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DRINKING WATER QUALITY AND ITS IMPACT ON COMMUNITY HEALTH ALONG THE EASTERN COAST OF GHANA

BY

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DECLARATION

I, Selom Esi Kumedzro, hereby declare that except for references made to other people's work of which I have duly acknowledge, this thesis is produced data that is based on my own research with steady guidance from my supervisors at the Institute for Environment and Sanitation Studies. I also declare that no prior publications of parts or whole of this thesis has been made, nor presented elsewhere for any award.

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DEDICATION

In dedication to the memory of my late Grandma Mrs. Alice Ama Akita and my Dad – Mr. Senam Etse Kumedzro, Mum – Dr. Mrs. Morkor Akita-Kumedzro, my sister - Sedem Esi Kumedzro and my good friend - Caleb Eli Acquah-Harrison for their toil for me and support towards my education.

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LIST OF ABBREVIATIONS

AKOC	Anyako Commercial Poly-tank
AKPV	Anyako Private Poly-tank
AKT	Anyako Reservoir
AKW	Anyako Well
AKS	Anyako Sachet
ANYW	Anyanui Well
ANYP	Anyanui Pipe
ATIP	Atiteti Pipe
C. Poly-tank	Commercial Poly-tank
E.C	*E. coli*
F.C	Faecal Coliform
P. Poly-tank	Private Poly-tank
T.C	Total Coliform
WHO STD	World Health Organization Standard

ABSTRACT

Diarrhoea is known to be the leading cause of high mortality, which is gotten from the intake of contaminated water and food sources. In Ghana, people are greatly affected by Diarrhea, therefore this research sought to evaluate and measure the quality of drinking water sources in communities along the Eastern coast of Ghana and its impact on human health. Sources of community drinking water which included Pipes, Wells, Poly-tanks and Sachets water in each community were mapped out.

A mixed method approach was used from the selection of the sample sites to the analysis of the data obtained. Forty samples were taken from the community drinking water sources, 19 from Anyako, 14 Anyanui and 6 from Atiteti whilst 15 water samples were taken from household drinking water storage containers based on the proportion that drank from the various categories of community drinking water in each study area. Water samples were examined for the presence of Coliform bacteria, *Salmonella, Shigella* and *Enterococcus* using the culture media and the buffered dilution water method, and Physiochemical parameters; Total Alkalinity, Nitrate Nitrogen, Phosphate, Sulphate, Calcium, Magnesium, Potassium and Sodium were analysed.

Collection & recording information on drinking water sources, ways water is managed and the general health and hygiene was done by observations, questionnaires and interviews with the locals in the study areas. Visits were made to the district assembly and the health centres in each community to gather data on the number of diarrhoea cases throughout the sampling period. The information was manually recorded and inserted in SPSS. The descriptive tool was used to determine the frequencies and percentages of the variables in the questionnaire. Chi-square test was executed to find the relationship between two variables. Data from the field and the lab were analysed using Microsoft Excel and a Statistical Package for Social Sciences (SPSS) version 26. Results were recorded in Excel and exported to SPSS for the Two-way Analysis of Variance to be done. The test run to determine the significant changes between the water samples in each month and during the sampling period was the Friedman's test.

Findings indicated no detection of *Salmonella, Shigella, Enterococcus* and *Vibrio cholerae* in the water sources. Within the three communities, the Physico-chemical parameters with good levels were dissolved oxygen, total alkalinity and sulphate and sodium. The other parameters recorded levels that were either below or exceeding the WHO standard of drinking water. The microbial quality of the water sources showed poly tank 5 in Anyako, Pipe 3, 2 and 6 in Atiteti

as well as Pipe 2, 4 and 5 in Anyanui as the only sources that had no changes in them during the period although statistically, Anyako was the only community to record significant changes within the samples from the water sources. Findings also showed an increase in the *E. coli* count in the household drinking water in their storage containers than in the community drinking water sources, although this did not account for the high number of diarrhoea cases in each of the community especially in women and in children. This was an indication that the high cases of diarrhoea in Anyako, Atiteti and Anyanui could be due to other predicting factors. The high *E. coli* counts in the drinking water source at the community level and the household level was a result to the manner by which the residents handled the water as well as poor sanitation and personal hygiene, the cost oof water and their educational level.

CHAPTER ONE

INTRODUCTION

1.1 Background

Water is a renewable natural resource which is a basic necessity for all living organisms. It adds to our requirements like the making of food while contributing to our socio-economic growth (Yeleliere *et al*, 2018). The world we live in is surrounded by water and yet not all countries have access to it. The earth is made up of 70% of water which exist naturally in all three states of matter liquid, solid and in gas form). Within the planet earth, 2.5% water is made up of fresh water with the rest being distributed throughout, with only < 1% fresh water made available.(Owusu *et al*.2016). Globally, USA has the largest portion of fresh water which has an estimate of 45% with the second of over 28% in Asia, then Europe with 15.50% followed by other continents with an estimate of 11.50% of fresh water. In Ghana, within the year 2014, the fresh water resources per capita was 1131 cubic meters per year, currently in the year 2022, the figure has reduced to 1018 cubic meters per year. (Yeleliere *et al*, 2018), the freshwater sources are made up of the surface water which are the Coastal River, systems, the Volta River systems and the South-Western River systems.

Coastal areas serve as a place of living to more than 60% of the population in the world even as 10% of the earth's land area is covered (Tang *et al*, 2022*;* De Haan *et al*, 2019). Coastal ecosystems are active elaborate systems that react in different manners to intense weather conditions (Boateng *et al*., 2016). These environmental challenges, which include coastal inundation, coastal resource degradation, cyclones, groundwater contamination and salinity intrusion (Boateng *et al*, 2016), have been enhanced by climate change and anthropogenic activities that alter the coastal area and its natural processes (Ekow, 2015; Appeaning Addo, 2015). According to a study by (Lombardi *et al* 2022) majority of the coastal areas in Europe which is 93% is under different pressures from human activities and 28% is affected by climate issues such as changes such as sea water movement, temperature, and salinity. Strong human activities in the areas surrounding the coast always impact the environment leading to an increase in coastal degradation, sea water intrusion leading to the reduction in the quality of water.

In Ghana's it is estimated that the coastline covers approximately 550km (Ishmeal *et al*, 2016). The coastal areas have also been described as low-lying and thus makes it prone to erosion processes (Ekow, 2015; Appeaning Addo, 2015).). However, in recent times the coastal areas have increasingly become vulnerable to numerous environmental problems such as flooding, and sea water intrusion which in turn affect other aspects of the lives of the people along the coast (National Adaptation Strategy, 2011). The shoreline of Ghana and the communities in the coastal areas, has fluctuated due to variations in the environment, of which climate change plays a major role according to Dadson *et al*. (2016). Some communities have been reduced to islands, the Keta Municipality is now seen to be a narrow stretch of land and is considered to be the worst part that has been affected by coastal erosion and it's still happening due to the rising sea levels along the West African Coastline (Naadi, 2016).

1.1.1 Water Quality and Diarrhoea

Both surface and ground water are the main sources of water for household and drinking purposes both in the rural and in the urban areas (Dominic *et al* 2016). Flooding in coastal areas due to climate changes can bring about contamination of nearby drinking water sources and pose serious water-related diseases such as diarrhoea for the inhabitants of these areas. It can be contaminated due to flooding, surface runoffs, the increase in population, the use of harmful agriculture products, industrialization and human activities (Maghrebi *et al* 2021). The major issue of access to poor quality of water is the contraction of water borne diseases such as diarrhoea. It was discovered that globally, a higher percentage of diarrhoea mortality is as a result of unsafe drinking water, poor sanitation and unhygienic practices (Komarulzaman *et al*, 2017).

In a report published by WHO, UNICEF on drinking water and sanitation, it was estimated that there was lack of access to good and safe drinking water to over 750 million people in the year 2011, and that 185 million of them relied on surface water for consumption and other domestic purposes. Eighty-three percent of the households in rural areas, consumed unsafe drinking water (WHO, UNICEF, 2013). The quality of ground water is one of the main problems of humanity since it has a direct association with the human health. In another 2021 report by UNICEF, in Ghana, 73% of households are at risk of drinking contaminated water, 93% of these same households do not treat the water from the sources before it is consumed. The use of contaminated water for consumption and other domestic uses decreases human health with diseases such as dysentery, typhoid and diarrhoea which if not treated properly may lead to death (Yeboah 2021). Some of the water sources within the communities in the coastal areas also dry up during the dry season, forcing the locals to rely on alternative sources of water which is considered not safe for drinking (Yasin *et al*, 2015). In a study by (Soboska *et al*, 2020), the most common source of drinking water contamination is faecal coliforms and *E. coli* and in areas where there is lack of good sanitation, which eventually leads to diarrhoea in humans.

Diarrhoea is one of the main causes of deaths among young children. The annual number of diarrhoea cases recorded is nearly 1.7 billion and it still remains a major threat to the public. This is a disease that occurs within all age groups and genders, although the it has been noted to be more common and severe in children especially those below the age of five years. One in nine deaths in young children are accounted for with diarrhoea worldwide. In Africa, it causes 16% of deaths in younger children, whereas in Ghana, it is known to be ranked in third place killing over 10,000 young children under the ages of five every year (WHO, 2014). It is estimated 94% of the disease is as a result of the environment and an association to the consumption of unsafe drinking water, poor hygiene, and poor socio-economic status (Asamoah *et al* 2016).

According to Mensah, (2011) the quality of drinking water sources in the district has no data on microbial safety. As such, there is the need to assess the quality of drinking water sources in selected coastal communities of Ghana and investigate the influence of climate change, social, economic and cultural factors.

1.2 Problem Statement

Water quality is affected by physical, chemical and biological factors, which may vary in intensity over time and space. Water supply may increase at the same time reducing the quality of the water and in some places, shortage of water wouldn't be much of a problem than the increases in flooding, runoff, or sea level rise. All these environmental effects and problems can cause the quality of water to reduce (EPA, 2017). The coastal communities in Ghana are vulnerable to flooding when the sea level rises as a result of climate change. This has led to the loss of infrastructures and the decline in the water quality (Mensah *et al*, 2012). Water quality reduction occurs when the water source has been contaminated with microbial pathogens such as faecal coliform and *E. coli* which is as a result of poorly maintained environment.

Problems in the environment, no knowledge on sanitation, as well as difficulty in accessing health centres have added to the surge of waterborne illnesses, one of which is diarrhoea, through the consumption of unsafe drinking water (Leyk *et al*, 2012). About two million cases of diarrhoea is documented annually. One point nine million are children below the ages of 5 that lead to death in developing countries (Tubatsi *et al*, 2015).

The selected communities located in the Keta Municipal Assembly are low lying with altitudes of 53 metres above sea level, making them vulnerable to flooding and water contamination. This study therefore assessed the quality of drinking water sources within the communities which included, pipes, wells reservoirs, and sachet water in the selected communities, the impact on community health, and the influence of Socio-economic factors on the quality of the water.

1.3 Research Questions

The questions on which the study was carried out were:

1. What are the changes in the quality of drinking water sources in the selected areas?
2. Which source of drinking water amongst the selected coastal areas is most suitable for consumption?
3. How does the quality of water cause diarrhoea?

1.4 Objectives

The main objective of the study is assessing the quality of drinking water sources in selected coastal communities along the eastern coast of Ghana and its effect on community health.

Specific objectives are to:

- To assess concentrations of physico- chemical and microbial parameters of drinking water sources in selected coastal communities of Ghana
- To explore the relationship between microbial water quality and the risk of diarrhoea.
- To examine the influence of socio-economic factors on water quality and incidence of diarrhoea.

1.5 Justification

In developing countries, the quality of drinking water is unceasingly being polluted for human consumption. Recent estimates show that, the quantity of water which is available in evolving regions of South Asia, Middle East and Africa is plummeting whereas in general the quality of water is deteriorating at a fast rate (Moshin *et al*, 2013). In low coastal aquifers, flooding also causes an effect to the quality of the groundwater, particularly in the aquifers with porous overload and high hydraulic conductivities, which offer less or no attenuation to contaminants which come from polluted surface water coming from the flooded river and lagoons (Heino *et al*, 2021). Water is considered unsafe for drinking when it is contaminated with pathogenic microorganisms due to insufficient sanitation and unhygienic practices (Bartram *et al*, 2010).

The occurrence of water-borne diseases including diarrhoea, has been attributed to unsafe water and unhygienic practices (Pande *et al*, 2018). Diarrhoea is a disease that is known to be the leading cause of high mortality in children all over the world, which is gotten from the intake of contaminated water and food sources. Globally, up to 780 million people have no access to quality drinking-water and about 2.5 billion live in unhygienic places leading to infection throughout developing countries (WHO, 2017). In Ghana, children below the ages of five are greatly affected by diarrhoea. In the wet season, an increase in flooding happens in many parts of Ghana as a result of climate change and of poor drainage systems which leads to the contamination of drinking water sources and eventually leading to the increase in the occurrence of diarrhoea when the contaminated water is used for the preparation of food as well as drinking (Ameyaw *et al*, 2017).

Since the source of drinking water can pose severe health problems for people, determining the drinking water quality in the selected communities will help to ascertain how safe the drinking water sources of these coastal communities are for human consumption as well as mitigate some problems associated with poor quality drinking water. There have been many studies on the assessment of water quality and its impact on community health done in the Volta region of Ghana and in the Keta district, but none have been done in Anyako, Atiteti and Anyanui which have reported high cases of diarrhoea according to a survey done prior to the study. The findings and results from this study will help researchers and policy makers to devise better climate change resilient policies to mitigate the effect or contribution of climate to the pollution of drinking water sources.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

Many studies had been done on the quality and taste of water sources worldwide and for different purposes. Aydin stated in his study that, water remains a vital resource that supports daily important functions such as domestic, agriculture and industrial activities (Yasin *et al*, 2015). Water quality is however threatened by human activities which affect both the quality and the quantity. These include poor waste disposal practices, poor protection of well heads, proximal sitting of pit latrines and sewage systems close to groundwater areas, and the method of fetching. Natural conditions such as geology of land-cover and flooding caused by storm surges and heavy rainfall also expose water sources to contamination (Norvivor, 2013).

2.2 Coastal communities and Drinking water

Globally coastal communities are important when dealing with trade, tourism of historical and archaeological sites, agriculture aquaculture and fishing. The importance of these communities is widely known but unfortunately, they are an ecosystem that is highly and extremely vulnerable to environmental challenges like sea level rise and coastal storms and flooding (DMA, 2022). In an article written by the Nation Ocean Service in 2021, coastal communities face a number of threats, which in turn greatly affect the livelihood and sustainability of the people living in the communities. In the Pacific Islands which is located in the United States, they face more catastrophic hazards such as tsunamis, floodings and even droughts (NOAA, 2021).

Climate change plays a major role in causing major problems and issues around the coast and the communities around the coast. Tidal flooding, together with coastal storms continue to increase which cause the water table to increase and the aquifers to get saltier. The health and safety of the locals in the coastal settlements are put at risk when their water and sewer infrastructure, recreational lifestyle characteristics are threatened by the effects of climate change.

In Ghana, Ada and Keta are partly located on the coastline which is about 560km. Coastal communities in Ada and in Keta are said to be serene and peaceful to live in. Despite these conditions, climate change and human activities have caused the communities to become exposed to environmental challenges some of which are just coastal and inland flooding, waterlogging, flooding, groundwater contamination and salinity intrusion and according to Kusi -Appiah in (2017). The effects of climate change have affected weather conditions in many parts of the world and there is now a great concern about global warming. Climate change which is as a result of an increase in the concentration of greenhouse gases which in turn affect groundwater recharge through changes in both precipitation and temperature. This will enable saltwater intrusion into groundwater systems and other water sources in coastal areas. Salinization of water sources can lead to a severe deterioration of the quality of existing fresh groundwater resources which can also create a reduction in the quantity of freshwater resources that is available in coastal aquifers. (Norvivor,2013). In the coastal areas the main sources of water are groundwater and surface water.

As explained by Abinah, (2013) water can be categorized into surface and groundwater, where surface water are streams, rivers, lakes and any form of water that exists into them causing them to be easily vulnerable to pollution and contamination. Groundwater, is water that exist beneath the soil in the water table and. its contamination depends on the chemical alteration being caused by factors such as human activities, and the seepage of chemicals into the soil. Rural communities in coastal areas depend on pipes, wells, and boreholes for water supply.

2.3 Water Quality and Contamination

Quality water source is one that has its physical, chemical and bacteriological parameters as safe for cooking and drinking. Water is considered unsafe for drinking when it is contaminated with pathogenic microorganisms (Mensah, 2011). The quality of water is the state of the water, that is its chemical, physical as well as its biological characteristics (Adaka *et al*,2021). The occurrence of water-borne diseases including Diarrhoea, cholera, typhoid fever, and dysentery, have been attributed to unsafe water and unhygienic practices (Pande *et al*, 2018). It is therefore imperative to assess water quality for drinking, domestic, industrial and agricultural purposes (Bhateria & Jain, 2016). Any potable water may be contaminated microbiologically due to insufficient sanitation and unhygienic practices (Bartram *et al*, 2010). People are exposed to unsafe levels of contaminants when their drinking water sources is polluted. The contamination of water may be by nutrients or microbiological contamination. There are different contaminants for every source of water, for instance with surface water there is mostly bacteria as well as microorganisms and with ground water there is an amount of toxic chemicals from seepages and nitrate and natural occurring salts from the leaching and the flow of water between mineral rocks beneath the soil (Abinah, 2013). From studies and research done in communities in the coastal areas, it is seen that wells may be contaminated during floodings and runoffs from nearby farms, sewage discharges and livestock droppings or by any other human activity such as construction that may take place close to the source of water. In my opinion, faecal contamination in water from septic tanks or human and animal droppings are far more serious as they pose serious health risk Water through pipes can only be contaminated from the source of the water or when there are breakages in the pipe distribution system. Suspended solids in water increase the number of bacteria within the water. these suspended solids are usually of natural origin, they are carried through runoff, and flooding (Norvivor, 2013).

In coastal areas, the rise in seawater or ocean surges combined may carry contaminants from urbanization and waste disposals into river channels (Ojolowo, 2017). The result of this contamination is the mineralization and nutrient loading in surface water (Ezekwe *et al*, 2015). Recent estimates show that, the quantity of water which is available in developing regions of South Asia, Middle East and Africa is reducing while in general the quality of water is deteriorating at a fast rate (Moshin *et al*, 2013). In low coastal aquifers, flooding also causes impact to the quality of the groundwater, particularly in the aquifers with porous overload and high hydraulic conductivities, which offer less or no attenuation to contaminants which come from polluted surface water coming from the flooded river and lagoons (Heino *et al*, 2021). In developing countries, the quality of drinking water is continuously being contaminated for human consumption.

In Ghana, large quantities of pollutants have been discovered in various drinking water sources, and it was discovered that they do not treat the water before consumption (Yeboah, 2021). The quality of most of the natural sources of drinking water have been reduced because they have been left unprotected from pollution due to several human activities. The locals in communities in the rural areas and small towns depend on these surface water more than those in the urban areas. This untreated and polluted water have been left for these dwellers to collect and consume which poses a risk to human health (Attua *et al*, 2014). Protection of drinking water sources consistently is the best way of ensuring safe drinking water (Amenu *et al*, 2013).

2.4 Assessment of Water Quality

Water quality parameters give an indication of the extent of damage that might have been caused to drinking water sources as a result of e.g., sea level rise causing flooding in these coastal communities. For example, a test for total coliform gives an indication of the presence of disease-causing pathogens. Good water for good health should be free of all microbial contaminants. Most types of coliform bacteria are considered harmless to human health, but there are some that can cause mild illnesses and a few which could also lead to grave waterborne diseases (Jambre *et al*, 2021).

The parameters analysed in this study were both physico- chemical (pH, total alkalinity, sodium, nitrate nitrogen, potassium, magnesium, phosphorus and calcium) and microbial parameters (Total coliform, faecal coliform, *Escherichia coliform* and *Salmonella spp, Shigella spp, Enterococcus spp, Vibrio cholerae spp*).

Nitrate Nitrogen

Nitrate nitrogen is the presence of nitrogen combined with nitrate ion. Groundwater sources contain a reasonable amount of nitrate nitrogen. Its concentration ranges from 1mg/l to 3mg/l, or in some cases it may range higher. They commonly occur in water sourced from wells and they are usually as a result of leaching and seepage of nutrients through soils that contain them. Another cause is from the use of fertilizers in the soil on farmlands, although the nitrates are one of the products obtained from the decomposition of animal waste. A sign of nitrates in the water source indicates the water source is polluted. Nitrate is toxic to the human health because the body further reduces the nitrates to nitrites and this usually takes place in the saliva of humans and in the gastrointestinal tract of infants especially during the first months after birth. Many studies have shown that sources that have higher concentrations have led to an illness in babies known as the blue baby condition, and in some cases death (Mensah, 2011).

Phosphate

The compound phosphate contains phosphorous which is a non-metallic element which can be found as inorganic phosphates within rocks and is important to life (WSS, 2018). The continuous running of water through such rocks tend to carry and transport phosphates, magnesium and even calcium (WSS, 2018). There are manmade sources that also cause phosphates to enter water sources such as during the treatment of water at the plants to prevent lead poisoning in the pipes (Rosales *et al* 2020), and through fertilizers, organic manure and organic waste. Too much of it causes eutrophication and depletes the oxygen content in the water (Extoxnet, 2022).

Phosphorous when in the form of phosphate is one of the essential elements but toxic when it is too much in water. Phosphates turn to enter the water through point and non-point sources. some of these sources include agriculture runoff, decomposition of rocks and minerals, direct input by animals and sedimentation, whilst that of point sources include industrial discharge, and waste from treatment plants (Mensah, 2011). High concentrations levels of phosphate in the water mean are as a result of pollution which will further lead to eutrophication. Phosphates are not considered toxic or harmful until they are at very high levels. High levels lead to problems in the digestive system

Sulphate

Sulphate which can be found in almost all waterbodies is mainly obtained when salts within sulfuric acids are dissolved (Moshin *et al* 2013). Acid rain which is formed when there is a catalytic oxidation of sulphur dioxide which combines with water vapour also add to the high levels of sulphate in water bodies.

High levels of sulphur in the water disrupts the disinfection process by using the residual chlorine that is in the distribution system. This could lead to the corrosion of the steel in the system and further lower the quality of the water, causing it to have both taste and odour. Sulphates are considered to detoxify and stimulate certain organs in the body. According to WHO in drinking water, sulphate levels should be at 250mg/L.

Total Alkalinity

Total alkalinity of drinking water is the measure of the capability of the water to be able to neutralize the acids. Naturally present in the water are carbonates, carbon dioxide, hydroxide ions and bicarbonates (TBA, 2022).

High concentrations of carbon-based mineral molecules result in the alkalinity of water. The hardness of water is due to the high alkalinity level. Drinking water should have 20 -200mmg of calcium carbonate per litre of water of alkalinity level though the recommended range is 30-400 ppm. Alkalinity is not harmful to human health, though water with low alkalinity cause changes in the pH of the water, leading to the corrosion of the metal pipes (Alley, 2017)

Sodium

Sodium which is one of the most abundant elements found on the earth can be found in soils, plants, water as well as in food. It is a silvery white metal which is highly reactive and never gotten in its uncombined state (Magutywa, 2021). The Sodium Ion is known to be ubiquitous in water due to many sodium salts having a high solubility. Usually, most of the water supplies contain less than 20mg/L but others exceed 250mg/L. Ground water contains a high concentration of sodium than surface water. Sodium can easily be detected by taste of the water.

Sodium salts in general are not toxic because mature kidneys are able to excrete sodium effectively, however acute effects such as nausea, muscular twitching and cerebral oedema occur and further lead to death (Mensah, 2011).

Magnesium

On earth the 8th most, abundant element is magnesium. This element is essential to living organism and is found in dolomite and magnesite. Sixty percent of bones and forty percent of muscles in the human body is made up of 25g of magnesium (Moshin *et al* 2013). Magnesium just like other earth metals cause hardness in water. A large number of minerals contain magnesium, it is washed from rocks which eventually ends up in the water. Magnesium is also gotten from the application of fertilizer and animal feed. There is no scientific evidence for the toxicity of magnesium in drinking water however, since higher concentrations causes water to become hard, WHO Guidelines has maximum level to be 150mg/l (WHO, 2017). Health wise, people what consume water with higher concentrations of magnesium show sudden cardiac deaths (Mensah, 2011).

Calcium

Calcium is an element which occurs naturally in water which is mainly provide by the earth's crust. Generally, the amount of calcium in rivers is 1-2ppm but in cases where there are limestones, the concentration of the calcium increases. Calcium is considered as essential to health of human. Calcium is present in water as an Ion and is important in indicating the hardness of water and causes the water to have a bitter taste. Due to its buffering ability, it acts as a pH stabilizer (Mensah, 2011)

The hardness of water as a result of calcium aids in the strengthening of bones and the teeth in humans. It also forms a protective coating in lead pipes as lead (II)carbonate which prevents the dissolving of lead into the water. Low calcium concentrations in the water causes colorectal cancer, osteoporosis, nephrolithiasis, hypertension as well as stroke (WHO, 2017). According to the WHO Guidelines the maximum level of calcium in drinking water is 200mg/l.

Potassium

Potassium is an important element which is rarely found in high levels within drinking water which could pose as a threat to human health. It occurs in the environment and in all water. Another source of potassium in drinking water is from the usage of potassium permanganate which is used as an oxidant in the treatment of water. In certain countries, potassium chloride is used in the exchange of ion for household water softening. This is used in place of, or at times mixed together with, sodium chloride, thus potassium ions would exchange with the calcium and magnesium ions (WHO, 2017).

The average potassium concentrations in drinking water that WHO set is a maximum contaminant level ay 30mg/l (WHO, 2017). An increase exposure to potassium is harmful to humans with health conditions relating to the kidney, the hear or for those that are taking medications that do not combine well with potassium.

Coliforms

Coliforms are defined as gram negative rod shaped which are non-spore forming and motile or non-motile bacteria which when incubated can ferment lactose with the production of acid and gas. The coliform is usually used as an indicator of water quality and can be found in the environment, soil and on vegetation. Though the coliforms do not cause serious illnesses, their presence is used as an indicator that there may be faecal origin (Daoliang *et al*, 2019). Therefore, testing for these bacteria can be an indication of whether the water is contaminated with other pathogenic bacteria. With microbiological quality, the WHO guidelines values which are given for total coliform, *E. coli* or faecal coliform, indicate that these should not be detected in any water sample of 100 mL (WHO, 2010).

Faecal Coliforms

Faecal coliform is known to be a subset of coliform, which respond at a high and increased temperature of 44.5 0C. A study done by (Lapworth *et al*, 2017) revealed that the existence of faecal coliforms in drinking groundwater shows the presence of disease-causing microorganisms responsible for gastro-intestinal diseases such as diarrhoea, cholera, typhoid and dysentery. They ferment lactose and produce gas at 44.5+/-0.20C within 24+/-2 hours. Faecal coliform includes *Esherichia, Klebsiella, Citrobacter* (60% to 90% of total coliforms are faecal coliforms) 90% of faecal coliform are *Escherichia coli* (Abinah 2013).

This particular group of total coliforms is said to be existing explicitly in the gut as well as in the faeces of warm-blooded animals. they are considered an accurate indicator of human and animal waste because than total coliforms because the source is more specific (NYSDP, 2011). Faecal contaminants which enter the supply of water lead to water contamination which further leads to the transmission of pathogens such as *Shigella spp*, *Salmonella spp*, *Vibrio cholerae* and *E. coli* (Bennet *et al*, 2018). A well or source of water has the potential to cause diseases if it is contaminated with faecal coliform (Wortzman *et al*,2020). Faecal contamination can happen as a result of many different sources like combined sewer overflows, leaking septic tanks, animal feed containers, and other sources.

Escherichia. Coli

Monitoring the microbial quality of drinking water source requires using microorganisms to detect contamination, the indicator commonly used when it comes to detecting faecal contamination is the *E. coli* (Bain, *et al*. 2014). When any water source shows a positive result in *E. coli it* shows that the water is contaminated or polluted with either human or animal waste which can go on further to cause diseases such as diarrhoea, dysentery and hepatitis (CDCP, 2010).

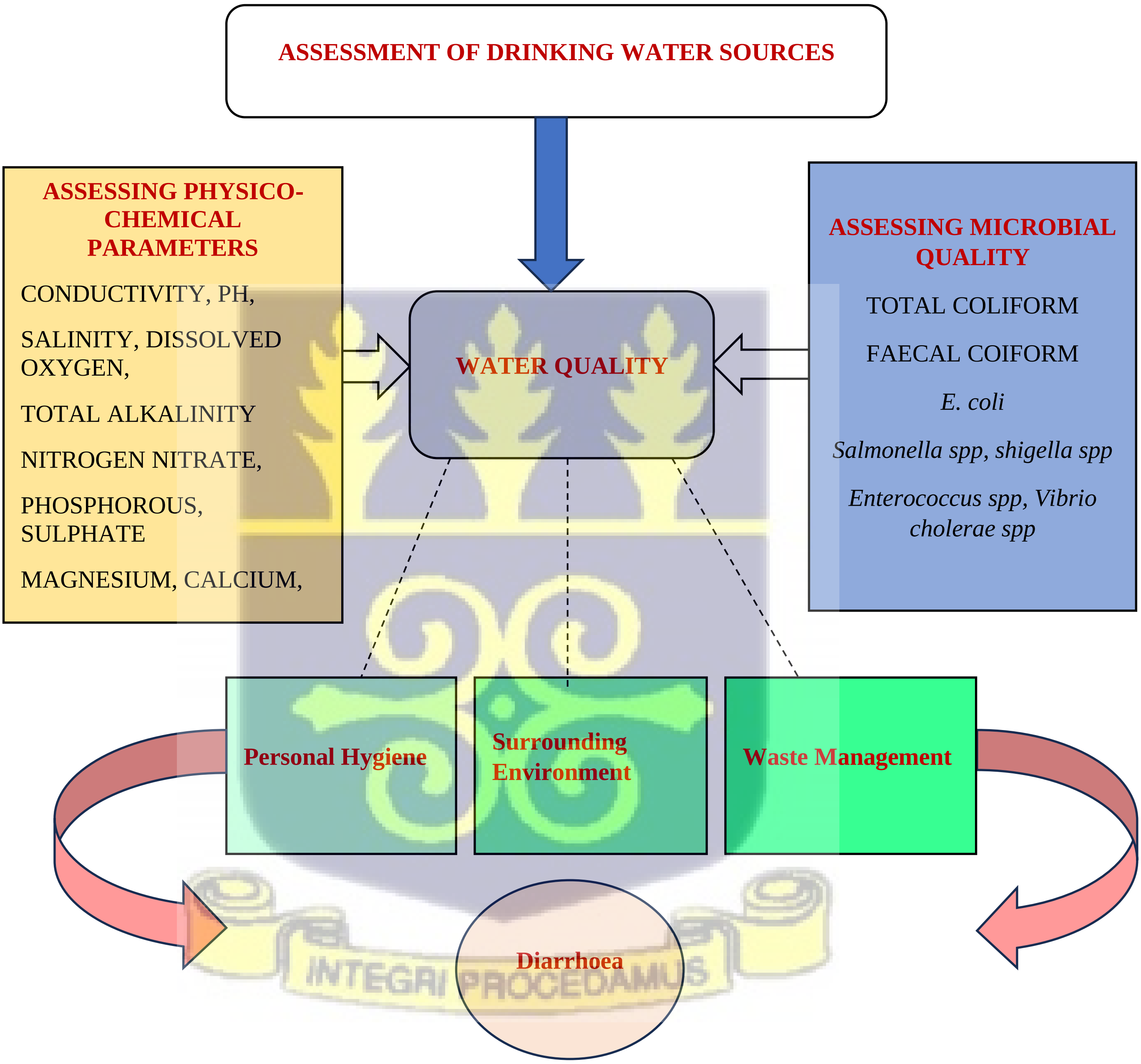
2.5 Socio economic Factors and Diarrhoea

Studies have proven that consuming untreated water form sources contaminated and polluted with *E. coli* may lead to the occurrence of waterborne diseases such as diarrhoea. Diarrhoea can be transmitted by so many ways but the common one of them all is known to be the improper use of water that is not treated as well as unhygienic conditions and poor sanitation of the environment. This was confirmed by studies done between 2010 to 2016 (Murray *et al*, 2010, Hunter *et al*, 2010). Diarrhoea is one of the diseases that is common in children mostly under the age of 5 years making it the second leading cause of death globally. In Africa, diarrhoea causes about 16% of deaths in children and within Ghana, the number of children that die as a result to the disease is about 10,000 every year hence is the third leading cause of death in children (Asamoah *et al* 2016).

Diarrhoea amongst young children is as a result of socio-economic factors. Studies and research have shown that, factors such as the educational status of household members, the occupation of each household members, the income of the household members and the age have contributed to the contraction of diarrhoea disease. This occurrence has an indirect link with the access to healthcare centres, access to safe water, environmental sanitation and the ability to use different methods in preventing the occurrence of the disease (Woldu et al, 2016). Washing hands with soap and water after using the toilets reduces the concentration of microorganisms which can contaminate the water and the use of clean water storage containers in households have decreased the risks of diarrhoea. Improper disposal of waste breeds insects which spread the diarrhoea causing pathogens to water and food (Id et al, 2018). Mothers with children are more at risk of contracting the diarrhoea disease since the young children are always around the mothers during eating, when they visit the toilet and when they play (Soboksa *et al* 2020).

In a study that was conducted by Daniel *et al* in 2019, it was mentioned that other studies done between 2001 to 2004 suggested that, the treatment of water in homes could further reduce the risk of contracting diarrhoea. Another study done in 2001 came out with an analysis that there was no relationship between water quality and the risk of diarrhoea and another also came out saying contamination was only in the drinking water sources and the not the sources at home.

2.6 Conceptual Framework



CHAPTER THREE

METHODOLOGY

3.1 Study Area

This study was conducted in three communities within the Keta Municipality, in the Volta Region of Ghana. The municipality covers a land area of 753.1km^2 with an estimated population of 78,862 as at the year 2021 (GSS, 2021). The largest lagoon in Ghana which is the Keta Lagoon is also located there. It lies within the Longitudes 0.30°E and 1.05°E as well as Latitudes 5.45°N and 6.005°N and is known to be located to the east of the Volta estuary, which is about 160km from Accra. Keta Municipality shares common borders together with Akatsi South District to the north, Ketu North and South District to the east, South Tongu District to the west and the Gulf of Guinea to the south and the water bodies enable water transportation which is economical than the road transport, and has potential for large scale commercial fishing.

Keta Municipality is low-lying coastal plain 53 metres above sea level and the lowest between 1 to 3.5 metres below sea level which makes it vulnerable to both tidal waves and sea erosion. As a result of this, a number of communities along the coastal areas have suffered sea erosion until the sea defence wall was set up and built to protect the rest of the land. The Three main geographic belts identified are, the narrow coastal strip, the lagoon basin of the middle belt and the plains of the north (GSS, 2021).

The elevation of the basin of the Keta lagoon below sea level and is made up of several lagoons and islands such as Anyako, Atiavi, Alakple, Seva, and Dudu. The basin is marshy as a result of the underlying sandy-clay geological formation. The lagoons are the main drainage.

The Keta municipality is primarily an agricultural district, with majority of the population engaged in crop farming, livestock keeping, fishing as well as other related trading activities. A varied range of industrial activities also take place in the Municipality. Most of the major towns in the Municipality have access to electricity. Pipe borne water is the major source of domestic water supply to the people. There are several other sources of water supply which are boreholes, rivers, hand-dug wells, dams and dugouts (GSS, 2010).

Anyako

Anyako is a town in the Keta Municipality and is bordered at the south by the Keta lagoon. The inhabitants of the town are mainly from the Ewe tribe. Its geographical coordinates are 6° 0' 0" North, 0° 55' 0" East. There has been no growth in the town for thirty years as a result of the sea erosion which affected commercial activities. For the past 12 years, the town has not had water as the pipes in the community are all damaged. The town therefore reach out to neighbouring towns such as Abor, to provide them with water daily.

Anyanui

Anyanui is a village located in the Keta Municipal District and is situated in Anlo, Volta, Ghana, its geographical coordinates are 5° 47' 0" North, 0° 44' 0" East. It is linked to Ada Foah by a small ferry which runs on Wednesdays for several villages along the way. Anyanui is vulnerable to coastal erosion and a $60 million project has been started to cover the 2.7 kilometres distance that is between Anyanui and another town named Akplortorkor (Anyanui, 2018). The community is known to have both pipes and wells as their sources of water.

Atiteti

Atiteti is a very small village also found in the Keta municipal which has longitudes 0°43'22.1"E and latitudes 5°46'14.7"N and is about 0.5 km south of the town Anyanui. There are six pipes located in the whole of Atiteti which are at vantage points for the residents to get access to water easily. The water is provided to them by Ghana Water Company Limited.

Map of Study Areas

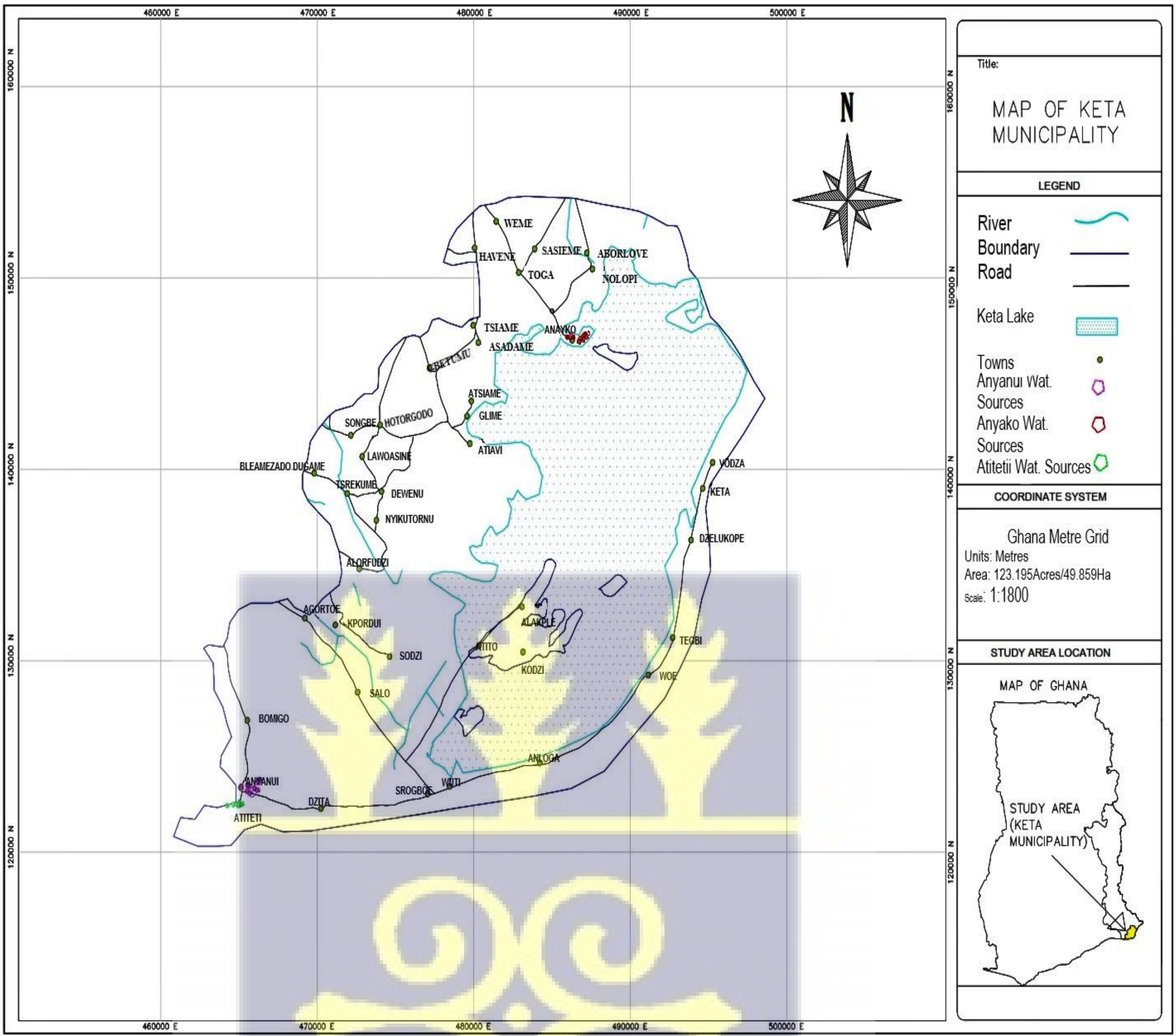


Plate 3. 1 Map of Volta Region of Ghana showing the study areas Anyako, Atiteti and Anyanui.

3.2 Selection of sampling sites

3.2.1 Sources of samples

The drinking water sources in each community was located with the help of the assembly man and community head and mapped out using a GPS. The samples taken from the Community drinking water sources were from Commercial and private poly-tanks, a well and a reservoir tank from Anyako, whilst that from Atiteti were pipes and in Anyanui, Pipes and Wells. Samples were also taken from various household drinking water containers such as plastic barrels, 10L yellow Gallons and earthen pots.

3.2.2 Sample Sizes

The samples were taken from all the sources of water that the locals drink from in the communities. Three samples were taken from each sample point.

Location	Coding	Total sampling points
Anyako	• AKO- Commercial Poly-tanks • AKPV-Private Poly-tanks • AKW- Wells • AKT- Tanks • AKS – Sachet	19
Atiteti	• ATIP- Pipes	6
Anyanui	• ANYW- Wells • ANYP- Pipes	14

Table 3. 1. Coding and sampling point in each community

Through the use of exploratory questions on the types of sources of drinking water during the survey of the communities, a proportion was found for each. Each category of drinking water source was different. Using each proportion of population that drink the different types of water, a desired sample size was calculated. Fifteen households were then randomly selected to collect the samples from the drinking water storage. The codes for the Household were *AKOH*, *ATIH* and *ANYH* for Anyako, Atiteti and Anyanui respectively.

3.3 Sampling Methods

3.3.1 **Physico – Chemical Parameters of Water from Water Sources**

3.3.1.1 Field Analysis

Field data collection, from March 2021 to August 2021. Samples from the drinking water sources was taken in March, May and in August, whilst the household water samples were once every month except in April in triplicates within the study areas. At each sampling point, the parameters that were measured were, pH, conductivity, salinity, total dissolved solids and dissolved oxygen, with a Horiba multiparameter probe. The water samples were taken to the laboratory to analyse for nitrogen nitrate (NO_3^- -N), phosphate (PO_4^3), total alkalinity, sulphate ($SO_4$2), calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) and microbial analysis (Total coliform, faecal coliform, *E. coli*, *Salmonella*, *Shigella*, *Enterococcus* and *Vibrio cholerae*).

