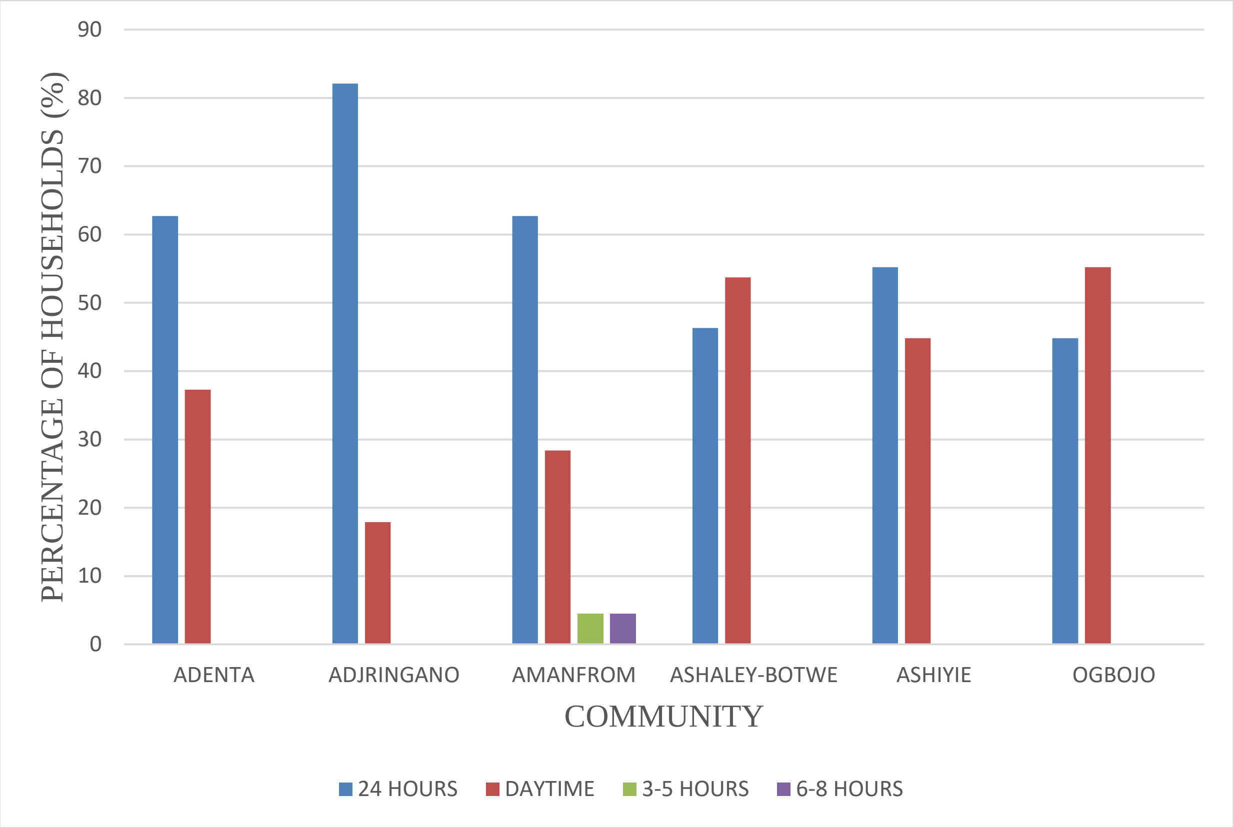

Figure 4.4.1: Accessible Time in a Day

4.4.2. Distance covered to access the water

As shown by Fig 4.4.2, 73% of the households were able to accessed a source of water over a distance less than 100 meters, 16% between 100 to 300 meters, 7% between 300 to 500 meters, 2% between 500 to 700 meters and 1% between 700 to 1100 meters. Households in Adjringano covers the shortest distance (within <100M to 500M) to access a water source.

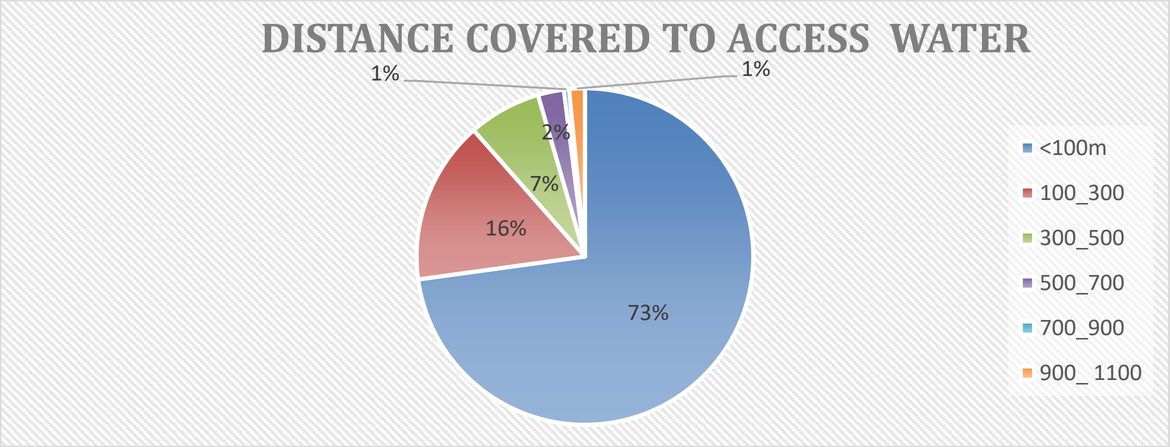

Figure 4.4.2: Average Distance covered to access water in the study area.

4.4.3 Cost Incurred Accessing a Water Source

4.4.3.1 Monthly Cost Incurred by Sachet Water Users

A maximum of GH¢ 70 and a least of GH¢ 10 is spent monthly on sachet water. Within a total of 313 households that use sachet water, 53 households spend GH¢10 to GH¢20, 112 households spend GH¢21 to GH¢30, 76 households spend GH¢31 to GH¢40, 59 households spend GH¢41 to GH¢50, 11 households spend GH¢51 to GH¢60 and 2 households spend GH¢61 to GH¢70 on sachet water monthly (table 4.4.3.1).

Table 4.4.3.1: Monthly Cost Incurred by Sachet Water Users

COMMUNITY	MONYHLY COST OF SACHET WATER USED (GH¢)						**Total**
	10 - 20	20 - 30	31 - 40	41 - 50	51 - 60	61 - 70	
ADENTA	3	11	19	13	1	0	**47**
ADJRIGANOR	4	11	19	15	1	1	**51**
AMANFROM	8	18	14	8	1	0	**49**
ASHIYIE	11	22	6	6	1	0	**46**
BOTWE	14	23	10	7	2	1	**60**
OGBOJO	13	27	8	10	5	0	**63**
Total	**53**	**112**	**76**	**59**	**11**	**2**	**313**

4.4.3.2 Monthly Cost Incurred Using Other Sources

Amount spent on other sources of water ranged from GH¢ 20 to GH¢ 80. 145 households spend GH¢21 to GH¢30, 138 households spend GH¢31 to GH¢40, 55 households spend GH¢41 to GH¢50, 4 households spend GH¢ 51 to GH¢60, 19 households spend GH¢61 to GH¢70 and 5 households spend GH¢71 to GH¢80 on main source of water monthly (table 4.4.3.2). Also, table 4.4.3.2 shows that cost of hand-dug wells, boreholes and tanker or vendor services are relatively low.

Table 4.4.3.2: Monthly Cost Incurred by using each main source

SOURCE_USED	MONTHLY COST (GH¢)							**Total**
	10 - 20	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	
Hand-dug_Well	0	24	5	8	1	0	0	**38**
Borehole	0	6	5	3	0	0	0	**14**
Water from tanker service providers	0	59	42	4	0	0	0	**105**
Pipe_borne	0	57	86	40	3	19	5	**210**
Total	**0**	**145**	**138**	**55**	**4**	**19**	**5**	**367**

4.5 Physico-Chemical Parameters Investigated

4.5.1 Turbidity

Mean turbidity recorded differ from each source. Sachet water recorded the lowest with a range of 1.38 to 1.86 NTU and boreholes recorded the maximum with the range 4.91 to 7.54 NTU. At 0.05 confidence level (4.5a), there is a significant different between the turbidity of different sources (p= .000).

4.5.2. Alkalinity

As shown in Table 4.5, mean alkalinity of water sources in boreholes were higher than the other sources with a maximum value of 309 mg/L as $CaCO^3$. Sachet water recorded the minimum value with the range of 5.5 to 21 mg/L as $CaCO^3$. At a confidence level of 0.05 (table 4.5b), there is a significant difference between the alkalinity of the sources of water (p= .000) .

4.5.3 Total Suspended Solids

In terms of total suspended solids (TSS), almost all the supply sources did not record any except for Ashaley-Botwe pipe borne water and Adenta hand-dug wells which recorded an average of 2.50 mg/L each (Table 4.5).

4.5.4 Electrical Conductivity

From Table 4.5, borehole supply sources recorded high electrical conductivity with a maximum of 677µscm^{-1}as compared to the other sources. Sachet water recorded the minimum values between 33 to 58.5 µscm^{-1}, pipe borne water recorded range between 81 to 544.5 µscm^{-1} and hand-dug wells between 67.5 to 596.5 µscm^{-1} Although there is no significant difference between electrical conductivity of we and dry season, at a confidence level of 0.05 (table 4.5a) there is a significant difference between the electrical conductivity of the water sources(p = .036).

4.5.5. Total Dissolved Solids (TDS)

The mean value of total dissolved solids of some hand-dug wells and some boreholes supply sources were high. The maximum value of 1209 mg/L was recorded by Ashaley-Botwe boreholes and the minimum of 15 mg/L recorded by Eva-pure sachet water. Where as pipe borne water ranged between 52.5 to 541 mg/L, hand-dug well ranged between 39.5 to 1044.5 mg/L. At a confidence level of

0.05 (table 4.5a), there is no significant difference between the mean TDS values of the sources of water (p = .236).

4.5.6 pH

The mean pH of supply sources (Table 4.5) range from 5.08 to 7.07. Boreholes and hand-dug wells recorded the lowest pH between the range 5.08 to 6.12 whiles sachet waters recorded the highest pH between the range 6.6 to 7.07. At a confidence level of 0.05 (Table 4.5b), there is a significant difference between the mean pH values of the sources of water (p=.006).

4.5.7 Temperature

Considering Table 4.5, the mean temperature recorded varies greatly with the community. The maximum temperature of 30.09 ^{o}C was recorded by Adenta pipe borne water and the minimum of 25.94 was recorded by Adjringano.

Table 4.5a: Mean Physico-chemical parameters of water sources in the study area compared to WHO standards.