Water samples for the laboratory analysis of nitrogen nitrate, phosphate, total alkalinity, sulphate, calcium, magnesium, sodium and potassium were taken in 250ml plastic bottles. Wearing gloves, the containers were filled to the brim to avoid pockets of air from forming and were tightly closed and placed into an ice chest with ice blocks to preserve the samples. The water samples for the microbial analysis were taken in new plastic bottled water. The bottles were filled halfway and covered shut but not tightly in order to allow the organisms in the water to get oxygen. All the bottles were wrapped with masking tape and labelled according to the decided codes.

Visits were made to the District Assembly as well as the health centres in each community to collect information on the number of diarrhoea cases throughout the sampling period.

3.3.2 Laboratory Analysis

3.3.2.1 Water Chemical Parameters

The chemical and microbial analysis of the water samples were done at the Ecological Laboratory and the Noguchi Memorial Institute for Medical Research both located in the University of Ghana, Legon. The water samples were analysed for nitrogen nitrate, phosphate, total alkalinity, sulphate, calcium, magnesium, sodium and potassium at the Ecological Laboratory using spectrophotometer (HACH 1996) and the Hach spectrophotometer Model DR. 2010.

Nitrogen- Nitrate (NO_3^- -N)

The method used for the Nitrate analysis was the 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 water sample was measured into sample cell of the Spectrophotometer and one Nitra Ver 5 Nitrate Powder Pillow was added to the water sample. The mixture was then shaken vigorously for 1 minute and allowed to stand for five minutes. An orange colour of the mixture indicated the presence of Nitrate. Another cell was filled with 10 mL of only the sample (blank) and placed in the spectrophotometer for calibration. The prepared sample was placed into the cell holder of the spectrophotometer to determine the Nitrate concentration at 500 nm in mg/L (HACH, 1996)

Phosphate-Phosphorus ($PO_4$3—P)

With the analysis of Phosphate- Phosphorus, the sample cell was filled with 10mL of water sample and one Phos Ver 3 Phosphate powder pillow reagent was added to the cell content (the prepared sample) and swirled instantly to mix. The mixture was left for a two-minute reaction period. Another sample cell was filled with 10mL of distilled water (blank) with the reagent added and placed into the cell holder of the spectrophotometer (HACH, 1996) for calibration at "890 nm". Once the reaction period was completed, the prepared sample was placed into the cell holder of the spectrophotometer and the concentration of phosphate determined in mg/L.

Sulphate ($SO_4$2-)

The Sulphate level in the sample was measured using Sulpha Ver 4 powder pillows in a direct reading Hach spectrophotometer Model DR. 2010. Approximately 10ml of the sample was poured into a sample cell. A Sulpha-4 Reagent powder pillow was introduced to the sample and mixed until dissolved. This mixture was allowed to react for 5 minutes. A second sample cell, acting as the blank, was filled with 10 mL of the sample and placed in the cell holder for calibration. Following the reaction time, the prepared sample was positioned in the cell holder, and the sulphate concentration was determined at 450 mm. The Sulphate ions in the sample reacted with barium in the Sulpha Ver 4 Sulphate Reagent, resulting in the formation of insoluble barium sulphate turbidity. The degree of turbidity formation is directly proportional to the sulphate concentration (HACH.-1996).

Total Alkalinity

The chemicals which were required to analyse the total alkalinity in the water samples were concentrated sulphuric acid, phenolphthalein indicator, mixed indicator, distilled water, methyl red and Bromo cresol green.

Preparation of reagents

- Sulphuric acid solution (0.02N)

About 50ml distilled water was measured and transferred into a 100ml volumetric flask. A concentration of 20ml of 0.1 Normality Sulphuric acid was measured and added slowly along the sides of the volumetric flask. The flask was topped up to the mark using distilled water.

- Mixed indicator

About 0.0200g Bromocresol green and 0.0040g methyl red were dissolved in 20ml distilled water.

Testing of the water sample

The burette was rinsed with 0.02N Sulphuric acid and discarded after which it was filled with the Sulphuric acid and adjusted to the zero mark and fixed in the burette stand. About 100ml of the water sample was pipetted and transferred into the conical flask. Three drops of phenolphthalein indicator were added to the content in the conical flask and the colour changed to pink. This change was due to the alkalinity of carbonate ions in the water sample. Carbonate alkalinity was determined by titration of the water sample to the phenolphthalein indicator endpoint.

The content in the conical flask was titrated against the 0.02N Sulphuric acid till the pink colour disappeared. The titre volume was noted and used to calculate phenolphthalein alkalinity.

To the same solution in the conical flask, 3 drops of mixed indicator was added and the colour of the solution changed to blue. The titration was continued from the point where it was stopped for the phenolphthalein alkalinity until the endpoint colour was reached (red colour change). The entire volume of the Sulphuric acid was noted and it was used in calculating the total alkalinity. The difference between the phenolphthalein alkalinity and total alkalinity gave the bicarbonate alkalinity.

Volume of Sulphuric acid at phenolphthalein endpoint= A

Normality of Sulphuric acid= 0.02N

Equivalent weight of $CaCO_3$= 50

Phenolphthalein alkalinity = $\frac{\text{A x 0.02N x 50 x 1000}}{\text{Volume of water sample}}$

Total volume of Sulphuric acid used= B

Total Alkalinity = $\frac{\text{B x 0.02N x 50 x 1000}}{\text{Volume of water sample}}$

3.3.2.2 Bacteriological Parameters

The microbial analysis of the water samples collected from the field was done at the Noguchi Memorial Institute for Medical Research using the culture media and the buffered dilution water method. OXOID CM1046 Brilliance^{TM} *E. coli*, was used to test for the presence of total coliforms, faecal coliforms and *E. coli* in the water sample, OXOID CM0099 S.S Agar was used to test for the presence of *Salmonella, Shigella*, the OXOID CM0333 T.C.B.S Cholera Medium to test for *Vibrio cholerae* and lastly the OXIOD CM1050 Chromogenic UTI Medium was used to test for the presence of *Enterococcus*.

Water samples from each of the three (3) sampling points were analysed for the presence of coliform bacteria using the culture media and the buffered dilution water method. *E. coli* medium is used to confirm the total coliforms as well as the faecal coliforms in the water sample.

Preparation of Buffered Solution

The stock solution of the buffer dilution water is prepared by dissolving 5 tablets of Potassium Buffer Saline which is a water- based salt solution, containing disodium hydrogen phosphate, sodium chloride and in some formulation potassium chloride and potassium dihydrogen phosphate, in 500mL of distilled water. The buffered water is then covered tightly and stored in the refrigerator.

Test for Coliform

Twenty-eight point one grams of the OXOID CM1046 Brilliance™ *E. coli* medium was measured and poured into 1 litre of distilled water. The mixture was brought to boil gently, with agitation to dissolve the powdery form of the medium completely. Once dissolved, the mixture was left to cool in a water bath set at a temperature of 50˚C.

Using a calibrated pipette, 9ml of the prepared Potassium Buffer Saline was poured into a sterile test tube then 1ml of the water sample was poured into the 9ml, once mixed, 1 ml was removed from the same mixture and discarded. Using the same mixture, 1ml was pipetted into a sterile petri dish. The prepared medium was poured into the petri dish containing the 1ml sample and swirled to mix. Once the mixture in the petri dishes had set, they were placed into the incubator at 37˚C and 44˚C for 24-48 hours.

After required period is complete, the total coliforms which are positive were **pink** in colour whilst the faecal coliforms were **violet** in colour.

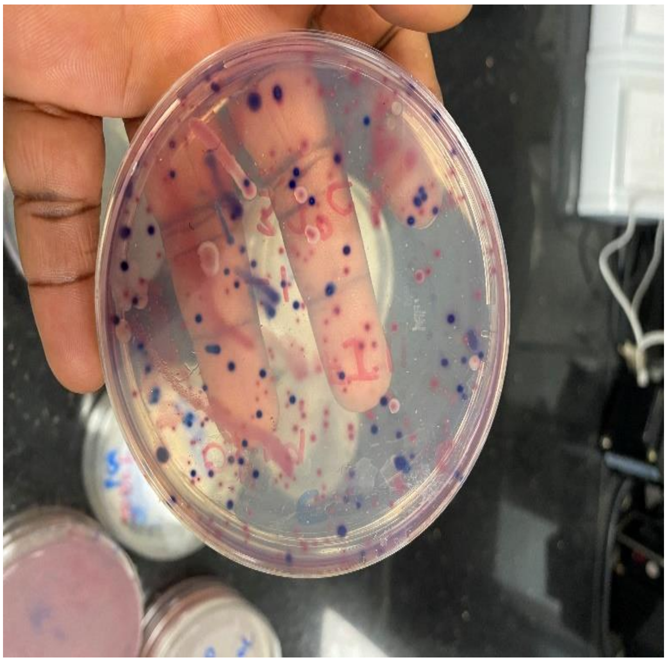


Plate 3. 2: A culture from a sample of water showing presence of total coliforms and faecal coliforms.

Test for presence of *Salmonella*, and *Shigella*

Sixty-three grams of the OXOID CM0099 S.S Agar was suspended in 1L distilled water and brought to boil with frequent agitation, the mixture was then allowed to simmer gently to dissolve the agar. Once fully dissolved the media was left to cool in the water bath with a set temperature of 50˚C. After cooling the media was mixed and poured into the sterile petri dishes.

The Agar plates were put into the hood together with the water sample, and an inoculating loop was used to streak gently on the surface of the media. The streaked media were incubated for 24 hrs at 37.7^{o}C.

After the required incubation time, the presence of *Salmonella* and *Shigella* in the water samples were black in colour.

Test for presence of *Enterococcus* Species.

Forty-three grams of the OXIOD CM1050 Chromogenic UTI Medium was suspended in 1 litre of distilled water and mixed. The mixture was then sterilized in an autoclave at 121°C for 15 minutes, removed and cooled in a water bath set at 50°C. The cooled mixture was then mixed again to re-suspend and poured into sterile petri dishes.

The chromo plates were put into the hood together with the water sample to avoid contamination, and an inoculating loop was used to streak gently on the surface of the media. The streaked media were incubated for 24 hrs at 37.7^{o}C.

After the required incubation time, the presence of *Enterococcus* in the water samples showed a blue colour.

Test for presence of *Vibrio Cholerae*

Eighty-eight grams of the OXOID CM0333 T.C.B.S Cholera Medium was suspended in 1 litre of distilled water. The mixture was brought to boil to dissolve the powdery medium completely. It was further left to cool in a water bath set at 50°C and poured into sterile petri dishes.

The vibrio plates were put into the hood together with the water sample to avoid contamination, and an inoculating loop was used to streak gently on the surface of the media. The streaked media were incubated for 24 hrs at 37.7^{o}C. After the incubation time, the presence of vibrio cholerae in the water samples showed a yellow colour.

Gram Staining

Gram staining is done to confirm if the coliform or growth on any media is what you are suspecting it to be. A colony of the organism is put on the surface of a slide using PBS and left to air dry or it is flamed.

Procedure

The colony of coliform organisms was smeared on a slide and dried with flame on the Bunsen burner. The fixed smear was covered with crystal violet stain for 30-60 seconds and rapidly washed off with clean water. The smear was covered with gram iodine for 30-60 secs and washed off with clean water. It was decolorized rapidly with acetone alcohol and washed immediately again with clean water, and covered with neutral red stain for 2 minutes. The red stain was washed away with clean water and the back of the slide was cleaned. In order for the smear to air dry, the slides were placed on a draining rack.

The smear was then examined microscopically, first with the 40X objective to check the staining and to see the distribution of the material and with the oil immersion objective to look for bacteria and cells. The condenser iris was fully opened when using the oil immersion lens.

The organisms were also be confirmed using the API index

Plate 3. 3 An image showing the examining of the smear of a colony of coliform organisms from a water sample under the microscope.

3.4 Questionnaires and Interviews

Collection and recording of information on drinking water sources and the ways water is managed as well as the general health and hygiene was done by observations, questionnaires and interviews with the locals in the study areas. The assembly men in each of the communities acted as translator due to the language barrier and also helped in setting up meeting with the locals. The sample size was for the questionnaires was calculated using the population of the households within the study areas, with the help of a sample size calculator. Interviews and observation were done each month the samples were collected, and the questionnaires administered during the last two months of the sampling, in July and in August. The houses were selected randomly with the help of the assembly man and the questionnaires administered to the household heads. The interviews were conducted with random persons within the community. Questions asked were on the drinking water sources in the community, how household drinking water is stored their personal hygiene and the health of the locals in relation to the drinking water source.

Community	Sample Size
Anyako	278
Atiteti	197
Anyanui	267

3.4.1 Collection of Diarrhoea Data

Various health centres were visited in each of the communities with the help of the assembly men. The cases of diarrhoea were discussed with the health workers, which further led to the formal request of the data for a period of years. The data was then compiled and sent to be used in the study.

3.5 Analysis of Data

3.5.1 Questionnaire and Interviews

The information from the questionnaires were manually recorded and inserted in SPSS. The descriptive tool in the software was used to determine the frequencies and percentages of the variables in the questionnaire. Chi-square test was run to determine the relationship between two variables between a socio-economic factor and the understanding of diarrhoea. Microsoft Excel was used to plot the graphs.

3.5.2 Water Quality Data

Data from the field and from the laboratory were analysed using Microsoft Excel and a Statistical Package for Social Sciences (SPSS) version 26. The results were recorded and arranged in the Excel and then exported to SPSS for the Two-way Analysis of Variance. The test run to determine the significant changes between the water samples in each month and during the sampling period was the Friedman's test. Significant differences shown, meant that $p<0.05$, hence a pairwise comparison test was further run to determine which exact month showed significant differences. A correlation test was run to determine the relationship between *E. coli* and the number of diarrhoea cases.

CHAPTER FOUR

RESULTS

4.1 Short- term changes in the quality of the drinking water sources in the selected communities.

Table 1-15 shows the findings of the short-term changes in the quality of the drinking water sources in each community selected. The mean microbial count is analysed to determine and check for changes in the microbial count and quality of the water source.

4.1.1 Total Mean Levels of Physico-chemical Parameters of Water Samples

Table 4.1.1 1.Mean results for indicated physico-chemical parameters in the water sampled from the community drinking water sources in Anyako.

CODE	Conductivity (ms/cm)	Salinity ppt	D.O mg/l	TDS g/l	pH
AKOC1	0.713 ±0.07	0.3±0.06	7.67±5.07	0.45±0.04	8.24±1.92
AKOC2	0.566 ±0.12	0.2±0.06	4.57±0.98	0.42±0.25	8.49±1.00
AKOC3	0.467 ±0.04	0.2±0.00	4.83±0.16	0.305±0.03	8.73±1.86
AKOC4	0.632 ±0.01	0.3±0.00	5.1±0.06	0.404±0.01	8.54±1.09
AKOC5	0.792 ±0.46	0.4±0.23	4.23±2.44	0.321±0.19	8.43±4.87
AKOC6	0.553 ±0.34	0.3±0.20	4.38±2.55	0.359±0.22	8.02±4.76
AKOC7	0.424 ±0.00	0.2±0.00	4.96±0.33	0.275±0.00	8.5±1.22
AKOC8	0.656 ±0.01	0.3±0.00	5.38±0.04	0.421±0.01	8.67±0.88
AKOC9	2.301 ±2.22	1.1±1.16	3.86±2.68	1.561±1.38	7.20±4.60
APV1	0.177 ±0.20	0.06±0.12	3.77±1.10	0.109±0.14	9.06±1.03
APV2	0.473 ±0.27	0.2±0.12	2.75±1.59	0.307±0.18	8.9±5.14
APV3	0.45 ±0.22	0.2±0.12	4.53±0.06	0.289±0.14	8.79±1.16
APV4	0.601 ±0.35	0.4±0.23	4.63±2.67	0.205±0.12	9.23±5.33
AKT1	0.134 ±0.08	0.1±0.06	2.25±1.30	0.087±0.05	9.45±5.46
AKW1	5.36 ±0.11	2.8±0.06	2.83±0.23	3.383±0.06	8.25±0.64
AKS1	0.076 ±0.00	0.06±0.06	4.32±0.16	0.052±0.00	9.2±0.21
AKS2	0.08 ±0.00	0.1±0.00	3.03±0.05	0.05±0.00	8.15±0.09
AKS3	0.255 ±0.33	0.1±0.00	4.63±0.08	0.044±0.00	8.3±0.14
AKS4	0.075 ±0.01	0.1±0.00	4.75±0.06	0.053±0.00	8.69±0.54
WHO Standards	0.8	0.2	6.5-8	<0.3-0.6	6.5 – 8.5

Details of the results are as follows:

Conductivity levels recorded in water samples collected from water sources.

The level of conductivity ranged from 0.075 to 5.366 mS/cm in all the community drinking water sources in Anyako. With the commercial poly-tanks, the level of conductivity ranged from 0.424 to 2.301 mS/cm, with the maximum level noted in AKOC9 and the lowest level in AKOC7. With the private poly-tanks, the level of conductivity in the water samples ranged from 0.177 to 0.601 mS/cm, with the highest level recorded in APV4 and the lowest in APV1.

The range of the level of conductivity in the drinking water sample sourced from the well AKTI and the reservoir AKT1 was 5.366 mS/cm l and 0.134 mS/cm respectively. Level of conductivity in water samples sourced from sachet was from 0.255 to 0.075 mS/cm, with the highest level recorded in AKS3 and the lowest level in AKS1.

Salinity levels recorded in water samples collected from water sources.

The level of salinity ranged from 0.06 to 2.8 mg/l in all the community drinking water sources in Anyako. With the commercial poly-tanks, the level of salinity within water sampled ranged from 0.2 to 1.1 mg/l, with the maximum level noted in AKOC2, AKOC3 and AKOC7 and the lowest in AKOC9. The highest level of salinity with the drinking water samples from the private poly-tanks varied from 0.06 to 0.4 mg/l with the maximum level in APV1 and the lowermost in APV4.

The range of salinity in the drinking water samples sourced from the well AKW1 and the reservoir AKT1 recorded as 2.8 mg/l and 0.1 mg/l correspondingly.

With the sachet water, the level of salinity in the water samples ranged from 0.06 to 1 mg/l, with the highest recorded in AKS1 and the lowest in the rest.

Dissolved Oxygen levels recorded in water samples collected from water sources.

The dissolved oxygen content ranged from 2.25 to 7.67 mg/l in all the community drinking water source in Anyako. With the commercial poly- tanks, the level of dissolved oxygen in the water samples ranged from 3.86 to 7.67 mg/l with the maximum from AKOC1 and AKOC9 having the lower level. With the private poly-tanks, the level of dissolved oxygen in the water samples ranged from 2.75 to 4.63 mg/l, with the highest in APV4 and the lowest in APV2.

The range of dissolved oxygen level in the samples sourced from the well AKW1 and the reservoir AKT1 was recorded as 2.83 mg/l and 2.25 mg/l respectively.

The range of the level of dissolved oxygen in the water samples sourced from the sachet, was from 3.03 to 4.7 mg/l. The maximum was recorded in AKS4 and the lowest in AKS2.

Total Dissolved Solids levels recorded in water samples collected from water sources.

Total dissolved solids ranged from 0.044 to 3.383 g/l in all the drinking water sources in Anyako. With the commercial poly-tanks, total dissolved solids level of the water samples ranged from 0.275 to 1.561 g/l with the highest level recorded in AKOC9 and the lowest in AKOC7. Within the private poly-tanks, total dissolved solids level of the water samples ranged from 0.109 to 0.307 g/l, with the highest recorded in APV2 and the lowest in APV1.

The range of total dissolve solids level in the drinking water samples from the well AKW1 and the reservoir AKT1 was recorded at 3.383 g/l and 0.087 g/l respectively. The level with the water samples sourced from the sachet water ranged from 0.044 to 0.05 g/l, the highest in AKS2 and lowest in AKS3.

pH

The pH level ranged from 7.20 to 9.45 in all the community drinking water sources in Anyako. With the commercial poly-tank, the pH level of the water samples ranged from 7.20 to 8.73 with the highest recorded in AKOC3 and the lowest in AKOC9.

The range of the pH level in the drinking water sample sourced from the private poly-tank was from 8.79 to 9.23 the maximum noted in APV4 and the lowermost in APV3. With the water samples sourced from the well AKW1 and the reservoir, the pH levels recorded as 8.25 and 9.45 respectively. The range from the water samples from the sachet was from 8.15 to 8.69, the maximum was observed in AKS4 and the minimum in AKS2.

ANOVA for physico-chemical parameters of water sources in Anyako.

ANOVA Table 1. Summary for Conductivity

Anyako	Total N	13
	Test Statistic	1.333[a]
	Degree Of Freedom	2
	Asymptotic Sig	.513

ANOVA Table 1; indicates that the P -value in Anyako is > 0.05, which means that for the concentration levels of conductivity, there were no significant differences between the samples in the sampling period.

ANOVA Table 2. Related-Samples Friedman's Two-Way Analysis of Variance Summary for Salinity

Anyako	Total N	10
	Test Statistic	1.333[a]
	Degree Of Freedom	2
	Asymptotic Sig	.513

ANOVA Table 2; indicates that the P -value is > 0.05, which means the concentration levels of salinity, had no significant changes between samples in the span of sampling in Anyako

ANOVA Table 3. Summary for Dissolved Oxygen

Anyako	Total N.	13
	Test Statistics	3.846[a]
	Degree of Freedom	2
	Asymptotic Sig	.146

ANOVA Table 3; indicates that P -value in Anyako is > 0.05, which means the concentration of Dissolved Oxygen, had no significant changes between samples in the course of sampling.

ANOVA Table 4. Summary for Total Dissolved Solids

Anyako	Total N	13
	Test Statistic	.667[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.717

ANOVA Table 4; indicates that the P -value in Anyako is > 0.05, which means the concentration of total dissolved solids, showed no significant changes between t samples in the sampling period.

ANOVA Table 5. Summary for Ph.

Anyako	Total N.	12
	Test Statistic	10.667
	Degree Of Freedom	2
	Asymptotic Sig	.005

Pairwise comparison.

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyako	M2 pH-M1 pH	1.000	.408	2.449	.014	.043
	M2 pH-M3pH	-1.000	.408	-2.449	.014	.043

ANOVA Table 5; indicates that P -value in Anyako < 0.05, which means the level of pH in each of the months sampled are significantly different. Pairwise comparison test was done to find out in month the samples taken had differences. In Anyako, the samples compared between May and March and the samples compared between May and August have significant differences between them.

Table 4.1.1 2 Mean results of the indicated physico-chemical parameters in the water samples from the community drinking water sources in Anyako.

CODE	Water Source	NO_3-N (mg/l)	PO_4^{3-} (mg/l)	Tot. Alk. (mg/l)	SO_4^{2-} (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)
AKOC1	C. Poly-tank	0.43±0.34	0.1±50.06	15.82±4.35	10.82±2.45	8.66±1.03	23.34±8.90	24.85±3.16	7.08±0.89
AKOC2	C. Poly-tank	0.4±0.13	0.25±0.28	16.58±0.70	11.26±1.51	6.03±4.48	12.36±1.61	37.84±9.21	2.73±
AKOC3	C. Poly-tank	0.49±0.28	0.4±0.34	16.02±2.80	11.96±1.89	3.77±0.58	16.57±5.94	38.69±10.84	2.63±2.96
AKOC4	C. Poly-tank	10.58±1.57	0.18±0.18	13.25±2.17	11.26±1.50	6.84±0.98	26.27±16.69	70.47±15.31	3.06±3.28
AKOC5	C. Poly-tank	0.5±0.29	0.17±0.10	25±14.43	16±9.24	8.34±4.82	25.76±14.87	125.96±72.72	6.58±3.80
AKOC6	C. Poly-tank	1.73±1.86	0.31±0.34	21±13.11	10.23±6.17	6.06±3.59	12.44±7.38	113.47±83.97	4.06±3.21
AKOC7	C. Poly-tank	0.38±0.10	0.1±0.01	16.81±1.65	11.02±1.23	4.16±0.70	13.03±1.95	62.5±51.96	3.8±4.90
AKOC8	C. Poly-tank	0.45±0.13	0.18±0.12	15.92±0.20	7.61±2.45	9.76±0.74	35.4±11.71	30.38±14.97	2.78±2.90
AKOC9	C. Poly-tank	0.43±0.25	0.12±0.14	150.63±156.38	21.85±20.49	95.33±102.87	156.6±151.34	101.41±81.70	14.88±15.97
APV1	P. Poly-tank	0.37±0.20	0.09±0.12	14.01±11.37	13.77±22.75	24.71±14.42	13.9±2.89	29.09±17.68	7.576±6.22
APV2	P. Poly-tank	0.33±0.23	0.48±0.27	23±20.55	4.05±5.66	9.91±6.18	19.37±11.60	38.95±29.29	3.91±3.44
APV3	P. Poly-tank	0.31±0.26	0.12±0.12	24±7.77	6.05±8.49	18.5±19.96	20.98±2.48	36.57±30.42	5.4±3.85
APV4	P. Poly-tank	0.5±0.29	0.42±0.24	24±13.86	2±1.15	8.64±4.99	0.38±0.22	62.05±35.82	6.73±3.89
AKT1	P. Poly-tank	0.9±0.52	0.14±0.08	62±35.80	5±2.89	33.74±19.48	2.68±1.55	21.67±12.51	5.79±3.35
AKW1	P. Poly-tank	2.25±1.23	0.1±0.07	73.16±152.83	161.4±164.74	41.5±31.84	58.45±48.66	78.58±60.36	33.36±25.58
AKS1	Sachet	0.5±0.00	0.08±0.00	6.13±4.14	1.22±1.07	3.76±4.54	0.74±1.09	2.81±1.53	0.1±0.02
AKS2	Sachet	0.38±0.02	0.11±0.00	5.92±1.64	2.11±1.83	3.3±4.93	1.06±1.67	3.33±2.49	3.67±3.09
AKS3	Sachet	0.46±0.06	0.16±0.01	5.27±1.07	1.33±1.15	2.92±4.39	0.76±1.07	3.97±3.10	0.76±0.54
AKS4	Sachet	0.5±0.00	0.16±0.01	4.08±0.00	1.005±1.41	4.19±5.39	1.07±1.31	3.01±3.72	0.58±0.63
WHO STDS		10	0.3	500	250	200	150	200	12

Detailed description of the results presented:

Nitrate Nitrogen levels recorded within samples taken from water sources.

The nitrate nitrogen levels ranged from 0.5 to 10.58 mg/l in the water samples from all the community sources of drinking water. With the commercial poly-tank, the level of nitrate nitrogen ranged from 0.38 mg/l to 10.58 mg/l, with maximum level in AKOC4 and the minimum in AKOC2. With the samples sourced from the private poly-tanks, the level of nitrate nitrogen ranged from 0.31 to 0.5 mg/l, the maximum level in APV4 and the minimum in APV3. The level of nitrate nitrogen in the water samples from the well AKW1 and reservoir AKT1 recorded as, 2.25 mg/l and 0.9 mg/l respectively.

The range of nitrate nitrogen in the drinking water samples sourced from the sachet was between 0.38 to 0.5 mg/l with maximum found in AKS1, AKS4 and the minimum found in AKS2.

Phosphate levels recorded in water samples collected from water sources.

The phosphate levels ranged from 0.08 to 0.48 mg/l in all the community drinking water sources in Anyako. With the commercial poly-tank, the phosphate levels of the water samples ranged from 0.1 to 0.4 mg/l, with the uppermost in AKOC2 and the low level in AKOC7. With the Private Poly-tanks, the phosphate levels of the water samples ranged from 0.09 to 0.48 mg/l, with the maximum in APV2 and the minimum in APV1.

The range of phosphate levels in the drinking water samples sourced from the well AKW1 and the reservoir recorded as 0.1 mg/l and 0.14 mg/l respectively. The water samples from the sachet water also had phosphate levels ranging from 0.08 -0.16 mg/l. the highest recorded in AKS3 and AKS4 and the lowest in AKS1.

Total Alkalinity levels recorded in water samples collected from water sources.

The total alkalinity levels ranged from 4.08 to 150.63 mg/l in all the community drinking water sources in Anyako. With the commercial poly-tank, the total alkalinity levels of the water samples ranged from 13.25 to 150.63 mg/l, with the highest recorded in AKOC9 and the lowest in AKOC4. With the private poly-tanks, the total alkalinity levels of the water samples ranged from 14.01 to 24 mg/l, with the maximum logged in APV3 and APV4 and minimum in APV1.

The range of total alkalinity in drinking water samples sourced from well AKW1 and reservoir recorded as 73.16 mg/l and 62 mg/l correspondingly. The water samples from the Sachet water also had total alkalinity levels ranging from 4.08 to 6.13 mg/l. The source with the extremely high levels was from AKS1 with the least level found in AKS4.

Sulphate levels recorded in samples of water from water sources.

The sulphate levels run from 1.005 to 161.4 mg/l in all the community drinking water sources in Anyako. With the commercial poly-tank, sulphate within water samples was between 7.61 to 21.85 mg/l, with a high recording in AKOC9 and low in AKOC8. With the private poly-tanks, the sulphate levels of the water samples ranged from 2 to 13.77 mg/l, with the maximum recorded in APV1 and the lowest in APV4.

The sulphate levels in the drinking samples of water sourced from the well AKW1 and the reservoir recorded as 161.4 and 5 mg/l respectively. The samples of water from the sachet also had sulphate ranging from 1.005 to 2.11 mg/l. The source with the extremely high levels was from AKS1 with the least level found in AKS4.

Calcium levels recorded in samples of water from water sources.

Calcium levels were between 2.92 to 95.33 mg/l in all community drinking water sources in Anyako. With the commercial poly-tank, the calcium levels of the samples of water were between 3.77 to 95.33 mg/l, the highest calcium level was from AKOC9 and AKOC3 had the lowest. With the private poly-tanks, the calcium levels of the water samples ranged from 8.64 to 24.71 mg/l, with the highest recorded in APV1 and the lowest in APV4.

The range of calcium levels in the drinking water samples sourced from the well AKW1 and the reservoir recorded as 41.5mg/l and 33.74 mg/l respectively. The water samples from the Sachet water also had calcium ranging from 2.92 to 4.19 mg/l, the highest recorded in AKS4 and the lowest in AKS3.

Magnesium levels recorded in samples of water collected from water sources.

The magnesium levels varied between 0.38 to 156.6 mg/l in all the community drinking water sources in Anyako. With the commercial poly-tank, the magnesium levels of the water samples ranged from 12.44 to 156.6 mg/l, with the highest recorded in AKOC9 and the lowest in AKOC2. With the private poly-tanks, the magnesium levels of the water samples ranged from 0.38 to 20.98 mg/l, with the highest recorded in APV3 and the lowest in APV4.

The range of magnesium levels in the drinking water samples sourced from the well AKW1 and the reservoir recorded as 58.45 mg/l and 2.68 mg/l respectively. The water samples from the sachet water also had magnesium ranging from 0.74 to 1.07 mg/l, the highest recorded in AKS4 and the lowest in AKS1.

Sodium levels recorded in water samples collected from water sources.

The sodium levels ranged from 2.81 to 125.96 mg/l in all the community drinking water sources in Anyako. With the commercial poly-tank, the sodium levels of the water samples ranged from 24.85 to 125.96 mg/l, with the highest recorded in AKOC5 and the lowest in AKOC1. With the private poly-tanks, the sodium levels of the water samples ranged between 29.09 to 62.05 mg/l, with the highest recorded in APV4 and the lowest in APV1.

The range of sodium levels in the drinking water samples sourced from the well AKW1 and the reservoir recorded as 78.58 mg/l and 21.67 mg/l respectively. The water samples from the sachet water also had sodium ranging between 2.81 to 3.97 mg/l, the highest recorded in AKS3 and the lowest in AKS1.

Potassium levels recorded in water samples collected from water sources.

The potassium levels ranged from 0.1 to 33.36 mg/l in all the community drinking water sources in Anyako. With the commercial poly-tank, the potassium levels of the water samples ranged between 2.73 to 14.85 mg/l, with the highest recorded in AKOC9 and the lowest in AKOC3. With the private poly-tanks, the potassium levels of the water samples ranged between 3.91 to 7.57 mg/l, with the highest recorded in APV1 and the lowest in APV2.

The range of potassium levels in the drinking water samples sourced from the well AKW1 and the reservoir recorded as 33.36 and 5.79 mg/l respectively. The water samples from the sachet water also had potassium ranging from 0.1 to 3.67 mg/l, the highest recorded in AKS2 and the lowest in AKS1.

ANOVA Table 6. Summary for Nitrogen Nitrate

Anyako	Total N	15
	Test Statistic	8.711
	Degree Of Freedom	2
	Asymptotic Sig	.013

Pairwise Comparisons

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyako	M2 NO_3-N -M1 NO_3-N	.933	.365	2.556	.011	.032

ANOVA Table 6: indicates that the P -value in Anyako is < 0.05, which means that the nitrate nitrogen concentration in each of the month sampled are significantly different. The level of concentration in March, May and August are significantly different. Pairwise comparison test was done to find out in month the samples taken had differences. The samples compared between May and August showed differences between them.

ANOVA Table 7. Summary for Phosphate

Anyako	Total N.	14
	Test Statistics	7.136
	Degree of Freedom.	2
	Asymptotic Sig.	.028

Pairwise Comparisons

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyako	M2 PO_4^{3-}-M1 PO_4^{3-}	.893	.378	2.362	.018	.054

ANOVA Table 7: indicates the P -value in Anyako is < 0.05, which means that the phosphate concentration in each of the months sampled are significantly different. Pairwise comparison test was done to find out in which month the samples taken had differences. The samples compared between May and March showed differences between them in Anyako and the samples compared between August and March showed the significant difference.

ANOVA Table 8. Summary for Total Alkalinity

Anyako	Total N.	15
	Test Statistics	5.250[a]
	Degree of Freedom.	2
	Asymptotic Sig value	.072

ANOVA Table 8: indicates that the P -value is >0.05, which means that the total alkalinity concentration in each of the months sampled have no significant difference between them

ANOVA Table 9. Summary for Sulphate

Anyako	Total N.	14
	Test Statistics	9.962
	Degree of Freedom	2
	Asymptotic Sig value	.007

Pairwise Comparisons Test

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyako	M3 SO_4^{2-}-M1 SO_4^{2-}	1.107	.378	2.929	.003	.010

ANOVA Table 9: indicates that the P -value in Anyako is < 0.05, which means that the sulphate concentration in each of the month sampled are significantly different. Pairwise comparison test was done to find out in which month the samples taken had differences. The samples compared between August and March showed differences between them.

ANOVA Table 10. Summary for Calcium

Anyako	Total N	15
	Test Statistic	2.793[a]
	Degree Of Freedom	2
	Asymptotic Sig	.247

ANOVA Table 10: indicates Anyako P-value > 0.05 hence there are no significant differences between the samples.

ANOVA Table 11. Summary for Magnesium

Anyako	Total N.	15
	Test Statistics	11.088
	Degree of Freedom.	2
	Asymptotic Sig Value	.004

Pairwise Comparison Test

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyako	M1 Mg-M3 Mg	-1.133	.365	-3.104	.002	.006
	M2 Mg-M3 Mg	-.867	.365	-2.373	.018	.053

ANOVA Table 11: indicates that the P -value in Anyako is < 0.05, which means that the magnesium concentration in each of the month sampled are significantly different. Pairwise comparison test was done to find out in which month the samples taken had differences. In Anyako, the samples compared between March and August as well as the samples compared with May and August showed significant differences

ANOVA Table 12. Summary for Sodium

Anyako	Total N.	15
	Test Statistics	4.192[a]
	Degree of Freedom.	2
	Asymptotic Sig value	.123

ANOVA Table 12: indicates that the P-value in Anyako is > 0.05 hence there are no significant differences between the samples.

ANOVA Table 13. Summary for Potassium

Anyako	Total N	15
	Test Statistics	4.073[a]
	Degree of Freedom	2
	Asymptotic Sig. value.	.131

ANOVA Table 13: indicates that the P -value is > 0.05 which mean that there are no significant differences between the samples. Comparing the samples in a month to samples in the other months show no significant difference.

Table 4.1.1 3. Mean results of the indicated physico-chemical parameters in the water samples from the community drinking water sources in Atiteti.

CODE	Water Sources	Conductivity (ms/l)	Salinity ppt	D.O mg/l	TDS mg/l	pH
ATIP1	Pipe	0.11±0.02	0.06±0.06	4.86±0.49	0.072±0.02	9.81±0.78
ATIP2	Pipe	0.08±0.05	0±0.00	4.5±0.32	0.052±0.00	9.65±0.60
ATIP3	Pipe	0.081±0.05	0±0.00	4.71±0.66	0.052±0.00	9.81±0.42
ATIP4	Pipe	0.092±0.06	0.03±0.06	4.82±0.01	0.06±0.01	9.7±0.75
ATIP5	Pipe	0.086±0.05	0±0.00	4.56±0.10	0.056±0.00	9.97±0.94
ATIP6	Pipe	0.082±0.05	0±0.00	4.39±0.01	0.377±0.28	9.6±0.68
WHO Standards		0.8	0.2	6.5-8	<0.3-0.6	6.5 – 8.5

Detailed description of the results.

Conductivity levels recorded in samples of water from water sources.

The conductivity levels ranged from 0.08 to 0.11 mS/cm in all the community drinking water sources in Atiteti. The highest level of conductivity was charted in ATIP1 and the lowest charted in ATIP2.

Salinity levels recorded in samples of water from water sources.

The salinity levels ranged between 0 to 0.06 ppt in all the community drinking water sources in Atiteti. The maximum level was documented in ATIP1 and ATIP4 and the rest had no record of salinity.

Dissolved Oxygen levels recorded samples of water collected from water sources.

The dissolved oxygen content ranged from 4.39 to 4.86 mg/l in all the community drinking water sources in Atiteti. The highest level of dissolved oxygen content was recorded in ATIP1 and the lowest in ATIP6.

Total Dissolved Solids levels recorded samples of water taken from water sources.

Total dissolved solids levels ranged from 0.052 to 0.377 mg/l in all the community drinking water sources in Atiteti. The highest level of total dissolved solids in water samples sourced from the pipes was recorded in ATIP1 and the lowest in ATIP6.

pH levels recorded in water samples collected from water sources.

The pH levels ranged from 9.6 to 9.97 in all the drinking water sources in Atiteti. The highest pH was recorded in ATIP5 and the lowest in ATIP6.

ANOVA for physical and chemical parameters of water samples from water sources in Atiteti.

ANOVA Table 14. Summary for Conductivity

Atiteti	Total N.	6
	Test Statistics	1.333[a]
	Degree of Freedom.	2
	Asymptotic Sig Value	.513

ANOVA Table 14; indicates that the P-value in Atiteti is > 0.05, which means the concentration levels of conductivity, had no significant differences between samples during the course of sampling.

ANOVA Table 15. Summary for Salinity

Atiteti	Total N.	6
	Test Statistics	.000[a]
	Degree of Freedom	2
	Asymptotic Sig value	1.000

ANOVA Table 15; indicates that the P -value in Atiteti is > 0.05, which means the concentration levels of salinity, had significant changes between the samples in the course of sampling.

ANOVA Table 16. Summary for Dissolved Oxygen

Atiteti	Total N.	6
	Test Statistics	5.333[a]
	Degree of Freedom	2
	Asymptotic Sig value	.069

ANOVA Table 16 indicates that the P -value in Atiteti is > 0.05, which means the concentration of Dissolved Oxygen, had no significant changes between samples in the course of sampling.

ANOVA Table 17. Summary for Total Dissolved Solids

Atiteti	Total N.	6
	Test Statistics	1.333[a]
	Degree of Freedom	2
	Asymptotic Sig value.	.513

ANOVA Table 17; indicates that the P -value in Atiteti is > 0.05, which means the concentration of total dissolved solids, had no significant changes between the samples in the course of sampling.

ANOVA Table 18. Summary for pH

Atiteti	Total N	6
	Test Statistic	12.000
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.002

Pairwise comparison.

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Atiteti	M2 pH-M1 pH	1.500	.577	2.598	.009	.028
	M2 pH-M3pH	-1.500	.577	-2.598	.009	.028

ANOVA Table 18; indicates that the P -value in Atiteti is < 0.05, which means that the level of pH in each of the months sampled are significantly different. Pairwise comparison test was done to find out in month the samples taken had differences. In Atiteti, the samples compared between May and March as well as samples compared between May and August have significant differences between them.

Table 4.1.1 4 Mean levels of the indicated physico-chemical parameters in the water samples from the community drinking water sources in Atiteti.

CODE	Water Source	NO_3-N (mg/l)	PO_4^{3-}(mg/l)	Total Alkalinity (mg/l)	SO_4^{2-} (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)
ATIP1	Pipe	0.16±0.12	0.24±0.13	25.66±0.88	2.32±3.10	3.33±0.80	6.17±0.45	15.137.05±	5.69±3.90
ATIP2	Pipe	0.3±0.10	0.1±0.06	26.77±1.83	1.77±1.58	3.66±1.14	6.41±0.61	11.47±4.32	5.55±3.93
ATIP3	Pipe	0.3±0.10	0.07±0.05	28.33±2.60	1.32±1.06	3.44±1.18	6.02±0.50	16.63±10.06	5.59±3.90
ATIP4	Pipe	0.35±0.05	0.06±0.03	27.33±5.77	1.72±1.50	3.55±0.63	6.26±0.45	12.58±5.62	5.35±3.72
ATIP5	Pipe	0.2±0.10	0.11±0.07	27.77±4.02	1.8±1.61	3.39±1.29	6.21±0.46	14.64±8.44	5.87±4.01
ATIP6	Pipe	0.28±0.15	0.11±0.11	30.22±1.02	2.01±1.92	14.94±19.41	11.11±9.66	11.52±2.54	15.92±14.98
WHO STD.		10	0.3	500	250	200	150	200	12

Detailed description of the results.

Nitrate Nitrogen levels recorded in water samples collected from water sources.

The nitrate nitrogen levels ranged from 0.2 to 0.35 mg/l in all the community drinking water sources in Atiteti. The maximum level was recorded in ATIP4 and the lowermost level in ATIP1.

Phosphate levels recorded in samples of water from water sources.

The level of phosphate concentration ranged from 0.07 to 0.24 mg/l in all the community drinking water sources in Atiteti. The highest level of phosphate was recorded in ATIP1 and the lowest in ATIP4.

Total Alkalinity levels recorded in water samples collected from water sources.

The levels of total alkalinity in the community ranged from 25.66 to 30.22 mg/l in all the community drinking water sources. The highest level of total alkalinity was found in ATIP6 and the lowest found in ATIP1.