	Average Turbidity (NTU)	**Average Alkalinity(ppm as $CaCO_3$)**	**AverageTSS (mg/l)**	**Average EC(µscm^{-1})**	**Average TDS(mg/L)**	**Average pH**	**Average Temperature(^{0}C)**
W.H.O STANDARD	**5 NTU**	**100– 500mg/L $CaCO_3$**		**(50-300 µs/cm)**	**1000mg/l**	**6.5 to 8.5 pH**	**22 to 29 °C**
SOURCES							
Adjringano-Pipe borne Water	1.86	36	0	87	52.5	6.91	25.94
Ashaley-Botwe Pipe borne Water	1.98	24	0	252	93.5	6.95	28.83
Adenta-Pipe borne Water	1.96	42	0	81	255.5	6.89	30.09
Ashiyie-Pipe borne Water	2.11	85	0	621	381.5	6.89	29.09
Amanfrom-Pipe borne Water	1.87	149	0	844.5	541	7	27.93
Ashaley-Botwe Borehole	11.43	309	0	1717	1209	5.69	29.24
Adenta-Borehole	13.07	236	0	1277.5	709.5	5.78	29.15
Ashiyie Borehole	10.51	279	0	802	525.5	5.28	27.54
Amanfrom Borehole	9.83	148.5	0	83.5	46	5.64	29.98
Ashaley-Botwe Hand-dug Well	3.7	144	0	76.5	45.5	5.97	27.66
Adenta Hand-dug Well	3.71	251	2.5	896.5	543	6.11	28.98
Ashiyie Hand-dug Well	3.3	142.5	0	820.5	818.25	5.08	28.2
Amanfrom Hand-dug Well	2.71	43	0	67.5	3044.5	5.8	26.24
Ogbojo Hand-dug well	3.03	30	0	72.5	39.5	6.12	28.01

Sachet Water A – Evapure	1.38	8	0	3	1.5	6.81	27.31
Sachet Water B - Voltic Cool	1.86	21	0	58.5	33	7.01	27.39
Sachet Water C - Ice Drop	1.45	10	0	33	19.5	7.01	26.87
Sachet Water D - Special Ice	1.59	10.5	0	52	30.5	6.9	26.66
Sachet Water E - Ice Cool	1.64	5.5	0	5.5	3.5	7	27.26

Table 4.5b: Comparison of water quality by One-Way ANOVA (At 0.05 confidence level)

PARAMETERS	**PIPE BORNE**	**BOREHOLES**	**HAND-DUG WELL**	**SACHET WATER**	**SIG.**
TURBIDITY	1.96^{A}	5.85^{B}	3.29^{C}	1.58^{A}	.000
ALKALINITY	67.2^{A}	243.1^{B}	122.1^{D}	11^{C}	.000
ELECTRICAL CONDUCIVITY	277.1^{A}	470^{B}	266.7^{A}	30.4^{C}	.036
TOTAL DISSOLVED SOLIDS	264.8^{A}	622.5^{B}	498.2^{C}	26.6^{D}	.236
pH	6^{A}	5.6^{B}	5.8^{B}	6^{A}	.006

Within rows, means with different superscript letters are statistically different, $p \leq 0.05$

Table 4.5c Paired Samples T-Test for physical parameters (At 0.05 confidence level)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Turbidity wet - Turbidity dry	1.59053	2.02739	.46511	.61336	2.56770	3.420	18	.003
Pair 2	Alkalinity wet - Alkalinity dry	9.88421	120.53339	27.65226	-48.21103	67.97945	.357	18	.725
Pair 3	TSS wet - TSS dry	.52632	1.57651	.36168	-.23354	1.28617	1.455	18	.163
Pair 4	EC wet - EC dry	-329.47368	789.27093	181.07117	-709.89009	50.94273	-1.820	18	.085

Pair 5	pH wet - pH dry	-1.20842	.60055	.13778	-1.49788	-.91897	-8.771	18	.000
Pair 6	TDS wet - TDS dry	-162.84211	521.23598	119.57973	-414.06981	88.38559	-1.362	18	.190
Pair 7	Temperature wet - Temperature dry	.07105	1.78092	.40857	-.78732	.92943	.174	18	.864

4.6 Nutrient Content

4.6.1 Anions

4.6.1.1 Phosphate

Mean phosphate content in the water supply sources were generally low with values ranging from 0.085 to 0.6 mg/L (as seen in figure 4.6.1.1). Ashaley-Botwe hand-dug well recorded the maximum phosphate content of 0.6 mg/L whiles Ashaley-Botwe pipe borne recorded the minimum of 0.029 mg/L. At a confidence level of 0.05 there was a statistically significant difference between groups as determined by one-way ANOVA (F = 3.143, p =0.056).

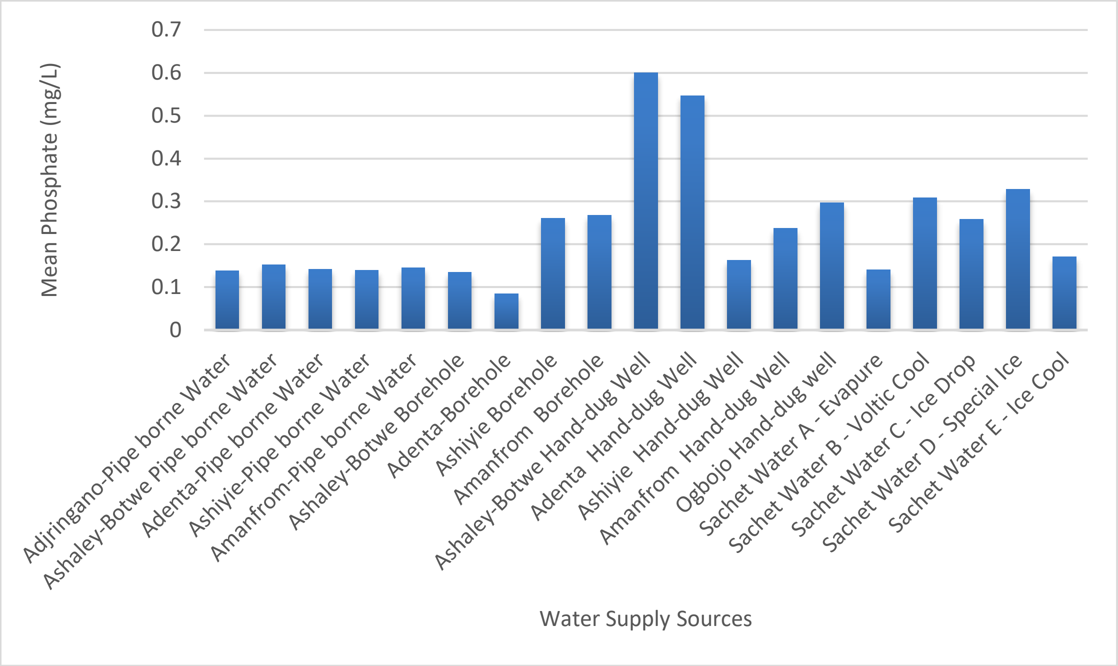

Figure 4.6.1.1: Comparison of mean phosphate in water sources

4.6.1.2 Sulphate

The mean sulphate content recorded was generally low for many supply sources. Sachet waters recorded the least sulphate content. Ashaley-Botwe hand-dug wells recorded the maximum of 148.0 mg/L whereas Eva-pure and Voltic cool sachet waters recorded the minimum of 2.5 mg/L. At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 1.695, p = 0.211)

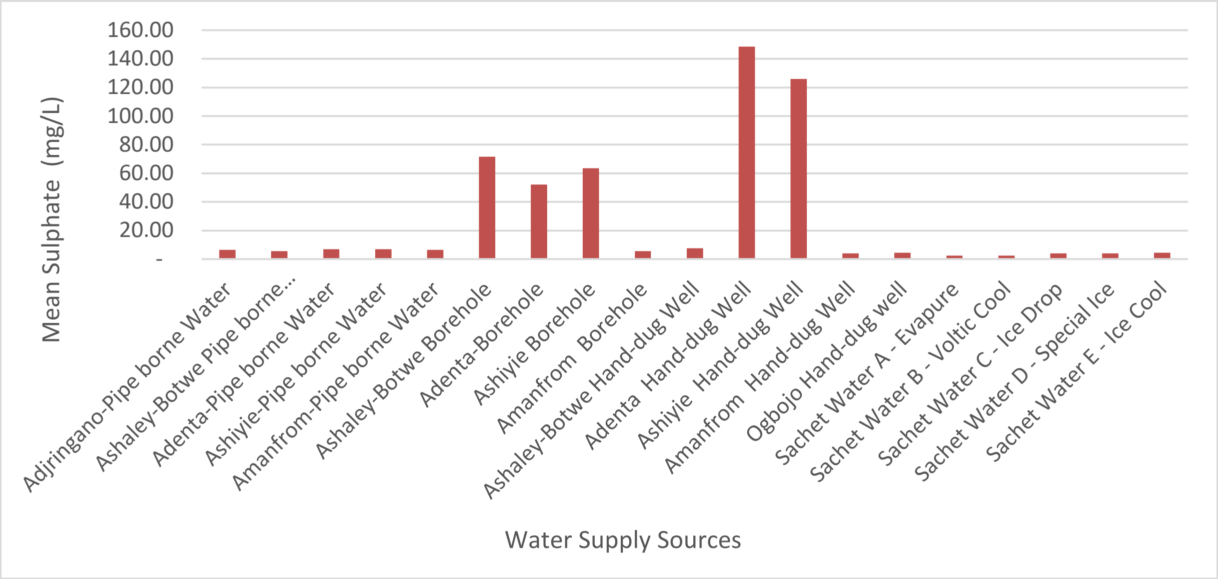

Figure 4.6.1.2: Comparison of mean sulphate in water sources

4.6.1.3 Nitrate

Mean nitrate content in sachet waters were low for most of the supply sources except for some hand-dug well and boreholes. Sachet waters recorded the lowest nitrate content between 0.1 to 0.9 mg/L whiles Adenta hand-dug well recorded the maximum of 1.5 to 18.6 mg/L.

At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 2.18, p =1.32)

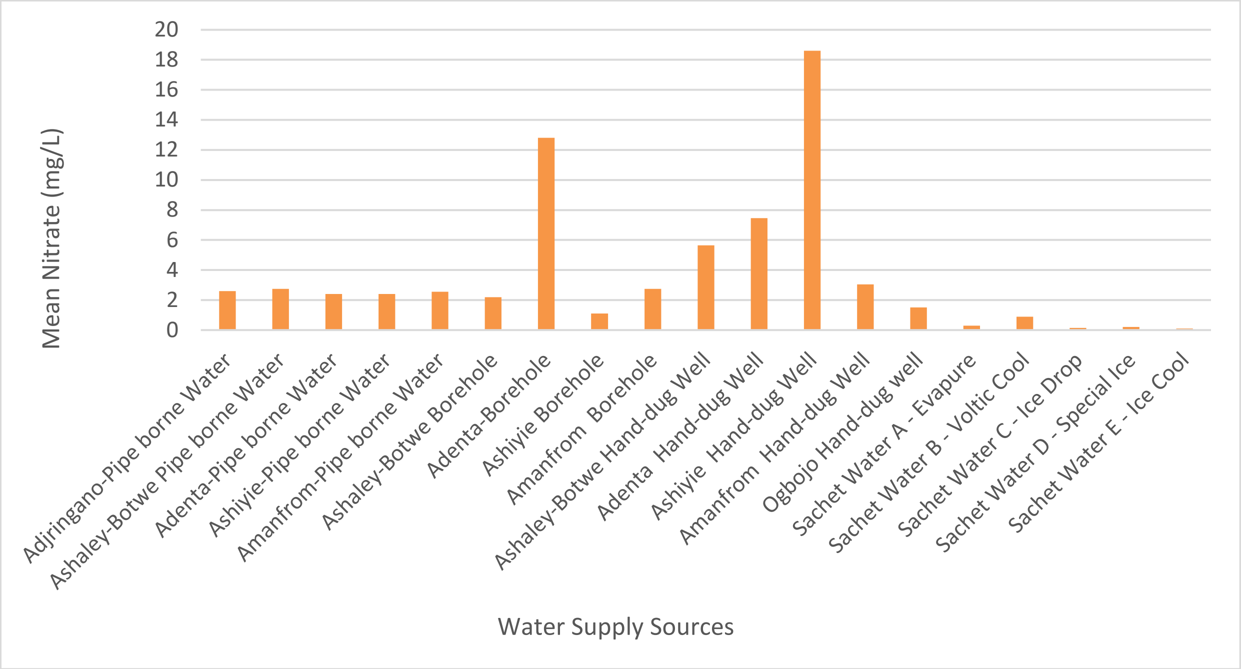

Figure 4.6.1.3: Comparison of mean nitrate in water sources

4.6.1.4 Fluoride

Fig 4.6.1.4 indicates that mean fluoride content was high in Adenta borehole water with 0.67 mg/L. The rest of the supply sources recorded low fluoride content with the least of 0.005mg/L recorded by Amanfrom hand-dug wells. At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 1.904, p =1.72)