Sulphate levels recorded in water samples collected from water sources.

The level of sulphate concentration ranged between 1.32 to 2.32 mg/l in all the community drinking water sources within the community. The highest level of sulphate was recorded in ATIP1 and the lowest recorded in ATIP3.

Calcium levels recorded in water samples collected from water sources.

The level of calcium concentration ranged between 3.33 to 14.94 mg/l in all the community drinking water sources located within Atiteti. The highest level of calcium was recorded in ATIP6 and the lowest recorded in ATIP1.

Magnesium levels recorded in water samples collected from water sources.

The level of magnesium concentration ranged from 6.02 to 11.11 mg/l in all the community drinking water sources in Atiteti. The highest level of magnesium was recorded in ATIP6 and the lowest recorded in ATIP3.

Sodium levels recorded in water samples collected from water sources.

The level of sodium concentration ranged from 11.47 to 16.43 mg/l in all the community drinking water sources in Atiteti. The highest level of sodium was recorded in ATIP1 and the lowest recorded in ATIP2.

Potassium levels recorded in water samples collected from water sources.

The level of potassium concentration ranged from 5.35 to 15.92 mg/l in all the community drinking water sources in Atiteti. The highest level of potassium was recorded in ATIP6 and the lowest recorded in ATIP4.

ANOVA for physico-chemical parameters of water samples from water sources in Atiteti.

ANOVA Table 19. Summary for Nitrogen Nitrate

Atiteti	Total N.	6
	Test Statistics	2.818[a]
	Degree of Freedom	2
	Asymptotic Sig	.244

ANOVA Table 19: indicates that the P -value in Atiteti is P-value > 0.05 hence there are no significant differences between the samples.

ANOVA Table 20. Summary for Phosphate

Atiteti	Total N	6
	Test Statistic	4.333[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.115

ANOVA Table 20: indicates. Atiteti has as a P-value>0.05 hence there are no significant differences between the samples.

ANOVA Table 21. Summary for Total Alkalinity

Atiteti	Total N.	6
	Test Statistic	4.957[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.084

ANOVA Table 21: indicates that the P -value in Atiteti is >0.05, which means that the total alkalinity concentration in each of the months sampled have no significant difference between them.

Anova Table 22. Summary for Sulphate

Atiteti	Total N.	6
	Test Statistics	10.333
	Degree Of Freedom	2
	Asymptotic Sig.	.006

Pairwise Comparison Test

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Atiteti	M3 SO_4^{2-}-M2 SO_4^{2-}	1.833	.577	3.175	.001	.004
	M3 SO_4^{2-}-M1 SO_4^{2-}	1.167	.577	2.021	.043	.130

ANOVA Table 22: indicates that the P -value in Atiteti is < 0.05, which means that the sulphate concentration in each of the month sampled are significantly different. Pairwise comparison test was done to find out in month the samples taken had differences. In Atiteti, the samples compared between August and May as well as August and March showed there were significant differences.

ANOVA Table 23. Summary for Calcium

Atiteti	Total N.	6
	Test Statistics	4.333[a]
	Degree of Freedom	2
	Asymptotic Sig	.115

ANOVA Table 23: indicates that Atiteti both have P-value > 0.05 hence there are no significant differences between the samples.

ANOVA Table 24. Summary for Magnesium

Atiteti	Total N.	6
	Test Statistics	5.333[a]
	Degree Of Freedom	2
	Asymptotic Sig.	.069

ANOVA Table 24: indicates that Atiteti has P-value >0.05 hence there are no significant differences between the samples.

Anova Table 25. Summary for Sodium

Atiteti	Total N.	6
	Test Statistics	10.333
	Degree of Freedom	2
	Asymptotic Sig.	.006

Pairwise Comparisons

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Atiteti	M3Na-M2Na	1.167	.577	2.021	.043	.130
	M3Na-M1Na	1.833	.577	3.175	.001	.004

ANOVA Table 25 indicates that the P -value in Atiteti is < 0.05, which means that the sodium concentration in each of the month sampled are significantly different. Pairwise comparison test was done to find out in which month the samples taken had differences. In Atiteti, the samples compared between August and May as well as the samples compared with August and March showed significant differences.

ANOVA Table 26. Summary for Potassium

Atiteti	Total N.	6
	Test Statistics	5.333[a]
	Degree of Freedom	2
	Asymptotic Sig.	.069

ANOVA Table 26: indicates that the P -value in Atiteti is > 0.05 which mean that there are no significant differences between the samples. Comparing the samples in a month to samples in the other months show no significant difference.

Table 4.1.1 5 Mean levels of the indicated physico-chemical parameters in the water samples from the community drinking water sources in Anyanui.

CODE	Water Sources	Conductivity (ms/l)	Salinity (ppt)	D.O (mg/l)	TDS (mg/l)	pH
ANYW1	Well	0.295±0.18	0.15±0.1	3.69±2.27	0.192±0.12	7.61±5.10
ANYW2	Well	0.305±0.12	0.1±0.06	2.86±0.03	0.154±0.06	9.08±0.13
ANYW3	Well	1.06±0.96	0.6±0.46	2.88±1.69	0.792±0.58	9.01±5.22
ANYW4	Well	1.763±0.39	0.8±0.23	2.73±0.58	1.131±0.26	7.71±1.06
ANYW5	Well	1.463±0.13	0.7±0.12	2.87±0.46	0.937±0.09	9.43±0.44
ANYW6	Well	0.256±0.03	0.1±0.00	2.72±0.62	0.131±0.02	9.44±0.48
ANYW7	Well	0.441±0.30	0.2±0.15	2.55±1.54	0.411±0.24	7.38±4.91
ANYW8	Well	0.543±0.05	0.2±0.06	2.78±0.32	0.329±0.01	9.01±1.37
ANYW9	Well	1.305±1.09	0.7±0.57	3.06±1.88	0.825±0.69	9.71±5.65
ANYP1	Pipe	0.062±0.04	0±0	4.36±0.31	0.218±0.29	9.69±0.51
ANYP2	Pipe	0.087±0.01	0±0	4.38±0.02	0.05±0.01	10.13±0.47
ANYP3	Pipe	0.075±0.05	0±0	3.98±2.31	0.041±0.03	9.66±5.58
ANYP4	Pipe	0.085±0.05	0±0	4.63±2.67	0.055±0.03	9.91±5.72
ANYP5	Pipe	0.077±0.05	0±0	4.62±2.65	0.055±0.03	10.05±5.76
WHO Standards		0.8	0.2	6.5-8	<0.3-0.6	6.5 – 8.5

Details of the results presented in the table are as follows:

Conductivity levels recorded in water samples collected from water sources.

The level of conductivity ranged from 0.62 to 1.763 mgS/cm in all the community drinking water sources in Anyanui. With the wells, the drinking water sampled ranged from 0.256 to 1.763 mgS/cm, with the highest level recorded in ANYW4 and the lowest in ANYW6. With the pipes, the water sampled ranged from 0.062 to 0.087 mgS/cm, with the highest level recorded in ANYP2 and the lowest in ANYP1.

Salinity levels recorded in water samples collected from water sources.

The level of salinity ranged from 0 to 0.8 ppt in all the community drinking water sources in Anyanui. With the wells, the drinking water sampled ranged from 0.1 to 0.8 ppt, with the highest level recorded in ANYW4 and the lowest in, ANYW2 and ANYW6. With the pipes, there the drinking water sampled had no record of salinity.

Dissolved Oxygen levels recorded in water samples collected from water sources.

The level of dissolved oxygen ranged from 2.55 to 4.63 mg/l in all the community drinking water sources in Anyanui. With the wells, the drinking water sampled ranged between 2.5 to 3.69 mg/l, with the highest level recorded in ANYW1 and the lowest in ANYW7. With the pipes, the level of dissolved oxygen content in the water sampled ranged between 3.98 to 4.62 mg/l, with the highest level recorded in ANYP5 and the lowest in ANYP3.

Total Dissolved Solids levels recorded in water samples collected from water sources.

The level of total dissolved solids ranged from 0.04 to 1.131 mg/l. in all the community drinking water sources in Anyanui. With the wells, the drinking water sampled ranged from 0.131 to 1.131 mg/l, with the highest level recorded in ANYW6 and the lowest in, ANYW4. With the pipes, the level of total dissolved solids in the water sampled ranged from 0.04 to 0.218 mg/l, with the highest level recorded in ANYP1 and the lowest in ANYP3.

pH

The level of pH ranged from 7.38 to 10.13 in all the community drinking water sources in Anyanui. With the wells, the drinking water sampled ranged between 7.38 to 9.71, with the highest level recorded in ANYW9 and the lowest in ANYW7. With the pipes, the level of pH in the water sampled ranged from 9.66 to 10.13, with the highest level recorded in ANYP2 and the lowest in ANYP3.

ANOVA for physical and chemical parameters of water samples from water sources in Anyanui.

ANOVA Table 27. Summary for Conductivity

Anyanui	Total N	7
	Test Statistic	1.333[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.513

ANOVA Table 27; indicates that the P -value in Anyanui is > 0.05, which means that for the concentration levels of conductivity, there were no significant differences between the samples in the sampling period.

ANOVA Table 28. Summary for Salinity

Anyanui	Total N	7
	Test Statistic	2.000[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.368

ANOVA Table 28; indicates that the P -value in Anyanui is > 0.05, which means that for the concentration levels of salinity, there were no significant differences between the samples in the sampling period.

ANOVA Table 29. Summary for Dissolved Oxygen

Anyanui	Total N	7
	Test Statistic	1.000[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.607

ANOVA Table 29; indicates that the P -value in Anyanui is > 0.05, which means that for the concentration Dissolved Oxygen, there were no significant differences between the samples in the sampling period.

ANOVA Table 30. Summary for Total Dissolved Solids

Anyanui	Total N	7
	Test Statistic	.609[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.738

ANOVA Table 30; indicates that the P -value in each Anyanui is >0.05, which means that for the concentration total dissolved solids, there were no significant differences between the samples in the sampling period.

ANOVA Table 31. Summary for pH

Anyanui	Total N	7
	Test Statistic	1.455[a]
	Degree Of Freedom	2
	Asymptotic Sig. (2-sided test)	.483

ANOVA Table 31; has a P-value> 0.05 hence there are no significant differences between the samples.

Table 4.1.1 6. Mean results of the indicated physico-chemical parameters in the water samples from the community drinking water sources in Anyanui.

CODE	Water Source	NO_3-N (mg/l)	PO_4^{3-} (mg/l)	Total Alkalinity (mg/l)	SO_4^{2-} (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)
ANYW1	Well	0.43±0.30	0.11±0.09	40.16±28.85	30±17.78	42.57±44.78	24.86±21.01	60.33±36.90	12.89±11.30
ANYW2	Well	0.84±0.31	0.14±0.08	48.33±31.32	37±24.25	31.28±49.25	22.61±27.06	42.09±12.89	9.27±12.30
ANYW3	Well	1.03±0.76	0.22±0.13	41.33±27.83	25.16±18.95	56.04±47.58	47.09±36.87	32.88±22.27	11.32±9.39
ANYW4	Well	1.38±0.37	0.23±0.07	83.33±64.38	160.24±83.03	52.67±22.01	42.22±38.82	68.13±60.99	28.46±26.37
ANYW5	Well	2.08±1.22	0.44±0.51	51.22±31.12	113.58±52.48	58.76±17.51	65.31±20.24	66.47±49.72	34.88±36.43
ANYW6	Well	0.46±0.32	0.09±0.10	44.22±17.51	28.37±20.76	29.58±39.56	26.65±27.84	40.25±16.41	26.47±19.56
ANYW7	Well	0.81±0.51	0.1±0.07	58±34.02	63.83±36.92	47.82±48.45	26.61±27.51	60.16±34.76	24±21.34
ANYW8	Well	0.87±0.29	0.17±0.14	61.55±10.08	77.14±17.49	35.28±39.36	32.08±32.14	67.71±20.15	13.23±16.39
ANYW9	Well	2.5±2.39	0.3±0.21	41.5±30.27	71±65.43	54.69±56.99	37.53±38.48	49.53±34.39	18.69±15.75
ANYP1	Pipe	0.53±0.31	0.11±0.12	21.22±8.48	1.03±0.22	4.38±1.88	7.04±2.73	16.99±14.47	3.49±3.11
ANYP2	Pipe	0.24±0.15	0.11±0.09	20.44±5.88	0.9±0.36	4.14±0.11	5.65±0.10	7.88±1.19	4.34±2.34
ANYP3	Pipe	0.31±0.18	0.09±0.06	22±13.32	1.08±1.11	19.71±19.08	5.713±3.33	6.31±3.76	6.5±4.37
ANYP4	Pipe	0.32±0.23	0.03±0.04	22.1±9.64	4.13±5.97	3.91±0.85	5.13±0.30	27.8±33.51	13.8±17.03
ANYP5	Pipe	0.2±0.15	0.06±0.07	17.66±10.29	0.16±0.10	11.83±10.88	11.03±8.37	14.73±10.29	8.18±8.46
WHO STD		10	0.3	500	250	200	150	200	12

Details of the results are as follows:

Nitrate Nitrogen levels recorded in water samples collected from water sources.

The nitrate nitrogen levels ranged from 0.2 to 2.08 mg/l in all sources of community drinking water. With the wells, the level of nitrate nitrogen in the water sampled ranged from 0.43 to 2.08 mg/l, with the highest level recorded in ANYW9 and the lowest in ANYW1. With the pipes, the drinking water sampled ranged from 0.2 to 0.53 mg/l, with the highest recorded in ANYP1 and the lowest recorded in ANYP5.

Phosphate levels recorded in water samples collected from water sources.

The phosphate levels ranged from 0.03 to 0.44 mg/l in all sources of community drinking water in Anyanui. With the Wells, the level of phosphate in the drinking water sampled ranged from 0.1 to 0.44 mg/l, with the highest level recorded in ANYW5 and the lowest in ANYW6. With the Pipes, the drinking water sampled ranged from 0.03 to 0.11 mg/l, with the highest recorded in ANYP1 and ANYP2 and the lowest in ANYP4.

Total Alkalinity levels recorded in water samples collected from water sources.

The total alkalinity levels ranged from 17.66 to 61.55 mg/l in all community sources of drinking water in Anyanui. With the wells, the level of total alkalinity in the drinking water sampled ranged from 40.16 to 83.33 mg/l, with the highest level recorded in ANYW4 and the lowest in ANYW1. With the pipes, the drinking water sampled ranged from 17.66 to 22.1 mg/l, with the highest recorded in ANYP4 and the lowest in ANYP5.

Sulphate levels recorded in water samples collected from water sources.

The sulphate levels ranged from 0.16 to 160.24 mg/l in all sources of community drinking water in Anyanui. With the wells, the level of sulphate in the drinking water sampled ranged from 25.16 to 160.24 mg/l, with the highest level recorded in ANYW4 and the lowest in ANYW3. With the pipes, the drinking water sampled ranged between 0.16 to 4.13 mg/l, with the highest recorded in ANYP4 and the lowest in ANYP5.

Calcium levels recorded in water samples collected from water sources.

The calcium levels ranged from 3.91 to 58.76 mg/l in all community sources of drinking water in Anyanui. With the wells, the level of calcium in the drinking water sampled ranged from 29.58 to 58.76 mg/l, with the highest level recorded in ANYW5 and the lowest in ANYW6. With the pipes, the drinking water sampled ranged from 3.91 to 19.71 mg/l, with the highest recorded in ANYP3 and the lowest in ANYP4.

Magnesium levels recorded in water samples collected from water sources.

The magnesium levels ranged from 5.13 to 65.31 mg/l in all community sources of drinking water in Anyanui. With the wells, the level of magnesium in the drinking water sampled ranged 22.61 to 65.31 mg/l, with the highest level recorded in ANYW5 and the lowest in ANYW6. With the pipes, the drinking water sampled ranged from 5.13 to 7.04 mg/l, with the highest recorded in ANYP1 and the lowest in ANYP4.

Sodium levels recorded in water samples collected from water sources.

The sodium levels ranged from 6.31 to 68.13 mg/l in all community sources of drinking water in Anyanui. With the wells, the level of sodium in the drinking water sampled ranged from 32.88 to 68.13 mg/l, with the highest level recorded in ANYW4 and the lowest in ANYW3. With the pipes, the drinking water sampled ranged from 6.31 to 16.99 mg/l, with the highest recorded in ANYP4 and the lowest in ANYP3.

Potassium levels recorded in water samples collected from water sources.

The potassium levels ranged from 3.49 to 34.88 mg/l in all community sources of drinking water in Anyanui. With the wells, the level of potassium in the drinking water sampled ranged from 9.27 to 34.88 mg/l, with the highest level recorded in ANYW5 and the lowest in ANYW2. With the pipes, the drinking water sampled ranged from 3.49 to 13.8 mg/l, with the highest recorded in ANYP4 and the lowest in ANYP1.

ANOVA for physical and chemical parameters of water samples from water sources in Anyanui.

ANOVA Table 32. Summary for Nitrogen Nitrate

Anyanui	Total N	14
	Test Statistic	2.392[a]
	Degree Of Freedom	2
	Asymptotic Sig	.302

ANOVA Table 32: indicates that the P -value in Anyanui is P-value> 0.05 hence there are no significant differences between the samples.

ANOVA Table 33. Summary for Phosphate

Anyanui	Total N	14
	Test Statistic	8.440
	Degree Of Freedom	2
	Asymptotic Sig	.015

Pairwise Comparisons

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyanui	M3 PO_4^{3-}-M1 PO_4^{3-}	1.036	.378	2.740	.006	.018

ANOVA Table 33: indicates the P -value in Anyanui is <0.05, which means that the phosphate concentration in each of the months sampled are significantly different. Pairwise comparison test was done to find out in which month the samples taken had differences. Samples compared between August and March showed the significant difference.

ANOVA Table 34. Summary for Total Alkalinity

Anyanui	Total N	14
	Test Statistic	.148[a]
	Degree Of Freedom	2
	Asymptotic Sig	.929

ANOVA Table 34: indicates that the P -value in Anyanui is >0.05, which means that the total alkalinity concentration in each of the months sampled have no significant difference between them.

ANOVA Table 35. Summary for Sulphate

Anyanui	Total N.	14
	Test Statistic	1.333[a]
	Degree Of Freedom	2
	Asymptotic Sig	.513

ANOVA Table 35: indicates that Anyanui has P-value> 0.05 hence there are no significant differences between the samples.

ANOVA Table 36. Summary for Calcium

Anyanui	Total N	14
	Test Statistic	12.444
	Degree Of Freedom	2
	Asymptotic Sig.	.002

Pairwise Comparisons

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyanui	M3 Ca-M2 Ca	1.286	.378	3.402	.001	.002
	M1 Ca-M2 Ca	-.857	.378	-2.268	.023	.070

ANOVA Table 36 indicates that the P-value in Anyanui is < 0.05, which means that the calcium concentration in each of the month sampled are significantly different. Pairwise comparison test was done to find out in which month the samples taken had differences. In Anyanui, the samples compared between August and May as well as the samples compared with March and May showed significant differences

ANOVA Table 37. Summary for Magnesium

Anyanui	Total N	14
	Test Statistic	3.111[a]
	Degree Of Freedom	2
	Asymptotic Sig	.211

ANOVA Table 37: indicates Anyanui has P-value>0.05 hence there are no significant differences between the samples.

ANOVA Table 38. Summary for Sodium

Anyanui	Total N.	14
	Test Statistic	.444[a]
	Degree Of Freedom	2
	Asymptotic Sig	.801

ANOVA Table 38: indicates Anyanui has P-value > 0.05 hence there are no significant differences between the samples. Pairwise comparison test was done to find out in month the samples taken had differences

ANOVA Table 39. Summary for Potassium

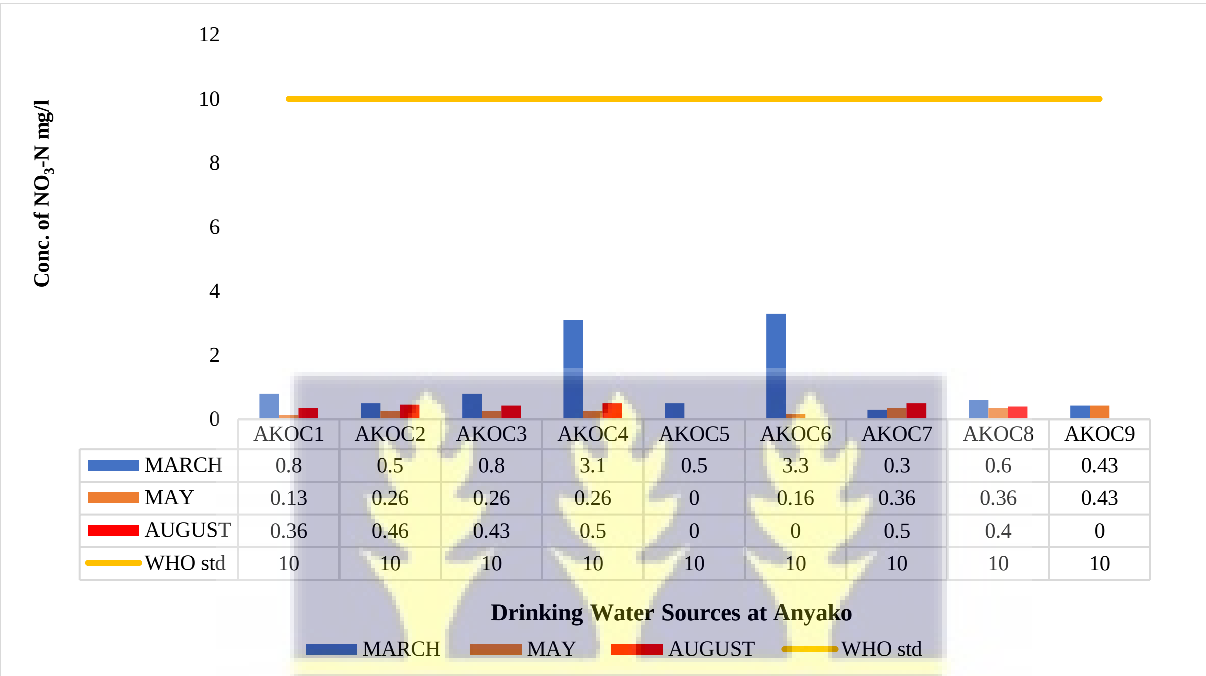
Anyanui	Total N.	14
	Test Statistic	3.111[a]
	Degree Of Freedom	2
	Asymptotic Sig	.211

ANOVA Table 39: indicates that the P -value in Anyanui > 0.05 which mean that there are no significant differences between the samples. Comparing the samples in a month to samples in the other months show no significant difference.

4.1.2 Monthly Levels of Chemical Parameters Concentration within the Community Drinking Water Sources in Each Study Area.

ANYAKO

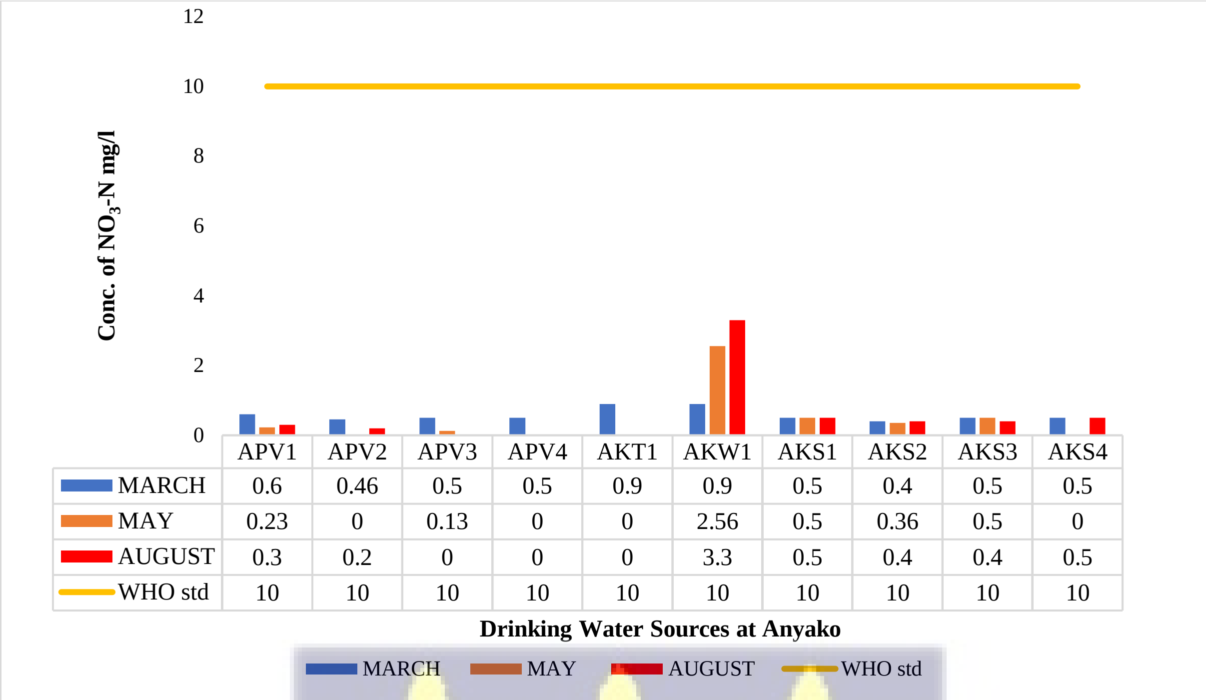
Nitrate nitrogen



	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	0.8	0.5	0.8	3.1	0.5	3.3	0.3	0.6	0.43
MAY	0.13	0.26	0.26	0.26	0	0.16	0.36	0.36	0.43
AUGUST	0.36	0.46	0.43	0.5	0	0	0.5	0.4	0
WHO std	10	10	10	10	10	10	10	10	10

Figure 4.1.2 1**.** A Bar chart showing monthly concentration levels of nitrate nitrogen in the community drinking water sources in Anyako:

The level of nitrate nitrogen varied in all the community drinking water sources during the sampling period. With the commercial poly-tanks, the level of nitrate nitrogen in the drinking water sampled ranged from 0.3 to 3.3 mg/ in March and from 0 - 0.43 mg/l in May and 0 to 0.5mg/l in August. The highest concentration was recorded in AKOC6, AKOC9 and AKOC7 within March, May and August respectively whilst the lowest was recorded in AKOC7, AKOC5 and AKOC9 in March, May and August. All the sources were within the WHO standard.

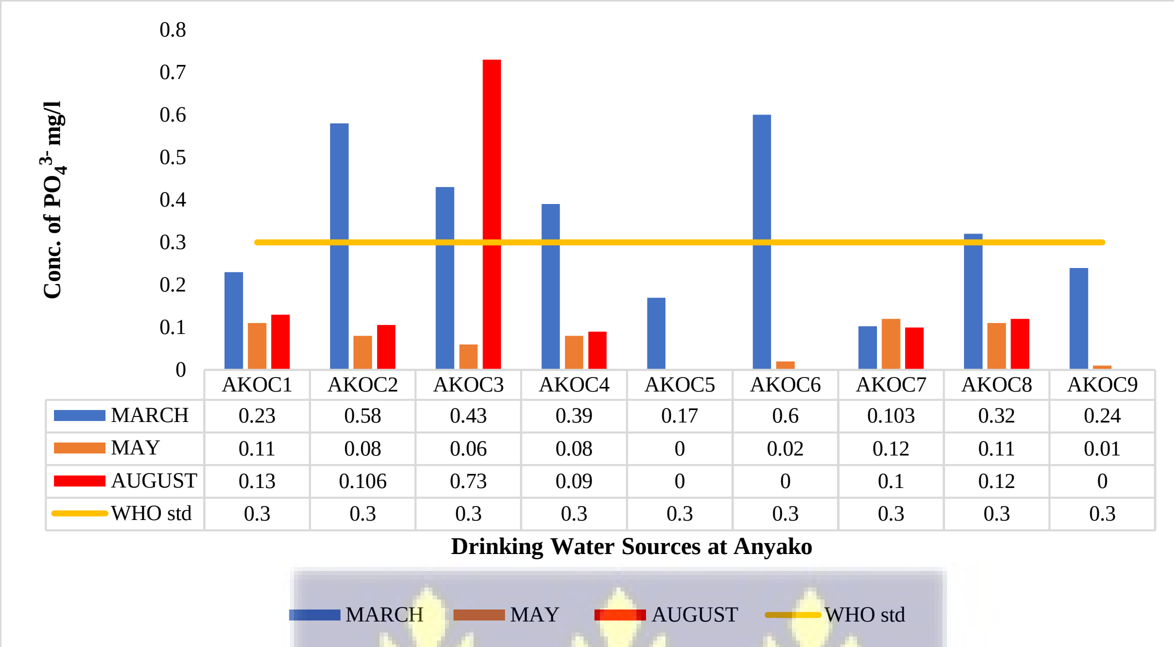


	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	0.6	0.46	0.5	0.5	0.9	0.9	0.5	0.4	0.5	0.5
MAY	0.23	0	0.13	0	0	2.56	0.5	0.36	0.5	0
AUGUST	0.3	0.2	0	0	0	3.3	0.5	0.4	0.4	0.5
WHO std	10	10	10	10	10	10	10	10	10	10

Figure 4.1.2 2 A Bar chart showing monthly concentration levels of nitrate nitrogen in the community drinking water sources in Anyako:

The level of concentration of nitrate nitrogen within the private poly-tanks ranged from 0 – 0.6 in March, 0 – 0.23 mg/l in May and 0 – 0.3 mg/l in August with the highest concentration for each month recorded at APV1. With the samples from the sachet, the concentrations ranged from 0.4mg/l- 0.5 mg/l in March, 0 - 0.5 mg/l in May, and 0.4 mg/l – 0.5mg/l in August. The highest concentration in March and May was recorded at AKS1 and AKS3 and in August recorded at AKS1 and AKS4. The lowest concentration was recorded in the rest of the sources for the month of March and August, whilst in May the lowest was recorded at AKS4. With the reservoir and the well, in March they both recorded a value of 0.9mg/l and in May, 0 and 2.56 mg/l and in August, 0 and 3.3 mg/l respectively. The sources all had values within the required WHO standard.

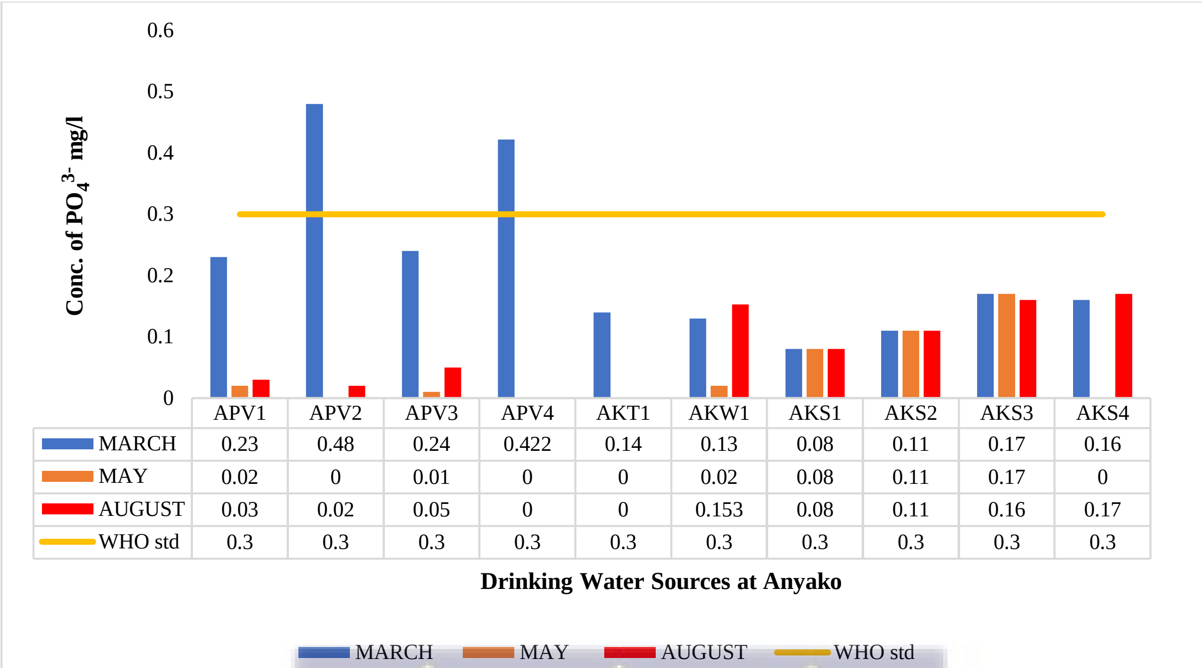
Phosphate



	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	0.23	0.58	0.43	0.39	0.17	0.6	0.103	0.32	0.24
MAY	0.11	0.08	0.06	0.08	0	0.02	0.12	0.11	0.01
AUGUST	0.13	0.106	0.73	0.09	0	0	0.1	0.12	0
WHO std	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Figure 4.1.2 3. A Bar chart showing monthly concentration levels of phosphate in the community drinking water sources in Anyako

The range of the concentration levels of phosphate differ in each community drinking water source within the community, and in the months sampled. With the commercial poly-tanks, the levels ranged from 0.17 mg/l to 0.103 mg/l in the first month which is March with the highest and lowest recording in AKOC7 and AKOC5 respectively. In May, the levels ranged from 0 to 0.12 mg/l with the highest and the lowest recorded in AKOC7, and August which had the highest and lowest recorded in AKOC3 and AKOC5, AKOC6, AKOC9 respectively. With the commercial poly-tanks, AKOC2, AKOC3, AKOC4 AKOC6 and AKOC8 fell out of the WHO standard in March, they were all within standard in May and in August.



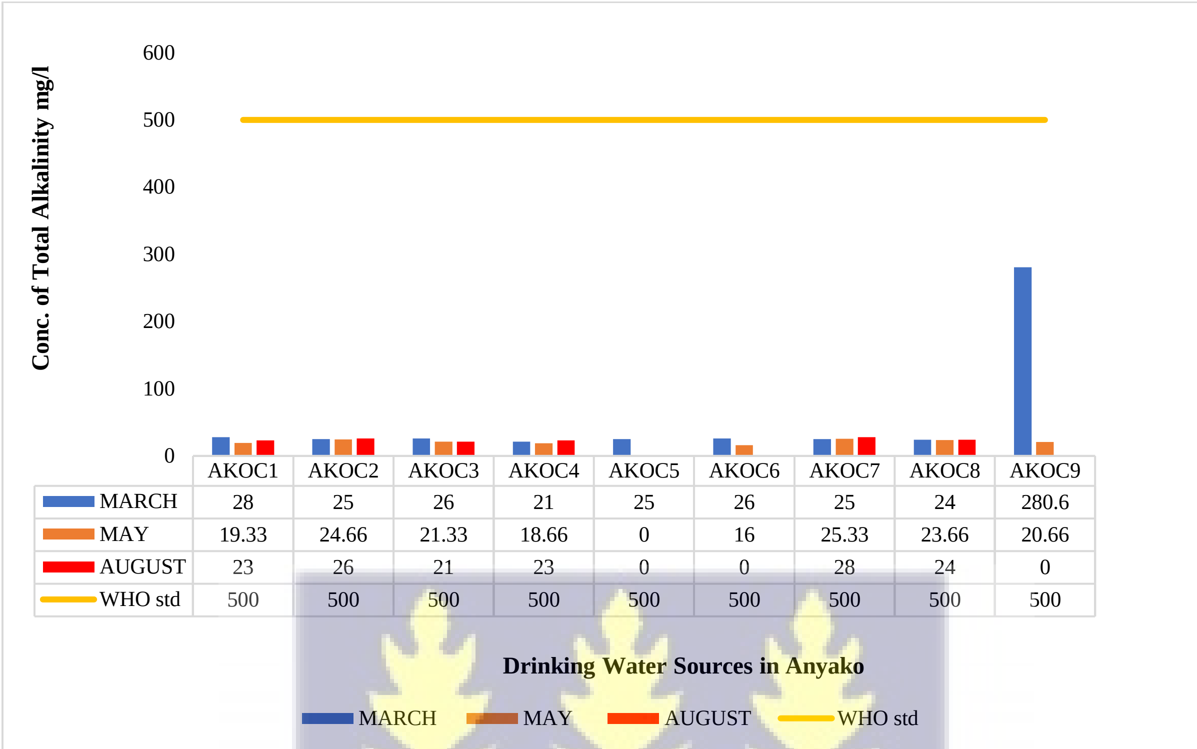
	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	0.23	0.48	0.24	0.422	0.14	0.13	0.08	0.11	0.17	0.16
MAY	0.02	0	0.01	0	0	0.02	0.08	0.11	0.17	0
AUGUST	0.03	0.02	0.05	0	0	0.153	0.08	0.11	0.16	0.17
WHO std	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Figure 4.1.2 4. Monthly levels of phosphate in the community drinking water sources in Anyako:

The levels of phosphate with the private poly-tanks, ranged from 0.23 mg/l to 0.48 mg/l in March with the highest and lowest recorded in APV2 and APV1, May from 0 to 0.02 mg/l with the highest in APV1 and the lowest in APV2 and APV4 and during August from 0 to 0.05 mg/l, with the highest recorded in APV3 and the lowest in APV4.

The sachet water samples had their ranges from 0.11 mg/l -0.17 mg/l in March and August and from 0 to 0.17 mg/l in May. The highest level in March and in May was recorded at AKS3 and AKS4 in August. The reservoir and the well had values of 0.14 mg/l and 0.13 mg/l respectively in March and 0 and 0.02 mg/l in May and 0 and 0.153 mg/l in August. In March APV2 and APV4 fell out of the WHO standard though the rest were within during the other months sampled.

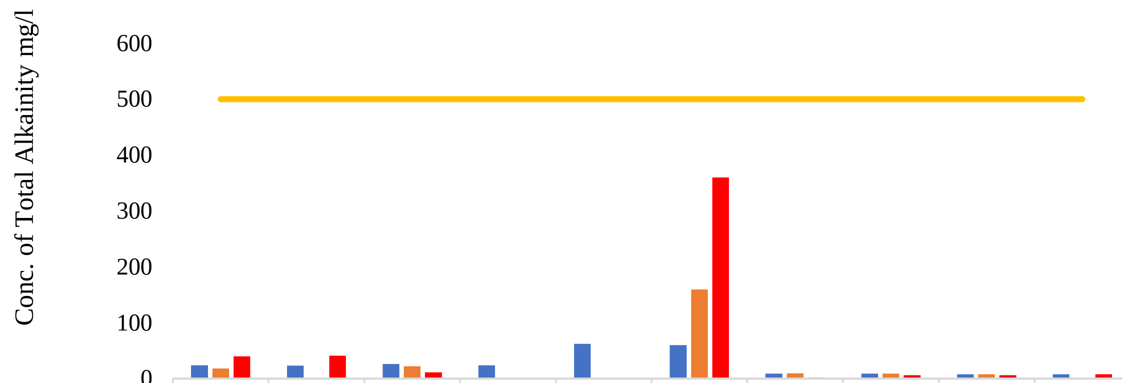
Total Alkalinity



	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	28	25	26	21	25	26	25	24	280.6
MAY	19.33	24.66	21.33	18.66	0	16	25.33	23.66	20.66
AUGUST	23	26	21	23	0	0	28	24	0
WHO std	500	500	500	500	500	500	500	500	500

Figure 4.1.2 5. A Bar chart showing monthly levels of total alkalinity in the community drinking water sources in Anyako:

The concentration levels of total alkalinity ranged from ranged from 0 to 280 mg/l in all the community drinking water sources in Anyako during the sampling period. With the commercial poly-tanks, the level of total alkalinity in the drinking water sampled ranged from 21 to 280 mg/l in March, with the highest recorded in AKOC9 and the lowest in AKOC4. May had levels which ranged from 0 to 24.66 mg/l with the highest recorded in AKOC2 and the lowest in AKOC5. The month of August also had levels which ranged from 0 to 28 mg/l with the highest recorded at AKOC7 and the lowest in both AKOC5 and AKOC6. All the sources were within the WHO standard.



	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	24	23	26	24	62	60	9	9	8	8
MAY	18	0	22	0	0	159.33	9.33	8.66	7.66	0
AUGUST	40	41	11	0	0	360	2	6	6	8
WHO std	500	500	500	500	500	500	500	500	500	500

Drinking Water Sources in Anyako

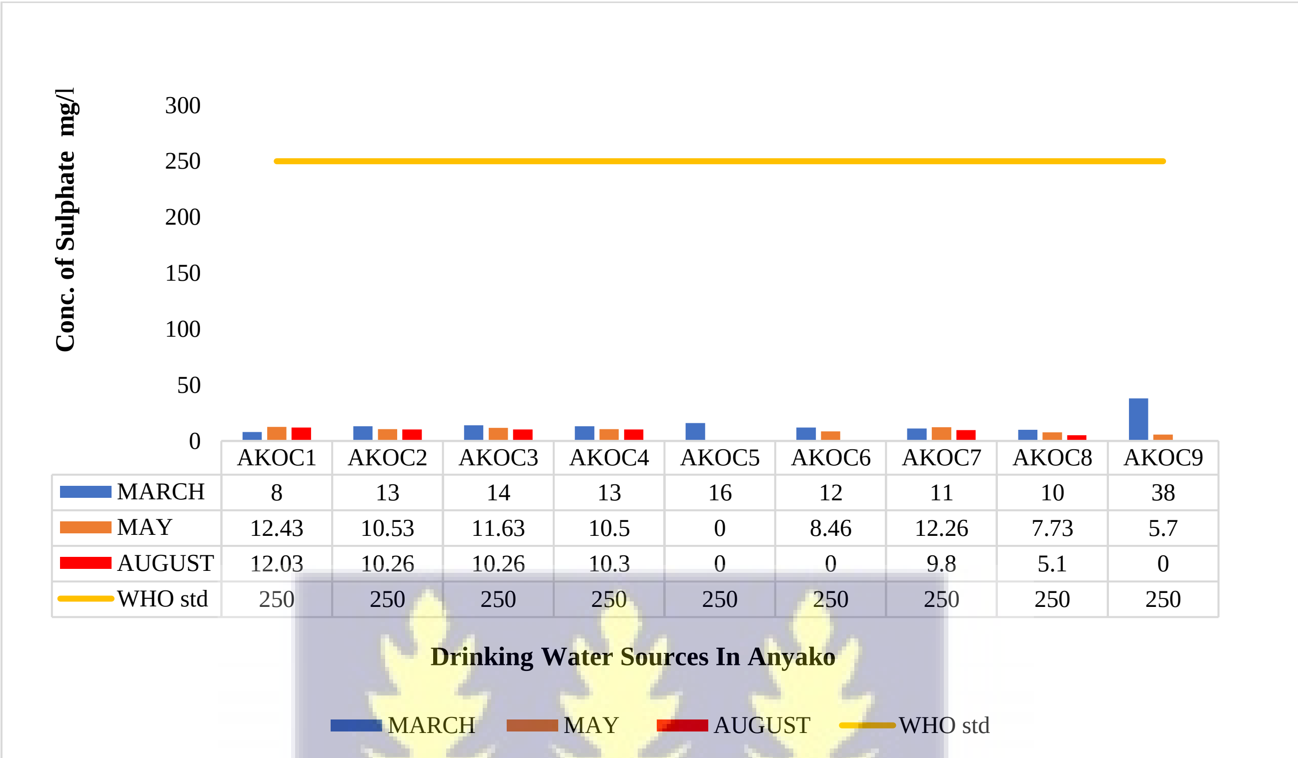
MARCH MAY AUGUST WHO std

Figure 4.1.2 6 A Bar chart showing monthly levels of total alkalinity in the community drinking water sources in Anyako

The level of concentration for the total alkalinity of the water sampled from with the private poly-tanks, ranged from 23 to 26 mg/l in March with the highest level recorded in APV3 and the lowest in APV2. In May and in August, the levels ranged from 0 to 22 mg/l with the highest in APV3 and from 0 to 41 mg/l with the highest in APV2 and the lowest in APV4 respectively.

The range of total alkalinity level in the drinking water samples sourced from the well and the reservoir, recorded as 60 mg/l and 62 mg/l respectively in March, 159.33 mg/l and 0 in May and lastly in August at 360 mg/l and 0. The water samples from the sachet had total alkalinity levels ranging from 8-9 mg/l in March with the highest recorded in AKS1 and AKS2 and the lowest in the remaining sachet water samples, from 0 to 7.66 mg/l in May with the highest recorded in AKS1 and the lowest in AKS4 and lastly from 2 mg/l to 8 mg/l in August with the highest in AKS4 and the lowest recorded in AKS1. In each of the months sampled, the water from the drinking water sources had levels within the required standard for total alkalinity.

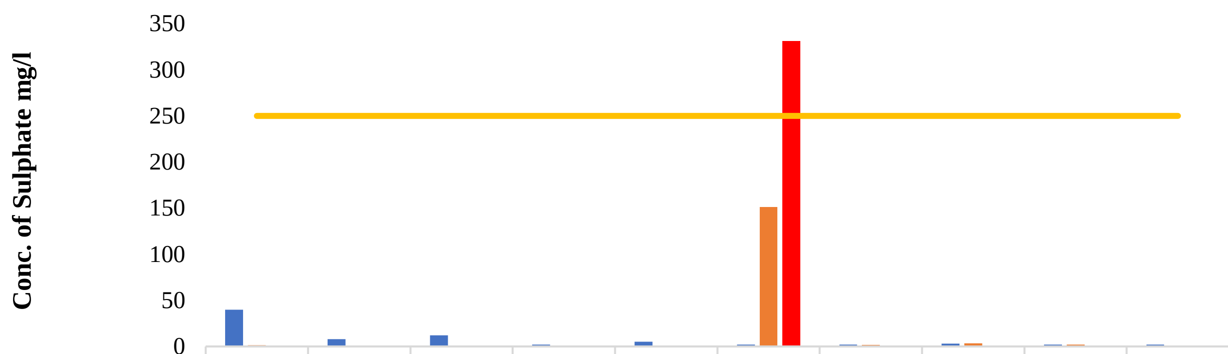
Sulphate



	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	8	13	14	13	16	12	11	10	38
MAY	12.43	10.53	11.63	10.5	0	8.46	12.26	7.73	5.7
AUGUST	12.03	10.26	10.26	10.3	0	0	9.8	5.1	0
WHO std	250	250	250	250	250	250	250	250	250

Figure 4.1.2 7. A Bar chart showing monthly concentration of sulphate in the community drinking water sources in Anyako

The level of sulphate ranged from 0 to 151.2 mg/l in all the community drinking water sources in Anyako during the sampling period. With the commercial poly-tanks, the level of sulphate in the drinking water sampled ranged from March, May and August, with values of 8 mg/l to 38 mg/l, 0 to 12.26 mg/l and 0 to 12.03 mg/l respectively. The highest recorded in March was from AKOC9 and the lowest in AKOC1, in May the highest was from AKOC7 and the lowest AKOC5 and in August the highest was from AKOC1 and the lowest in AKOC5, AKOC6 and AKOC9 all the samples had levels within the WHO standard of drinking water.



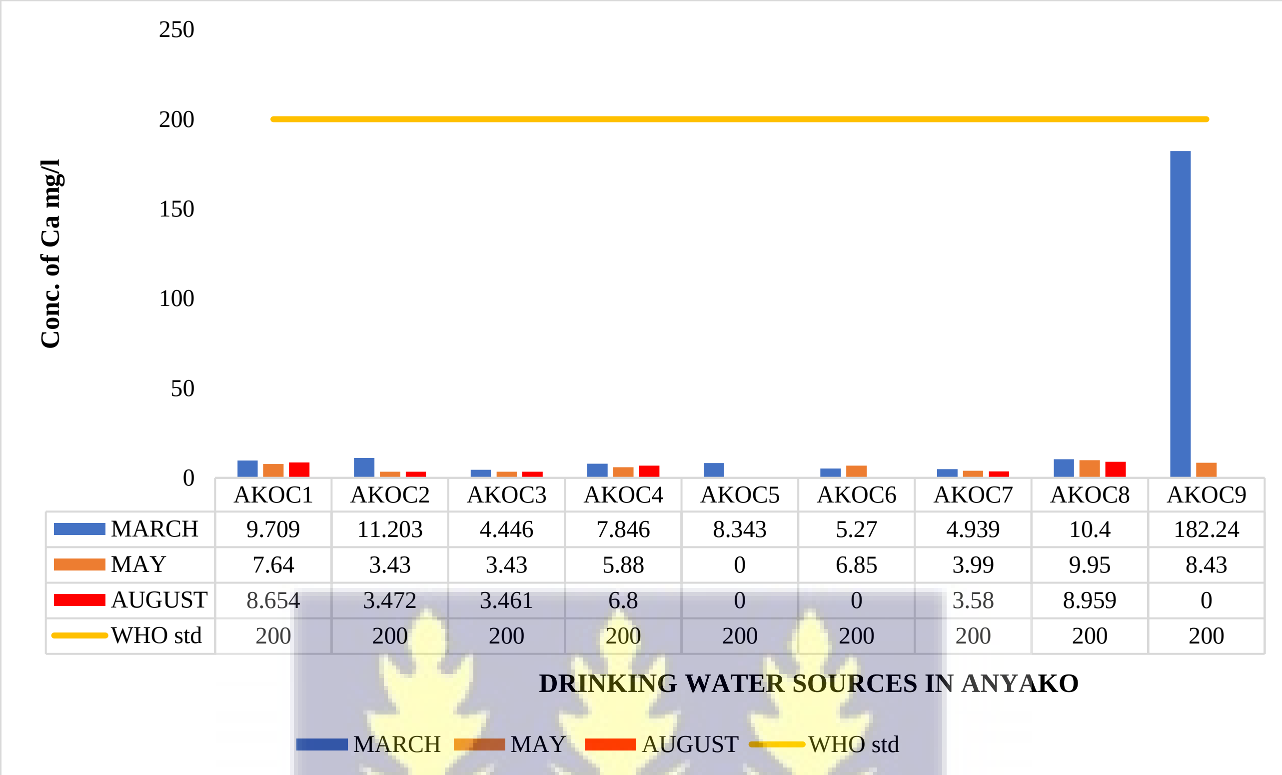
	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	40	8	12	2	5	2	2	3	2	2
MAY	1.23	0	0	0	0	151.2	1.66	3.33	2	0
AUGUST	0	0	0	0	0	331	0	0	0	0
WHO std	250	250	250	250	250	250	250	250	250	250

Figure 4.1.2 8. A Bar chart showing monthly concentration of sulphate in the community drinking water sources in Anyako

The range of the sulphate levels within the water sampled from the private poly-tanks, ranged from 0 to 331 mg/l during the months that the samples were collected. In the first month, March, the levels ranged from 2 mg/l to 40 mg/l with the highest recorded in APV1 and the lowest recorded in APV4. In May the only one source which was APV1 had and record of sulphate within it and in August, no source had sulphate within it.

The range of sulphate level in the drinking water samples sourced from the well AKW1 and the reservoir, AKT1 recorded as 2 mg/l and 5 mg/l respectively in March. In May and August there was no recording for the water sampled from the reservoir, but the samples from the well had a record of 151.2 mg/l and 331 mg/l respectively. In August, the level of the water sampled from the Well was above the standard according to WHO, the other sources within the months sampled were all within the standard. The water samples from the sachet also had sulphate levels ranging from 2 to 3 mg/l in March with the highest level recorded in AKS2 and the rest recording the same in May the highest which was 3.33 mg/l was recorded in AKS2 and the lowest in AKS4. In August there was no record of sulphate within the samples.

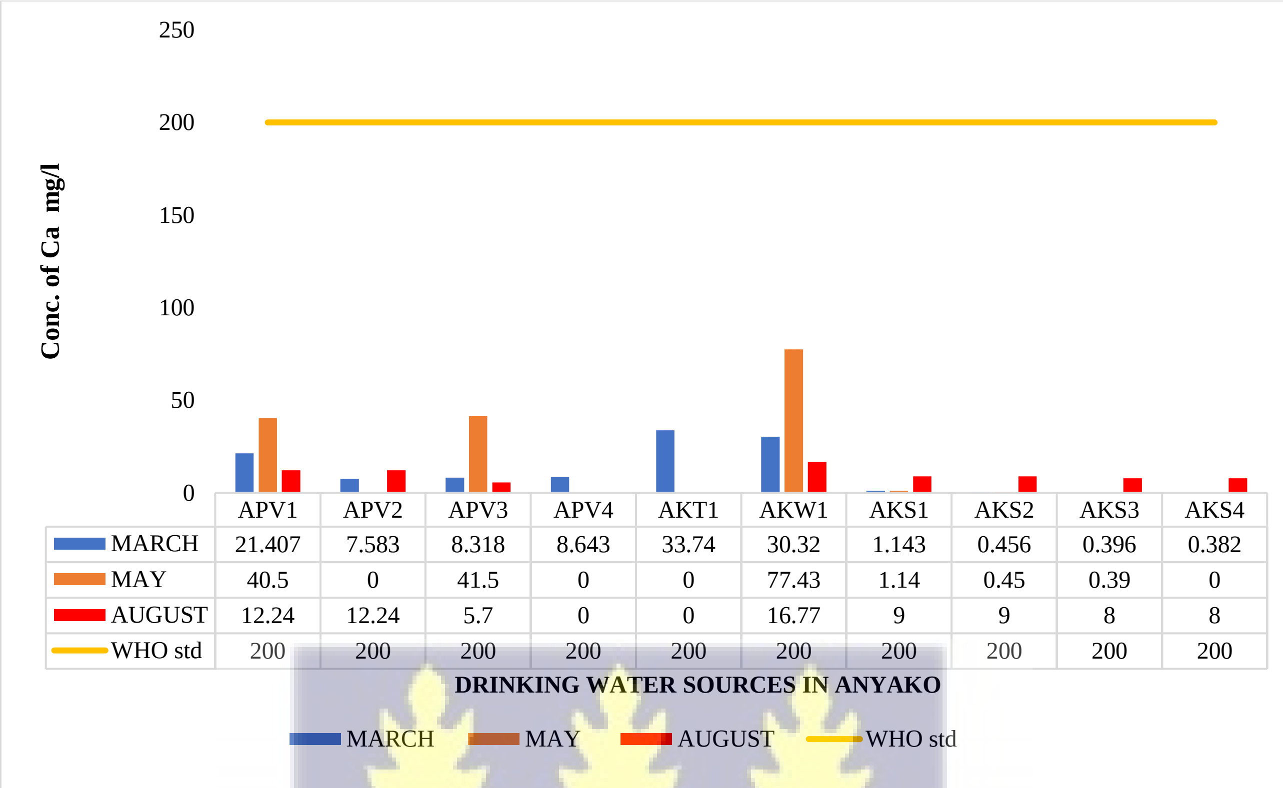
Calcium



	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	9.709	11.203	4.446	7.846	8.343	5.27	4.939	10.4	182.24
MAY	7.64	3.43	3.43	5.88	0	6.85	3.99	9.95	8.43
AUGUST	8.654	3.472	3.461	6.8	0	0	3.58	8.959	0
WHO std	200	200	200	200	200	200	200	200	200

Figure 4.1.2 9. A Bar chart showing monthly concentration of calcium in the community drinking water sources in Anyako.

The levels of calcium in the water samples ranged from 0.38 to 182.2 mg/l. in all the community drinking water sources in March, in May it ranged from 0 to 9.95 mg/l and from 0 to 8.959 mg/l in August. With the commercial poly-tanks, the level of calcium in the drinking water sampled ranged from 0 to 182.24 mg/l. it ranged from 4.446 mg/l to 182.24 mg/l with the highest recorded in AKOC9 and the lowest in AKOC3 in March, 0 to 9.95 mg/l in May, with the highest level recorded in AKOC8 and the lowest recorded in AKOC5 and 0 to 8.959 mg/l in August, with the highest recorded in water sampled from AKOC8 and the lowest in AKOC5. All the sources of drinking water sampled had levels of calcium that were within the required standard of drinking water according to WHO.



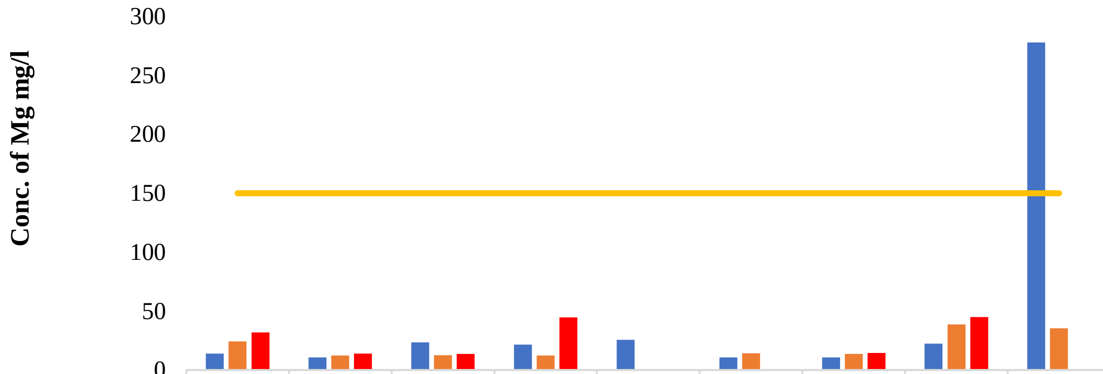
	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	21.407	7.583	8.318	8.643	33.74	30.32	1.143	0.456	0.396	0.382
MAY	40.5	0	41.5	0	0	77.43	1.14	0.45	0.39	0
AUGUST	12.24	12.24	5.7	0	0	16.77	9	9	8	8
WHO std	200	200	200	200	200	200	200	200	200	200

Figure 4.1.2 10 Bar chart showing monthly concentration of calcium in the community drinking water sources in Anyako.

The level of concentration within the water sampled from the private poly-tanks, was from 7.583 mg/l to 21.41 mg/l in March, with the highest level recorded in APV1 and the lowest in APV2. In May, the range was from 0 to 40.5 mg/l with the highest level recorded in APV1 and the lowest in APV2 and APV4.The range of calcium level in the drinking water samples sourced from the well and the reservoir, recorded as 30.32 mg/l and 33.77 mg/l respectively in March. In May and in August, there was no record of calcium within the samples from the reservoir though within the samples from the wells, there were levels of 77.43 mg/l and 16.77 mg/l respectively.

The water samples from the sachet had calcium levels ranging between 0.4 to 1.143 mg/l in March with the highest level recorded in AKS1 and the lowest in AKS4. In May the level of concentration was from 0 to 1.14 mg/l, the highest was from AKS1 and the lowest which had no record was AKS4. In August, the range was between 8 mg/l to 9 mg/l. AKS1 and AKS2 recorded the highest levels and AKS3 and AKS4 recorded the lowest levels. Within each of the three months, the drinking sources had level within the WHO standard of 200 mg/l.

Magnesium

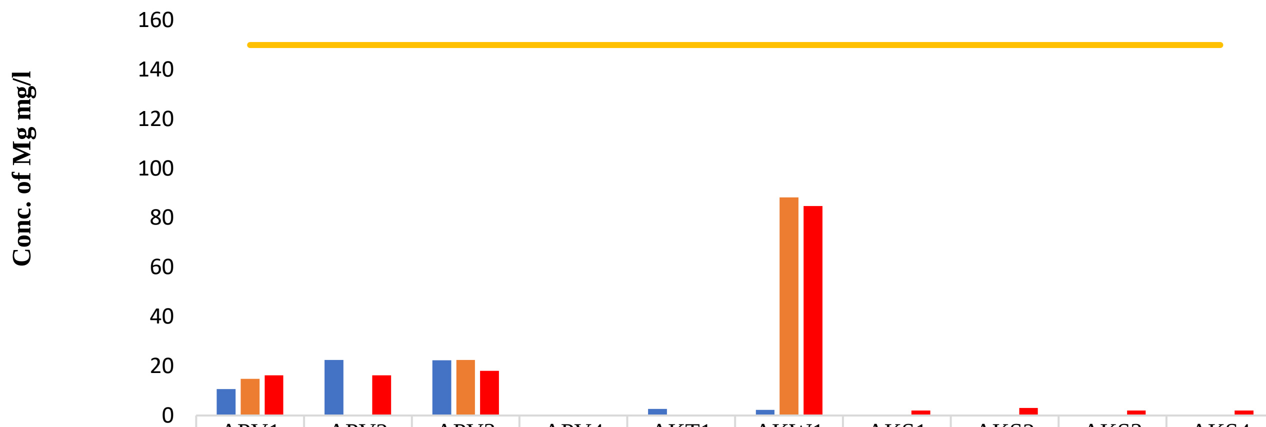


	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	14.042	10.82	23.416	21.59	25.76	10.73	10.83	22.38	278
MAY	24.21	12.25	12.7	12.43	0	14.15	13.77	38.78	35.33
AUGUST	31.77	14.03	13.61	44.81	0	0	14.51	45.05	0
WHO std	150	150	150	150	150	150	150	150	150

Figure 4.1.2 11. A Bar chart showing monthly levels of magnesium in the community drinking water sources in Anyako.

The magnesium levels ranged from 0.108 to 278 mg/l. in all the community drinking water sources. With the commercial poly-tanks, the level of magnesium in the drinking water sampled ranged from 10.73 mg/l to 278 mg/l, with the highest recorded in AKOC9 and the lowest in AKOC6 in March. The magnesium levels in the month of May ranged from 0 mg/l to 38.78 mg/l with the highest in AKOC8 and the lowest in AKOC5, whilst in the month of August, the levels ranged from 0 to 45.05 mg/l with the highest in the AKOC8 and the lowest in AKOC5, AKOC6 & AKOC9.

According to the required WHO drinking water standards for magnesium the level of the samples from the commercial poly-tanks in the month of May and August were all within the required level, though in March only the samples from AKOC9 were above the standard.



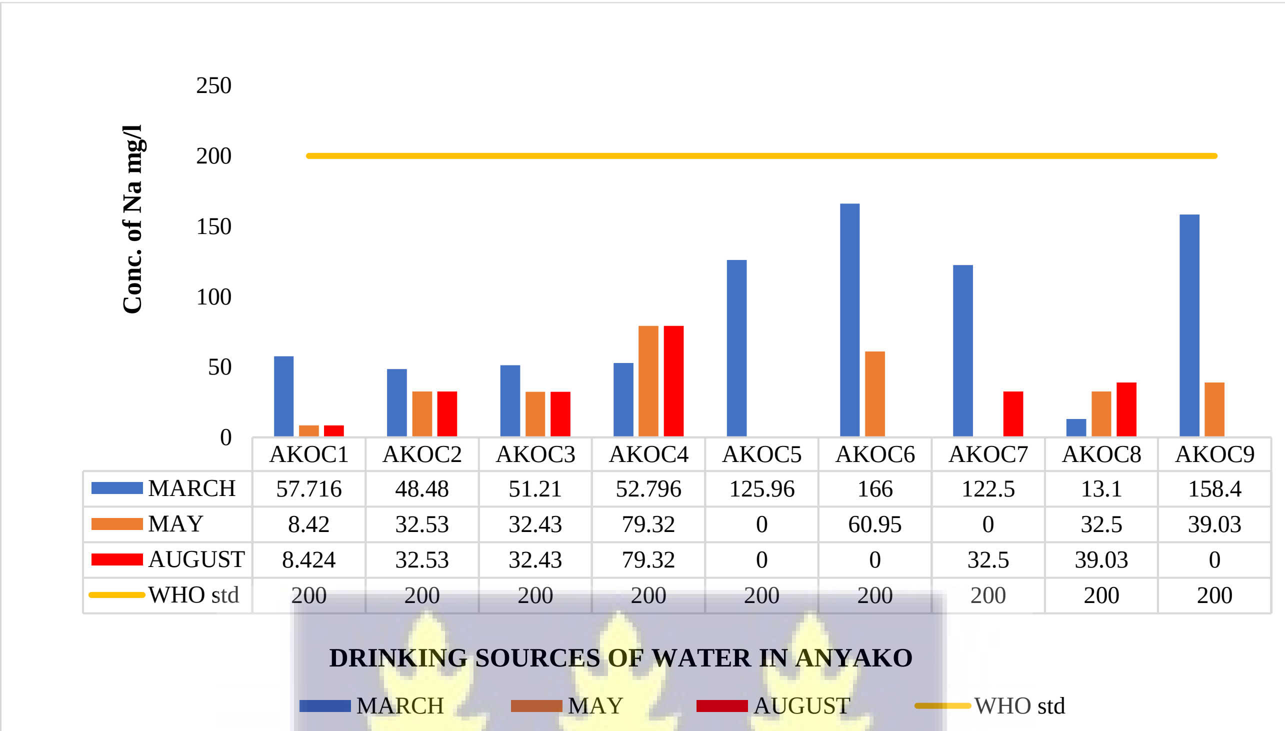
	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	10.68	22.45	22.38	0.388	2.68	2.3	0.12	0.108	0.153	0.143
MAY	14.8	0	22.44	0	0	88.3	0.12	0.1	0.15	0
AUGUST	16.24	16.29	18.12	0	0	84.75	2	3	2	2
WHO std	150	150	150	150	150	150	150	150	150	150

Figure 4.1.2 12 A Bar chart showing monthly concentration of magnesium in the community drinking water sources in Anyako.

The range of magnesium levels within the water sampled from the private poly-tanks, ranged from 0 to 22.44 mg/l. In March, the highest level of magnesium was from the source APV2, in May and August both from APV3. The lowest level was recorded at the APV4 in March, APV2 and APV4 in May and APV4 in August. With the samples from the reservoir, only the March had a level of 2.68 mg/l whilst there was no recording in May and August which both had a value of 0. The water samples sourced from the wells had levels of 2.3 mg/l, 88.3 mg/l and 84.75 mg/l in March, May and August respectively.

The range of levels in the water samples from the sachet water ranged from 0 to 0.153 mg/l. in March the highest which was 0.153 mg/l was recorded from AKS3 and the lowest from AKS1, in May the highest was AKS3 with 0.15 mg/l and the lowest with no recording from AKS4. In August, the range was between 2 mg/l and 3 mg/l with the highest level recorded from AKS2 and the lowest in the rest. All the sources of drinking water fell within the WHO standard of drinking water in each of the months hence is of good quality.

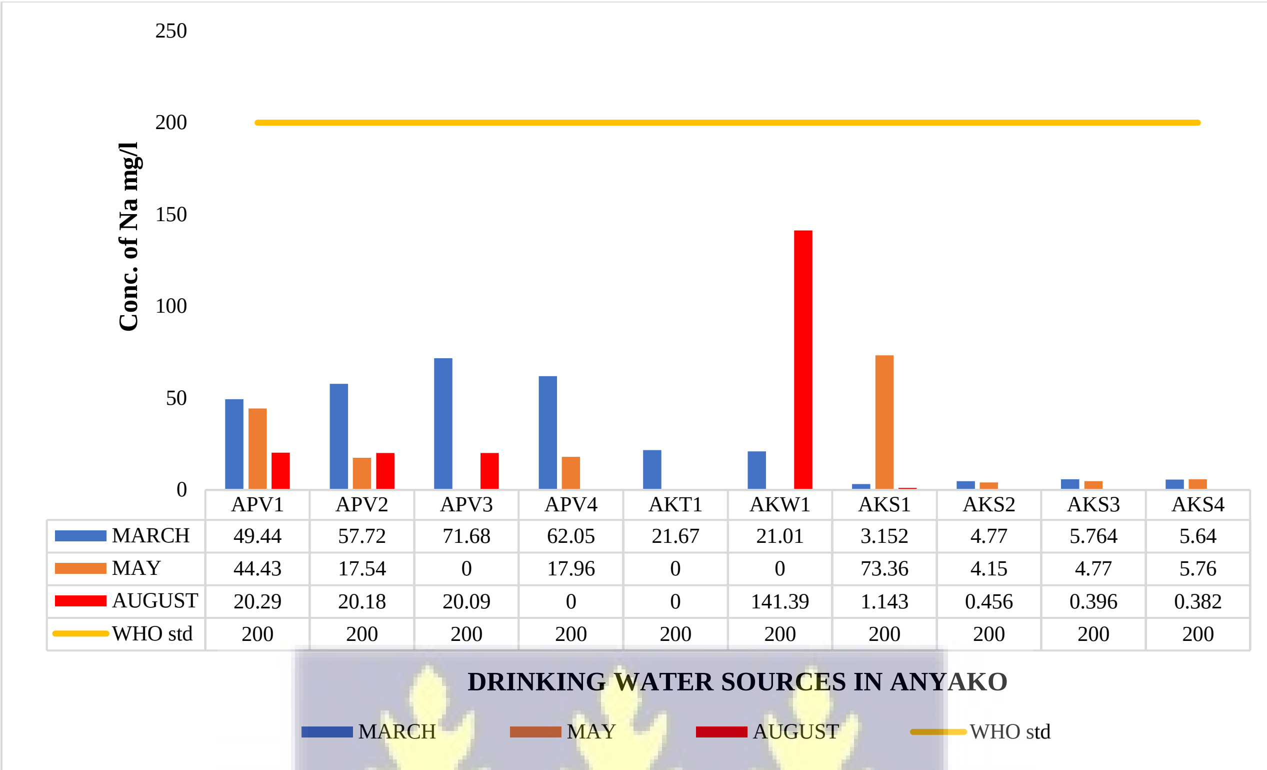
Sodium



	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	57.716	48.48	51.21	52.796	125.96	166	122.5	13.1	158.4
MAY	8.42	32.53	32.43	79.32	0	60.95	0	32.5	39.03
AUGUST	8.424	32.53	32.43	79.32	0	0	32.5	39.03	0
WHO std	200	200	200	200	200	200	200	200	200

Figure 4.1.2 13.A Bar chart showing monthly concentration of sodium in the community drinking water sources in Anyako.

The sodium levels ranged between 0 to 166 mg/l. in all the community drinking water sources. With the commercial poly-tanks, the level of sodium in the drinking water sampled ranged from 13.1 mg/l to 166 mg/l in March with the highest recorded in AKOC6 and the lowest in AKOC8. In May, the levels ranged from 0 to 79.32 mg/l with the highest in AKOC4 and the lowest in AKOC5 and AKOC7. In August, the range was between 0 and 79.32 mg/l with the highest recorded in AKOC4 and the lowest in AKOC5, AKOC6 and AKOC9. All the water samples from the various drinking sources are of good quality in sodium as the levels were all within the WHO standard of 200 mg/l.



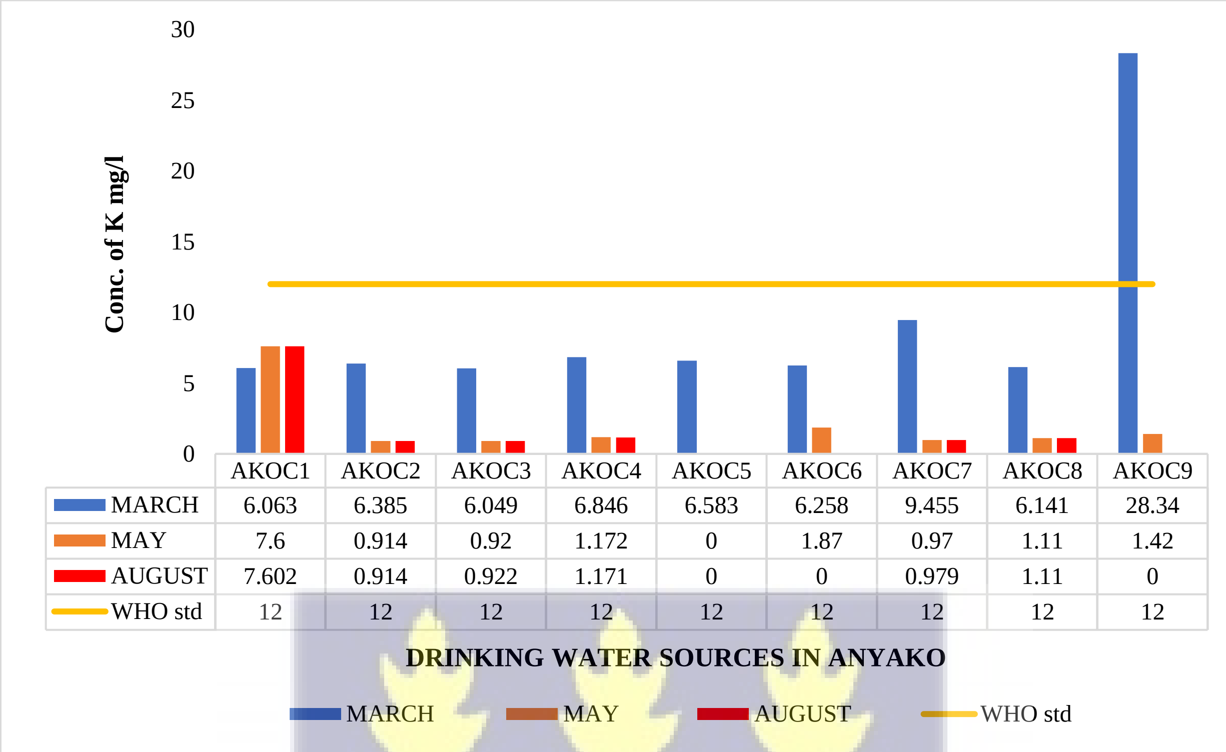
	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	49.44	57.72	71.68	62.05	21.67	21.01	3.152	4.77	5.764	5.64
MAY	44.43	17.54	0	17.96	0	0	73.36	4.15	4.77	5.76
AUGUST	20.29	20.18	20.09	0	0	141.39	1.143	0.456	0.396	0.382
WHO std	200	200	200	200	200	200	200	200	200	200

Figure 4.1.2 14.A Bar chart showing monthly levels of sodium in the community drinking water sources in Anyako.

The range of sodium levels of the water sampled from within the private poly-tanks, were between 0 to 71.68 mg/l. The range of levels in March was between 0 to 71.68 mg/l with the highest level recorded in APV3 and the lowest in APV1, in May from 0 to 44.43 mg/l with the highest in APV1 and the lowest recorded at APV3 and in August from 0 to 20.29 mg/l with the highest in APV1 and the lowest in APV4. With the samples sourced from the reservoir, the only month that had a recording of sodium was March with a level of 21.67 mg/l and within the well, the highest recording was in the month of August with a level of 141.39 mg/l.

The water samples from the sachet had sodium levels ranging between 0.382 mg/l to 73.36 mg/l, in March the highest level was recorded from AKS3 and the lowest in AKS1, in May the highest was in AKS1 and the lowest in AKS2 and in August the highest was from AKS1 and the lowest in AKS4. All the water samples sources from the various sources were all within the required standard of WHO.

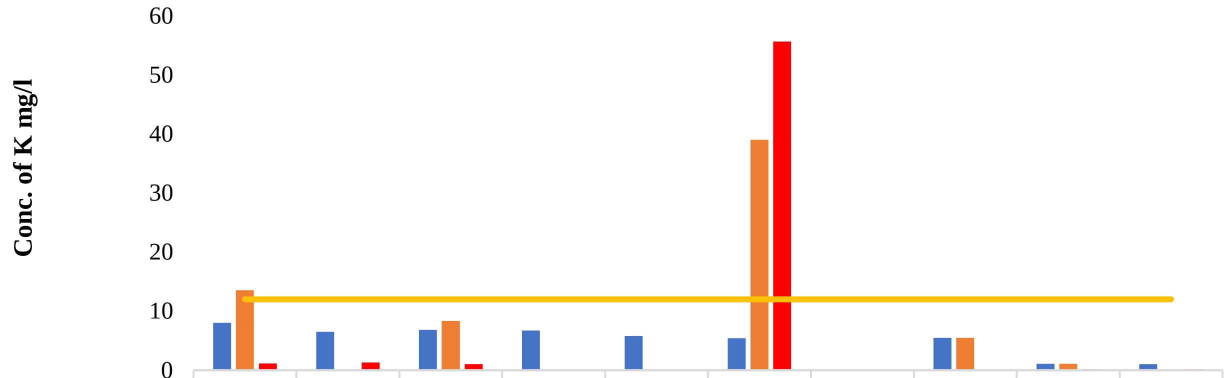
Potassium



	AKOC1	AKOC2	AKOC3	AKOC4	AKOC5	AKOC6	AKOC7	AKOC8	AKOC9
MARCH	6.063	6.385	6.049	6.846	6.583	6.258	9.455	6.141	28.34
MAY	7.6	0.914	0.92	1.172	0	1.87	0.97	1.11	1.42
AUGUST	7.602	0.914	0.922	1.171	0	0	0.979	1.11	0
WHO std	12	12	12	12	12	12	12	12	12

Figure 4.1.2 15 A Bar chart showing monthly levels of potassium in the community drinking water sources in Anyako.

The levels of potassium ranged from 0.09 mg/l to 55.6 mg/l. in all the community drinking water sources. In March, May and August, the levels with the commercial poly-tanks all ranged between 6.049 mg/l to 28.34 mg/l, from 0 to 7.6mg/l and between 0 to 7.602 mg/l respectively. The highest level in march was recorded at AKOC9 and the lowest at AKOC3, in May the highest was from AKOC1 and the lowest from AKOC5 and in August, the highest level was recorded at AKOC1 and the lowest at AKOC5, AKOC6 and AKOC7. All the sources with the exception of AKOC9 in the month of March were within the standard of drinking water by WHO.



	APV1	APV2	APV3	APV4	AKT1	AKW1	AKS1	AKS2	AKS3	AKS4
MARCH	8.008	6.511	6.845	6.737	5.796	5.432	0.09	5.467	1.085	1.032
MAY	13.57	0	8.33	0	0	39	0.09	5.46	1.08	0
AUGUST	1.15	1.31	1.05	0	0	55.65	0.13	0.107	0.143	0.143
WHO std	12	12	12	12	12	12	12	12	12	12

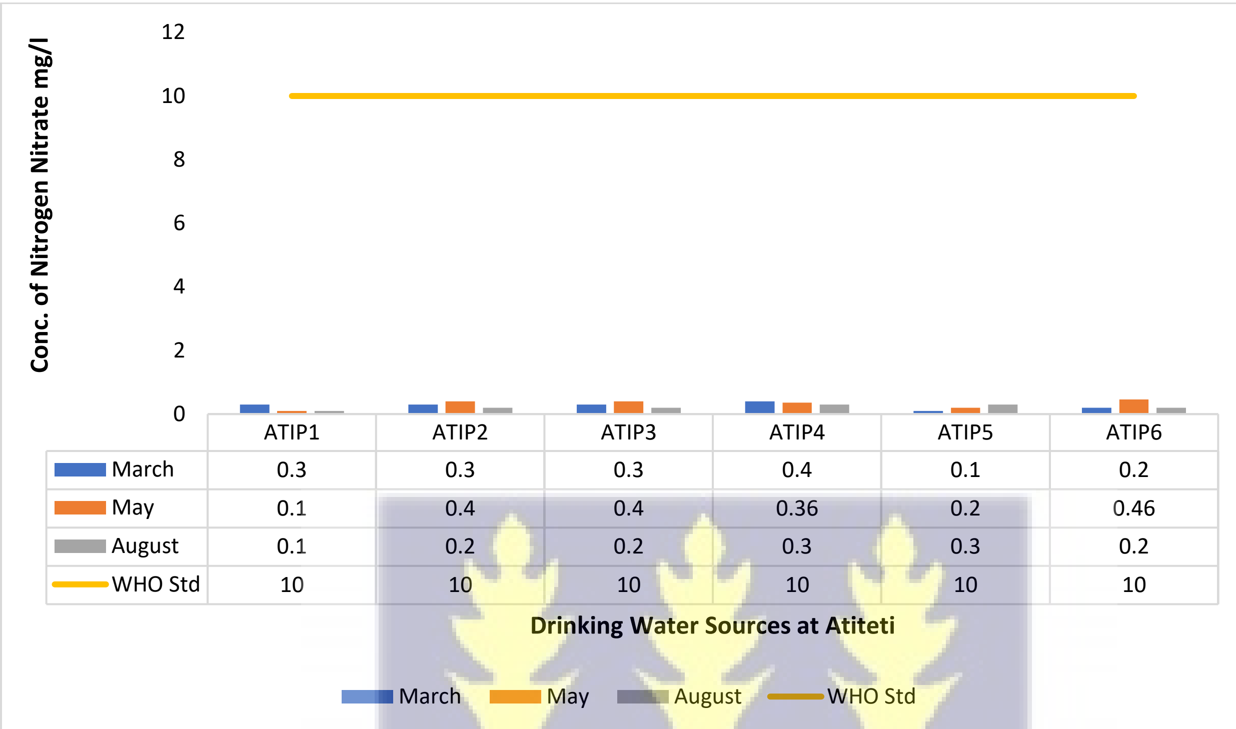
Figure 4.1.2 16 A Bar chart showing monthly levels of potassium in the community drinking water sources in Anyako.

The level of potassium within the water sampled from the private poly-tanks, ranged from 0 to 55.65 mg/l. In March, May and August, the levels were between 6.511 mg/l to 8.008 mg/l, from 0 to 13.57 mg/l and from 0 to 1.31 mg/l respectively. The highest level recorded in March was from APV1 and the lowest level recorded at APV2. In May the highest level was recorded at APV1 and the lowest recorded at APV2 and APV4. In August, the highest and the lowest level of potassium was recorded at APV2 and APV4 respectively.

The potassium level in the drinking water samples sourced from the well in each month varied with the highest in the month of August followed by May then March with levels of 55.65 mg/l, 39 mg/l and 5.432 mg/l respectively. The samples sourced from the reservoir, recorded as 5.432 mg/l in March and no recording in May and August. The water samples from the sachet had potassium levels ranging between 0.09 to 5.47 mg/l, with the highest level recorded in AKS2 and the lowest in AKS1 in March and between 0 to 5.46 mg in the month of May, with the highest in AKS2 and the lowest in AKS4. In August, the range of the levels were between 0.107 mg/l to 0.143 mg/l with the highest in AKS3 and AKS4 and the lowest in AKS2. In March all the sources were within WHO standard. In May, APV1 and AKW1 were above the standard and in August AKW1 was above the standard of 12 mg/l0.

ATITETI

Nitrogen Nitrate



	ATIP1	ATIP2	ATIP3	ATIP4	ATIP5	ATIP6
March	0.3	0.3	0.3	0.4	0.1	0.2
May	0.1	0.4	0.4	0.36	0.2	0.46
August	0.1	0.2	0.2	0.3	0.3	0.2
WHO Std	10	10	10	10	10	10

Figure 4.1.2 17.A Bar chart showing monthly levels of nitrate nitrogen in the community drinking water sources in Atiteti.

The nitrate nitrogen levels ranged from 0.1 to 0.4 mg/l in all the community drinking water sources in Atiteti. The sources sampled in March had a range of levels between 0.1 mg/l to 0.4 mg/, with the highest level from ATIP4 and the lowest level from ATIP5. The levels in May were slightly different as they ranged from 0.1 mg/l to 0.4 mg/l with the highest level from three sources, ATIP2, ATIP3 and ATIP6 with the lowest from ATIP1. In August, the drinking water sources had levels between 0.1 mg/l to 0.3 mg/l with the highest from ATIP4 and the ATIP5. The lowest level was from ATIP1. Water sampled from all the pipes in the community, had levels not above the WHO required standard form drinking water.

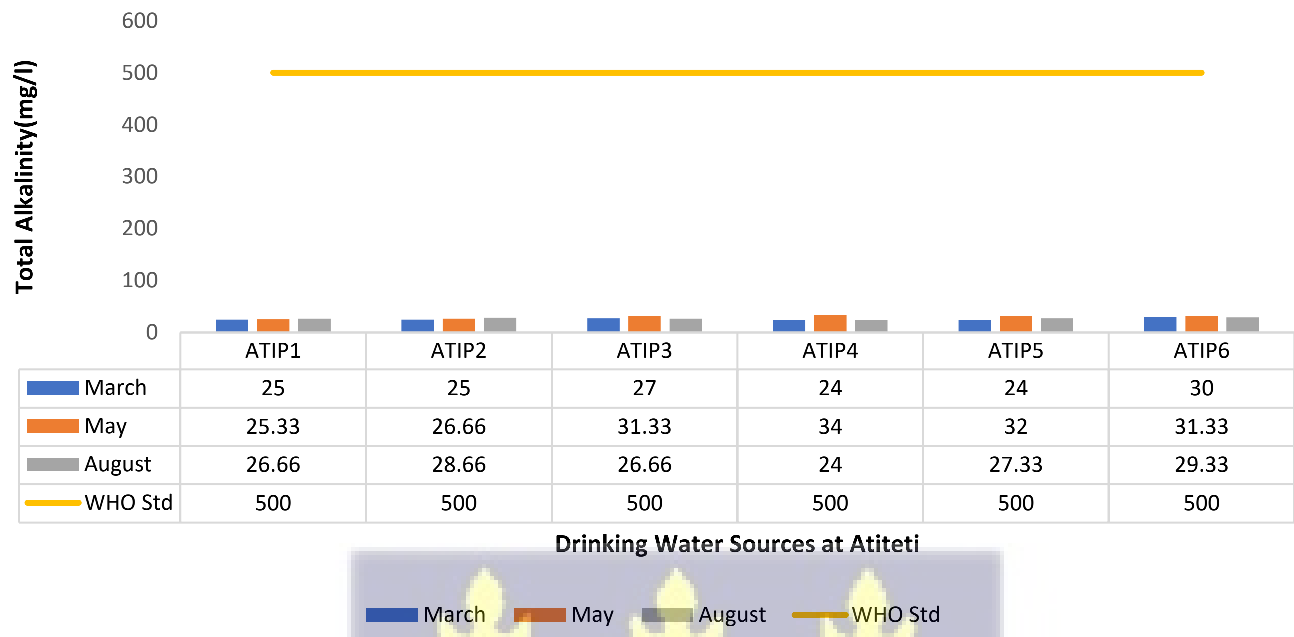
Phosphate

	ATIP1	ATIP2	ATIP3	ATIP4	ATIP5	ATIP6
March	0.25	0.13	0.05	0.05	0.08	0.03
May	0.23	0.07	0.1	0.07	0.15	0.06
August	0.01	0.01	0.01	0.01	0.01	0.24
WHO Std	0.3	0.3	0.3	0.3	0.3	0.3

Figure 4.1.2 18 Bar chart showing monthly levels of phosphate in the community drinking water sources in Atiteti.