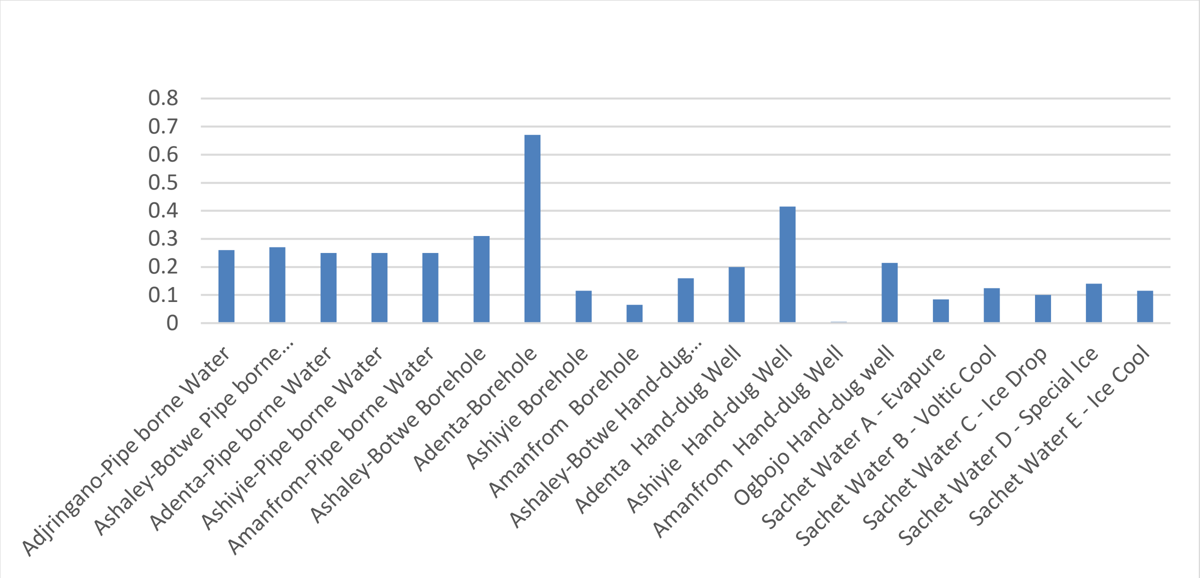

Figure 4.6.1.4: Comparison of mean fluoride in water sources

4.6.1.5 Chloride

From Fig 4.6.1.5, mean chloride content ranged from 1.915 mg/L to 217.51. Ice cool sachet water recorded the least with 1.915 mg/L whilst Adenta hand-dug wells recorded the highest with 217.51 mg/L. The other sources aside hand-dug wells values for chloride were fluctuating between the communities. At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 2.868, p =0.71)

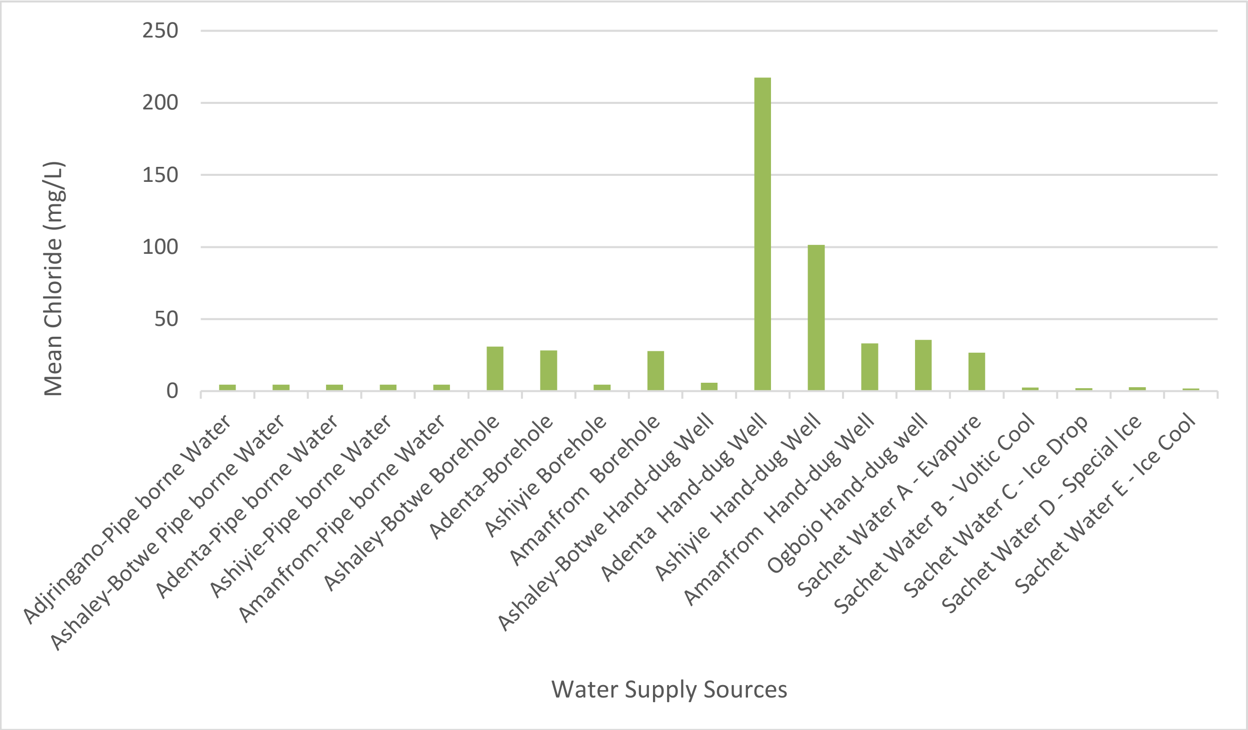

Figure 4.6.1.5: Comparison of mean chloride in water sources

4.6.2 Cations

4.6.2.1 Sodium

Values recorded by boreholes and hand-dug wells were higher than those recorded in pipe borne and sachet water. Sachet and pipe borne waters recorded the least values (0.5915 mg/L to 3.972 mg/L) for sodium content. Some boreholes and hand-dug wells recorded high sodium content with Ashaley-Botwe hand-dug well recording the highest of 181.756 mg/L. At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 3.39, p =0.46)

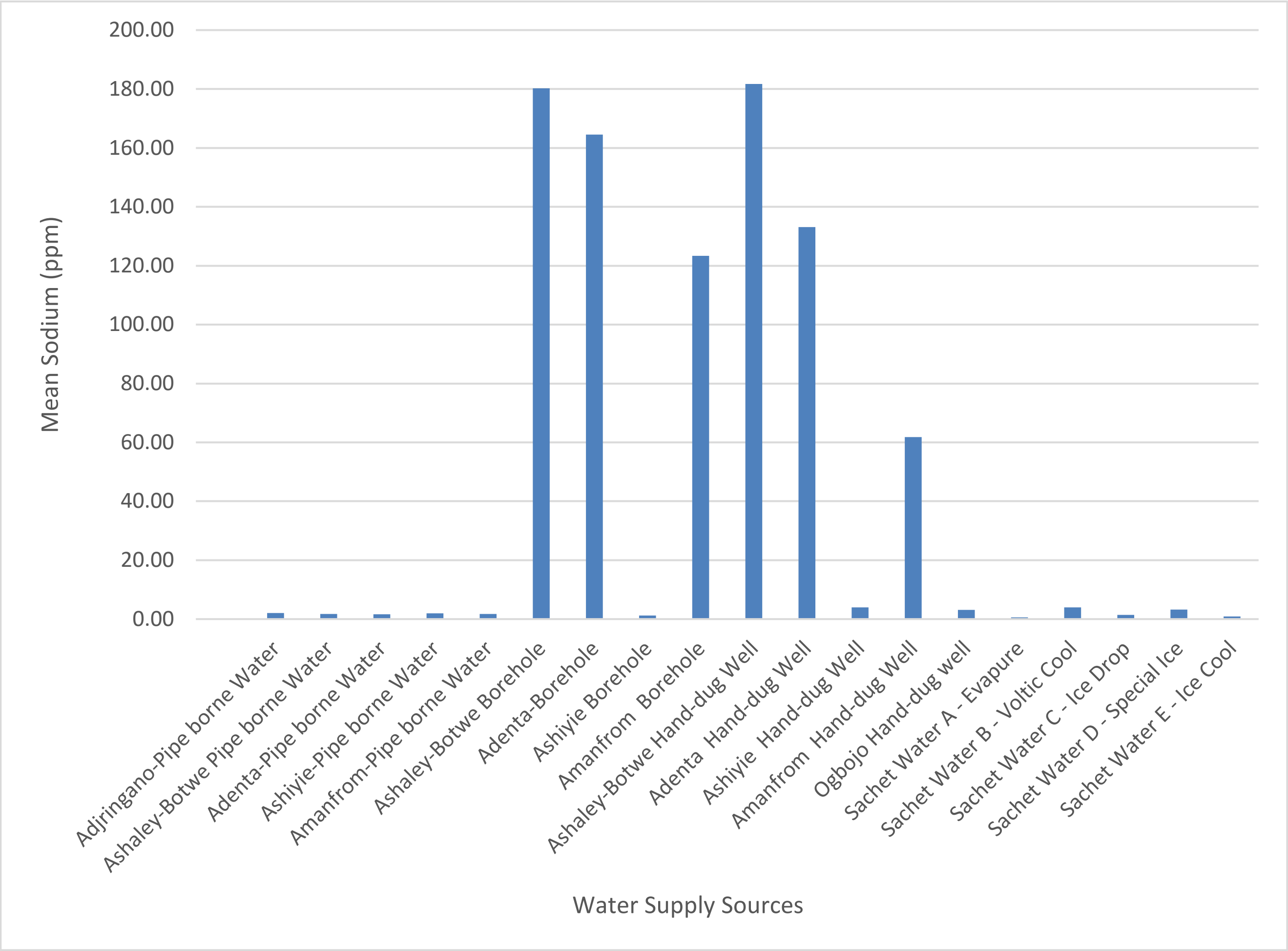

Figure 4.6.2.1: Comparison of mean sodium in water sources

4.6.2.2 Potassium

Fig 4.6.2.2 shows that some boreholes and some hand-dug wells recorded high potassium content. Ashaley-Botwe hand-dug well recorded the highest potassium content of 19.571 mg/L whereas Eva-pure recorded the least of 0.03 mg/L.