The phosphate levels ranged from 0.01 mg/l to 0.25 mg/l in all the community drinking water sources in Atiteti. The sources sampled in March had a range of levels between 0.03 mg/l to 0.25 mg/l, with the highest level from ATIP1 and the lowest level from ATIP6. The levels in May varied as they ranged from 0.06 mg/l to 0.23 mg/l with the highest level from ATIP1, and the lowest from ATIP6. In August, the drinking water sources had levels between 0.01 mg/l to 0.24 mg/l with the highest from ATIP1 and the lowest from the rest of the sources. Water sampled from all the pipes in the community, were all within the required standard of 0.3 mg/l by WHO.

Total Alkalinity



	ATIP1	ATIP2	ATIP3	ATIP4	ATIP5	ATIP6
March	25	25	27	24	24	30
May	25.33	26.66	31.33	34	32	31.33
August	26.66	28.66	26.66	24	27.33	29.33
WHO Std	500	500	500	500	500	500

Figure 4.1.2 19.A Bar chart showing monthly concentration of total alkalinity in the community drinking water sources in Atiteti

The levels of total alkalinity ranged between 24 mg/l to 34 mg/l in all the community drinking water sources in Atiteti. The sources sampled in March had a range of levels between 24 mg/l to 30 mg/, with the highest level from ATIP6 and the lowest level from ATIP4. The levels in May ranged from 25.33 mg/l to 34 mg/l with the highest level in ATIP4, and the lowest from ATIP1. In August, the drinking water sources had levels between 24 mg/l to 29.33 mg/l with the highest from ATIP6 and the lowest from ATIP4. Water sampled from all the pipes in the community, were all within the required standard of 500 mg/l for total alkalinity by WHO.

Sulphate

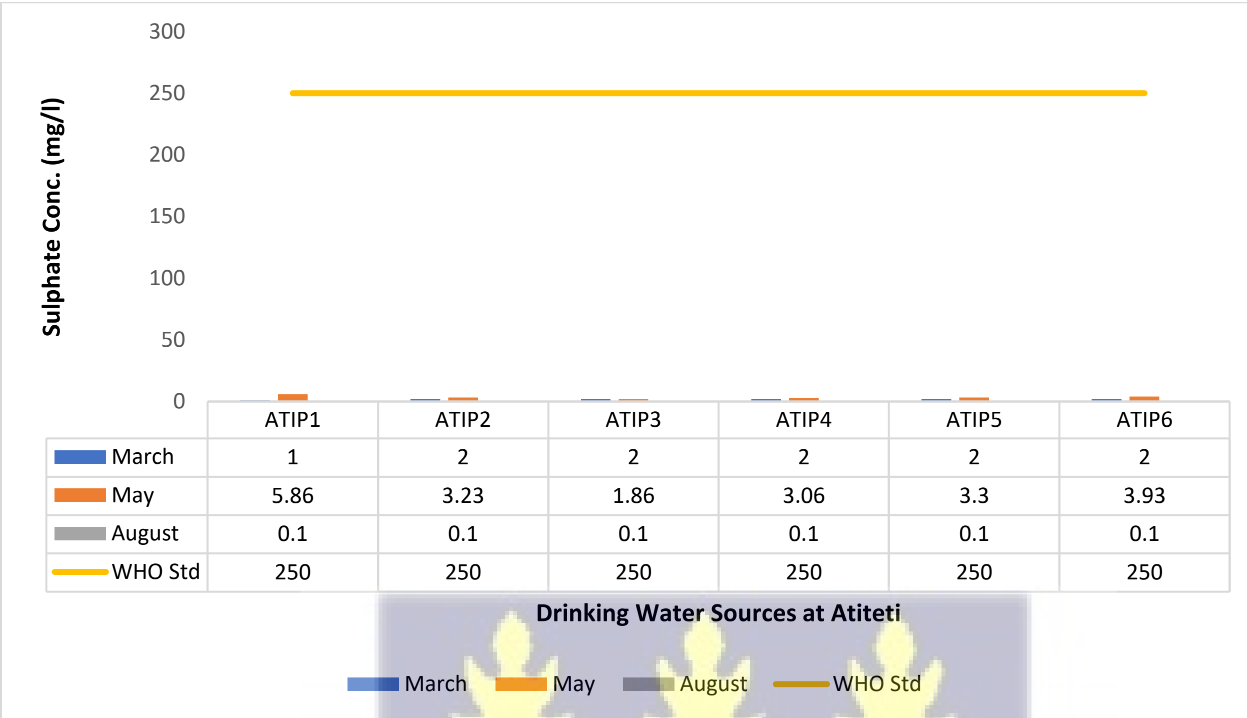
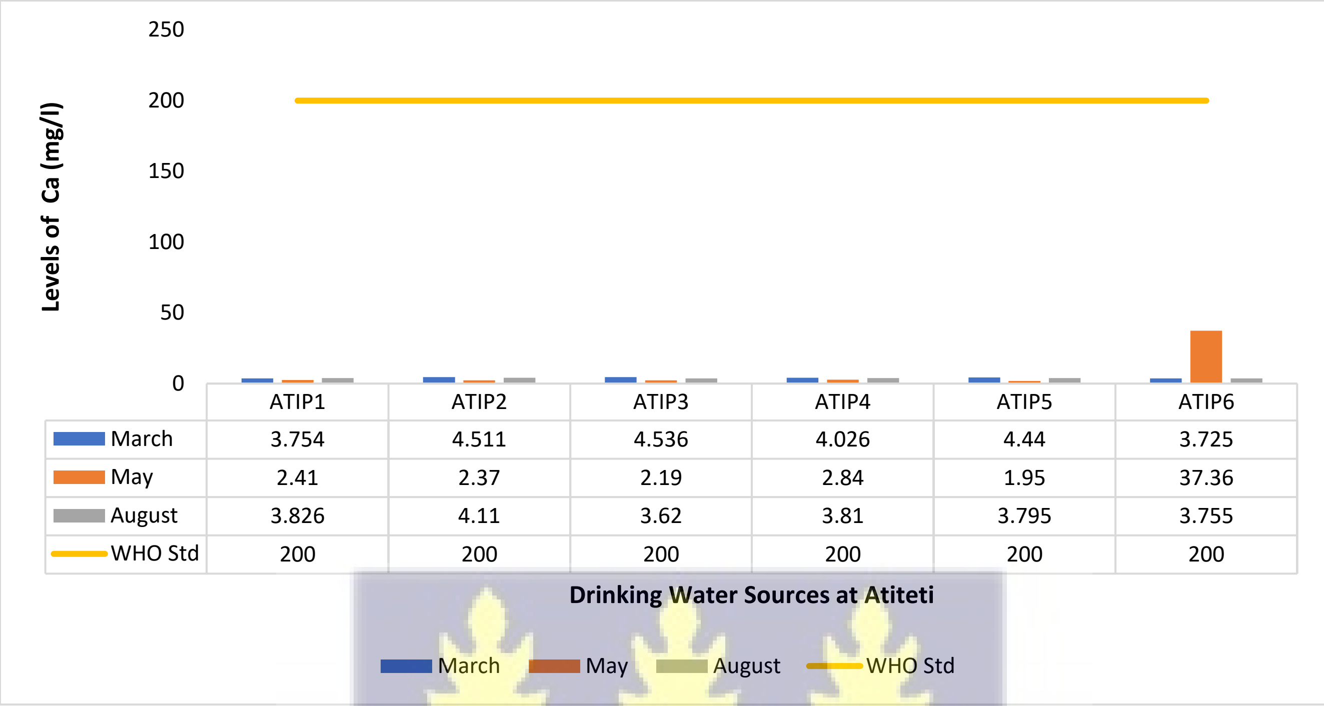


Figure 4.1.2 20.A Bar chart showing monthly concentration of sulphate in the community drinking water sources in Atiteti

The levels of sulphate ranged between 0.1 mg/l to 5.86 mg/l in all the community drinking water sources in Atiteti. The sources sampled in March had a range of levels between 1 mg/l to 2 mg/, with the highest level from all the sources but ATIP1. The levels in May ranged from 1.86 mg/l to 5.86 mg/l with the highest level in ATIP1, and the lowest from ATIP3. In August, the drinking water sources had the same levels of 0.1 mg/l. Water samples sourced from each of the pipes in the community, were all within the required standard of 250 mg/l for sulphate by WHO.

Calcium

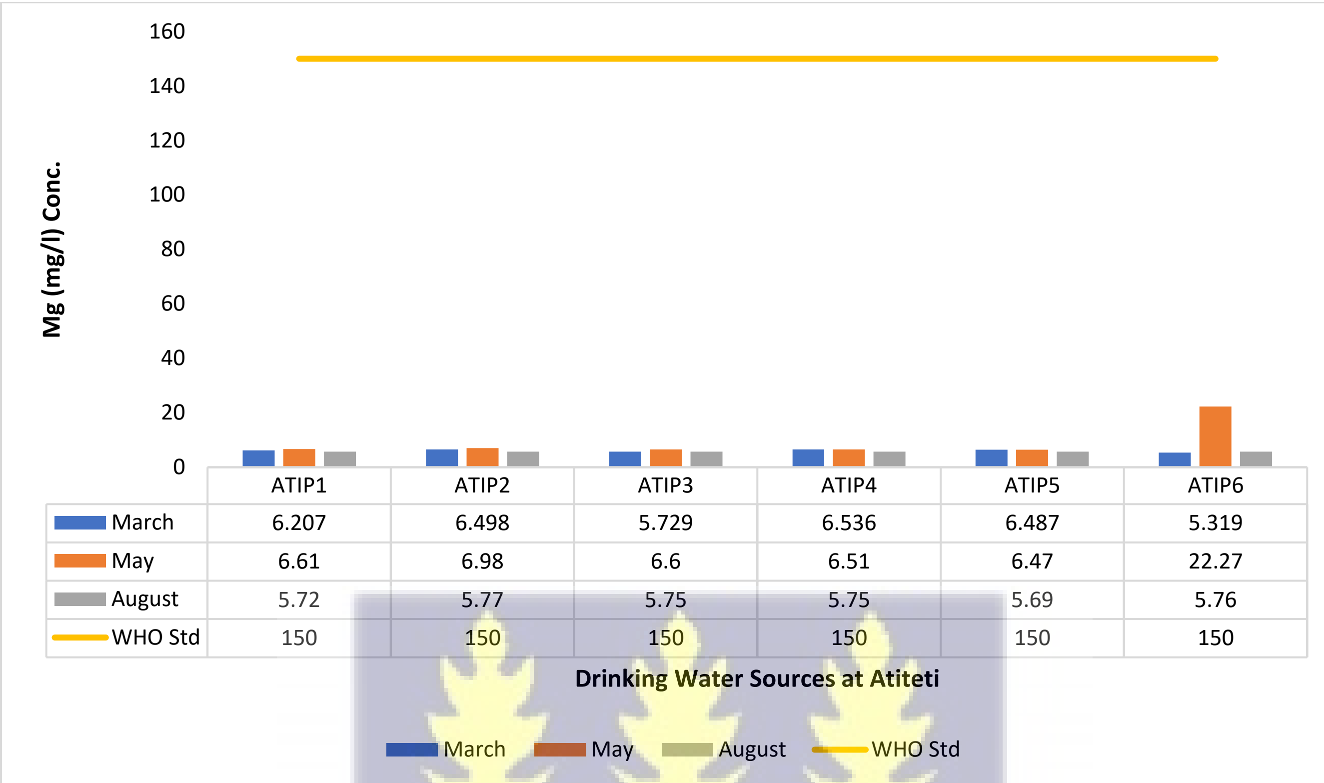


	ATIP1	ATIP2	ATIP3	ATIP4	ATIP5	ATIP6
March	3.754	4.511	4.536	4.026	4.44	3.725
May	2.41	2.37	2.19	2.84	1.95	37.36
August	3.826	4.11	3.62	3.81	3.795	3.755
WHO Std	200	200	200	200	200	200

Figure 4.1.2 21.A Bar chart showing monthly concentration of calcium in the community drinking water sources in Atiteti.

The levels of calcium ranged between 1.95 mg/l to 37.36 mg/l in all the community drinking water sources in Atiteti. The sources sampled in March had a range of levels between 3.75 mg/l to 4.53 mg/, with the highest level from ATIP3 and the lowest level from ATIP6. The levels in May ranged from 1.95 mg/l to 37.36 mg/l with the highest level in ATIP6, and the lowest from ATIP5. In August, the range of levels were from 3.62 mg/l to 4.11 mg/l with the highest level from ATIP2 and the lowest level from ATIP3. All the water samples from each of the pipes in the community, fell within the required standard of drinking water by WHO.

Magnesium

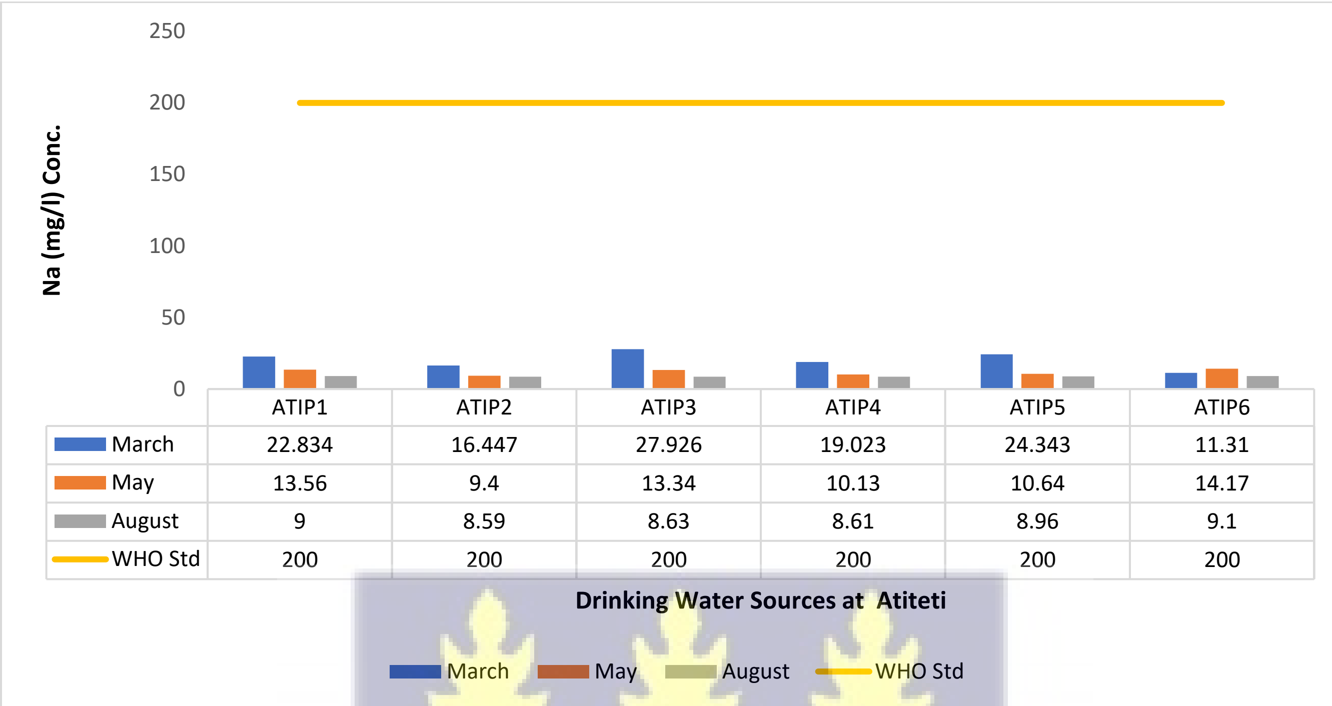


	ATIP1	ATIP2	ATIP3	ATIP4	ATIP5	ATIP6
March	6.207	6.498	5.729	6.536	6.487	5.319
May	6.61	6.98	6.6	6.51	6.47	22.27
August	5.72	5.77	5.75	5.75	5.69	5.76
WHO Std	150	150	150	150	150	150

Figure 4.1.2 22.A Bar chart showing monthly levels of magnesium in the community drinking water sources in Atiteti.

The level of magnesium concentration ranged between 5.69 mg/l to 22.27 mg/l in all the community drinking water sources. The range of the levels in March was between 5.31 mg/l to 6.72 mg/l with the highest level from ATIP4 and the lowest in ATIP6. In May, the magnesium levels were between 6.47 mg/l to 22.27 mg/l, with the highest level recorded from ATIP6 and the lowest from ATIP5. Within the month of August, the range of the magnesium level was between 5.69 mg/l to 5.77 mg/l with the highest in ATIP2 and the lowest in ATIP5. The sources of drinking water in Atiteti were all within the WHO standard of 150 mg/l for magnesium in drinking water.

Sodium

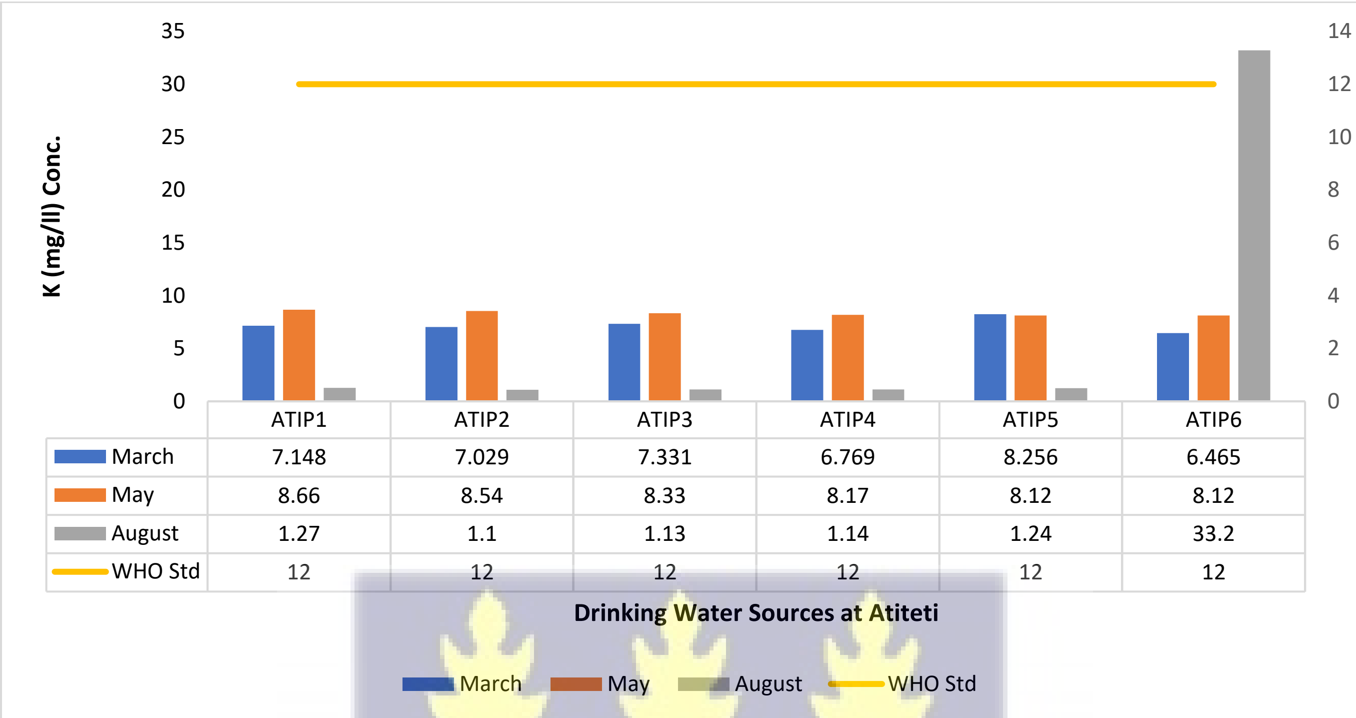


	ATIP1	ATIP2	ATIP3	ATIP4	ATIP5	ATIP6
March	22.834	16.447	27.926	19.023	24.343	11.31
May	13.56	9.4	13.34	10.13	10.64	14.17
August	9	8.59	8.63	8.61	8.96	9.1
WHO Std	200	200	200	200	200	200

Figure 4.1.2 23 A Bar chart showing monthly levels of sodium in the community drinking water sources in Atiteti.

The level of sodium concentration ranged from 8.61 mg/l to 27.92 mg/l in all the community drinking water sources. In the March, May and August, the levels ranged between 11.31 mg/l to 27.926mg/l, with the highest in ATIP3 and the lowest level from ATIP6, from 9.4mg/l to 14.17 mg/l with the highest level from ATIP6 and the lowest from ATIP2, from 8.61 mg/l to 9.1 mg/l with the highest level from ATIP6 and the lowest level from ATIP4. The drinking water sources had levels that were all within the WHO standard of 200 mg/l.

Potassium



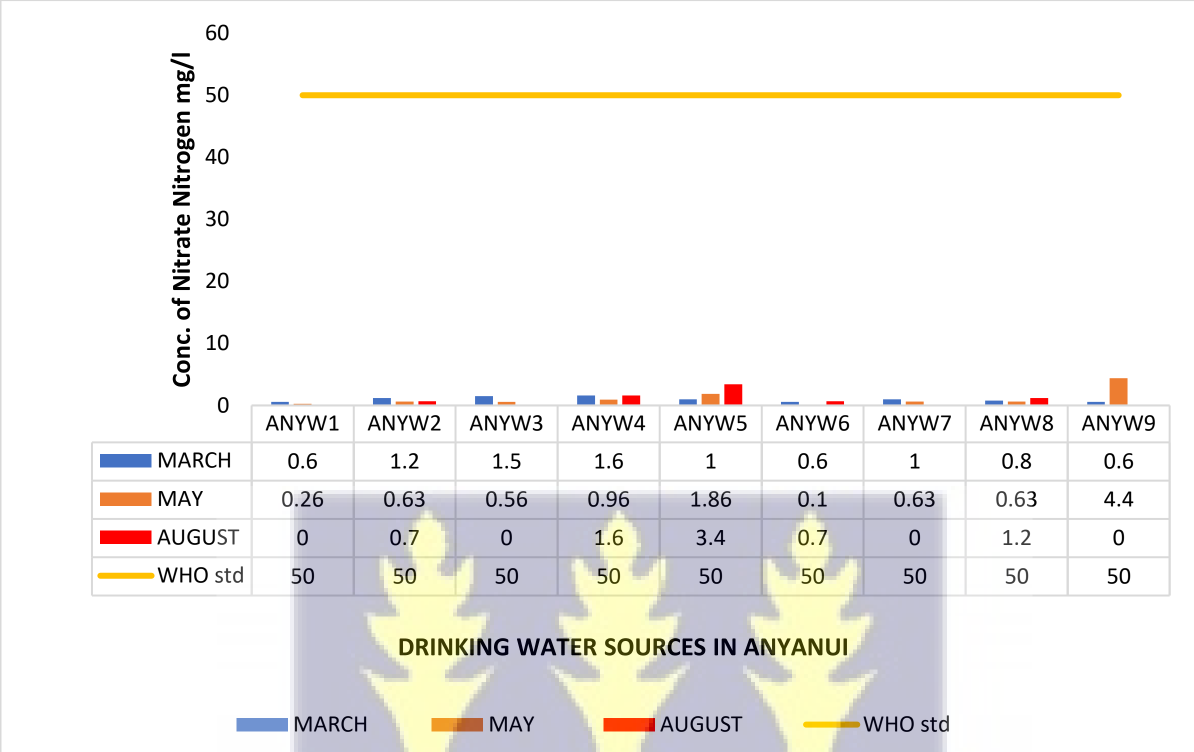
	ATIP1	ATIP2	ATIP3	ATIP4	ATIP5	ATIP6
March	7.148	7.029	7.331	6.769	8.256	6.465
May	8.66	8.54	8.33	8.17	8.12	8.12
August	1.27	1.1	1.13	1.14	1.24	33.2
WHO Std	12	12	12	12	12	12

Figure 4.1.2 24 Bar chart showing monthly concentration levels of potassium in the community drinking water sources in Atiteti.

The level of potassium within the sampled water ranged between 6.465mg/l to 33.2mg/l in all the community drinking water sources in Atiteti. The range of the levels in March was from 6.465mg/l to 8.256mg/l with the highest level of concentration recorded in ATIP5 and the lowest recorded in ATIP6. In May, the range was between 8.12mg/l to 8.66mg/l with the highest level from ATIP1 and the lowest level from the sources ATIP5 &ATIP6. The levels of potassium differed in August having a range of 1.1mg/l to 33.2mg/l, with the highest level in ATIP6 and the lowest in ATIP2. In both March and May, all the levels of the sources were within the WHO standard and in August, the only source which was above the standard of drinking water was from ATIP6.

ANYANUI

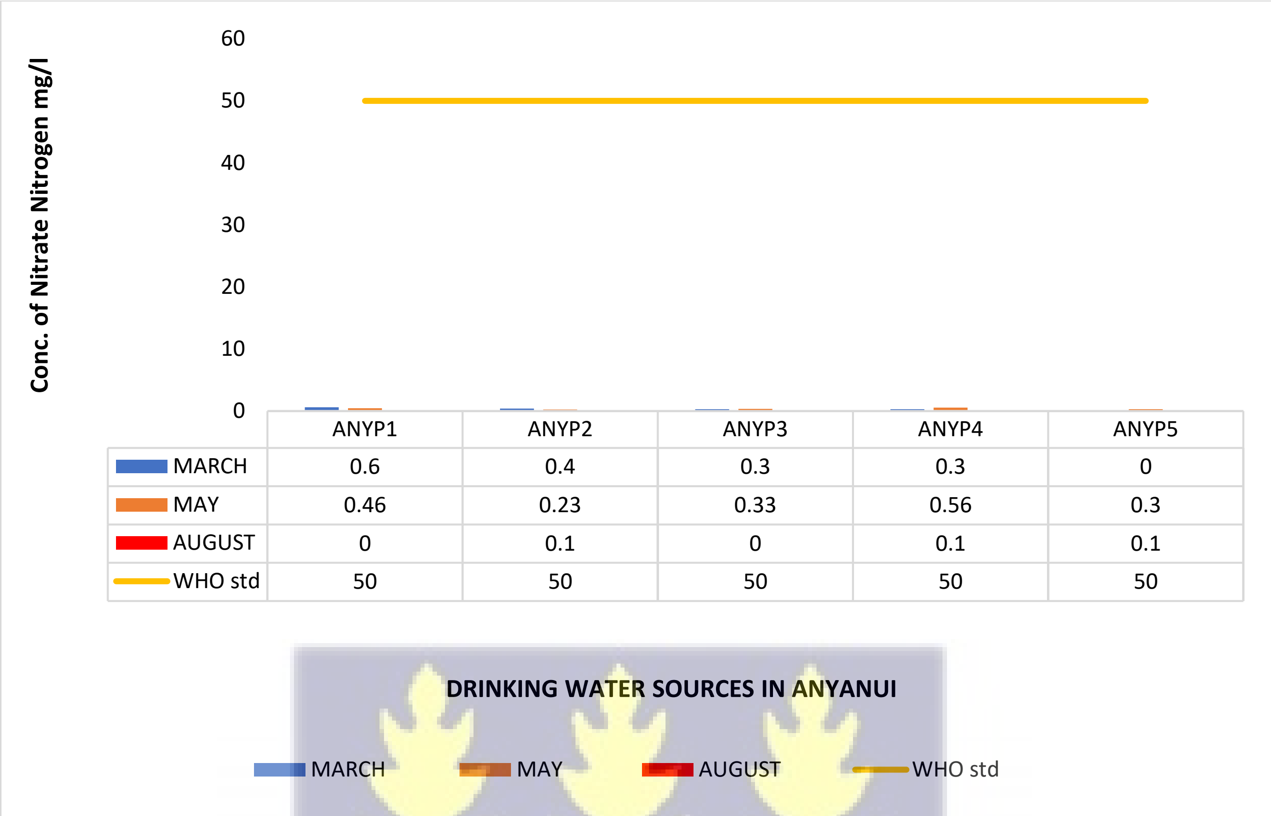
Nitrate Nitrogen



	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	0.6	1.2	1.5	1.6	1	0.6	1	0.8	0.6
MAY	0.26	0.63	0.56	0.96	1.86	0.1	0.63	0.63	4.4
AUGUST	0	0.7	0	1.6	3.4	0.7	0	1.2	0
WHO std	50	50	50	50	50	50	50	50	50

Figure 4.1.2 25 A Bar chart showing monthly levels of nitrate nitrogen in the community drinking water sources in Anyanui.

The nitrate nitrogen levels ranged from 0.3 to 1.5 mg/l in all sources of drinking in Anyanui. With the Wells the level of nitrate nitrogen in the water samples ranged from 0.6 to 1.5 mg/l in March, with the highest recorded in ANYW5 and the lowest recorded in ANYW1, ANYW3, ANYW7. In May, the levels ranged from 0.1mg/l to 4.4 mg/l, with the highest level from the source ANYW9 and the lowest from the source ANYW6 and in August, the levels ranged between 0.7 mg/l to 3.4 mg/l. with the highest from ANYW5 and the lowest in both ANYW2 and ANYW6. The water sampled from the wells had levels of nitrate nitrogen falling within the WHO water standard of 50 mg/l.

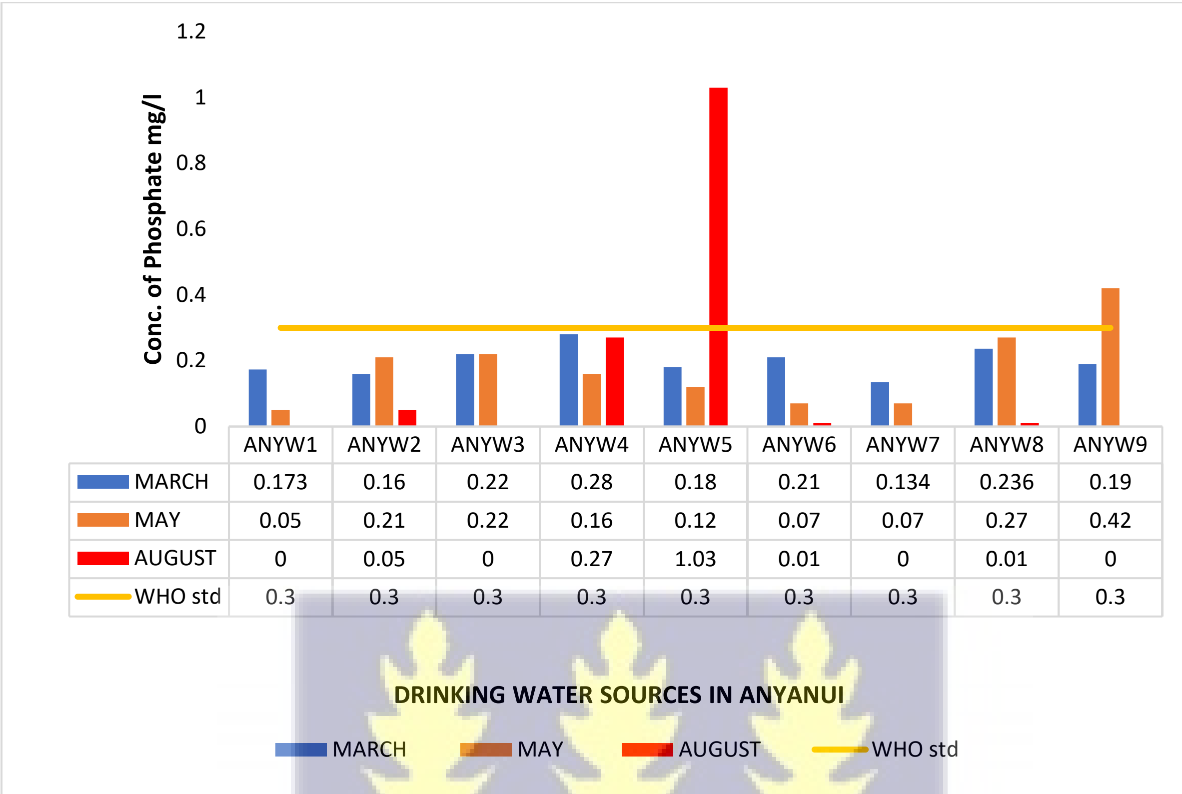


	ANYP1	ANYP2	ANYP3	ANYP4	ANYP5
MARCH	0.6	0.4	0.3	0.3	0
MAY	0.46	0.23	0.33	0.56	0.3
AUGUST	0	0.1	0	0.1	0.1
WHO std	50	50	50	50	50

Figure 4.1.2 26. A Bar chart showing monthly concentration of nitrate nitrogen in the community drinking water sources in Anyanui.

The range of nitrate nitrogen in the drinking water samples sourced from the pipes in March was between 0.3 to 0.6 mg/l, with the highest recorded in ANYP1 and the lowest in ANYP3. Within the month of May, the range of levels was between 0.23 mg/l to 0.56 mg/l with the highest in ANYP4 and the lowest from ANYP2.All the pipe sources had levels well within the required standard of drinking water according to WHO.

Phosphate



	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	0.173	0.16	0.22	0.28	0.18	0.21	0.134	0.236	0.19
MAY	0.05	0.21	0.22	0.16	0.12	0.07	0.07	0.27	0.42
AUGUST	0	0.05	0	0.27	1.03	0.01	0	0.01	0
WHO std	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Figure 4.1.2 27 A Bar chart showing monthly levels of phosphate in the community drinking water sources in Anyanui.

The phosphate levels ranged between 0.01 to 1.03 mg/l in the sources of drinking water. With the wells, the level of phosphate in the drinking water samples in March ranged between 0.16 mg/l to 0.18 mg/l, with the highest recorded in ANYW5 and the lowest recorded in ANYW2. In May, the levels ranged from 0.07 mg/l to 0.27 mg/l with the highest level from the source ANYW8 and the lowest level from two sources, ANYW6 & ANYW7. The levels in the month of August when analysed had levels ranging from 0.01 mg/l to 1.03 mg/l. Samples from ANYW5 had the highest level and the lowest ANYW6 & ANYW8. March and May samples had levels in within the WHO standards and in August the only source with levels higher than the required standard was ANYW5.

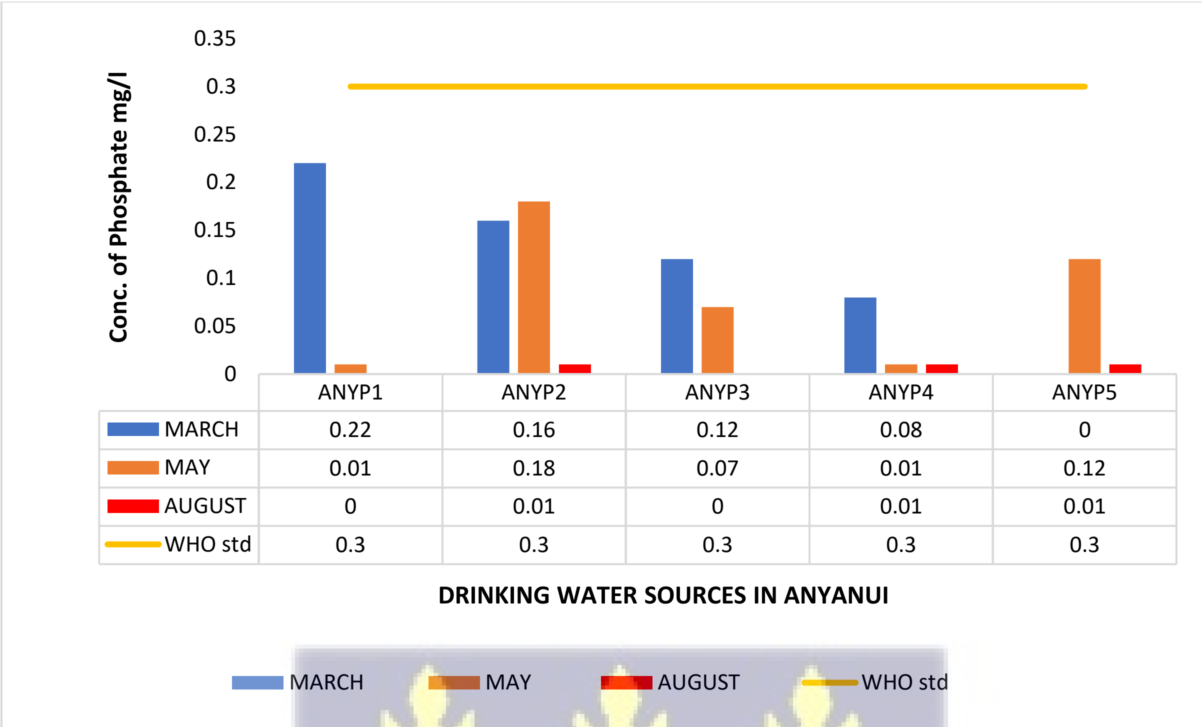
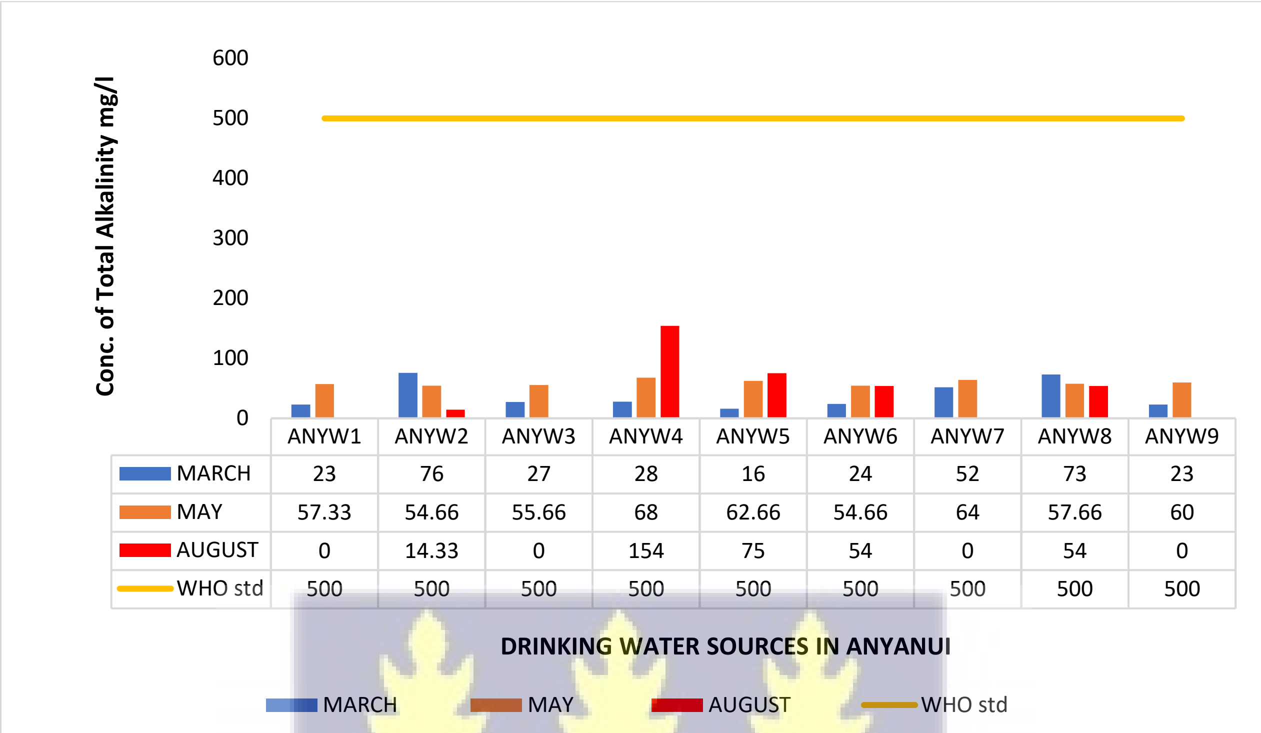


Figure 4.1.2 28. A Bar chart showing monthly concentration levels of phosphate in the community drinking water sources in Anyanui.

The range of phosphate in the water samples sourced from the pipes was from 0.01 to 0.22 mg/l in March with the highest level of concentration recorded in all but ANYP1 and ANYP3 and in May, the levels ranged from 0.01 mg/l to 0.18 mg/l with the highest in ANYP2 and the lowest from two sources which were ANYP1 and ANYP4. All the levels of the pipes though some higher than others, were within the required WHO standard.

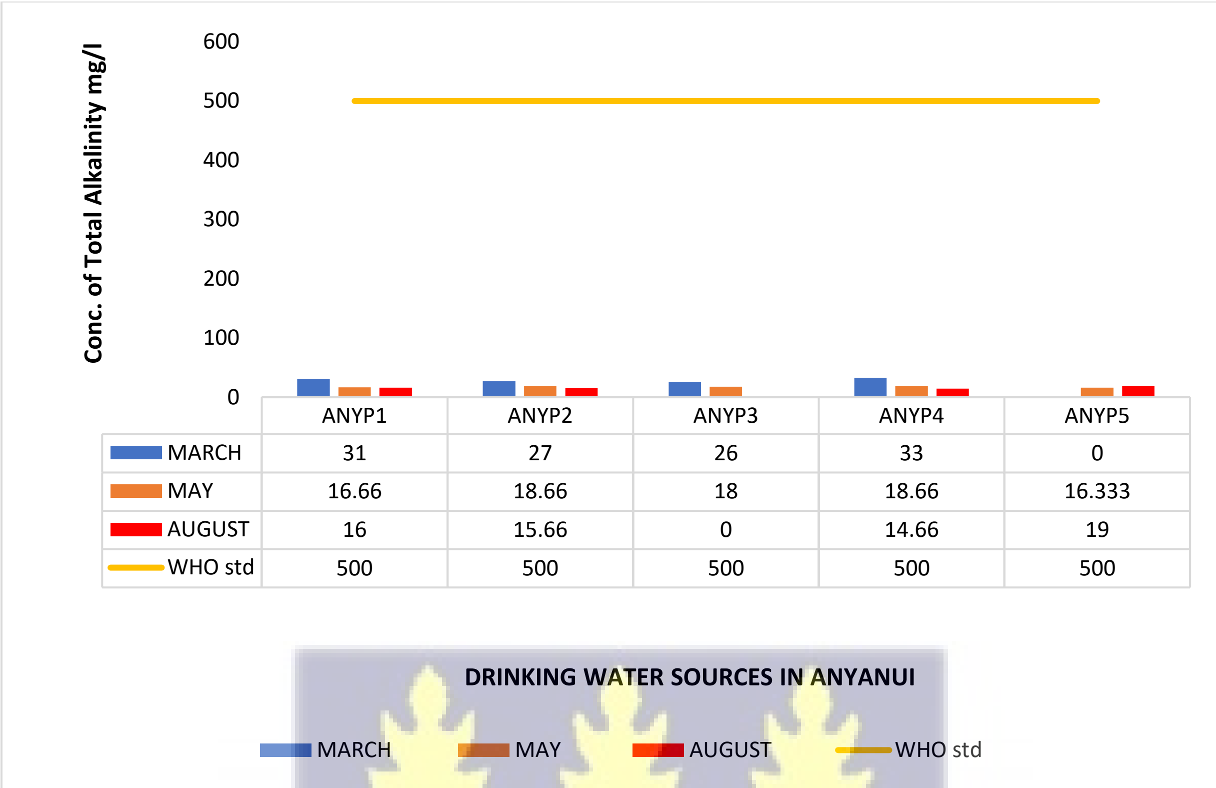
Total Alkalinity



	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	23	76	27	28	16	24	52	73	23
MAY	57.33	54.66	55.66	68	62.66	54.66	64	57.66	60
AUGUST	0	14.33	0	154	75	54	0	54	0
WHO std	500	500	500	500	500	500	500	500	500

Figure 4.1.2 29. A Bar chart showing monthly levels of total alkalinity in the community drinking water sources in Anyanui.

The total alkalinity levels ranged from 14.00 to 154.00 mg/l in the community sources of drinking. With the wells, the level of total alkalinity in the drinking water samples range from 16 mg/l to 76 mg/l in March with the highest recorded in ANYW2 and the lowest recorded in ANYW5. The levels in the May were higher than that of March with ranges between 54.66 mg/l to 68 mg/l, with the highest from ANYW4 and the lowest from ANYW2. In August, the range was between 14.33 mg/l to 154 mg/l with the highest in ANYW4 and the lowest in ANYW2. According to the WHO standard, the level of total alkalinity concentration within the samples from the sources were within the standard which shows good quality.

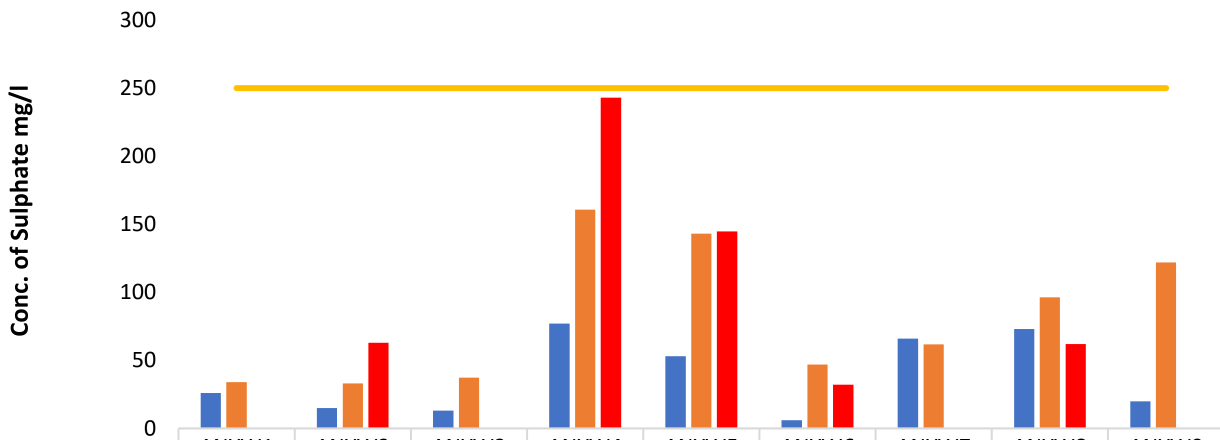


	ANYP1	ANYP2	ANYP3	ANYP4	ANYP5
MARCH	31	27	26	33	0
MAY	16.66	18.66	18	18.66	16.333
AUGUST	16	15.66	0	14.66	19
WHO std	500	500	500	500	500

Figure 4.1.2 30. A Bar chart showing monthly concentration of total alkalinity in the community drinking water sources in Anyanui.

The level of total alkalinity in the pipes were lower than the levels in the wells. The range of total alkalinity in the water samples sourced from the pipes was from 26.00 mg/l to 33.00 mg/l with the highest level of concentration recorded in ANYP4 and the lowest recorded in and ANYP3 in March. In May the range was between 16.33 mg/l to 18.66 mg/l with the highest from two sources ANYP2 and ANYP4 and the lowest from ANYP5. August levels recorded ranged from 14.66 mg/l to 19.00 mg/l, with the highest level from ANYP5 and the lowest level from ANYP4. The levels of each of the pipes were all within the WHO standard.

Sulphate

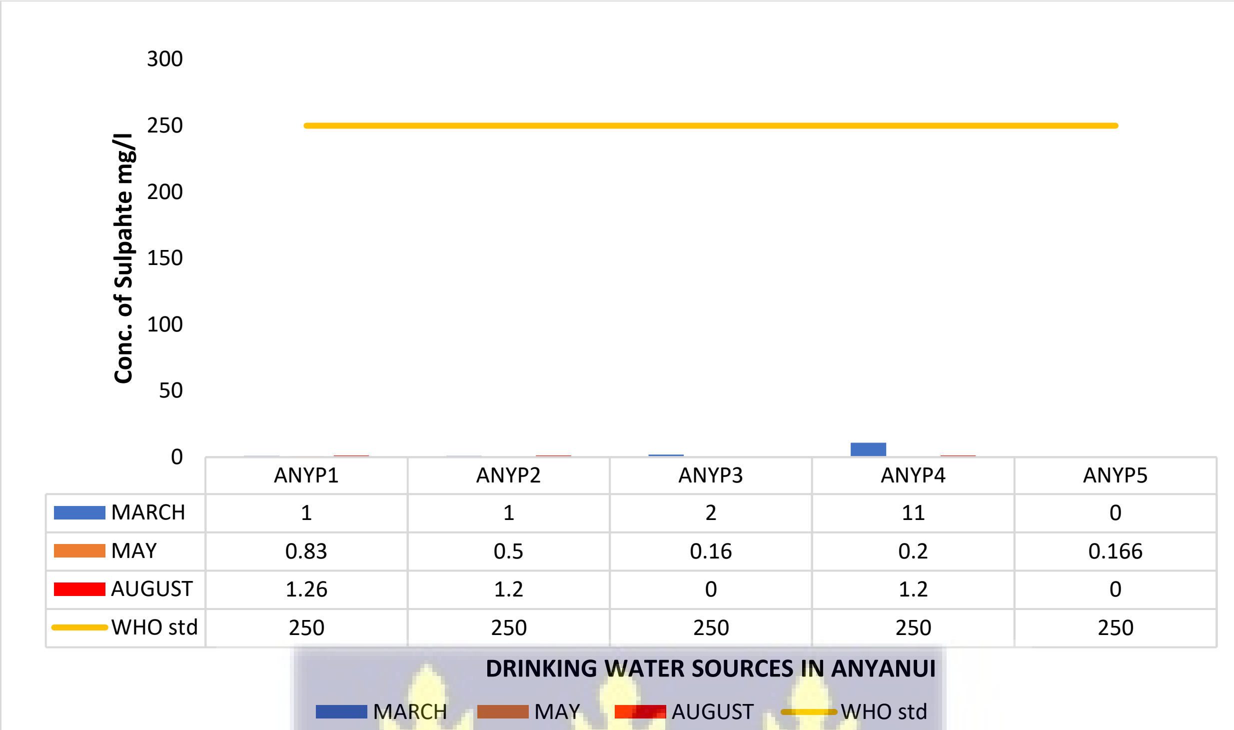


	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	26	15	13	77	53	6	66	73	20
MAY	34	33	37.33	160.66	143	47	61.66	96.33	122
AUGUST	0	63	0	243.06	144.76	32.13	0	62.1	0
WHO std	250	250	250	250	250	250	250	250	250

Figure 4.1.2 31. A Bar chart showing monthly levels of sulphate in the community drinking water sources in Anyanui.

The sulphate levels Anyanui ranged between 1.00 mg/l to 243.06 mg/l in the community sources of drinking water. With the Wells, the level of sulphate in the drinking water samples ranged from 6.00 to 77.00 mg/l in March, with the highest recorded in ANYW4 and the lowest recorded in ANYW6. In May, the levels ranged from 33.00 mg/l to 160.66 mg/l, with the highest and lowest level in ANW4 & ANYW2 respectively.

The sources in the wells were high but had levels of sulphate within the WHO standards of drinking water.

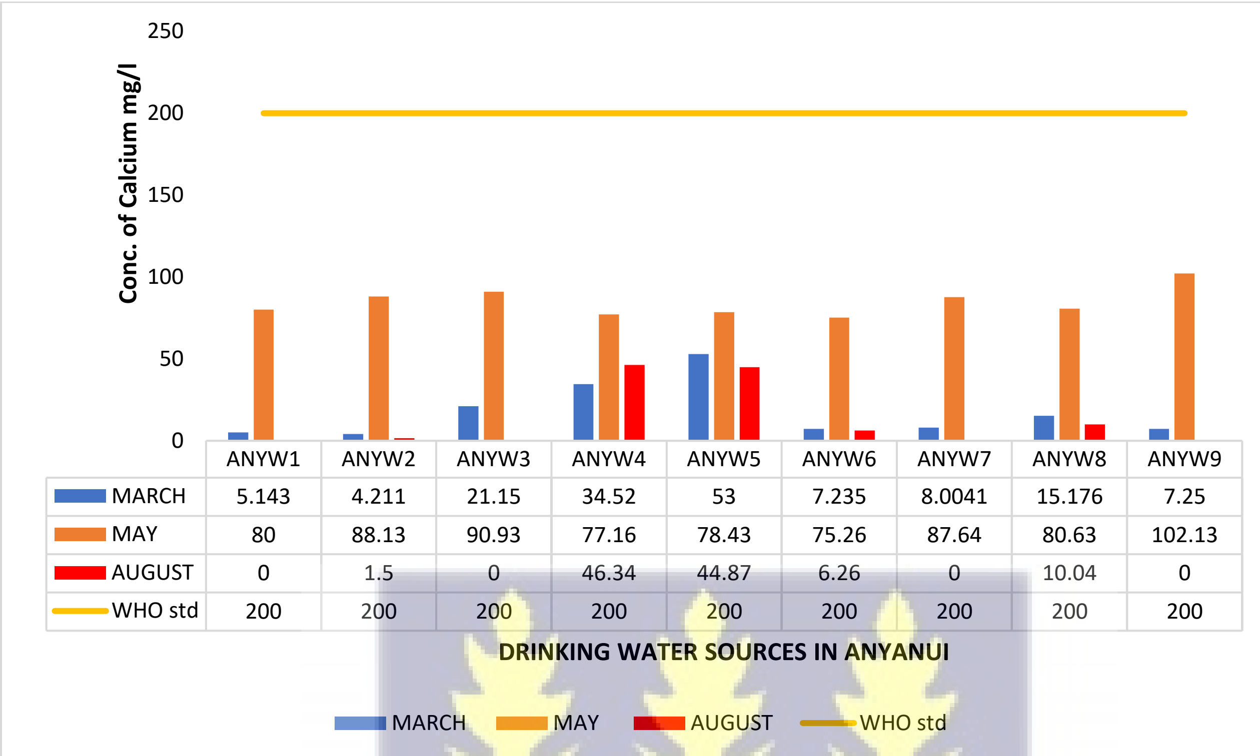


	ANYP1	ANYP2	ANYP3	ANYP4	ANYP5
MARCH	1	1	2	11	0
MAY	0.83	0.5	0.16	0.2	0.166
AUGUST	1.26	1.2	0	1.2	0
WHO std	250	250	250	250	250

Figure 4.1.2 32. A Bar chart showing monthly concentration of sulphate in the community drinking water sources in Anyanui.

The range of sulphate levels in the water samples sourced from the pipes was between 1.00 mg/l to 11.00 mg/l in March and the highest and the lowest level was from ANYP4 and ANYP1 & ANYP2. In May, the levels were between 0.5 mg/l to 0.83 mg/l with the highest level of concentration recorded in all but ANYP1 and the lowest recorded in ANYP3 and ANYP4 and in the last month August, with the exception of two sources, ANYP3 and ANYP5 the sources had the same level of sulphate concentration which were also within the WHO required standard of 250.00 mg/l.

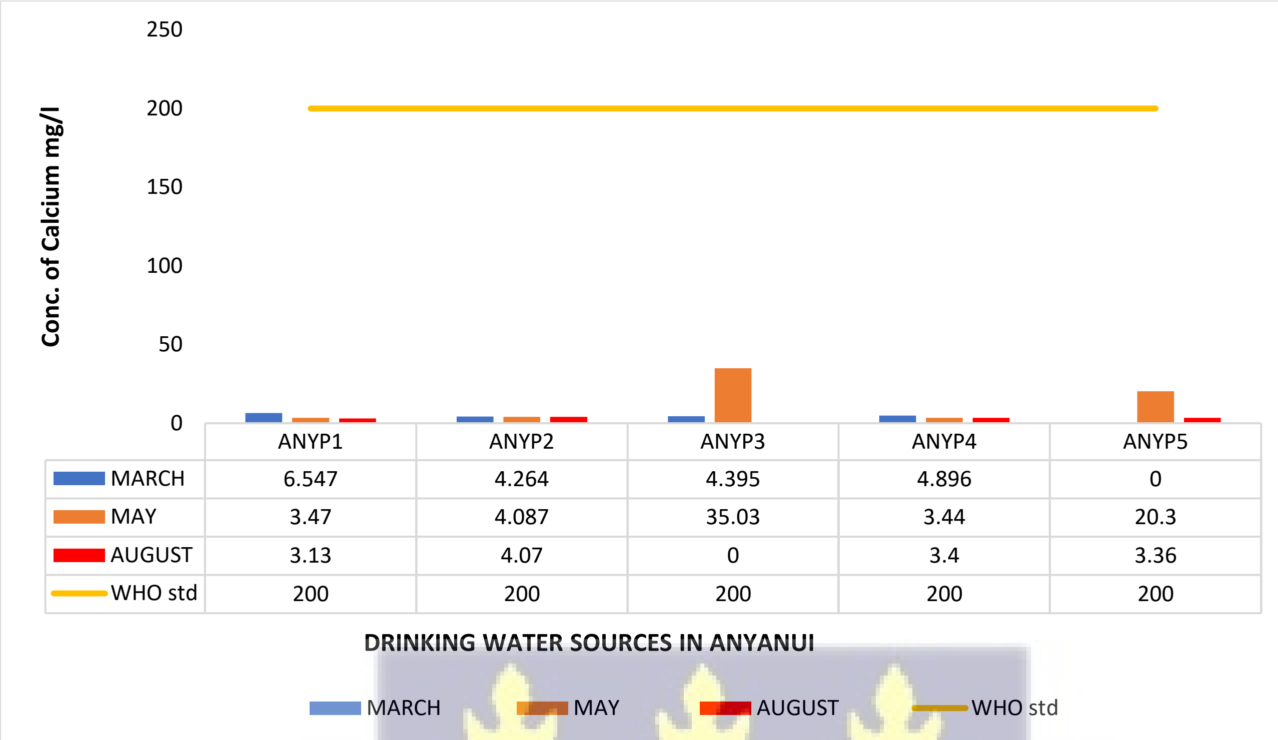
Calcium



	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	5.143	4.211	21.15	34.52	53	7.235	8.0041	15.176	7.25
MAY	80	88.13	90.93	77.16	78.43	75.26	87.64	80.63	102.13
AUGUST	0	1.5	0	46.34	44.87	6.26	0	10.04	0
WHO std	200	200	200	200	200	200	200	200	200

Figure 4.1.2 33. A Bar chart showing monthly levels of calcium in the community drinking water sources in Anyanui.

The calcium levels ranged from 1.5 mg/l to 102.13 mg/l in the community sources of drinking water. In March, the Wells had calcium levels in the drinking water samples ranging from 4.21 to 34.52 mg/l, with the highest recorded in ANYW3 and the lowest recorded in ANYW2. In May the levels ranged from 77.16 mg/l to 102.11 mg/l, with the highest and the lowest level from ANYW9 & ANYW4 respectively. The levels were not above the WHO standard of 200.00 mg/l.

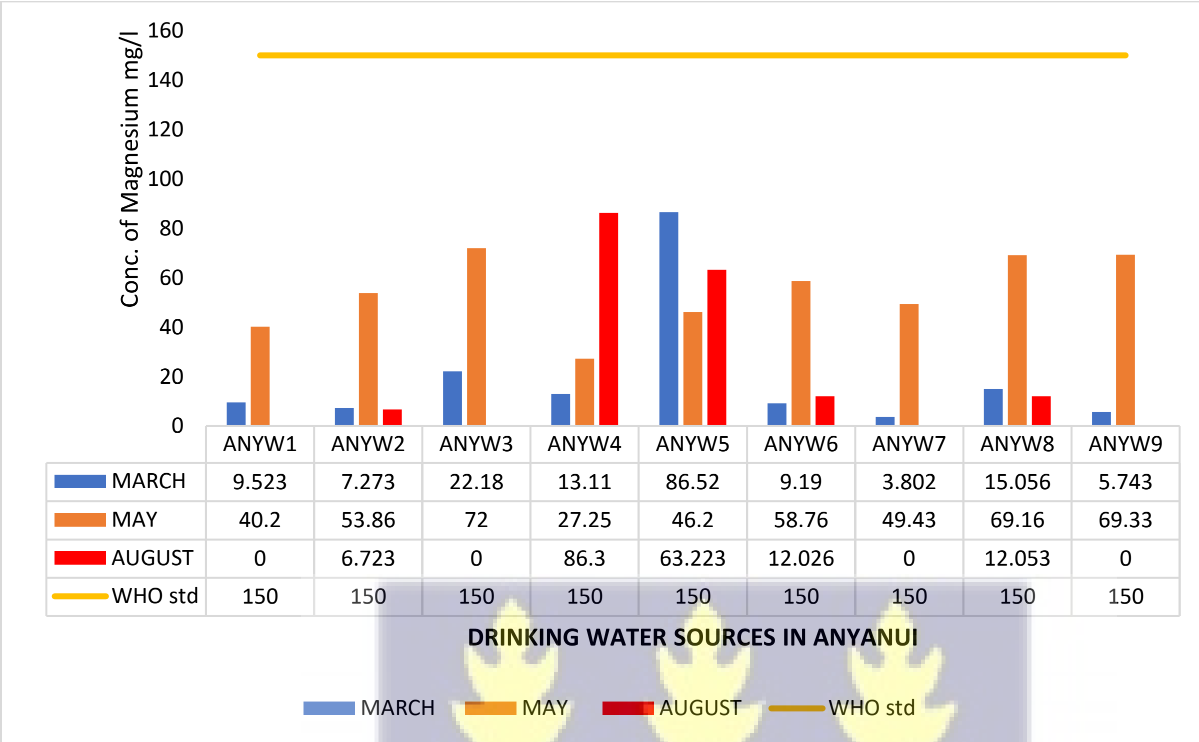


	ANYP1	ANYP2	ANYP3	ANYP4	ANYP5
MARCH	6.547	4.264	4.395	4.896	0
MAY	3.47	4.087	35.03	3.44	20.3
AUGUST	3.13	4.07	0	3.4	3.36
WHO std	200	200	200	200	200

Figure 4.1.2 34 .A Bar chart showing monthly concentration of calcium in the community drinking water sources in Anyanui.

The range of calcium levels in the water samples sourced from the Pipes was found to be between 4.264 mg/l to 6.547 mg/l with the highest level of ANYP1 and the lowest recorded in ANYP2 in March. May calcium levels were between 3.44 mg/l to 35.03 mg/l with the highest recorded from ANYP3 and the lowest in ANYP4. In August, the levels were from 3.13 mg/l to 4.07 mg/l with the highest and the lowest recorded from ANYP2 & ANYP1 respectively. All the sampled water sources from the pipes in Anyanui had levels within the WHO required standard.

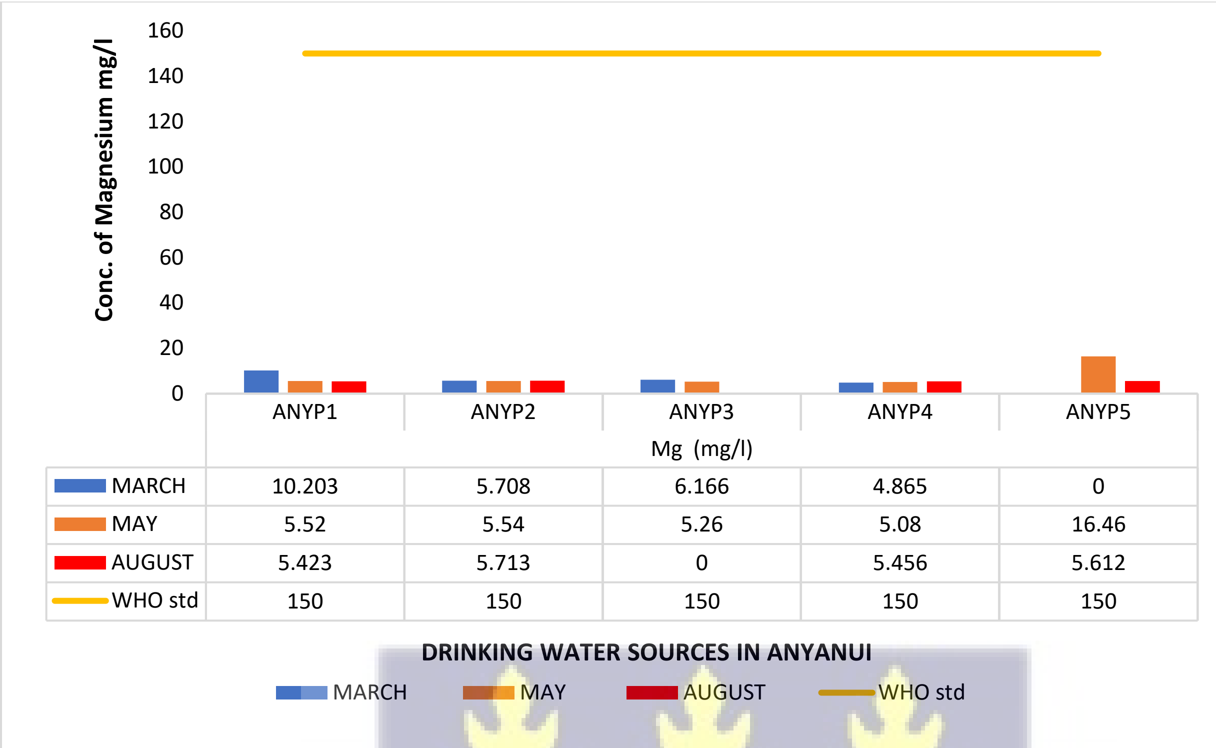
Magnesium



	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	9.523	7.273	22.18	13.11	86.52	9.19	3.802	15.056	5.743
MAY	40.2	53.86	72	27.25	46.2	58.76	49.43	69.16	69.33
AUGUST	0	6.723	0	86.3	63.223	12.026	0	12.053	0
WHO std	150	150	150	150	150	150	150	150	150

Figure 4.1.2 35 A Bar chart showing monthly concentration of magnesium in the community drinking water sources in Anyanui

The magnesium levels ranged from 3.80 mg/l to 86.52 mg/l in the community sources of drinking water during the sampling period. With the wells in March, the level of magnesium in the drinking water samples ranged between 3.80 mg/l to 86.52 mg/l, with the highest recorded in ANYW7 and the lowest recorded in ANYW5. In May, the levels ranged between, 27.25 mg/l to 72.00 mg/l, with the highest from ANYW3 and the lowest level from ANYW4. The magnesium levels in August were slightly different from the other months as it ranged between 0 to 86.3 mg/l, with the highest in ANYW4 and the lowest in ANYW1 &ANYW7. They all fell within the WHO standard of drinking water.

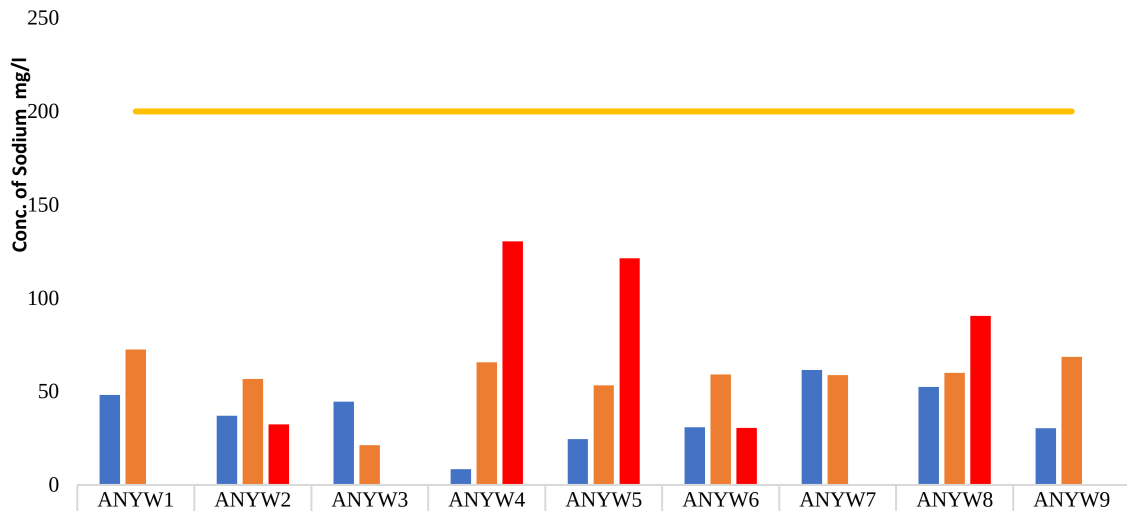


	ANYP1	ANYP2	ANYP3	ANYP4	ANYP5
MARCH	10.203	5.708	6.166	4.865	0
MAY	5.52	5.54	5.26	5.08	16.46
AUGUST	5.423	5.713	0	5.456	5.612
WHO std	150	150	150	150	150

Figure 4.1.2 36. A Bar chart showing monthly concentration of magnesium in the community drinking water sources in Anyanui

The range of magnesium in the water samples sourced from the pipes was between 5.70 mg/l to 10.20 mg/l in March, with the highest level of concentration was recorded in all but ANYP1 and the lowest recorded in ANYP2. In May the levels were between 5.26 mg/l to 16.46 mg/l, with the highest in ANYP5 and the lowest in ANYP3. August levels ranged from 0 to 5.71 mg/l with the highest in ANYP2 and the lowest in ANYP3. The levels were all within the WHO standard of 150.00 mg/l which means the water in terms of magnesium is of good quality.

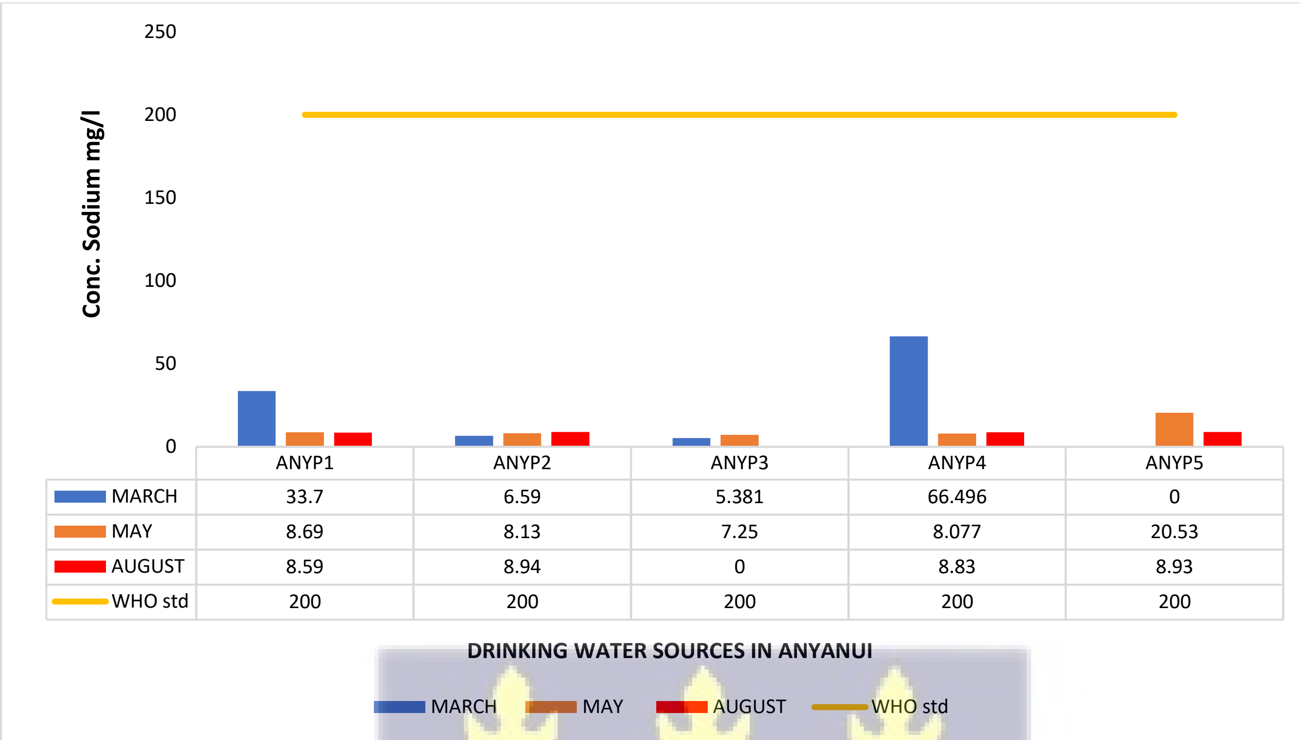
Sodium



	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	48.17	37.1	44.53	8.452	24.6	30.94	61.536	52.536	30.43
MAY	72.5	56.73	21.23	65.6	53.4	59.2	58.8	60.03	68.63
AUGUST	0	32.45	0	130.36	121.43	30.61	0	90.58	0
WHO std	200	200	200	200	200	200	200	200	200

Figure 4.1.2 37. A Bar chart showing monthly concentration levels of sodium in the community drinking water sources in Anyanui.

The sodium levels ranged between 5.38 to 130.36 mg/l in the community sources of drinking water during in the months sampled. In March and wit the wells, the level of sodium in the drinking water samples ranged from 8.45 to 61.53 mg/l, with the highest recorded in ANYW7 and the lowest recorded in ANYW4. In May, the levels were between 21.23 mg/ to 72.5 mg/l with the highest from the source, ANYW1 and the lowest ANYW3. August had levels between 0 to 130 mg/l with the highest from ANYW4 and the lowest from four other sources which were AYW1, 3, 7 and 9. Though the levels in August were higher than in March and in May they all fell within the required standard set by WHO



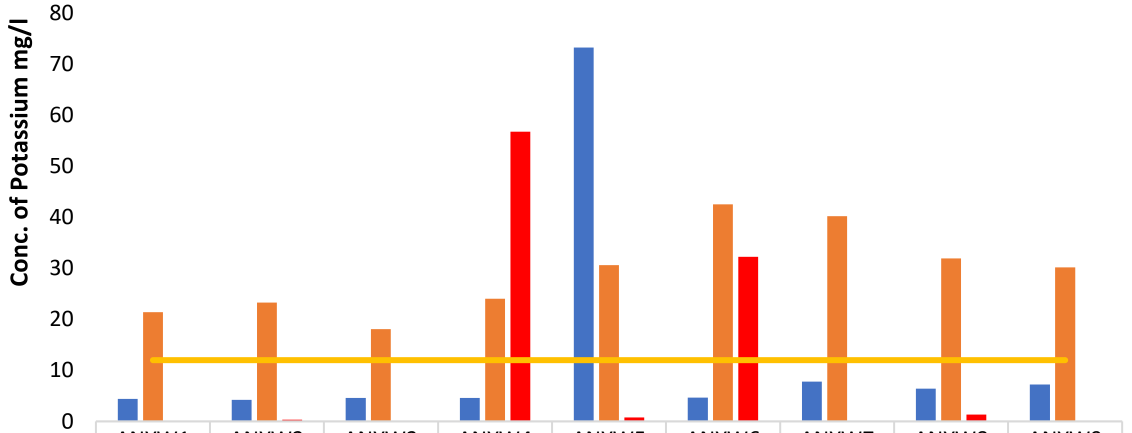
	ANYP1	ANYP2	ANYP3	ANYP4	ANYP5
MARCH	33.7	6.59	5.381	66.496	0
MAY	8.69	8.13	7.25	8.077	20.53
AUGUST	8.59	8.94	0	8.83	8.93
WHO std	200	200	200	200	200

Figure 4.1.2 38. A Bar chart showing monthly concentration of sodium in the community drinking water sources in Anyanui.

The range of the concentration level of sodium in the water samples sourced from the Pipes was from 5.38 to 66.49 mg/l with the highest level of concentration recorded ANYP4 and the lowest recorded in ANYP3 within the first month, March. In May, the concentration levels were between 7.25 mg/l to 20.53 mg/l with the highest recorded from ANYP5 and the lowest level from ANYP3.

In August the level of concentration was between 0 to 8.93 mg/l. The highest was recorded from ANYP5 and the lowest from source ANYP3. March recorded higher levels than that of May and August, though each month had the levels within the WHO standard.

Potassium



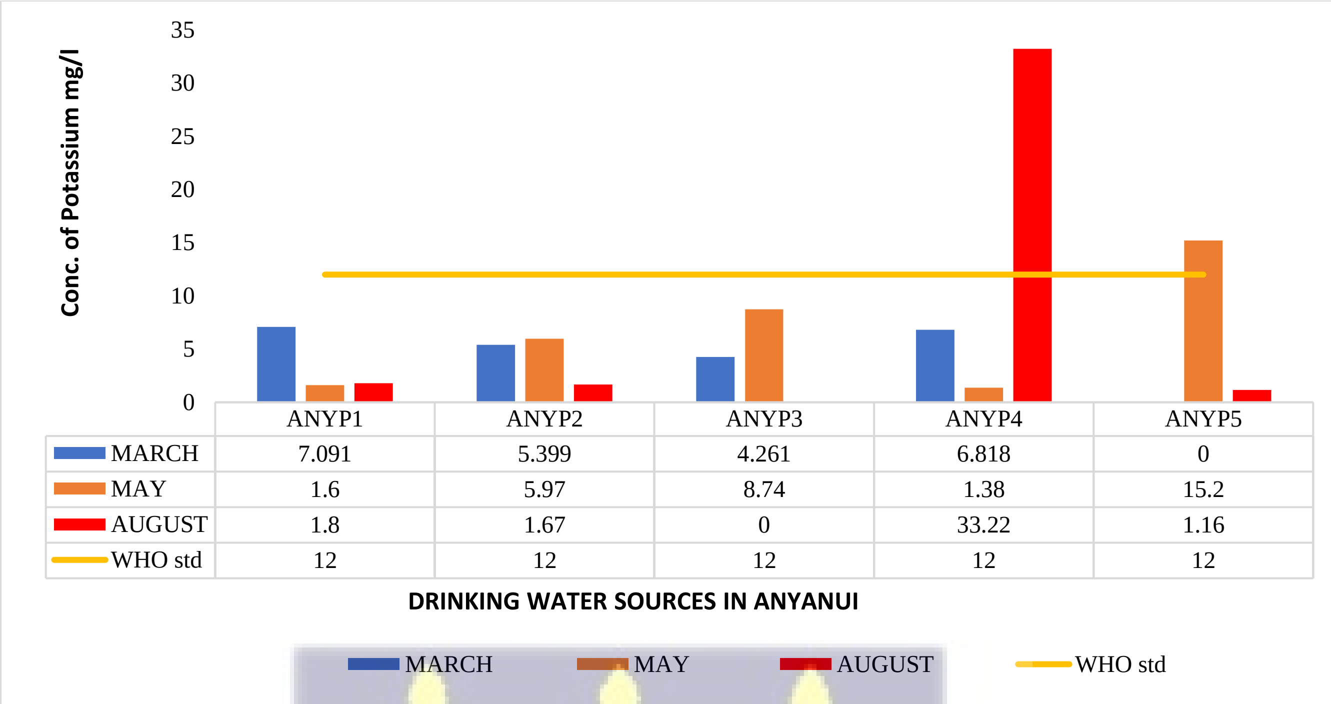
	ANYW1	ANYW2	ANYW3	ANYW4	ANYW5	ANYW6	ANYW7	ANYW8	ANYW9
MARCH	4.382	4.211	4.59	4.58	73.26	4.679	7.776	6.405	7.231
MAY	21.4	23.3	18.06	24.06	30.63	42.5	40.23	31.93	30.16
AUGUST	0	0.31	0	56.76	0.77	32.26	0	1.36	0
WHO std	12	12	12	12	12	12	12	12	12

DRINKING WATER SOURCES IN ANAYNUI

MARCH MAY AUGUST WHO std

Figure 4.1.2 39. A Bar chart showing monthly concentration of potassium in the community drinking water sources in Anyanui.

The potassium levels ranged from 0.31 mg/l to 73.26 mg/l in all the community sources of drinking water. In March and within the wells, the level of potassium in the drinking water samples ranged from 4.21 mg/l to 73.26 mg/l, with the highest recorded in ANYW5 and the lowest recorded in ANYW2. In May, it was between 18.06 mg/l to 42.23 mg/l with the highest level in ANYW6 and the lowest in ANYW2. In August it differed with a range which was between 0 to 56.76 mg/l, and the highest was recorded from ANYW4 and the lowest from four other sources, ANYW1, 3, 7 & 9. In March the sources were all within the WHO standard whilst in May all the sources were above the standard. In August two out of the nine wells were above the standard.



	ANYP1	ANYP2	ANYP3	ANYP4	ANYP5
MARCH	7.091	5.399	4.261	6.818	0
MAY	1.6	5.97	8.74	1.38	15.2
AUGUST	1.8	1.67	0	33.22	1.16
WHO std	12	12	12	12	12

Figure 4.1.2 40 A Bar chart showing monthly levels of potassium in the community drinking water sources in Anyanui.

The range of the level of concentration for potassium in the water samples sourced from the pipes in March was between 5.39 mg/l to 7.09 mg/l with the highest level of concentration recorded in all but ANYP1 and the lowest recorded in ANYP5. In May the levels had a range of 1.38 mg/l to 15.2 mg/l with the highest level in ANYP5 and the lowest level in ANYP4. In August, the ranges were between 0 to 33.22 mg/l with the highest in ANYP4 and the lowest in ANYP3. All the sources had levels within the WHO standard in March and in May only one sources ANYP5 was above the required standard. In August it was ANYP4 that showed levels above the standard unlike the other drinking water sources.

4.1.3 Mean Record of Microbial Parameters Count in Water Sources from Each Community.

Table 4.1.3. 1 Mean microbial count of samples from community drinking water sources in Anyako.

CODES	Water Source	Total Coliform (cfu/100 ml)	Faecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)
AKOC1	Commercial Poly-tank	23 ±13.28	2 ±1.15	3 ±1.73
AKOC2	Commercial Poly-tank	1605 ±925.78	5 ±2.89	0 ±0.00
AKOC3	Commercial Poly-tank	11 ±2.89	0 ±0.00	0 ±0.00
AKOC4	Commercial Poly-tank	188 ±108.54	5 ±2.89	1 ±0.58
AKOC5	Commercial Poly-tank	0 ±0	0 ±0.00	0 ±0.00
AKOC6	Commercial Poly-tank	85 ±58.69	5 ±3.54	0 ±0.00
AKOC7	Commercial Poly-tank	2092 ±1207.82	0 ±0.00	0 ±0.00
AKOC8	Commercial Poly-tank	2012 ±1161.63	322 ±185.91	0 ±0.00
AKOC9	Commercial Poly-tank	5 ±3.54	0 ±0.00	0 ±0.00
APV1	Private Poly-tank	30 ±17.32	15 ±8.66	0 ±0.00
APV2	Private Poly-tank	68 ±39.26	8 ±4.62	6 ±3.46
APV3	Private Poly-tank	81 ±46.77	38 ±26.87	12 ±6.93
APV4	Private Poly-tank	48 ±27.71	0 ±0.00	0 ±0.00
AKT1	Reservoir	91 ±52.54	1 ±0.71	0 ±0.00
AKW1	Well	1027 ±588.61	5 ±1.53	0 ±0.00
AKS1	Sachet Water	0 ±0.00	0 ±0.00	0 ±0.00
AKS2	Sachet Water	2 ±1.15	0 ±0.00	0 ±0.00
AKS3	Sachet Water	1 ±0.58	0 ±0.00	0 ±0.00
AKS4	Sachet Water	0 ±0.00	0 ±0.00	0 ±0.00
WHO STANDARDS		0	0	0

Details of the results are presented as follows:

Total Coliform Count in Water Samples.

The total coliform counts range was from 0 to 2092 cfu/100 ml in all the community drinking water sources in Anyako. With the commercial poly-tanks, total coliform load of the water samples ranged from 0 to 2092 cfu/100 ml, with the highest count recorded in AKOC7 and the lowest AKOC5. All but one sample from the commercial poly-tanks, AKOC5, had counts of total coliform. The range of total coliform counts in the drinking water sample sourced from the private poly-tanks was between 30 to 81 cfu/100 ml and 0 to 2 cfu/100 ml in sachet water. The highest count with the water samples from the private Poly- tanks was 81cfu/100 ml in APV3 and the lowest was 30 cfu/100 ml in APV1. With the sachet water samples, the highest count was 2 cfu/100 ml in

AKS2 and the lowest was AKS1 and AKS4. The count for water in the well (AKW1) was 1027 cfu/100 ml and 91 cfu/100 ml for water in the reservoir (AKT1).

Faecal Coliform Counts in Water Samples.