At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 3.326, p =0.48)

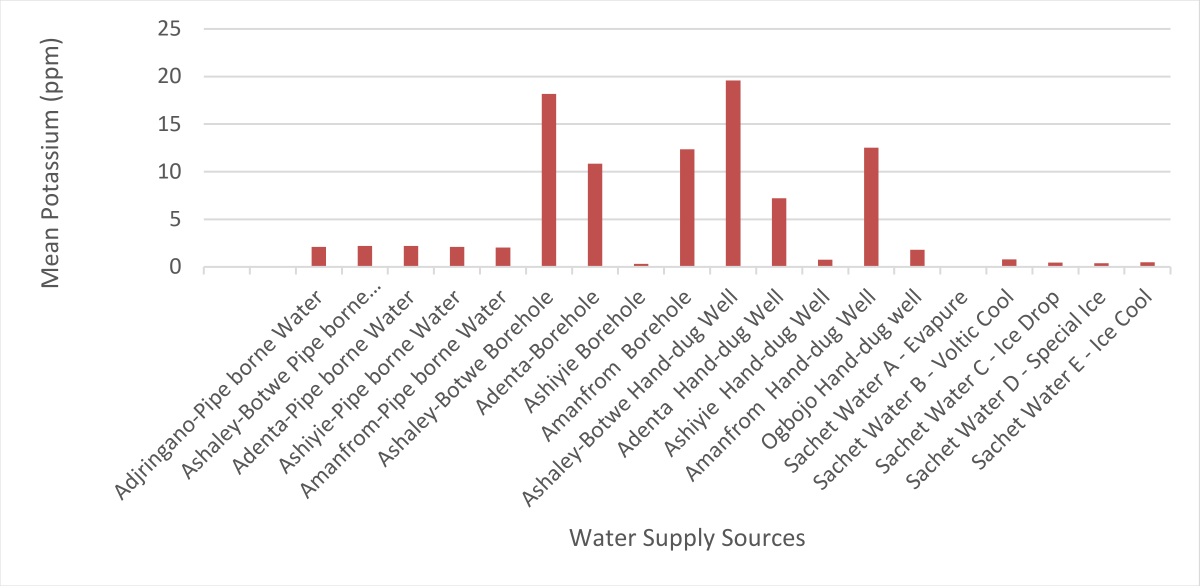

Figure 4.6.2.2: Comparison of mean Potassium in water sources

4.6.2.3 Calcium

Fig 4.6.2.3 shows that boreholes recorded the maximum calcium content of 139.24 mg/L by Adenta boreholes. Ice-cool sachet waters recorded the minimum content of calcium of 0.178 mg/L.At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 3.96, p =0.29)

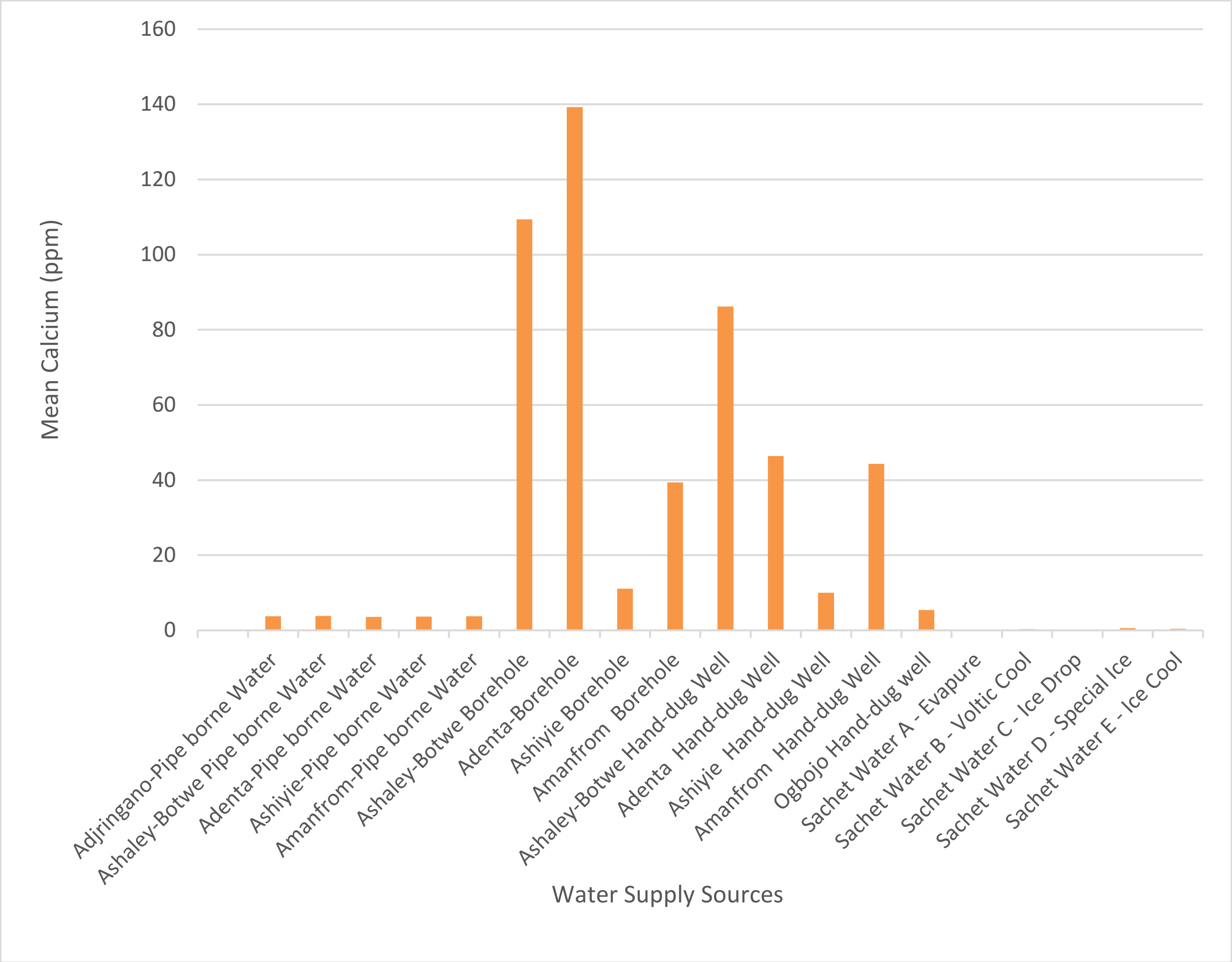

Figure 4.6.2.3: Comparison of mean Calcium in water sources

4.6.2.4 Magnesium

Boreholes were found to contain high amount of magnesium with a range between 24.85 to 68.95 mg/L. Whiles hand-dug wells were between the range 18.04 to 59.85 mg/L, pipe borne water were between 14.77 to 15.20 mg/L and sachet waters' were between 0.15 to 0.67 mg/L. At a confidence level of 0.05 there was no statistically significant difference between groups as determined by one-way ANOVA (F = 2.538, p =0.96)

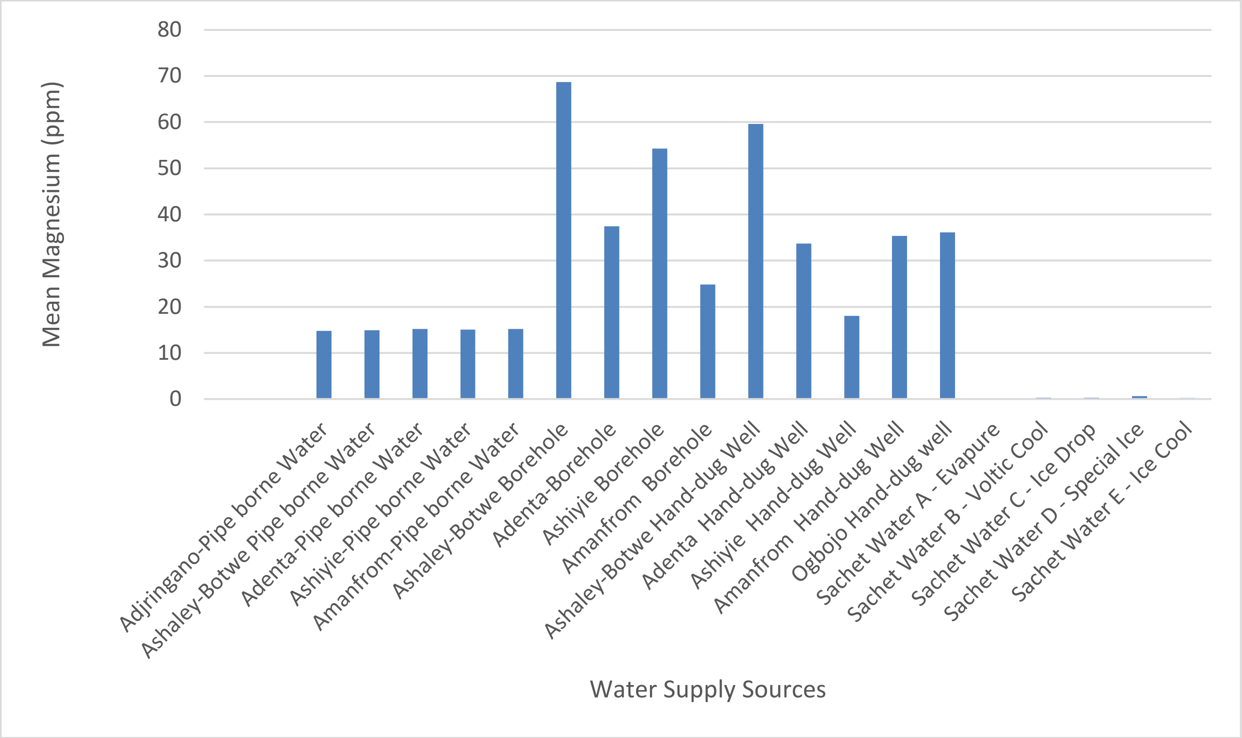

Figure 4.6.2.4: Comparison of mean magnesium in water sources

Table 4.6: Comparison of nutrients in water sources by one-way ANOVA

Parameters	Sources	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F	Sig.
					Lower Bound	Upper Bound		
Potassium	pipe-borne	27842.8000	25983.33220	11620.09942	-4419.7681	60105.3681	6.844	.004
	boreholes	103507.2500	75709.94083	37854.97041	-16964.1607	223978.6607		
	hand-dug-wells	8374.6000	7827.60393	3500.61090	-1344.6540	18093.8540		
	sachet water	2790.8000	2236.17177	1000.04642	14.2260	5567.3740		
Calcium	pipe-borne	210808.0000	333785.77629	149273.53714	-203641.7815	625257.7815	.848	.489
	boreholes	132062.7500	180417.27321	90208.63661	-155021.3923	419146.8923		
	hand-dug-wells	136209.4000	175512.48580	78491.56983	-81718.1348	354136.9348		
	sachet water	1798.2000	1528.22502	683.44300	-99.3420	3695.7420		
Magnesium	pipe-borne	46770.4000	63513.10540	28403.92423	-32091.5364	125632.3364	1.455	.267
	boreholes	37885.5000	29170.06252	14585.03126	-8530.5789	84301.5789		
	hand-dug-wells	23689.6000	23608.36468	10557.98165	-5624.0565	53003.2565		
	sachet water	137.4000	139.18800	62.24677	-35.4247	310.2247		
Phosphate	pipe-borne	135.2000	92.00924	41.14778	20.9554	249.4446	.868	.479
	boreholes	187.2500	91.55099	45.77549	41.5719	332.9281		

	hand-dug-wells	250.0000	198.55226	88.79527	3.4648	496.5352		
	sachet water	241.4000	82.73633	37.00081	138.6693	344.1307		
Sulphate	pipe-borne	2450.0000	2307.32529	1031.86724	-414.9227	5314.9227	1.695	.211
	boreholes	4812.5000	2952.22374	1476.11187	114.8532	9510.1468		
	hand-dug-wells	5810.0000	7270.26478	3251.36125	-3217.2260	14837.2260		
	sachet water	350.0000	93.54143	41.83300	233.8530	466.1470		
Nitrate	pipe-borne	120.2000	117.25059	52.43606	-25.3858	265.7858	3.863	.031
	boreholes	109.0000	122.59690	61.29845	-86.0790	304.0790		
	hand-dug-wells	363.2000	292.62809	130.86726	-.1458	726.5458		
	sachet water	6.0000	5.91608	2.64575	-1.3458	13.3458		
Fluoride	pipe-borne	53.6000	46.62403	20.85090	-4.2914	111.4914	.548	.657
	boreholes	69.5000	34.53983	17.26992	14.5394	124.4606		
	hand-dug-wells	130.6000	182.65623	81.68635	-96.1977	357.3977		
	sachet water	68.0000	57.34108	25.64371	-3.1984	139.1984		
Chlorine	pipe-borne	1674.4000	1080.81603	483.35562	332.3896	3016.4104	1.891	.174
	boreholes	15912.2500	13979.46168	6989.73084	-6332.1931	38156.6931		
	hand-dug-wells	33104.4000	40047.67635	17909.86533	-16621.3579	82830.1579		

	sachet water	7180.4000	10878.85850	4865.17343	-6327.4869	20688.2869		
Sodium	pipe-borne	49759.6000	42635.22156	19067.05073	-3179.0197	102698.2197	1.202	.343
	boreholes	394928.0000	565098.91937	282549.45968	-504270.4840	1294126.4840		
	hand-dug-wells	329121.4000	563196.66047	251869.20350	-370179.6172	1028422.4172		
	sachet water	3086.0000	2031.25478	908.40476	563.8641	5608.1359		