Faecal coliform counts ranged from 0 to 322 cfu/100 ml in all the community drinking water sources in Anyako. With the commercial poly-tanks, the faecal coliform load of the water samples ranged from 0 to 322 cfu/100 ml with the highest count recorded in AKOC8 and the lowest in AKOC3, AKOC5, AKOC7 and AKOC9.

The range of faecal coliform counts in the community drinking water sample sourced from the private poly-tanks was from 0 to 38 cfu/100 ml and no recording in water sample sourced from sachet. The highest count of the water sourced from the private poly-tanks was recorded in APV3 and the lowest APV4. The count in the community drinking water sourced from the well AKW1 was 5 cfu/100 ml and 1 cfu/100 ml from the reservoir AKT1.

Escherichia coli Counts in Water Samples.

E. coli counts ranged from 0 to 12 cfu/100 ml in all the community drinking water sources in Anyako. With the commercial poly-tanks, *E. coli* count of the water samples ranged from 0 to 5 cfu/100 ml, with the highest count recorded in AKOC1 and the lowest AKOC2, AKOC3, AKOC5, AKOC6, AKOC7, AKOC8 and AKOC9. The range of *E. coli* count in water sample sourced from the private poly-tanks was from 0 to 3 cfu/100 ml, with the highest recorded in APV3 and the lowest APV1 and APV4. Water samples sourced from sachet water did not record any *E. coli*.

There was no recording of *E. coli* within the water samples sourced from the well AKW1 and the reservoir AKT1.

Table 4.1.3. 2 Mean microbial count of samples from the community drinking water sources in Atiteti.

CODES	Water source	Total Coliform (cfu/100 ml)	Faecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)
ATIP1	Pipe	0 ±0.00	0 ±0.00	0 ±0.00
ATIP2	Pipe	1 ±0.58	0 ±0.00	0 ±0.00
ATIP3	Pipe	0 ±0.00	0 ±0.00	0 ±0.00
ATIP4	Pipe	2 ±1.15	0 ±0.00	0 ±0.00
ATIP5	Pipe	8 ±4.62	2 ±1.15	0 ±0.00
ATIP6	Pipe	0 ±0.00	0 ±0.00	0 ±0.00
WHO STD		0	0	0

Details of the results are presented as follows:

Total Coliform Count in Water Samples.

The total coliform count of water samples in Atiteti varied between 0 to 8 cfu/100 ml in all the community drinking water sources all of which are pipes. The highest count was sampled from ATIP5.

Faecal Coliform Count in Water Samples.

The faecal coliform count in the water samples varied between 0 to 2cfu/100 ml in the community drinking water sources. The highest was 2 cfu/100 ml which was water sampled from ATIP5.

Escherichia coli Count in Water Samples.

The presence of *E. coli* was not observed in water samples sourced from the pipes in Atiteti.

Table 4.1.3. 3. Mean microbial count of samples from the community drinking water sources in Anyanui.

CODES	Water Source	Total Coliform (cfu/100 ml)	Faecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)
ANYW1	Well	14 ±8.49	5 ±2.12	3 ±2.12
ANYW2	Well	17 ±7.37	6 ±3.46	0 ±0.00
ANYW3	Well	14 ±4.24	3 ±0.71	0 ±0.00
ANYW4	Well	2052 ±1168.31	19 ±10.12	0 ±0.00
ANYW5	Well	607 ±165.08	169 ±84.62	0 ±0.00
ANYW6	Well	28 ±7.51	12 ±3.61	1 ±0.58
ANYW7	Well	2069 ±562.15	199 ±130.81	1 ±0.71
ANYW8	Well	37 ±5.13	4 ±1.15	0 ±0.00
ANYW9	Well	2611 ±1846.26	2020 ±1428.36	0 ±0.00
ANYP1	Pipe	2 ±1.15	0 ±0.00	0 ±0.00
ANYP2	Pipe	0 ±0.00	0 ±0.00	0 ±0.00
ANYP3	Pipe	4 ±2.83	3 ±2.12	2 ±1.41
ANYP4	Pipe	0 ±0.00	0 ±0.00	0 ±0.00
ANYP5	Pipe	0 ±0.00	0 ±0.00	0 ±0.00
WHO STANDARDS		0	0	0

Details of the results are presented as follows***:***

Total Coliform Count in Water Samples.

The total coliform counts were between 0 to 2611 cfu/100 ml in all the community drinking water sources in Anyanui.

With the wells, total coliform load of the water samples varied from 14 to 2611 cfu/100 ml, with the highest count recorded in ANYW9 and the lowest in ANYW1 and ANY3.

The range of total coliform count in the community drinking water samples sourced from the pipes, was from 0-4cfu/100 ml, with the highest count recorded in ANYP3 and the lowest count in ANYP2, ANYP4 and ANYP5.

Faecal Coliform Count in Water Samples.

Faecal coliform counts ranged from 0 to 2020 cfu/100 ml in all the community drinking water sources in Anyanui. Within the wells, faecal coliform load of the water samples ranged between 5 to 2020 cfu/100 ml, with the highest recorded in ANYW9 and the lowest in ANYW3.

The range of faecal coliform count in the drinking water samples sourced from the pipes was from 0 to 3 cfu/100 ml with the highest recording in ANYP3. There was no record of faecal coliform within the other pipe sources.

Escherichia coli Count in Water Samples.

E. coli count ranged from 0 to 3 cfu/100 ml in the community drinking water sources in Anyanui. With the wells, *E. coli* of the water samples ranged from 0 to 3 cfu/100 ml, with the highest count recorded in ANYW1 and the lowest in ANYW2, ANYW3, ANYW4, ANYW8 and ANYW9. The rest of the samples from the wells showed no record of *E. coli*.

Ranges of *E. coli* count within drinking water samples sourced from Pipes was 0 to 3 cfu/100 ml with the maximum count noted in ANYP3, the rest of the sources had no record of *E. coli.*

ANOVA for microbial parameters in each community.

ANOVA Table 40. Summary for Total Coliform in Anyako

Anyako	Total N	13
	Test Statistic	8.914
	Degree Of Freedom	2
	Asymptotic Sig.	.012
Atiteti	Total N	6
	Test Statistic	2.000[a]
	Degree Of Freedom	2
	Asymptotic Sig.	.368
Anyanui	Total N	9
	Test Statistic	2.545[a]
	Degree Of Freedom	2
	Asymptotic Sig.	.280

Pairwise Comparisons

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Anyako	March – May	-.923	.392	-2.353	.019	.056

ANOVA Table 40: indicates that the P -value in community Anyako is < 0.05 which means that the total coliform counts in each of the month sampled are significantly different. Example, Total coliform counts in March, May and August have differences between them. Atiteti and Anyanui both have P-value>0.05 hence there are no significant differences between the samples. Pairwise comparison test was done to find out which month the samples had differences. The samples compared between March and May showed differences between them

ANOVA Table 41. Summary for Fecal Coliform

Anyako	Total N	12
	Test Statistic	8.316
	Degree Of Freedom	2
	Asymptotic Sig	.016
Atiteti	Total N	6
	Test Statistic	2.000[a]
	Degree Of Freedom	2
	Asymptotic Sig	.368
Anyanui	Total N	9
	Test Statistic	.111[a]
	Degree Of Freedom	2
	Asymptotic Sig	.946

ANOVA Table 41: shows a P -value of < 0.05 in Anyako which means that the faecal coliform counts in each of the month sampled are significantly different. Faecal coliform counts in March, May and August have differences between them. Atiteti and Anyanui both have P-value> 0.05 hence there are no significant differences between the samples.

ANOVA Table 42. Summary for *Escherichia coli*

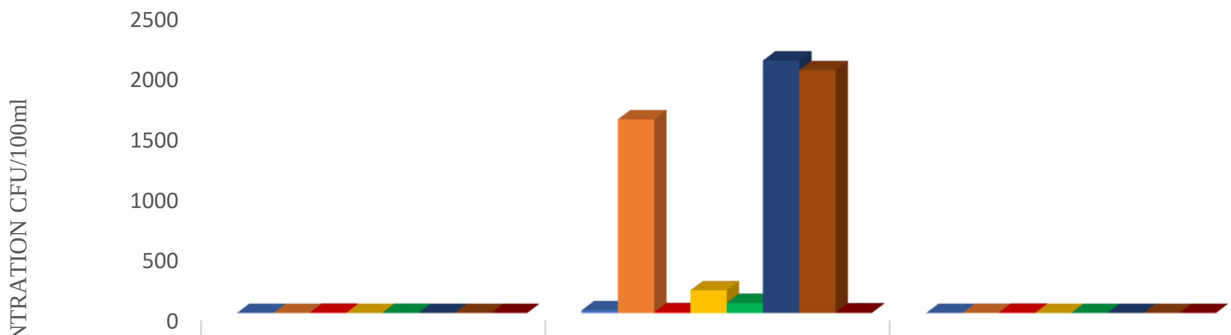
Anyako	Total N	13
	Test Statistic	6.000
	Degree Of Freedom	2
	Asymptotic Sig	.050
Atiteti	Total N	6
	Test Statistic	.000[a]
	Degree Of Freedom	2
	Asymptotic Sig	1.000
Anyanui	Total N	9
	Test Statistic	2.000[a]
	Degree Of Freedom	2
	Asymptotic Sig	.368

Pairwise Comparison.

COMMUNITY	Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Anyako	March -August	.000	.392	.000	1.000	1.000
	March - May	-.346	.392	-.883	.377	1.000
	August -May°	.346	.392	.883	.377	1.000

ANOVA Table 42: shows a P -value of <0.05 in Anyako, which means that the *E. coli* counts in each of the month sampled are significantly different. *E. coli* counts in March, May and August have differences between them. Atiteti and Anyanui both have P-value>0.05 hence there are no significant differences between the samples.

4.1.4 Monthly Levels of Microbial Parameters In Each Community



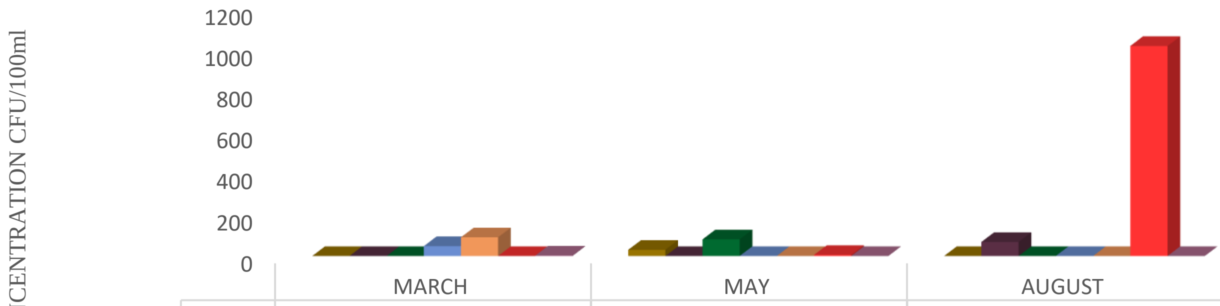
	MARCH	MAY	AUGUST
AKOC1	0	23	0
AKOC2	0	1604	1
AKOC3	2	7	2
AKOC4	0	188	0
AKOC6	1	84	0
AKOC7	0	2092	0
AKOC8	0	2012	0
AKOC9	0	5	0

MONTHS

Figure 4.1.4. 1. A Bar chart showing results of the monthly levels of total coliform recorded in community drinking water sources in Anyako.

Total Coliform Count in Water Samples.

The count of the total coliform varied from 0-91 cfu/100 ml in all the community drinking water sources in Anyako in March, 0-2092cfu/100 ml in May and 0-1022 cfu/100 ml in August. In March, the commercial poly-tanks, had total coliform load which ranged from 0-2 cfu/100 ml, with the most count recorded in AKOC3 and the lowest count recorded in the rest of the water samples but AKOC6 which had a count of 1 cfu/100 ml. In May, the maximum count was noted in AKOC7 and the low count in the sachet water samples but in August, the highest count within the commercial poly-tanks was recorded in AKOC3 and the low count documented in the rest of the water sources but AKOC2 which had a count of 1 cfu/100 ml.



	MARCH	MAY	AUGUST
APV1	0	30	0
APV2	0	0	68
APV3	0	81	0
APV4	48	0	0
AKT1	91	0	0
AKW1	0	5	1022
AKS2	2	0	0

Figure 4.1.4. 2. A Bar chart showing results of the monthly levels of total coliform recorded in community drinking water sources in Anyako.

Total Coliform Count in Water Samples.

The count of total coliform ranged from 0-91 cfu/100 ml in all the community drinking water sources in Anyako in March, 0-2092cfu/100 ml in May and 0-1022 cfu/100 ml in August. Within the month of March in the private poly-tanks the count ranged from 0-48 cfu/100 ml, with the highest count recorded in APV4 and the lowest in the rest of the sources. In May the highest count was recorded in APV3 with count of 81 cfu/100 ml. The counts in August, ranged from 0-68 cfu/100 ml, with the highest count recorded in APV2 and the lowest in the rest of the sources. The range of total coliforms in the drinking water samples sourced from the well and reservoir are 0 cfu/100 ml and 91 cfu/100 ml in March. There were no observations of coliform present with the water samples from the reservoir in May and in August but the recorded count in the Well was 5 cfu/100 ml and 1022 cfu/100 ml respectively.

With the samples sourced from the sachet water the total coliform count ranged from 0-2 cfu/100 ml in March with the highest recorded in AKS2, and 0-1 cfu/100 ml in August with the highest recorded in AKS3, there was no recording in the month of May, with the highest recorded in AKS2 and the lowest in the rest of the samples.

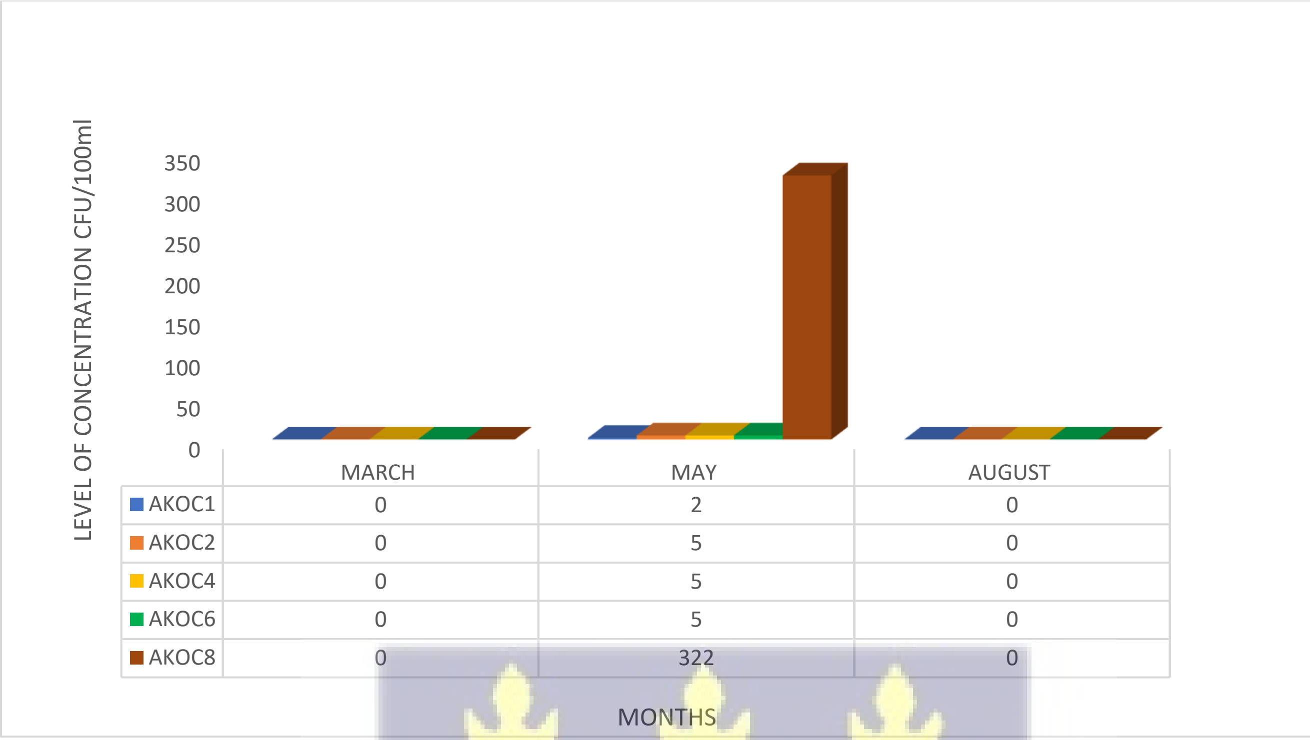
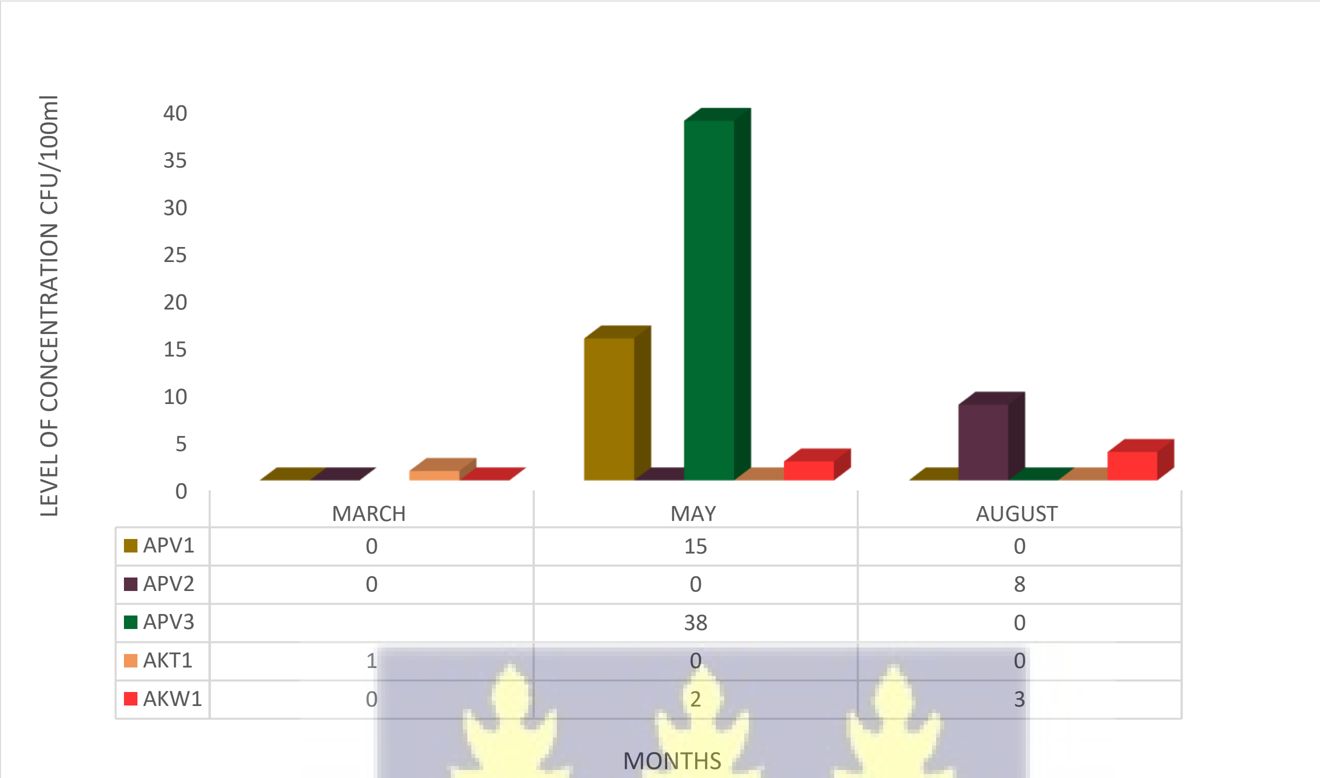


Figure 4.1.4. 3. A Bar chart showing the levels of faecal coliform recorded in the community drinking water sources in Anyako.

Faecal Coliform Count in Water Samples.

The count of faecal coliform in March ranged from 0-1 cfu/100 ml in all the community drinking water sources in Anyako, in May it ranged from 0-322 cfu/100 ml and from 0-8 cfu/100ml in August. With the commercial poly-tanks, there was no recording of faecal coliform with the drinking water samples though in the month of May, the faecal count in the commercial poly-tanks ranged from 0-322 cfu/100 ml with the highest recorded in AKOC. In August, there were no recordings in the water samples.

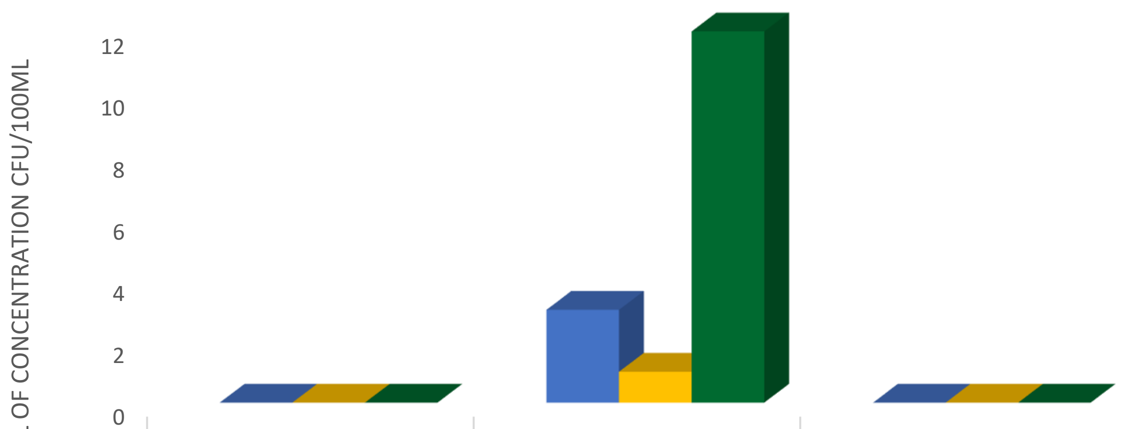


	MARCH	MAY	AUGUST
APV1	0	15	0
APV2	0	0	8
APV3		38	0
AKT1	1	0	0
AKW1	0	2	3

Figure 4.1.4. 4. A Bar chart showing results of the monthly levels of faecal coliform recorded in community drinking water sources in Anyako.

Faecal Coliform Count in Water Samples.

The count of faecal coliform in March ranged from 0-1 cfu/100 ml in all the community drinking water sources in Anyako, in May it ranged from 0-322 cfu/100 ml and from 0-8 cfu/100ml in August. With the private poly-tanks, the well and the sachet water, there was no recording of faecal coliform with the drinking water samples in March, though in the month of May the faecal count in the private poly-tanks recorded at 38 cfu/100 ml at APV3 and 2 cfu/100 ml at AKW1 in the sample from the well. In August, there were no recordings in the rest of the water samples with the exception of that from APV2 and AKW1 with counts of 8 cfu/100 ml and 3 cfu/100 ml respectively.



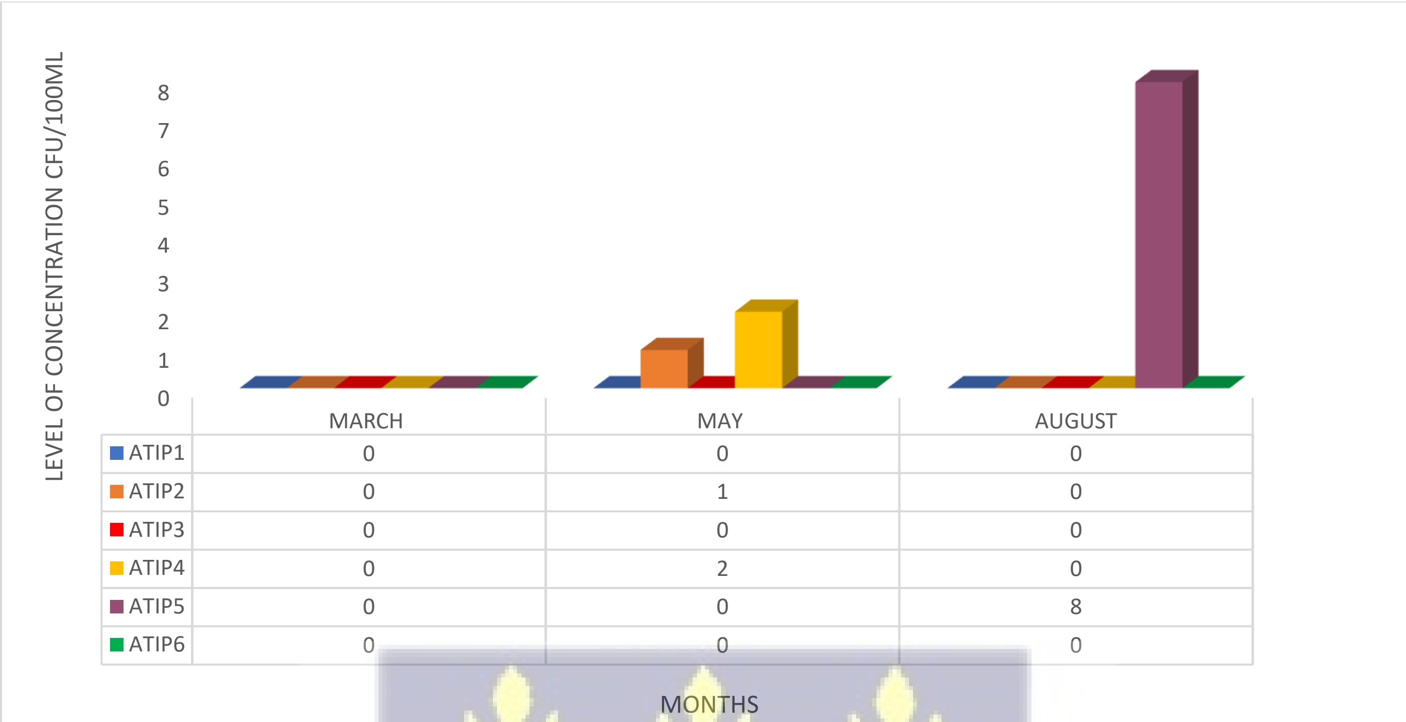
	MARCH	MAY	AUGUST
AKOC1	0	3	0
AKOC4	0	1	0
APV3	0	12	0

Figure 4.1.4. 5. A Bar chart showing the levels of *E. coli* recorded in the community drinking water sources in Anyako.

Escherichia coli Count in Water Samples.

There was no recording of *E. coli* with all the water sampled from the community drinking water sources in Anyako during the month of March and August for AKOC1 AKOC4 and APV3, though in May, the *E. coli* count ranged from 0-12 cfu/100 ml. With the commercial poly-tanks, the highest count was recorded in AKOC1 in May and with the private poly-tanks the highest recording of *E. coli* count in the water samples was recorded at APV3 with a count of 12 cfu/100.

There was no record of *E. coli* for the rest of the water sources in the three months sampled.



	MARCH	MAY	AUGUST
ATIP1	0	0	0
ATIP2	0	1	0
ATIP3	0	0	0
ATIP4	0	2	0
ATIP5	0	0	8
ATIP6	0	0	0

Figure 4.1.4. 6 A Bar chart showing the monthly levels of the total coliform recorded in the community drinking water sources in Atiteti.

Total Coliform Count in Water Samples.

There was no recording of total coliform with the water samples from all the community drinking water sources in Atiteti in March though in May it ranged from 0- 2 cfu/100ml with the highest in ATIP4 and 0-8 cfu/100ml in August with the highest recording in ATIP5.

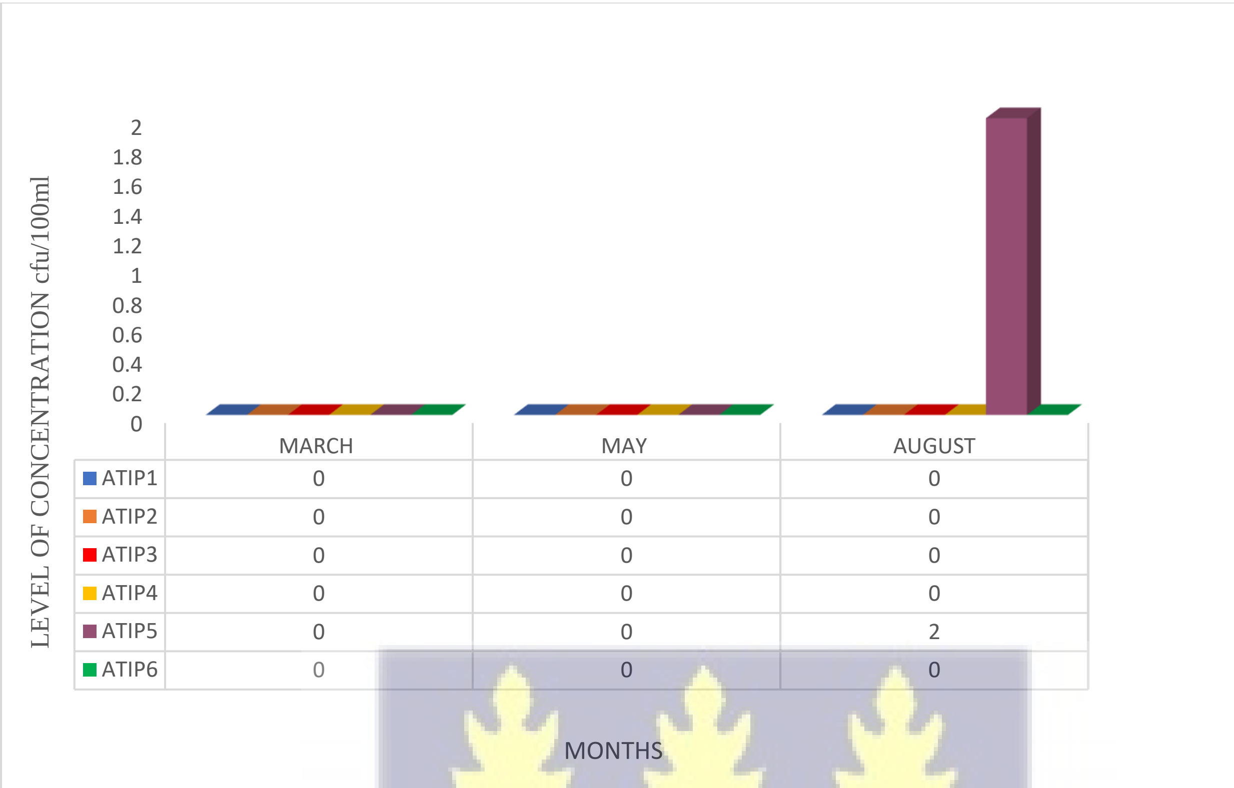


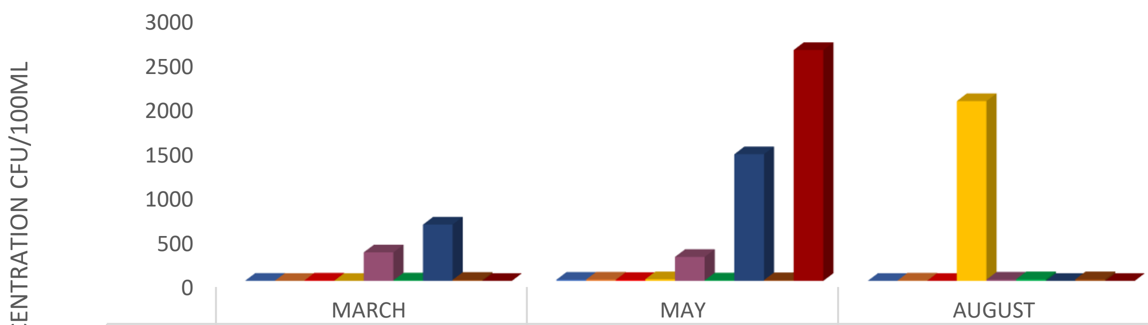
Figure 4.1.4. 7. A Bar chart showing the monthly levels of the faecal coliform recorded in the community drinking water sources in Atiteti.

Faecal Coliform Count in Water Samples.

There was no recording of faecal coliform with the water samples from all the community drinking water sources in Atiteti in March and in May. Faecal coliform was present in a water sample from ATIP5 in August with a count of 2 cfu/100 ml.

Escherichia coli Count in Water Samples.

There was no recording of *E. coli* with the water samples from all the community drinking water sources in Atiteti in March, May and August.



	MARCH	MAY	AUGUST
ANYW1	1	13	0
ANYW2	0	14	3
ANYW3	4	10	0
ANYW4	0	19	2033
ANYW5	322	271	14
ANYW6	5	5	18
ANYW7	637	1432	0
ANYW8	11	8	18
ANYW9	0	2611	0

Figure 4.1.4. 8. A Bar Chart showing monthly levels of total coliform recorded in the community drinking water sources in Anyanui.

Total Coliform Counts in Water Samples.

Total coliform counts varied between 0 to 637 cfu/100 ml in all the community drinking water sources in Anyanui in the March, in May the counts ranged from 0-2611 cfu/100 ml and in August it ranged from 0-2033 cfu/100 ml. With the wells, total coliform load of the water samples was between 0 to 637 cfu/100 ml, with the highest count recorded in ANYW7 and the lowest in ANYW1 in the month of March and the highest count in May was recorded in ANYW9 and the lowest in ANYW6, whilst ANYW4 recorded the highest and the lowest in ANYW5 in August.

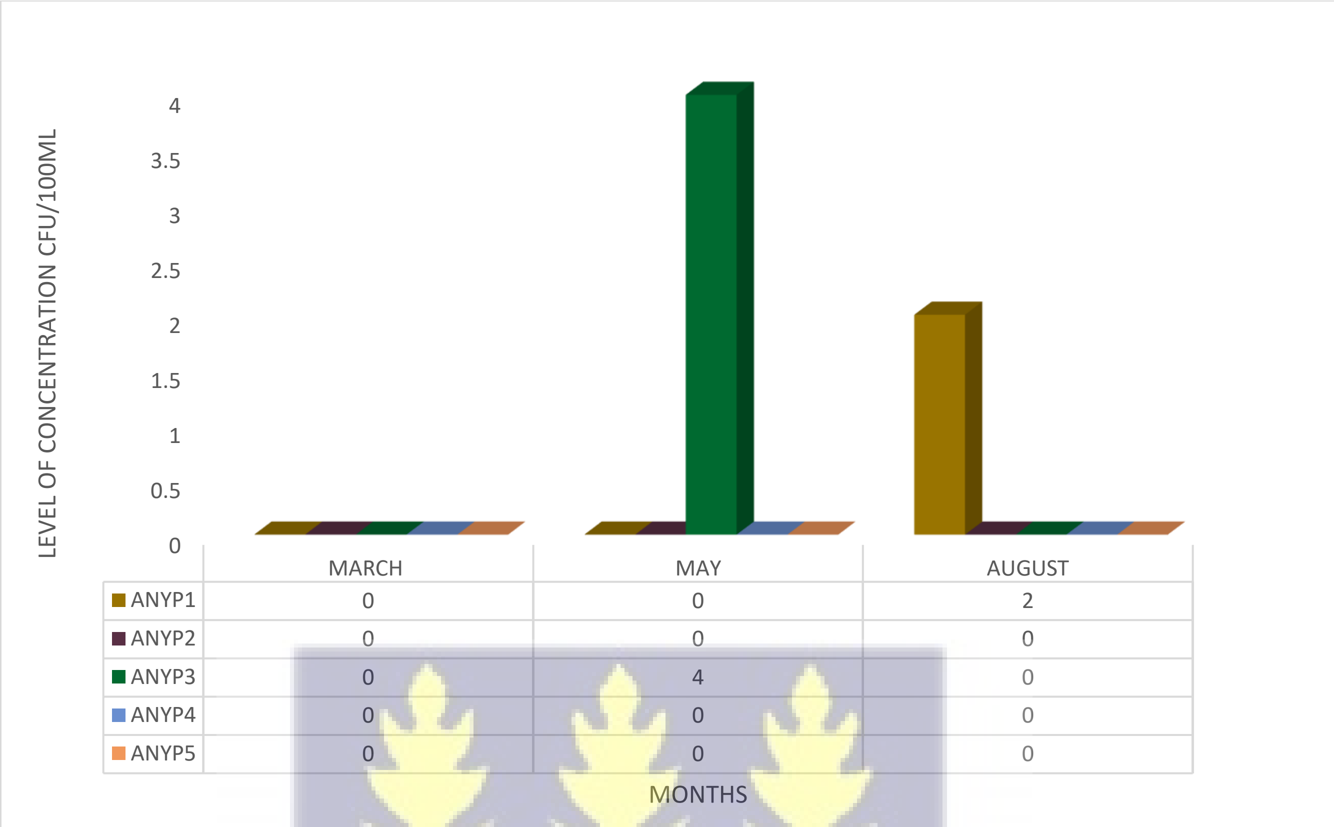
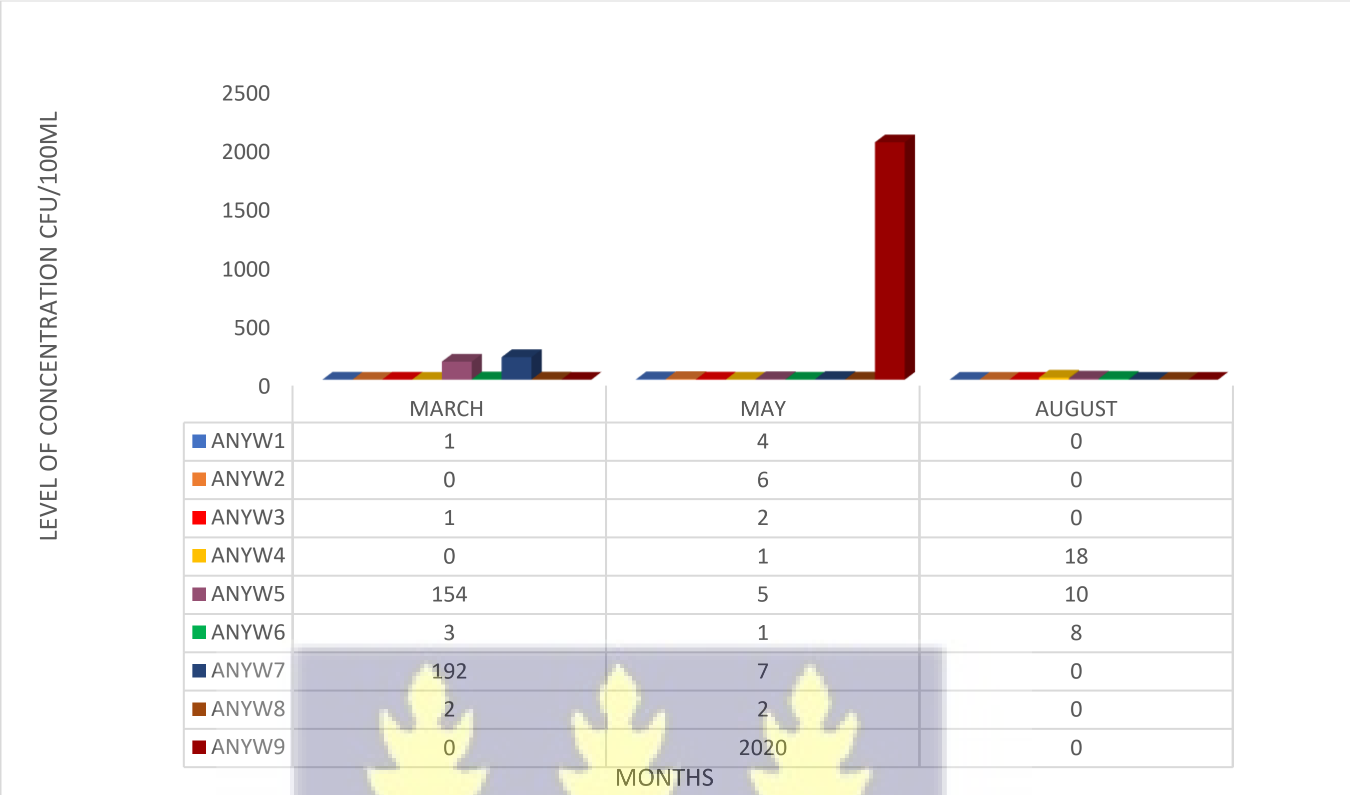


Figure 4.1.4. 9. A Bar Chart showing monthly levels of total coliform recorded in the community drinking water sources in Anyanui.

Total Coliform Counts in Water Samples.

There was no record of total coliform count with the water samples sourced from the pipes in March though in May and August, only one source had a recording of total coliform. This was recorded at ANYP3 and ANYP1 respectively.

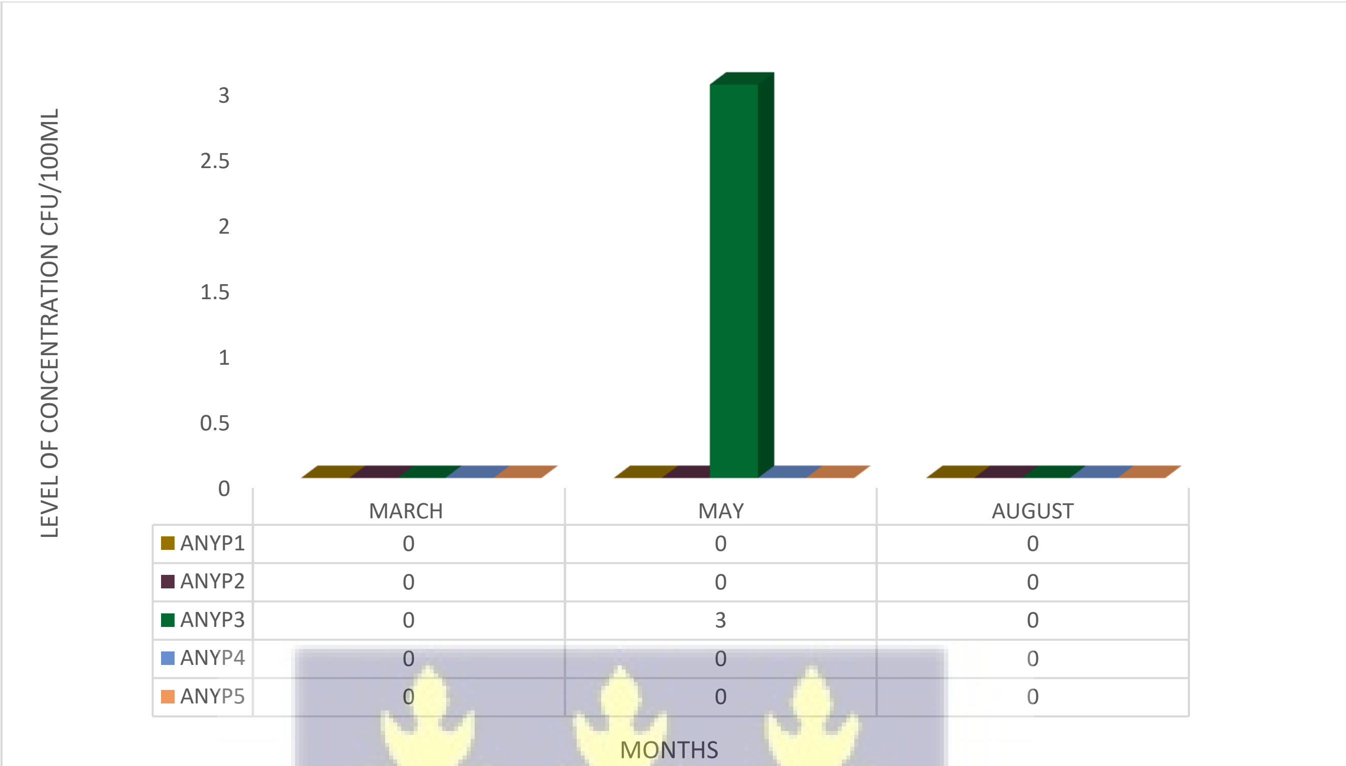


	MARCH	MAY	AUGUST
ANYW1	1	4	0
ANYW2	0	6	0
ANYW3	1	2	0
ANYW4	0	1	18
ANYW5	154	5	10
ANYW6	3	1	8
ANYW7	192	7	0
ANYW8	2	2	0
ANYW9	0	2020	0

Figure 4.1.4. 10. A Bar Chart showing monthly levels of faecal coliform recorded in the community drinking water sources in Anyanui.