4.7. Bacterial Load

4.7.1 Total Plate Count

Considering table 4.7a, the total bacteria count recorded was much less in pipe borne water in each community than its counterparts. Whereas pipe borne water bacteria count were between 1.5 * 10^2 to 3.5 * 10^2 cfu/mL, sachet waters' were between 1.25 *10^3 to 1.65 *10^3 cfu/mL, boreholes were between 2.15*10^3 to 2.60 *10^3 cfu/mL and hand-dug wells were 2.4 *10^3 to 3.3 *10^3 cfu/mL.

At 0.05 confidence level, there is a significant difference between total bacteria count of the various water sources.

4.7.2 Total Coliform

Generally, maximum values were recorded by boreholes between the range 2 to 9 cfu/100mL. Whereas pipe borne water and sachet water recorded the minimum coliform count between 0 to 1cfu/100mL, hand-dug wells recorded between 1 to 4100mL (table 4.7a). At 0.05 confidence level, there is a significant difference between total coliform count of the water sources.

Table 4.7a: Bacteriological analysis of water supply sources in Adenta municipality.

SOURCES	MEAN TOTAL PLATE COUNT (CFU/mL)	MEAN TOTAL COLIFORM (CFU/100mL)	MEAN FEACAL COLIFORM (CFU/100mL)
Adjringano-Pipe borne Water	150	0.5	0
Ashaley-Botwe Pipe borne Water	250	1	0
Adenta-Pipe borne Water	300	0.5	0
Ashiyie-Pipe borne Water	200	1	0
Amanfrom-Pipe borne Water	350	1	0
Ashaley-Botwe Borehole	2350	8.5	0
Adenta-Borehole	2600	6.5	0
Ashiyie Borehole	2150	3.5	0
Amanfrom Borehole	2200	2	0
Ashaley-Botwe Hand-dug Well	2750	2	0
Adenta Hand-dug Well	3300	1	0
Ashiyie Hand-dug Well	2450	3.5	0
Amanfrom Hand-dug Well	2800	2.5	0
Ogbojo Hand-dug well	2900	3.5	0
Sachet Water A - Evapure	1650	0.5	0
Sachet Water B - Voltic Cool	1250	0.5	0
Sachet Water C - Ice Drop	1250	1	0
Sachet Water D - Special Ice	1500	0	0
Sachet Water E - Ice Cool	1250	0.5	0

Table 4.7 b: Comparison of bacteria in water sources by one-way ANOVA

Parameter	Sources	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F	Sig.
					Lower Bound	Upper Bound		
Total Plate Count	pipe-borne	250.0^{A}	7.905.694	3.535.534	1.518.378	3.481.622	143.870	.000
	boreholes	2325.0^{B}	20.207.259	10.103.630	20.034.574	26.465.426		
	hand-dug-wells	2840.0^{C}	30.700.163	13.729.530	24.588.071	32.211.929		
	sachet water	1380.0^{D}	18.574.176	8.306.624	11.493.711	16.106.289		
Total Coliform	pipe-borne	1.0^{A}	.27386	.12247	.4600	11.400	9.463	.001
	boreholes	5.0^{B}	292.617	146.309	.4688	97.812		
	hand-dug-wells	3.0^{C}	106.066	.47434	11.830	38.170		
	sachet water	1.0^{A}	.35355	.15811	.0610	.9390		

Within columns, means with different superscript letters are statistically different, $p \leq 0.05$

CHARPTER FIVE

DISCUSSION

5.1 Sources of Water and its Uses

The domestic water supply sources available to communities studied were rain harvesting, pipe borne water, hand-dug well, boreholes, sachet water and tanker service providers or vendor services which were used for drinking, cooking, washing and bathing purposes.. The dependency of less income groups on public taps, water vendors, hand-dug wells and boreholes might be as result of the inability of government or lack of funds by Ghana Water Company Limited to supply enough water to keep in pace with the growing population in the peri-urban areas (Nyarko, 2008). Also pipe borne water that was peculiar to areas such as Adenta, Adjringano and Ashaley-Botwe might be due to these communities been inhabited by certain class of individuals or people of affluence.

Most households from each community use other sources apart from their main source. Since one of the determinants for selecting a water source for drinking is its quality, sachet water is most dependent upon (Fig 4.3.1) despite the availability of other sources (Fig 4.3.1.2). This might be due to increase in concern of the safety of other sources of water especially pipe borne water, the salty nature of some of the hand-dug wells and boreholes and the perception that the quality of water from public pipe stands, hand-dug wells and water bought from the tankers service providers or vendor services can be compromised during transport (Obiri-Danso *et al.*, 2003). Doria, (2006) however opined that there are cases where pipe-borne water are purer and safer than sachet water.

Beside drinking, most households were not that particular about the source of water for other uses such as cooking, washing and bathing. Using water from other sources other than pipe borne water to cook is deemed safe as residents believed that the water will boil and most pathogens might be killed through the process of cooking. Washing and bathing also involve the use of detergents that will remove or kill the germs or pathogen either in the water or on the body and clothes.

5.2 Availability of Water Sources

In general there was a higher frequency of water sources to the households since majority of the households were able to access a water source over a distance less than 100 meters and 24 hours a day. This is due to the fact that communities such as Adenta and Adjringano had most of the dwelling units connected to pipe borne water whiles households in the other communities had reservoirs to store water bought from tanker service providers and in-house hand-dug wells and boreholes. Communities such as Ashaley-Botwe and Ogbojo had most of the household not been able to access their main source of water an entire day because most inhabitant of these communities get access to water vendor services that open at particular times.

In terms of drinking water, Ogbojo community had a high dependency rate on sachet water (63 households out of 67 sampled used sachet water) which is due to inhabitants access to vendor-service providers. The number of bags of sachet water used by a household depends on the size of a household, availability of alternative drinking water sources, purchasing power and the availability of the sachet.

Boreholes and hand-dug wells were low in terms of cost, hence was patronised by low income households. Low household water expenditure for users of boreholes and hand-dug wells may be due to the fact that the owners do not pay monthly bills for accessing it and also believe it can be accessed all-time for longer period. However, high expenditure of pipe borne water sources may be due to the type of housing unit. This is because, base on the Ghana Water Company Limited billing system, estate housing units have their bills drawn from a cumulative meter point. Also, the dependence on sachet water as main drinking water source express some financial stress on the inhabitants. However, the study revealed pipe borne water as the best for drinking purposes which is in agreement to the opinion of Doria, (2006). Low expenditure of most household in Ashaley Botwe, Ogbojo, Ashiyie and Amanfrom on sachet water indicates the financial status of the inhabitants hence their ability to buy less expensive sachet water. High expenditure on sachet water of households in Adenta and Adjringano indicates that most of the inhabitant have taste for most popular, and expensive and well packaged brands as well as indicating their financial status.

5.3 Physico-chemical Quality

There were considerable variation in the physico-chemical parameters of the samples across the sampling communities.

The turbidity of pipe borne water, hand-dug wells and sachet water were low and did not exceed GSA and WHO (2011) drinking water quality of 5 NTU. The high clarity of pipe borne water and sachet water indicate that the filtration processes were adequately done in all the production centres and also there is no leakages along the pipe lines underground whiles low turbidity in the hand-dug well might be due to the fact that water is not seeping down the water table such that fine particles from the aquifer are stable and not mixed with the water (Kettridge *et al.*, 2014). Unlike sachet water, pipe borne water and hand-dug wells, boreholes were highly turbid. Whereas high turbidity in Ashaley-Botwe, Adenta and Ashiyie boreholes may be caused by incorrectly sized borehole filters leading to entry of sediments(Donelly *et al.*, 2000), that of wells might be due to in-filtration or seeping of water into the wells (http//www.filterwaer.com, 2003). Schafer et al. (2010) found turbidities in the range of <2–266 NTU in most borehole water throughout Ghana. Cloudy water is not just unappealing but can also pose a health risk by serving as food and shelter to other micro-organisms in the water, protect pathogens against disinfectants (http//www.filterwaer.com, 2003). Also higher turbidity might be as a result of larger particles such as organic matter, pathogens and dissolved solids and also rivers that are the raw sources of water in pipe borne water production may get contaminated from soil run off and as high turbidity waters are difficult to filter (Schwartz *et al.*, 2000).

The electrical conductivity measured for the water sources were higher than the background levels(50-300 µs/cm). Also, most hand-dug wells and boreholes recorded high values which might be so, because, groundwater is susceptible to high mineral salt concentration which comes from the dissolution of minerals in the soil as a result of human activities such as construction of boreholes and hand-dug wells which disturb mineralized rocks and could release ions into the water to increase the ionic content, and subsequently the conductivity of the water (Ntengwe, 2006). Thus, it provides an indication that the composition of the water particularly the mineral concentration has changed (Deekae *et al.*, 2010). Tay and Kortatsi (2007) also observed conductivity range of 134–7,780 lS/cm with the highest value of 7,780 lS/cm occurring at Pokuase. The amount of electrical charge on each ion, ion mobility, and water temperature all have an influence on conductivity. Hence high electrical conductivity of water indirectly shows the concentration of dissolved solids, which can affect the flavour and salinity of the water. Therefore, conductivity is important because it allows guidelines to be established for water that make it acceptable to users as well as an indication of contamination from sources such as human excreta.

Mean total dissolved solids (TDS) was very low. Ashaley-Botwe boreholes and Amanfrom hand-dug wells recorded TDS of 1209 and 3044.5 mg/L respectively. This is confirmed by the results of Anhwange et al., (2012)

High TDS in ground water indicate that there is high amount of materials such as carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions within the earth and dissolved in the water sources. TDS concentration beyond 500 mg/L, decreases palatability and may cause gastrointestinal irritation and constipation effects. High TDS can also cause an increase in surface water temperature, because the suspended and dissolved particles absorb heat from sunlight. This can cause dissolved oxygen (DO) levels to fall even further. Dissolved and suspended particles in a water can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. GSA and WHO guideline values for TDS is 1000 mg/l and all other sources were below this permissible level hence clean for human consumption contrary to results obtained by Meena et al., (2012). The differences in the levels of contamination were because of different sources studied and other factors such as type of cover, and rainfall amount (Kiptum et al., 2012).

The level of TSS was zero in most of the sources. Except with Adenta hand-dug wells which recorded an average of 2.50 mg/L each. High TSS in wells could be dangerous to human health when the water is consumed without filtering. TSS has tendency to shield harmful micro-organisms.

Most pH values of boreholes and hand-dug wells sources were acidic and also falls below the WHO and GSA guideline for drinking water (i.e. 6.5 to 8.5 pH). The observed pH values is similar to the results obtained by Akinbile et al. (2011) in an analysis of water samples from some boreholes near a landfill in Akure, Nigeria. Kortatsi (2006) also reported values between 3.7 and 6.9, whilst a mean of 5.71 was reported by Asante et al., (2007) in the Takwa township area. The low pH might be due to the nature of soil surrounding the boreholes and hand-dug wells. The soil might be more acidic (R.F. Fisher et al., 1996) due to the increased rain fall (naturally acidic), compared to the dry Savannah (Manassaram et al., 2006). Low water pH can cause gastrointestinal irritation in sensitive individuals and also heavy metals such as cadmium, lead and chromium dissolve more easily in more acidic water (lower pH) and this is important because many heavy metals also become much more toxic when dissolved in water (Mesner and Geiger, 2010). Low pH influences the taste and odour of water significantly (Ojo et al., 2012) and increases the solubility of nutrients like phosphates and nitrates, thereby corroding pipes in drinking water distribution systems and releases lead, cadmium, copper, zinc and solder into drinking water. Pipe borne and sachet water recorded values that were within the GSA and WHO standard for drinking water. The mean values obtained by Fasunwon et al. (2008), Adetunde et al. (2011) and Nkansah et al. (2010) in similar studies are comparable to this value.

This indicates that biochemical reactions such as metal toxicity and solubility for the sachet and pipe borne water was effectively checked to ensure no harm to befall consumers.

Temperature of any water body depends upon several factors amongst which are the time, season and water depth. Variations in temperatures in the study area followed the ambient temperature pattern (Agbaire et al., 2009). Mean temperatures value recorded varied for the different water sources. And The variation in water temperature could have been affected by the weather, storm water and groundwater influx (Whitehead *et al.,* 2009). Also high water temperatures in pipe borne water, hand-dug wells and boreholes is in accordance with results obtained by Parmar et al., (2012).This high temperature is an indication that, the external environment such as the soil surrounding the water had high temperatures (Tang & Feng, 2001). Temperature is a factor influencing bacterial growth (Gardner *et al.,* 2012). Thus warm climatic zones support rapid bacterial growth than cold climatic zones (WHO, 2003). The concentration of dissolved gases and their solubility in water is also influenced by temperature (Deekae *et al.*, 2010). Increased temperatures also increases the concentration of total dissolved solids through the evaporation of water leading to decrease in water volumes.

Alkalinity in pipe borne water were low as compared to the other sources. This low alkalinity might be as a result of the water having low buffering capacity or the water might come from or passed through areas rich with granites and sandstones (Kirby *et al.*, 2005). Although within the GSA and WHO desirable limit for total hardness (100–500 mg/L as $CaCO_3$), boreholes and hand-dug wells recorded the maximum. Alkalinity of most underground water is determine by the soil and bedrock through which the water passed, hence high alkalinity might be due to high amount of bicarbonate, carbonate and hydroxide compounds in the water (Panno *et al.,* 2003).

All water sources contained some nutrients, though at different levels. Low phosphate content in pipe borne water and sachet water depicts efficient purification processes. Comparatively high phosphate content in Ashley- Botwe and Adenta hand-dug wells might be the use of fertilizers for agriculture or residential gardening lands close to some of these sources which are carried into surface water through run-off and into ground water (APHA,1998). Although, hand-dug wells recorded the maximum value, they were however below the U.S EPA recommended safe value of 2.5 mg/L.

Low sulphate content of sachet water and pipes depicts that purification processes were not compromised or the raw water source used was much clean off sulphates. Groundwater such as borehole from Amanfrom, hand-dug wells from Ashaley-Botwe and Ogbojo might have low oxidation of sulphite ores or no shales in the surrounding soil (Railsback, 2003) which is also in agreement with values obtained by Amoako et.,al (2011). However, Adenta and Ashiyie hand-dug wells recorded high values like that of Tay and Kortatsi (2007). This high values recorded might be due to abundant sulphate ion in the earth's crust surrounding theses sources (Railsback, 2003). All the other water sources were below the GSA and WHO (2004) limit of 250mg/L.

Nitrate in natural waters may be traced to percolating nitrate from sources such as decaying plant and animal materials, agricultural fertilizers as well as domestic sewage (Adeyeye et al., 2004). Generally, the origin of nitrates in natural waters comes from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilizers (EPA, 2001). Many of the water sources recorded low nitrate content compared to the GSA and WHO guidelines limit of 10 mg/L except for Adenta borehole and Ashiyie hand-dug well. This high concentration therefore may be the use of pesticides, fertilizers, and other materials to increase agricultural yields that normally runs off into surface water and consequently seeps into underground water. This is essentially in agreement with reports by Vinger et al. (2012) that effluents from pit latrines and chemical fertilizers applied to maize field were responsible for nitrate pollution. Nitrate is toxic when present in excessive amounts in drinking water and in some cases may cause methemoglobinemia in infants (Zheng *et al.*, 2015). The health effects of nitrate are the consequences of its ready conversion to nitrite in the body (Straskraba and Tundisi, 1999). The low levels of nitrates in the water therefore pose no risks to human health.

According to Community Water and Sanitation Agency (CWSA, 2009), fluoride is one of the most reactive non-metal compounds that are common in groundwater in Ghana. Studies. Hence it is not surprising that whereas Adenta borehole water recorded the highest fluoride content of 0.67mg/L, all other sources recorded lower values. This high value recorded is however below the GSA and WHO standard of 1.5 mg/L and also not in agreement with value recorded by Amoako *et al* (2011). High fluoride in Adenta borehole water might be that the bedrock geology is dominated by granites and some birimian rocks (British Geological Survey, 2001). Fluoride has a significant mitigating effect against dental caries if the concentration is approximately 1 mg/L (Armfield *et al.,* 2013). However, continuous consumption of higher concentrations can cause dental fluorosis and in extreme cases even skeletal fluorosis (Dai *et al.*, 2011). High fluoride concentrations are especially critical in developing countries, largely because of lack of suitable infrastructure for treatment (Freestra et al., 2007). The low values recorded by sachet water and pipe borne water depicts effective purification processes.

The results from the various sources indicated presence of chlorine residual. According to Chlorine Residual Testing Fact Sheet, the presence of chlorine residual in water indicates that sufficient amount of chlorine was added initially to the water to inactivate the bacteria and some viruses that cause diarrhoea disease and against recontamination during storage. It goes on further to assert that the presence of free chlorine residual in drinking water is correlated with the absence of disease-causing organisms, and thus is a measure of the portability of water. Sachet water, pipe borne water and boreholes sources recorded low chloride values of 1.915 to 30.79 mg/L while hand-dug wells recorded 5.74 to 217.5 mg/L. In a related study, Muruka et al. (2012) established that the presence of coliforms in 98% of sampled wells implied that there was practically no chlorination. High chloride content in hand-dug wells might have occurred naturally or deposits of underground salts, and pollution from septic systems. Although, none of the sources were above the GSA and WHO (2011) recommended limit of 250 mg/L in drinking water and chloride ions are non-cumulative toxins, however, an excess amount of which, if taken over a period of time, can lead to a health hazard as well as leading to corrosion of metals (Tay *et al.*, 2008).

Calcium, magnesium and sodium content was very low in sachet and pipe borne water samples. Low content of calcium, magnesium and sodium in sachet water pipe borne water depict effective purification process of the brands used in the area. However, boreholes and hand-dug wells recorded high values for these parameters. Normally, the presence of these nutrient in higher amount in ground water indicates the soil and rocks surrounding the source have these nutrients embedded in them and can easily dissolve in the water body (Hwang *et al.*, 2005). High calcium, magnesium and sodium in water sources confer hardness of the water source (Momeni *et al.*, 2014). Although hard water do not affect health, but its a nuisance due to mineral build up on fixtures and poor soap performance. It also affects the taste of the water (http://www.water-research.net>hardness). WHO has giving a permissible limit of

200 mg/L for sodium, it is believed that a level of 20 mg/L in drinking water can minimize the risk to hypertensive persons and heart patients (Sievers, E., 2005).

Mean potassium content like other cations were very low in sachet and pipe borne water used in the area and high in ground water. High phosphate content of pipe borne water as compared to sachet water might be due to the use of potassium chloride in treatment devices such as water softeners (Kerwick *et al*., 2005) . Also higher potassium content in boreholes and hand-dug wells might as be as a result of the fact that some of these sources were surrounded by gardens and since potassium fertilizers can strongly be held by clay particles in soil, hence leaching of potassium through the soil profile and into ground waters. Excess potassium intake can interfere with magnesium intake (WHO, 2009).

5.5 Bacteriological Quality

There was much considerable variation in the bacteriological quality of the samples across the sampling points. The bacteriological quality (either total bacterial count or coliform)of the samples was unsatisfactory since the results obtained were not in WHO permissible unit. Almost all sources recorded high bacteria count and contained some coliform bacteria. The maximum bacteria and coliform count of boreholes and hand-dug wells may be attributable to source of organic pollution like agricultural and household wastes and the sanitary integrity of the sources. Also the large number of total bacteria count in sachet water analysed might be due to over used filters and mishandling of vendors. The presence of large number for total plate count of bacteria do not necessarily indicate a health risk as pathogenic water borne bacteria's are generally heterotrophic (Allen et al., 2004). More-so, WHO guideline requires that water proposed for drinking should not contain any pathogen or zero micro organisms indicative of faecal contamination.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The main purpose of the study was to identify and investigate the various sources of water, its uses in households and its availability in terms of distance covered, cost involved and the time of the day the water can be assessed. The study also sought to, among others, determine physico-chemical and bacteriological quality, and the source of water supply suitable for drinking.

Six communities were strategically chosen after a reconnaissance survey for the study. These communities were Adjringano, Adenta, Amanfrom, Ashaley-Botwe, Ashiyie and Ogbojo. The study was undertaken in two phases. The first phase involved social survey at the selected communities. The second phase involved the determination of water quality of the various sources at the selected communities comprising physico-chemical and bacteriological analysis. The quality of water samples were analysed for wet and dry season.

It was found from the study that, pipe-borne water, hand-dug well, rain harvesting, borehole and sachet water were the sources mainly used in the communities studied. The households from lesser income groups do not have pipe connections in their homes and most of them are depended on public taps, water vendors, hand-dug wells and boreholes. The sources are used for drinking, cooking, washing and bathing purposes. Whereas 77.9% of the households depended upon sachet water for drinking 22.1% depended on bottled water and other sources. For other household chores, other sources other than sachet water were used. Communities such as Adjringano, Adenta, Botwe and Amanfrom mostly used pipe borne water for such purposes whiles Ashyie and Ogbojo used hand-dug well and water from the tankers service providers.

It was discovered that Adenta and Adjringano had most of the dwelling units connected to pipe borne whiles households in Amanfrom and Ashiyie do not have in-house connection to pipe borne water but had reservoirs to store water bought from tanker service providers and in-house hand-dug wells and borehole hence could access water 24 hours. Ashaley-Botwe and Ogbojo had most of the household not been able to access their main source of water an entire day because most inhabitant of these communities get access to water vendor services that open at particular times. In terms of expenditure on drinking water, most household spent extra on buying sachet water. Ashaley-Botwe and Ogbojo accessed sachet water at a lower cost (i.e.between GH¢10 to GH¢20) whiles majority of the households in Adenta and Adjringano did so at a higher cost between GH¢30 to GH¢50. A household spent a minimum of GH¢ 21 and a maximum of GH¢ 80 monthly on water supply sources used for other purposes. Boreholes and hand-dug wells sources were less expensive to access for example, users of boreholes and hand-dug wells spend as less as GH¢20 to GH¢40 to access such sources. Pipe borne water was expensive in some households.

In terms of physico-chemical parameters, there were considerable variation. The turbidity of pipe borne water, hand-dug wells and sachet water were low and did not exceed WHO (2011) drinking water quality of 5 NTU whiles that of boreholes were highly turbid between the range 4.91 to 7.54 NTU. The electrical conductivity measured for the water sources were higher than the background levels(50-300 µs/cm). Borehole supply sources recorded a maximum electrical conductivity of 677µscm^{-1}as compared to the other sources. Sachet water recorded the minimum values between 33 to 58.5 µscm^{-1}, pipe borne water recorded a range between 81 to 544.5 µscm^{-1}, hand-dug wells between 67.5 to 596.5 µscm^{-1} and boreholes between 83.5 to 677.5µscm^{-1}. Ashaley-Botwe borehole and Amanfrom hand-dug well recorded the maximum TDS of 1209 and 3044.5 mg/L respectively. TSS was generally nill in most sources except for Ashaley-Botwe pipe borne water and Adenta hand-dug wells which recorded an average of 2.50 mg/L each (Table 4.5). Most pH values of the pipe borne, boreholes and hand-dug well sources were acidic and also below the WHO guideline for drinking water (i.e. 6.5 to 8.5 pH) except Eva-pure and Ice-cool sachet water which recorded between 6.54 to 6.71 respectively. Mean temperatures value recorded varied for the different water sources. The maximum temperature of 30.09 ^{o}C was recorded by Adenta pipe borne water and the minimum of 25.94 was recorded by Adjringano. Alkalinity in pipe borne water were low as compared to the other sources.

All water sources contained some nutrients, though at different levels. Mean phosphate content in the water supply sources were generally low with values ranging from 0.029 to 0.6 mg/L (fig. 4.6.1.1). Although, hand-dug wells recorded the maximum value, they were however below the U.S EPA recommended safe value of 2.5 mg/L. sulphate content recorded was generally low for many supply sources. Sachet waters recorded the least sulphate content. Ashaley-Botwe hand-dug wells recorded the maximum of 148.0 mg/L whereas Eva-pure and Voltic cool sachet waters recorded the minimum of 2.5 mg/L. Many of the water sources recorded low nitrate content compared to the WHO guidelines limit of 10 mg/L except for Adenta borehole and Ashiyie hand-dug well which recorded the maximum of 148.0 mg/L.

Whereas Adjringano pipe borne water recorded the maximum fluoride content of 1.6mg/L, all other sources recorded lower values. Concentration of chloride were low in sachet water, pipe borne water and boreholes sources. High chloride content in hand-dug wells might have occurred naturally or deposits of underground salts, and pollution from septic systems. Calcium, magnesium and sodium content was very low in sachet water samples. Whereas boreholes and hand-dug wells recorded high values for these parameters, pipe born water recorded comparatively low values. Mean potassium content like other cations was very low in sachet water and high in ground water. High phosphate content of pipe borne water as compared to sachet water might be due to the use of potassium chloride in treatment devices such as water softeners (Kerwick *et al.*, 2005).

Almost all sources recorded high bacteria count and contained some coliform bacteria but none contained faecal coliform bacteria. the total bacteria count recorded was much less in pipe borne water in each community than its counterparts. Whereas pipe borne water bacteria count were between $1.5 * 10^2$ to $3.5 * 10^2$ cfu/mL, sachet waters' were between $1.25 *10^3$ to $1.65 *10^3$ cfu/mL, boreholes were between $2.15*10^3$ to $2.60 *10^3$ cfu/mL and hand-dug wells were $2.4 *10^3$ to $3.3 *10^3$ cfu/mL (table 4.7a). Maximum values of total coliform were recorded by boreholes between the range of 2 to 9 cfu/100mL.

6.2 Conclusion

The study revealed that;

Pipe borne water is widely used than other supply sources. As much as 52.2% depend upon pipe borne water for other purposes. All water sources is available to the residents. 55.2 to 82.1% could access water 24 hours and 73% cover less than 100 metres to access a particular source.

Sachet water is inevitably in high demand as a major source of drinking water. 77.9% of households purchase sachet water. Hence water expenditure of most households has been increased by the additional cost of purchasing sachet water for drinking. Also, pipe borne water was not accessible to all in terms of cost. Lower income groups depended upon the use of hand-dug wells and boreholes that came at a lower cost of GH¢21 to GH¢41.

Physico-chemically, most hand-dug wells and boreholes are unsatisfactory for drinking. They had low pH or acidic pH values, high turbidity, EC, TDS values and high nutrient contents.

Bacteriologically, all sources were safe for drinking since they contain no faecal coliform .

Generally, pipe borne water was the safest for drinking. It is physico-chemically and bacteriologically wholesome

6.3 Recommendation

Based on the findings of the study, the following recommendations are made to help improve the quality of well water in the study area.

1. The Municipal Assemblies in conjunction with GWCL should aid residents in testing their hand-dug well and borehole waters and make available disinfectants free or cheaper to improve the quality status of wells found to be contaminated.

2. Aquifer vulnerability assessment should be conducted such as the DRASTIC (Depth, Recharge, Aquifer, Soil, Topographic slope, Impact of vadose zone, Conductivity of aquifer) approach by Aller et al., (1994) to ascertain the impacts of depth, recharge, aquifer, soil, topography, impact of vadose zone and conductivity on the levels of contamination in the area which this study has not been able to cover.
3. There is the need for awareness campaigns to alert sachet water producers on the effect of deviation from the standards of drinking water on human health.
4. The Food and Drug Authority and the Ghana Standard Authority should pick samples of sachet water from the market randomly to analyse their quality.

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APPENDICES

APPENDIX A: Social Survey

HOUSEHOLD SURVEY INSTRUMENT ADENTAN MUNICIPALITY– (QUESTIONNAIRE)

This questionnaire is designed to aid the collection of data to research into the above topic. It would be appreciated if you could help complete this questionnaire. Responses would be treated confidentially and would be used strictly for academic purposes.

Please tick [√] or write the correct answers where appropriate.

Name of the enumerator... Date............... Sig...............

Community.......................................

SECTION A: HOUSEHOLD CHARACTERISTICS

1. Gender a. Male [ ] b. Female [ ]
2. Age a.15yrs [ ] b.15-24yrs [ ] c.25-34yrs [ ] d. 35-44yrs [ ] e.45 – 60yrs [ ] f. 60 & above [ ]
3. Marital status a. Single [ ] b. Married[ ] c. Divorced [ ] Separated [ ] Widowed [ ]
4. Level of education a. None[ ]b.Basic[] c.Secondary[ ] d.Tertiary[ ]

Other (specify)...................

5. Religion: a. Christian [ ] b. Islamic [ ] c. Traditional [ ] d.Pagan[ ]

e.Others (please specify)...

6. How long have you been in this community? a. Less than 5 yrs [ ]

b. 5-10 [ ] c. 11-15 [ ] d. 16-20[ ] e. 21-25[ ] f. 26-30[ ]

g. over 30 years [ ]

Other (please specify) ....

7. Who owns the house you live in? a. Self-owned [ ] b. Rented [ ] c. Family house [ ]

Other (please specify) ....

8. Household size a. Below 2 [ ] b. 2 – 4 [ ] c. 4 – 6 [ ] d. 6 – 8 [ ]

e) 8 – 10 [ ] other(please specify) ……………

SECTION B: SOURCES OF WATER

9. What source of water do you use the most?

a. Hand-dug well [ ] c.Borehole [ ] e. Rainwater [ ]

b. Tankers [ ] d. Pipe borne [ ] f. Sachet water [ ]

10. Is the water source shared? Yes [ ] No [ ]

11. Is this water source seasonal? Yes [ ] No [ ]

12. If YES, in which season is it available?

a. Dry season [ ] b. Rainy season [ ] c. Both [ ]

13. Do you have to pay for water from this source?Yes [ ] No [ ]

14. How often is water available from this source?

a.Daily [ ] b. Every other day [ ] c. Once a week [ ] d. Twice a week [ ] e. Irregular [ ]

15. How long is the water available on a daily basis from this source?

a. All the time (24 hrs) [ ] d. d. 3-5 hours [ ]

b. b. During daylight hours [ ] e. e. 6-8 hours [ ]

c. c.1-2 hours [ ]

16. Distance from home (in meters)? ……………………….

17. Is the water source fit for drinking purposes?Yes [ ] No [ ]

18. If NO, what source do you drink? a.Sachet water [ ] b. Bottled water[ ]

19. If sachet water, what brand do you prefer? ……………………………………

20. Which source do you use for cooking?

Hand-dug well [ ] Borehole [ ] Rainwater [ ] Tankers [ ]

Pipe borne [ ]

21. Which source do you use for washing? Hand-dug well [ ] Borehole [ ]

Rainwater [ ] Tankers [ ] Pipe borne [ ]

22. Which source do you use for bathing? Hand-dug well [ ] Borehole [ ]

Rainwater [ ] Tankers [ ] Pipe borne [ ]

C. WATER CONSUMPTION AND COST

23. How many bags of sachet water do your household use in a week?

……………….

24. What is the cost per bag? ………………………………..

25. On estimate, how much do u spend on sachet water in a month?

GH¢10 to GH¢20 [ ] GH¢21 to GH¢30 [ ] GH¢31 to GH¢40[ ]

GH¢41 to GH¢50 [ ] GH¢61 to GH¢70 [ ] GH¢51 to GH¢60 [ ]

26. Do you pay for your main source? Yes [ ] No [ ]

27. If yes, how often do you pay?

Daily [ ] Weekly [ ] Monthly [ ]

28. If daily, what is the price of water per gallon/jerry can? ……………..

29. If monthly, how much? ………………………………….

APPENDIX B: Demographic characteristics

Table B1: Demographic characteristics on gender, age and educational level

COMMUNITY	GENDER		AGE					EDUCATIONAL LEVEL			
	MALE	FEMALE	15_24	25_34	35_44	45_60	>60	none	basic	secondary	tertiary
ADENTA	25	42	12	21	21	11	2	9	18	26	14
ADJRIGANOR	35	32	33	16	14	4	0	2	15	27	23
AMANFROM	32	35	13	25	12	13	4	12	29	20	6
ASHIYIE	28	39	18	21	20	8	0	4	20	40	3
ASHALEY-BOTWE	43	24	16	26	17	6	2	3	13	33	18
OGBOJO	47	20	38	7	19	0	3	8	18	24	17
TOTAL	**210**	**192**	**130**	**114**	**103**	**42**	**11**	**38**	**113**	**170**	**81**

Table B2: Demographic characteristics on years lived in the community and household size.

COMMUNITY	YEARS LIVED IN THE COMMUNITY (YEARS)							HOUSEHOLD SIZE				
	<5	5_10	11_15	16_20	21_25	26_30	> 30	<2	2_4	4_6	6_8	8_10
ADENTA	28	20	13	3	3	0	0	4	20	28	4	11
ADJRIGANOR	37	23	2	0	5	0	0	2	43	19	0	3
AMANFROM	25	16	11	7	2	2	4	16	24	14	13	0
ASHIYIE	24	22	4	9	1	0	7	1	37	23	6	0
ASHALEY-BOTWE	20	31	9	1	2	0	4	6	27	20	8	6
OGBOJO	14	22	5	9	7	0	10	0	39	17	11	0
TOTAL	**148**	**134**	**44**	**29**	**20**	**2**	**25**	**29**	**190**	**121**	**42**	**20**

APPENDIX C: Cost incurred

Table C1: Cost incurred using sachet water per community

COMMUNITY	NUMBER OF SACHET WATER BAGS USE WEEKLY				
	1 BAG	2 BAGS	3BAGS	4BAGS	5BAGS
ADENTA	4	22	18	3	0
ADJRIGANOR	9	29	9	2	2
AMANFROM	10	15	18	6	0
ASHIYIE	9	23	11	3	0
ASHALEY-BOTWE	14	23	15	6	2
OGBOJO	10	29	16	5	0
TOTAL	56	141	87	25	4

APPENDIX D: Physico-chemical quality

Table D2: Mean physical parameters in wet and dry season

SOURCES	Turbidity		ALKALINITY(ppm as $CaCO_3$)		TSS(mg/l)		EC(μscm^{-1})		TDS(mg/L)		pH		Temperature(^{0}C)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Adjringano-Pipe borne Water	2.06	1.66	34	38	0	0	88	86	57	48	6.81	7.01	26.42	25.45
Ashaley-Botwe Pipe borne Water	2.60	1.37	30	18	0	0	233	271	150	37	6.90	7.00	29.21	28.44
Adenta-Pipe borne Water	2.10	1.82	36	48	0	0	71	91	46	465	7.00	6.79	30.64	29.54
Ashiyie-Pipe borne Water	2.70	1.52	30	140	0	0	317	925	206	557	6.75	7.02	29.09	29.09
Amanfrom-Pipe borne Water	2.09	1.66	272	26	0	0	1610	79	1030	52	7.02	6.99	26.98	28.88
Ashaley-Botwe Borehole	13.80	9.06	268	350	0	0	828	2606	530	1888	4.81	6.56	30.26	28.22
Adenta-Borehole	15.80	10.33	268	204	0	0	828	1721	530	889	4.81	6.74	30.26	28.03
Ashiyie Borehole	11.80	9.22	270	288	0	0	24	1580	16	1035	4.73	5.83	29.63	25.45
Amanfrom Borehole	11.50	8.16	270	27	0	0	100	67	48	44	6.05	5.22	29.63	30.33

Ashaley-Botwe Hand-dug Well	4.82	2.58	254	34	0	0	83	70	55	36	5.45	6.48	28.62	26.7
Adenta Hand-dug Well	4.02	3.41	254	248	5	0	233	1560	150	936	5.11	7.11	28.62	29.33
Ashiyie Hand-dug Well	3.70	2.22	4	281	0	0	53	1588	603,5	1033	4.63	5.53	28.95	27.45
Amanfrom Hand-dug Well	3.10	2.33	22	64	0	0	53	82	6035	54	4.63	6.97	26.2	28.27
Ogbojo Hand-dug well	3.98	2.07	24	36	0	0	68	77	44	35	5.47	6.77	27.8	28.21
Sachet Water A - Evapure	1.69	1.07	4	12	0	0	3	3	1	2	6.6	7.01	26.3	28.32
Sachet Water B - Voltic Cool	2.37	1.34	10	32	0	0	65	52	32	34	7.00	7.01	26.6	28.17
Sachet Water C - Ice Drop	1.70	1.20	8	12	0	0	23	43	11	28	7.02	7.00	26.5	27.24
Sachet Water D - Special Ice	2.16	1.01	8	13	0	0	37	67	17	44	7.00	6.79	26.1	27.22
Sachet Water E - Ice Cool	2.12	1.16	2	9	0	0	1	10	0	7	6.9	7.07	26.2	28.32

Table D3: Mean anions in wet and dry seasons

SOUCES OF WAER	PO$_4^{3-}$(mg/l)		SO$_4^{2-}$mg/L)		NO^{3-} (mg/L)		F$^-$ (mg/L)		Cl$^-$ (ppm)	
	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY
Adjringano-Pipe borne Water	0.133	0.142	6.000	7.000	2.2	2.8	0.23	0.29	4.35	4.77
Ashaley-Botwe Pipe borne Water	0.133	0.170	6.000	7.000	2.2	3.0	0.24	0.30	4.33	4.71
Adenta-Pipe borne Water	0.125	0.159	6.000	8.000	2.1	2.7	0.23	0.27	4.35	4.75
Ashiyie-Pipe borne Water	0.133	0.145	6.000	8.000	2.1	2.7	0,23	0.27	4.32	4.74
Amanfrom-Pipe borne Water	0.134	0.156	6.000	7.000	2.2	3.0	0.24	0.26	4.35	4.77
Ashaley-Botwe Borehole	0.058	0.212	18.000	125.000	3.2	1.2	0.45	0.17	7.09	54.487
Adenta-Borehole	0.058	0.112	18.000	86.000	3.2	22.4	0.45	0.88	7.09	49.543
Ashiyie Borehole	0.310	0.212	5.000	122.000	1.3	0.9	0.01	0.22	53.175	27.943
Amanfrom Borehole	0.310	0.225	5.000	6.000	1.3	4.2	0.01	0.12	53.175	2.212
Ashaley-Botwe Hand-dug Well	0.770	0.431	3.000	12.000	3.2	8.1	0.1	0.22	3.545	7.943
Adenta Hand-dug Well	0.770	0.324	222.000	75.000	10.7	4.2	0.28	0.12	194.975	45.06
Ashiyie Hand-dug Well	0.075	0.225	222.000	30.000	3.2	33.9	0.28	0.55	194.975	7.821
Amanfrom Hand-dug Well	0.120	0.354	0.044	4.000	3.8	2.3	0	0.01	53.175	12.993

Ogbojo Hand-dug well	0.394	0.199	4.000	5.000	1.0	1.1	0.31	0.12	53.175	17.725
Sachet Water A - Evapure	0.083	0.199	4.000	1.000	0.5	0.1	0.03	0.14	53.175	0.089
Sachet Water B - Voltic Cool	0.554	0.064	3.000	2.000	1.4	0.4	0.11	0.14	3.545	1.508
Sachet Water C - Ice Drop	0.272	0.243	3.000	5.000	0.0	0.3	0.16	0.04	3.545	1.246
Sachet Water D - Special Ice	0.093	0.562	3.000	5.000	0.0	0.4	0.15	0.13	3.545	1.942
Sachet Water E - Ice Cool	0.220	0.122	3.000	6.000	1.0	0.1	0.05	0.18	3.545	0.284

Table D3: Mean cations in wet and dry seasons

SOURCES OF WATER	Na+(mg/L)		K+(mg/L)		Ca2+(mg/L)		Mg2+(mg/L)	
	WET	DRY	WET	DRY	WET	DRY	WET	DRY
Adjringano-Pipe borne Water	2.258	1.874	2.101	2.123	3.663	3.923	14.42	15.12
Ashaley-Botwe Pipe borne Water	2.266	1.122	2.191	2.152	3.642	4.036	14.69	15.22
Adenta-Pipe borne Water	2.031	1.231	2.213	2.201	3.294	3.942	14.36	15.99
Ashiyie-Pipe borne Water	2.274	1.661	2.072	2.213	3.789	3.623	14.85	15.33
Amanfrom-Pipe borne Water	2.202	1.282	2.021	2.091	3.523	3.925	14.96	15.44
Ashaley-Botwe Borehole	79.92	280.44	7.47	28.88	98.24	120.55	28.17	109.22
Adenta-Borehole	79.92	249.12	7.47	14.21	98.24	180.24	2.77	66.92
Ashiyie Borehole	1.11	265.55	0.66	14.03	18.02	90.75	28.17	46.77
Amanfrom Borehole	1.11	4.22	0.66	1.40	18.02	2.41	2.77	2.99
Ashaley-Botwe Hand-dug Well	0.603	245.65	0.39	24.03	2.11	60.75	0.438	46.92
Adenta Hand-dug Well	120.3	243.21	22.93	16.21	83.52	20.36	64.51	54.66
Ashiyie Hand-dug Well	120.3	135.12	22.93	8.15	83.52	88.91	64.51	14.22
Amanfrom Hand-dug Well	3.71	1.23	0.13	0.008	17.55	4.11	0.617	8.08

Ogbojo Hand-dug well	1.80	4.51	2.07	1.52	6.21	4.62	4.06	3.16
Sachet Water A - Evapure	0.71	0.47	0.006	0.054	0.112	0.331	0.02	0.01
Sachet Water B - Voltic Cool	4.40	3.53	0.58	0.992	0.213	0.423	0.024	0.04
Sachet Water C - Ice Drop	1.32	1.45	0.91	0.006	0.133	0.224	0.606	0.03
Sachet Water D - Special Ice	3.53	2.98	0.44	0.308	0.213	0.883	0.014	0.12
Sachet Water E - Ice Cool	0.471	1.32	0.34	0.609	0.213	0.612	0.011	0.04

APPENDIX E: WHO and Ghana Water Quality Standard

Parameter	Method No.	Unit	Value	GS 175-1	WHO Guideline
Turbidity	3	NTU		5	5
Colour (apparent)	2	Hz		5	15
Odour		-	-	Inoffensive	Inoffensive
pH	4	pH Units		6.5-8.5	6.5-8.5
Conductivity	1	µS/cm		-	-
Tot. Susp. Solids (SS)	5	mg/l		0	-
Tot. Dis. Solids (TDS)	6	mg/l		1000	1000
Sodium	30	mg/l		200	200
Potassium	29	mg/l		30	30
Calcium	23	mg/l		200	200
Magnesium	26	mg/l		150	150
Total Iron	31	mg/l		0.3	0.3
Ammonia (NH_4-N)	13	mg/l		0.00 – 1.5	0.00 – 1.5

Chloride	24	mg/l		250	250
Sulphate (SO_4)	19	mg/l		250	250
Phosphate (PO_4-P)	17	mg/l		-	-
Manganese	26	mg/l		0.4	0.4
Nitrite (NO_2-N)	14	mg/l		1.0	1.0
Nitrate (NO_3-N)	15	mg/l		10	10
Total Hardness (as $CaCO_3$)	25	mg/l		500	500
Total Alkalinity (as $CaCO_3$)	22	mg/l		-	-
Calcium Hardness (as $CaCO_3$)	23	mg/l		-	-
Mag. Hardness as $CaCO_3$)	26	mg/l		-	-
Fluoride	20	mg/l		1.5	1.5
Bicarbonate (as $CaCO_3$)	22	mg/l		-	-
Carbonate	22	mg/l		-	-
Aluminium	-	mg/l		0.20	0.20

Free Chlorine	-	mg/l		-	-
Lead	-	mg/l		0.01	0.01
Copper	-	mg/l		2.0	2.0
Cadmium	-	mg/l		0.003	0.003
Chromium	-	mg/l		0.05	0.05
Mercury	-	mg/l		0.001	0.001
Arsenic	-	mg/l		0.01	0.01
Cyanide	-	mg/l		0.07	0.07
Zinc	-	mg/l		-	-
Barium	-	mg/l		0.7	0.7
Selenium	-	mg/l		0.01	0.01
Antimony	-	mg/l		0.0.02	0.02
Nickel	-	mg/l		0.02	0.02