Faecal Coliform Count in Water Samples.

Faecal coliform counts ranged from 0 to 192 cfu/100 ml in all the community drinking water sources in March, 0-2020 cfu/100 ml in May and 0-18 cfu/100 ml in August. With the wells, faecal coliform load of the water samples ranged from 0 to 192 cfu/100 ml, with the highest recorded in ANYW7 and the lowest in ANYW2, ANYW3 and ANYW9 in March, in May the counts ranged from 0-2020 cfu/100 ml with the highest count recorded in samples from ANYW9 and the lowest from ANYW4 and ANYW6. In August the count ranged from 0-18 cfu/100 ml with the highest recorded at ANYW4 and the lowest in ANYW2.

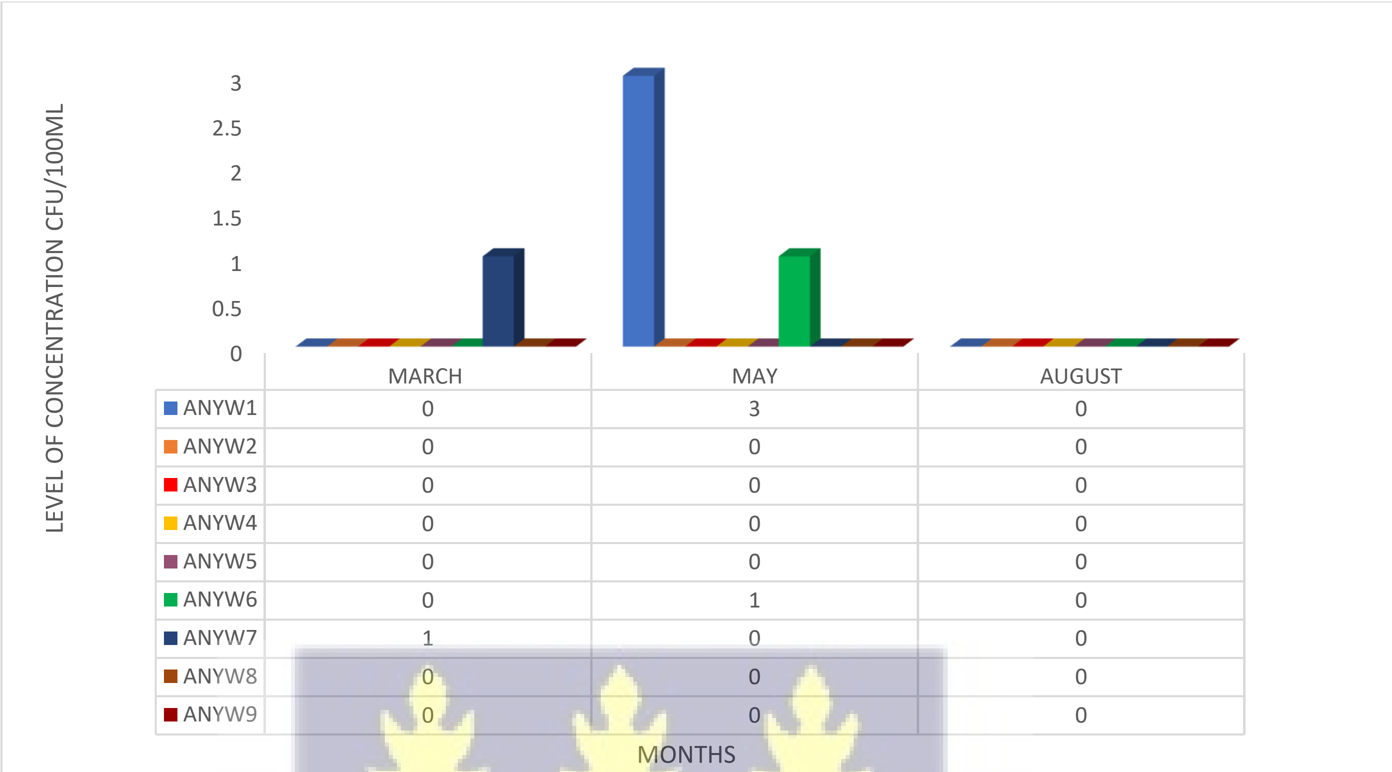


	MARCH	MAY	AUGUST
ANYP1	0	0	0
ANYP2	0	0	0
ANYP3	0	3	0
ANYP4	0	0	0
ANYP5	0	0	0

Figure 4.1.4. 11**.** A Bar Chart showing monthly levels of faecal coliform recorded in the community drinking water sources in Anyanui.

Faecal Coliform Count in Water Samples.

There was no record of faecal coliform count within the water samples sourced from the pipes in both March and August. In May there was a recording of faecal count in samples from one pipe which was ANYP3 and no recordings in the other pipes.



	MARCH	MAY	AUGUST
ANYW1	0	3	0
ANYW2	0	0	0
ANYW3	0	0	0
ANYW4	0	0	0
ANYW5	0	0	0
ANYW6	0	1	0
ANYW7	1	0	0
ANYW8	0	0	0
ANYW9	0	0	0

Figure 4.1.4. 12.A Bar Chart showing monthly levels of *E. coli* recorded in the community drinking water sources in Anyanui.

Escherichia coli Count in Water Samples.

E. coli count ranged between 0 to 1 cfu/100 ml in the community drinking water sources in March, 0-3 cfu/100 ml in May and no record in August. With the wells, *E. coli* of the water samples ranged from 0 to 3 cfu/100 ml, with the highest count recorded in ANYW7 in March and the highest count in May was recorded in water sampled from ANYW1.

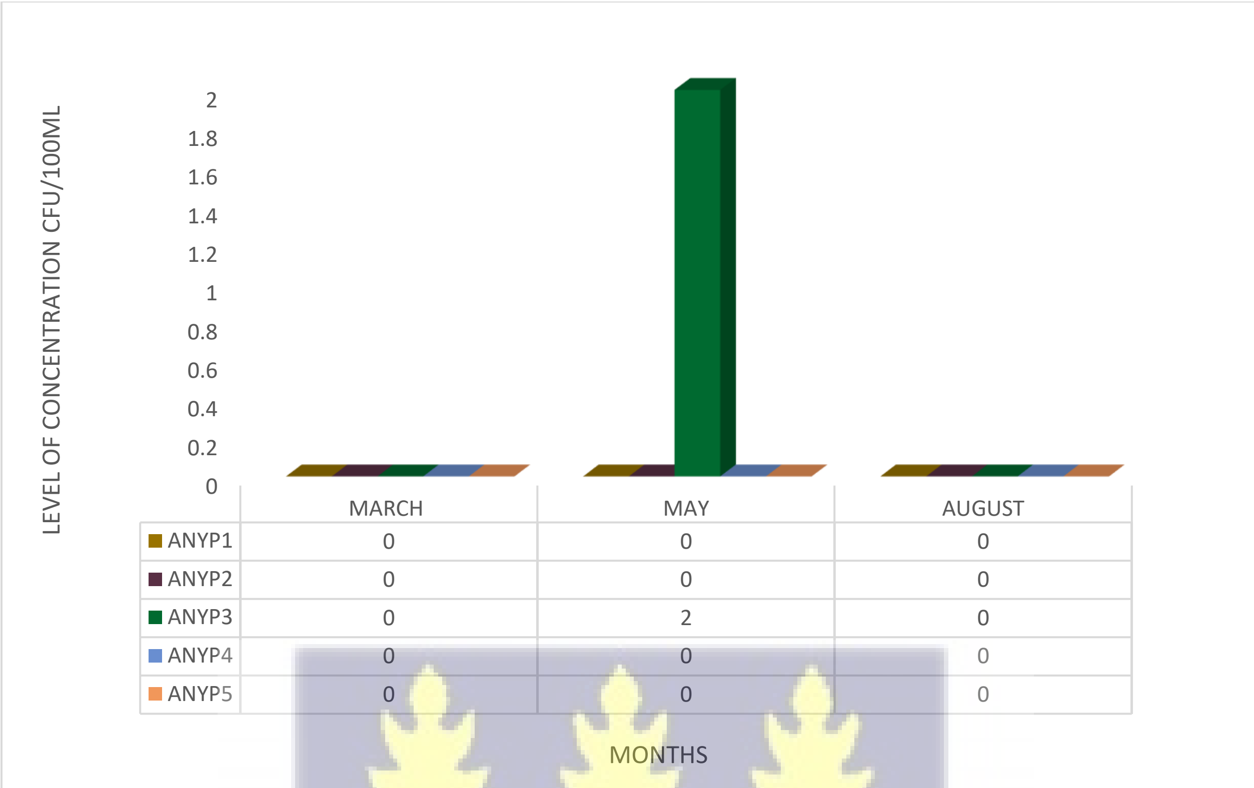


Figure 4.1.4. 13. A Bar Chart showing monthly levels of *E. coli* recorded in the community drinking water sources in Anyanui.

Escherichia coli Count in Water Samples.

There was no record of *E. coli* with all the pipe sources in the March and in August although in the month of May there was a record of *E. coli* count with water sampled from ANYP3 with 2 cfu/100 ml.

4.1.5 Detection of Bacteria species

Table 4.1.5 1. Detection of different bacteria species in water samples from community drinking water sources in Anyako.

CODES	*Salmonella*	*Shigella*	*Enterococcus*	*Vibrio cholerae*
AKOC1	-ve	-ve	-ve	-ve
AKOC2	-ve	-ve	-ve	-ve
AKOC3	-ve	-ve	-ve	-ve
AKOC4	-ve	-ve	-ve	-ve
AKOC5	-ve	-ve	-ve	-ve
AKOC6	-ve	-ve	-ve	-ve
AKOC7	-ve	-ve	-ve	-ve
AKOC8	-ve	-ve	-ve	-ve
AKOC9	-ve	-ve	-ve	-ve
APV1	-ve	-ve	-ve	-ve
APV2	-ve	-ve	-ve	-ve
APV3	-ve	-ve	-ve	-ve
APV4	-ve	-ve	-ve	-ve
AKT1	-ve	-ve	-ve	-ve
AKW1	-ve	-ve	-ve	-ve
AKS1	-ve	-ve	-ve	-ve
AKS2	-ve	-ve	-ve	-ve
AKS3	-ve	-ve	-ve	-ve
AKS4	-ve	-ve	-ve	-ve

Detailed description of the results:

Enumeration of *Salmonella* count in water samples from water sources

There was no detection of *Salmonella* within the samples from all the community drinking water sources.

Enumeration of *Shigella* count in water samples from water sources

There was no detection of *Shigella* within the samples from all the community drinking water sources.

Enumeration of *Vibrio cholerae* count in water samples from water sources

There was no observation of *Vibrio cholerae* within the samples from all the community drinking water sources.

Table 4.1.5 2. Bacterial species in water samples from drinking water sources in Atiteti.

CODES	*Salmonella*	*Shigella*	*Enterococcus*	*Vibrio cholerae*
ATIP1	**-ve**	**-ve**	**-ve**	**-ve**
ATIP2	**-ve**	**-ve**	**-ve**	**-ve**
ATIP3	**-ve**	**-ve**	**-ve**	**-ve**
ATIP4	**-ve**	**-ve**	**-ve**	**-ve**
ATIP5	**-ve**	**-ve**	**-ve**	**-ve**
ATIP6	**-ve**	**-ve**	**-ve**	**-ve**

Detailed description of the results:

Enumeration of *Salmonella* count in water samples from water sources.

There was no detection of *Salmonella* within the samples from all the community drinking water sources.

Enumeration of *Shigella* count in water samples from water sources.

There was no detection of *Shigella* within the samples from all the community drinking water sources.

Enumeration of *Vibrio cholerae* count in water samples from water sources.

There was no observation of *Vibrio cholerae* within the samples from all the community drinking water sources.

Table 4.1.5 3. Detection results of different bacteria species in water samples from community drinking water sources in Anyanui.

CODES	*Salmonella*	*Shigella*	*Enterococcus*	*Vibrio cholerae*
ANYW1	-ve	-ve	-ve	-ve
ANYW2	-ve	-ve	-ve	-ve
ANYW3	-ve	-ve	-ve	-ve
ANYW4	-ve	-ve	-ve	-ve
ANYW5	-ve	-ve	-ve	-ve
ANYW6	-ve	-ve	-ve	-ve
ANYW7	-ve	-ve	-ve	-ve
ANYW8	-ve	-ve	-ve	-ve
ANYW9	-ve	-ve	-ve	-ve
ANYP1	-ve	-ve	-ve	-ve
ANYP2	-ve	-ve	-ve	-ve
ANYP3	-ve	-ve	-ve	-ve
ANYP4	-ve	-ve	-ve	-ve
ANYP5	-ve	-ve	-ve	-ve

Detailed description of the results:

Enumeration of *Salmonella* count in water samples from water sources.

There was no detection of *Salmonella* within the samples from all the community drinking water sources.

Enumeration of *Shigella* count in water samples from water sources.

There was no detection of *Shigella* within the samples from all the community drinking water sources.

Enumeration of *Vibrio cholerae* count in water samples from water sources.

There was no observation of *Vibrio cholerae* within the samples from all the community drinking water sources.

4.2 Exploring the link between Microbial Water Quality and the Risk of Diarrhoea

The results below are the findings used to explore the relationship between the quality of the drinking water and the risk of diarrhoea. Results show the household water sources contain more count than in the community drinking water sources. The presence of *E. coli* in drinking water sources causes diarrhoea if not treated. Data from stored Household sources (at point of use-POU) is used in relation to the number of diarrhoea cases obtained from various health centres.

4.2.1 Total Mean Count of *E. coli* in Household Drinking Water for Each Community.

Table 4.2.1. 1. Mean *Escherichia coli* count in water samples from household drinking water in Anyako.

CODES	*E. coli* cfu/100ml
AKOH1	0
AKOH2	6
AKOH3	242
AKOH4	10
AKOH5	0
AKOH6	0
AKOH7	0
AKOH8	21
AKOH9	1
AKOH10	4
AKOH11	34
AKOH12	0
AKOH13	0
AKOH14	24
AKOH15	1

Detailed description of the results is presented.

Escherichia coli count of water samples from household drinking water.

E. coli count in household drinking water sources ranged from 0 to 242 cfu/100 ml in Anyako. The highest count was recorded in Household 3 with a count of 242 cfu/100 ml followed by Household 11 with a count of 34 cfu/100 ml, Household 14 with a count of 34 cfu/100 ml, Household 8 with a count of 21 cfu/100 ml. The rest recorded between 0 to 10 cfu/100 ml in the water.

Table 4.2.1. 2 Mean *Escherichia coli* count in water sampled from household drinking water in Atiteti.

CODES	*E. coli* cfu/100ml
ATIH1	10
ATIH2	3
ATIH3	4
ATIH4	6
ATIH5	0
ATIH6	10
ATIH7	2
ATIH8	0
ATIH9	108
ATIH10	10
ATIH11	0
ATIH12	3
ATIH13	3
ATIH14	0
ATIH15	10

Details of results presented in the table.

Escherichia coli count in water samples from household drinking water.

E. coli count within the household drinking water sources ranged from 0 to 108 cfu/100 ml in Atiteti. The highest count was within Household 9 with a count of 108 cfu/100 ml. This was followed by a count of 10 cfu/100 ml recorded from Household 1, Household 6, Household 10 and Household 15. The rest recorded counts between 0 to 6 cfu/100 ml.

Table 4.2.1. 3. Mean *Escherichia coli* count in water samples from household drinking water in Anyanui.

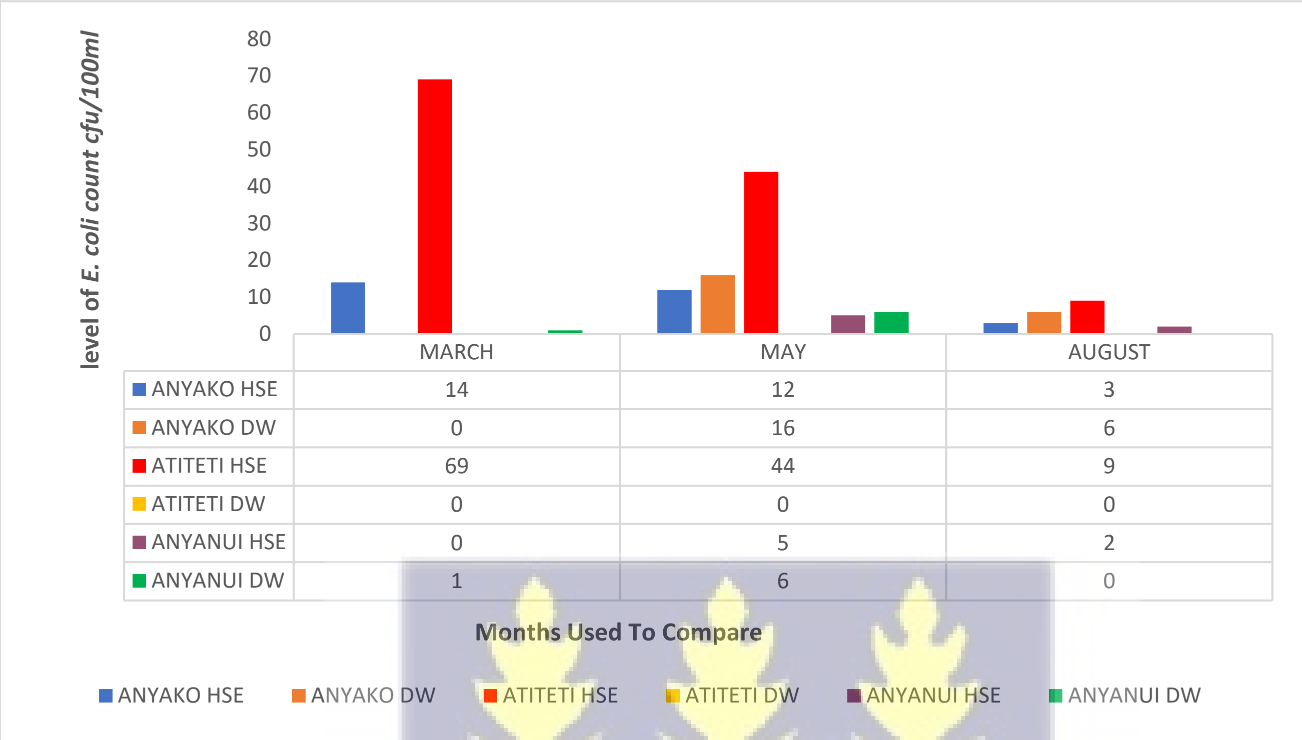
CODES	*E. coli* cfu/100ml
ANYH1	7
ANYH2	42
ANYH3	0
ANYH4	0
ANYH5	0
ANYH6	30
ANYH7	0
ANYH8	32
ANYH9	2
ANYH10	5
ANYH11	15
ANYH12	23
ANYH13	0
ANYH14	6
ANYH15	7

Detailed description of results presented:

Escherichia. coli count in water samples from household drinking water sources.

E. coli count within the household drinking water sources varied from 0 to 42cfu/100 ml in Anyanui. The maximum count was within Household 9 with a count of 42 cfu/100 ml followed by Household 8 which had a count of 32 cfu/100 ml, then by Household 6 with a count of 30 cfu/100 ml. This was again followed by Household 12 which had a count of 23 cfu/100 ml and Household 11 with a count of 15 cfu/100 ml. the rest of the Households had counts between 0 to 7 cfu/100 ml.

4.2.2 Monthly *E. coli* Count in Community Drinking Water Sources and Household Drinking Water



	MARCH	MAY	AUGUST
ANYAKO HSE	14	12	3
ANYAKO DW	0	16	6
ATITETI HSE	69	44	9
ATITETI DW	0	0	0
ANYANUI HSE	0	5	2
ANYANUI DW	1	6	0

Figure 4.2.2. 1 A Bar chart showing the comparison between the levels of *Escherichia coli* count in the community drinking water sources and the household drinking water sources in the communities for each month**.**

Escherichia coli in Community Drinking water source in Anyako

The count of *E. coli* within the community drinking water sources in Anyako ranges from 0 to 16 cfu/100 ml in all the drinking water sources between the period of sampling. In March the range of count was 0 cfu/100 ml, in May it was between 0 to 16 cfu/100 ml and between 0 to 6 cfu/100 ml in August. The highest count in the community drinking water sources in Anyako was in May and the lowest count was in March.

Escherichia coli in Household Drinking water source in Anyako

The count of *E. coli* within the household drinking water in Anyako ranges from 0 to 14 cfu/100 ml in all the drinking water sources between the period of sampling. In March the range of count was between 0 to 14 cfu/100 ml, in May it was between 0 to 12 cfu/100 ml and between 0 to 3 cfu/100 ml in August. The highest count of *E. coli* within the water sources in the Households was recorded in the month of March and the lowest was recorded in August.

Escherichia coli in Community Drinking water source in Atiteti

There was no count of *E. coli* within the community drinking water sources in Atiteti between the period of sampling and, in each month, sampled.

Escherichia coli in Household Drinking water in Atiteti

The count of *E. coli* within the household drinking water in Atiteti ranges from 0 to 69 cfu/100 ml in all the drinking water sources between the period of sampling. In March the range of count was between 0 to 69 cfu/100 ml, in May it was between 0 to 44 cfu/100 ml and between 0 to 9 cfu/100 ml in August. The highest count was recorded in March and the lowest was recorded in August.

Escherichia coli in Community Drinking water source in Anyanui

The counts of *E. coli* within the community drinking water sources in Anyanui ranges from 0 to 6 cfu/100 ml between the period of sampling. In March the range of count was 1 cfu/100 ml, in May it was between 0 to 6 cfu/100 ml and 0 cfu/100 ml in August. The highest counts of *E. coli* were recorded in May and the lowest was in August.

Escherichia coli in Household Drinking water in Anyanui

The counts of *E. coli* within the household drinking water in Anyanui ranges from 0 to 5 cfu/100 ml between the period of sampling. In March the range of count was 0 cfu/100 ml, in May it was between 0 to 5 cfu/100 ml and between 0 to 2 cfu/100 ml in August. The highest count was in May and the lowest was in March.

4.2.3 Diarrhoea occurrence and *Escherichia coli* in each community

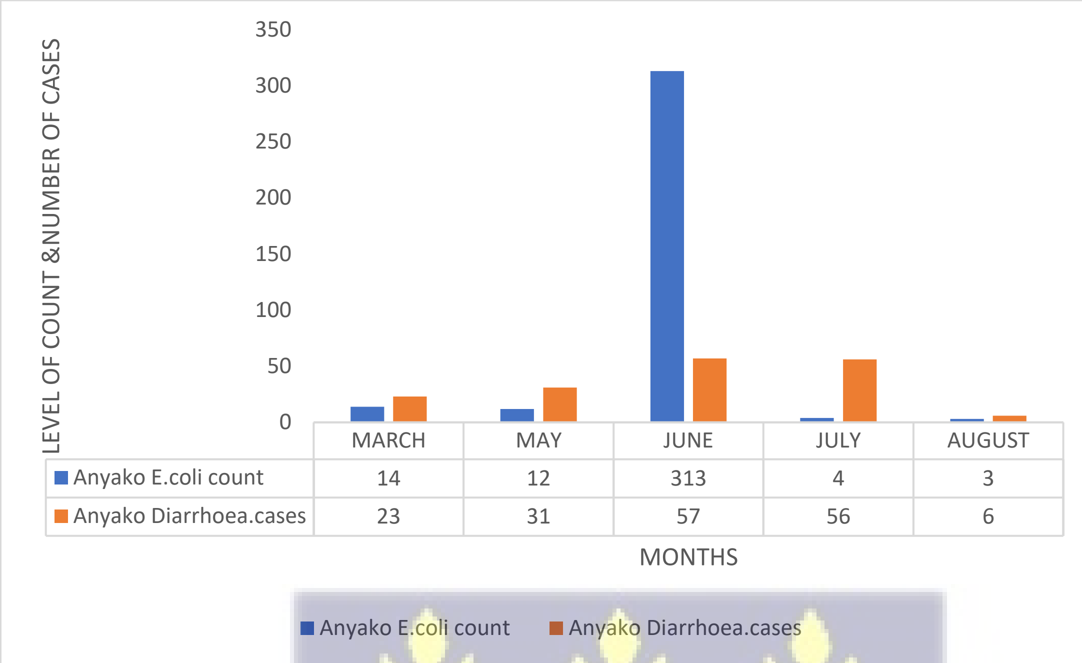


Figure 4.2.2. 2. Relationship between Diarrhoea occurrence and *Escherichia coli* in Anyako.

The number of diarrhoea cases in March recorded was 23 when the *E. coli* count was 14 cfu/100 ml. In May, the recorded diarrhoea cases increased to 31 when the *E. coli* count decreased to 12 cfu/100 ml. In June, the diarrhoea cases showed a steep rise to 57 with the *E. coli* count rising sharply to 313 cfu/100 ml. The diarrhoea cases fell slightly in July as *E. coli* count also declined sharply to 4 cfu/100 ml. In August the diarrhoea cases took a gradual fall to 6 cases as the *E. coli* continued to drop to 3 cfu/100 ml. The highest recording of diarrhoea cases was in June with the least recording in August.

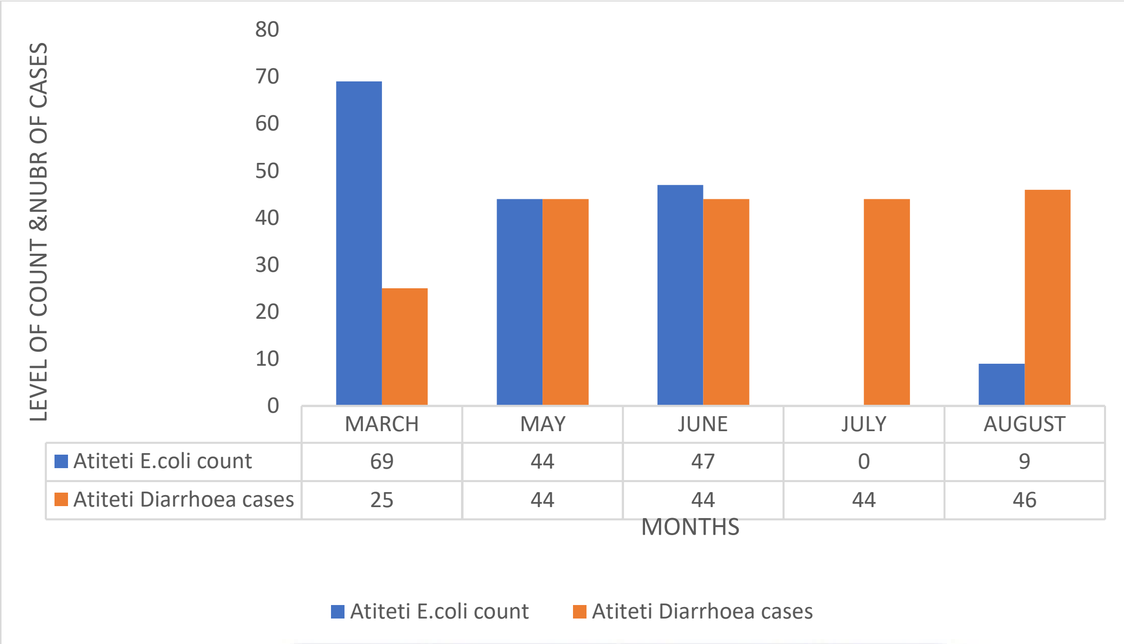
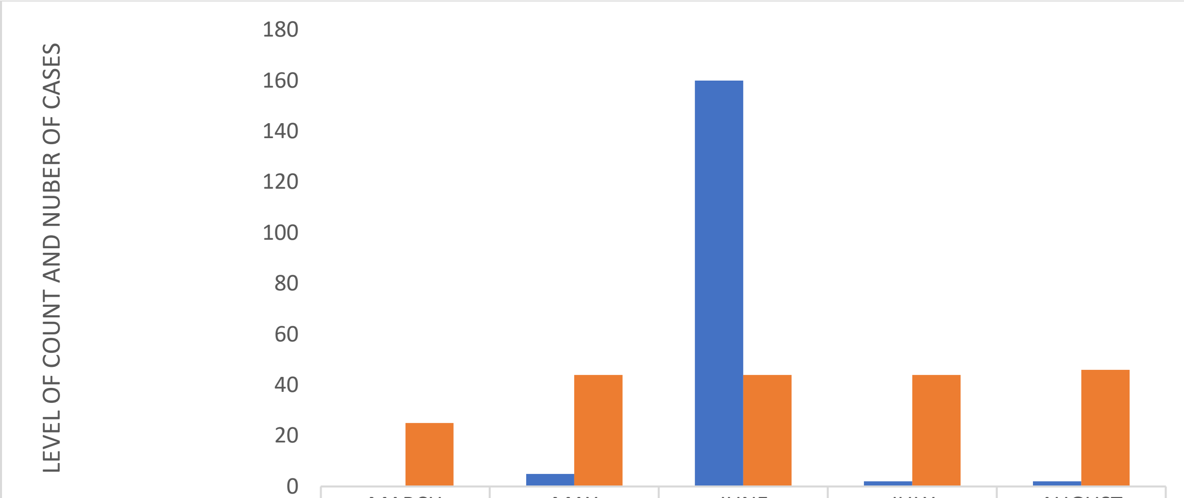


Figure 4.2.2. 3. Relationship between Diarrhoea occurrence and *Escherichia coli* in Atiteti.

The number of diarrhoea cases recorded in March was 25 when the *E. coli* count was 69 cfu/100 ml the diarrhoea cases rose to a number of 44 cases as *E. coli* dropped slightly to 44 cfu/100 ml. in June the diarrhoea cases remained steadily with 44 cases as a slight increase showed of 47 cfu//100 ml in the *E. coli* count. Still with 44 cases in July, the *E. coli* dropped sharply to 0 cfu/100 ml and increased sharply again to 9 cfu/100 ml as the diarrhoea cases also increased to 46 cases in August. The highest recording of diarrhoea cases was in the month of August with the least recording in March.



	MARCH	MAY	JUNE	JULY	AUGUST
Anyanui E.coli count	0	5	160	2	2
Anyanui Diarrhoea cases	25	44	44	44	46

Figure 4.2.2. 4 Relationship between Diarrhoea occurrence and *Escherichia coli* in Anyanui.

The number of diarrhoea cases recorded in March was 25 when the *E. coli* count was at 0 cfu/100 ml. In May, the recorded diarrhoea cases rose to 44 when the *E. coli* count was 5 cfu/100 ml. The diarrhoea cases remained steadily at 44 as the *E. coli* count took a sharp increase to 160 cfu/100 ml in June and dropped sharply to 2 cfu/100 ml in July. In August the cases of diarrhoea increased slightly to 46 cases as the *E. coli* remained at 2 cfu/100 ml. The highest recording of diarrhoea cases was in August with the least recording in March.

4.2.4 Relationship between the *E. coli* counts and the diarrhoea cases in each community.

Anyako

Table 4.2.4. 1: Correlation table between *E. coli* and number of diarrhoea cases in Anyako.

Anyako	*E. coli* count	Diarrhoea cases
E. coli count	1	0.57
Diarrhoea cases	0.57	1

Where Pearson's Correlation is "r" hence r=0.57. For a perfect relationship r=1.0

The Pearson's Correlation coefficient is moderately strong which means in Anyako, the number of *E. coli* counts tend to have a moderate relation with the number of diarrhoea cases.

Atiteti

Table 4.2.4. 2 Correlation table between *E. coli* and number of diarrhoea cases in Atiteti.

Atiteti	*E. coli* count	Diarrhoea cases
E. coli count	1	-0.72
Diarrhoea cases	-0.72	1

Where Pearson's Correlation is "r" hence r= -0.72. For a perfect relationship r=1.0

Pearson's coefficient in determining the relationship between the *E. coli* count and the diarrhoea cases is low hence there is no relationship between the two variables in Atiteti.

Anyanui

Table 4.2.4. 3 Correlation table between *E. coli* and number of diarrhoea cases in Anyanui.

Anyanui	*E. coli* count	Diarrhoea cases
E. coli count	1	0.23
Diarrhoea cases	0.23	1

Where Pearson's Correlation is "r" hence r=-0.23. For a perfect relationship r=1.0

Within Anyanui, there is a low or a weak relationship between the number of *E. coli* counts with the number of diarrhoea cases.

Between the three communities, the high or low counts of *E. coli* in Atiteti and Anyanui have no correlation to the number of diarrhoea cases. This means there is a possibility of the number of cases increasing in the communities due to other factors and not the *E. coli* count

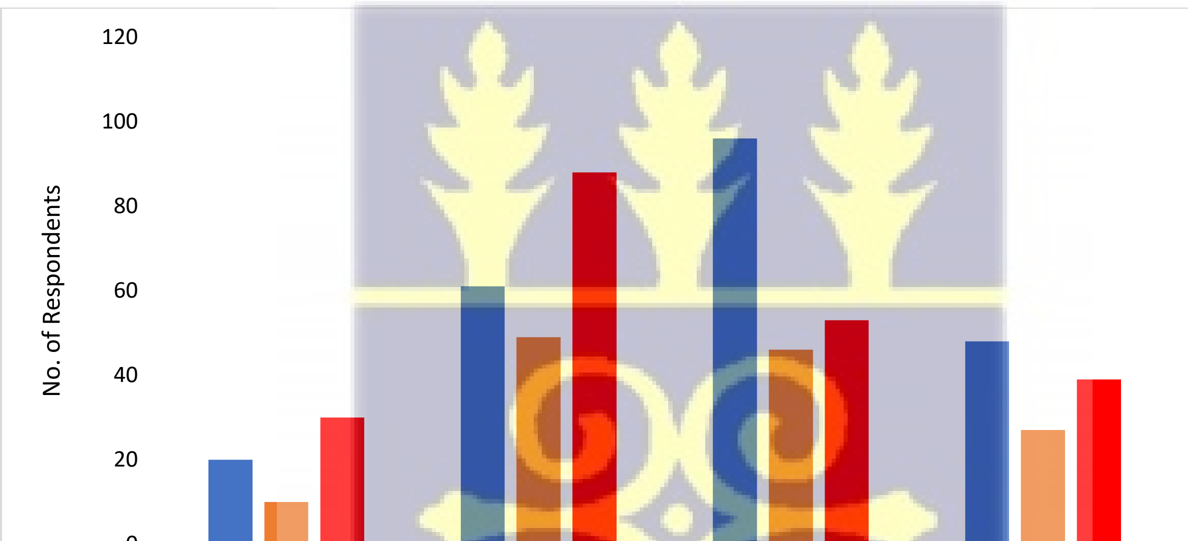
4.3 Examining the Influence of Socio-economic factors on Water Quality and Incidence of Diarrhoea.

This section shows the results and findings that will be used to examine the influence of socio-economic factors on both water quality and the incidence of diarrhoea. The results and findings were obtained from the use of Questionnaires and interviews of respondents within the three communities.

4.3.1 Background Information on Respondents.

The gender of the respondents was 54.7% for males and 45.3% for females in Anyako, 23.5% for males and 76.5% for females in Atiteti and 26.2% for males and 73.8% in Anyanui. And some of the various occupations of the respondents were fishmongers, business men/women, traders, security personals, students, fishermen to mention a few.

4.3.2 Age Distribution of Respondents.

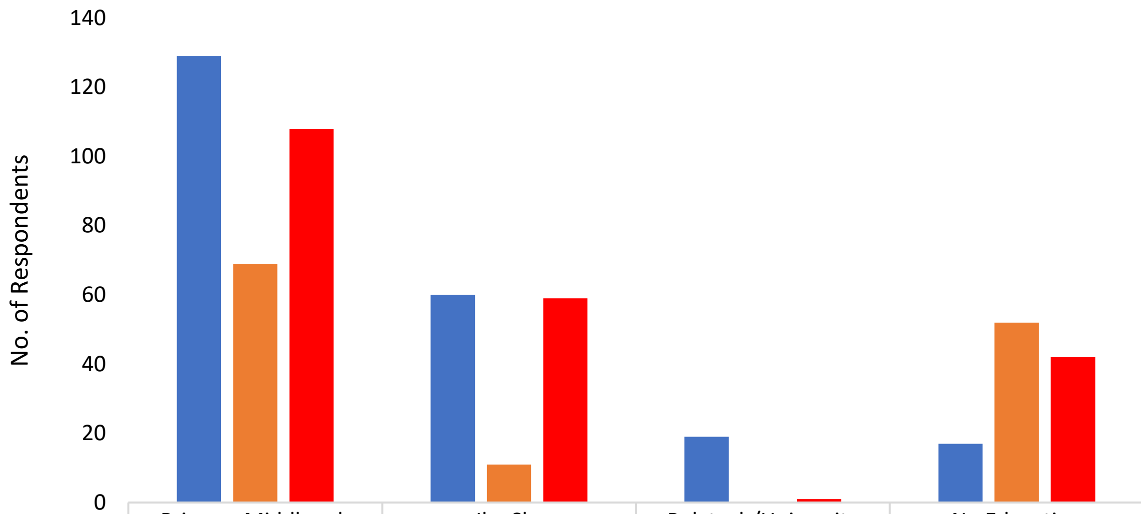


	18-30	31-43	44-55	56 & Above
Anyako	20	61	96	48
Atiteti	10	49	46	27
Anyanui	30	88	53	39

Figure 4.3.2 1. Bar chart showing the levels of the Ages of the respondents in each community.

Figure 4.3.2 indicates that the highest number of respondents in Anyako was within the age group 44-55 years followed by 31-43 years, 31-43 in both Atiteti and Anyanui followed by 44-55 years. The highest age group had the highest number of respondents which represented 96 respondents in Anyako 49 respondents in Atiteti and 88 respondents in Anyanui.

4.3.3 Educational Level of Respondents



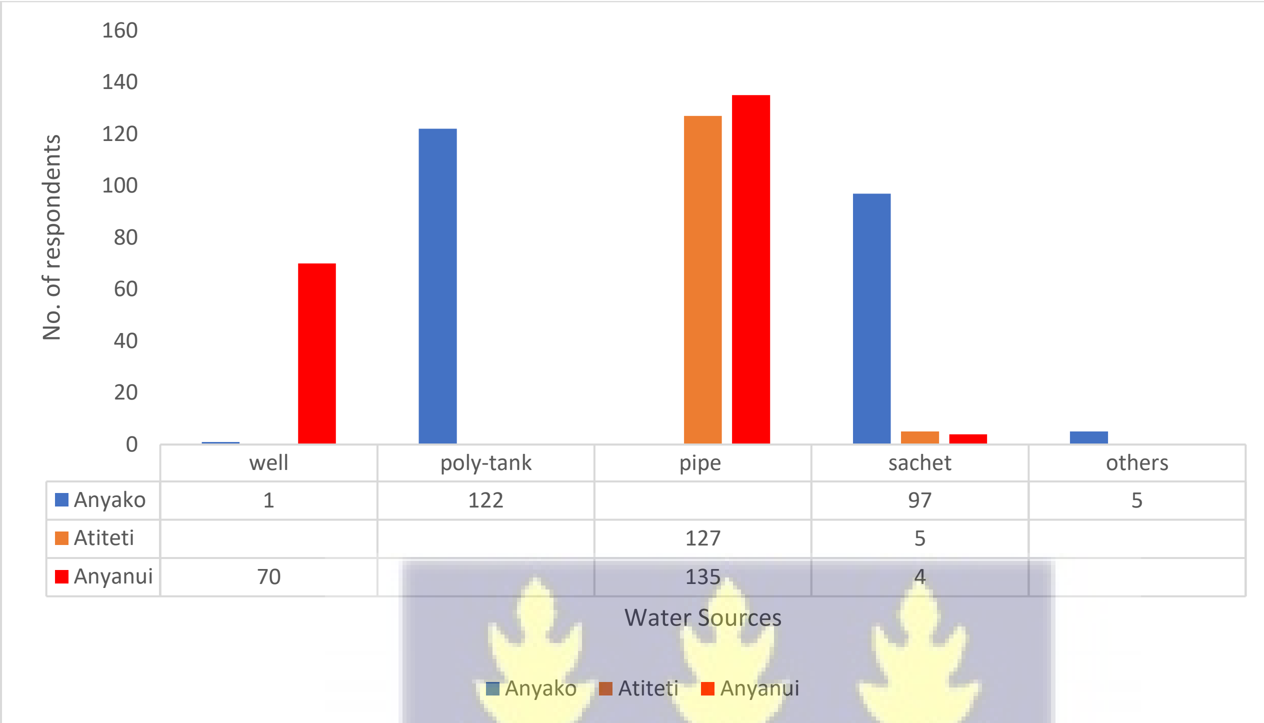
	Primary-Middle sch	Jhs-Shs	Polytech/University	No Education
Anyako	129	60	19	17
Atiteti	69	11	0	52
Anyanui	108	59	1	42

Educational Level of Respondents

Figure 4.3.3 1**.** Bar graph showing the levels of the educational level of respondents in each community.

From figure 4.3.3.1, the number of respondents that had basic education are 129, 69 and 108 in Anyako, Atiteti and Anyanui respectively. Those that had secondary education were 60, 11 and 59 respondents in Anyako, Atiteti and Anyanui, whilst those who had no education at all were 17, 52 and 42 of the respondents in Anyako, Atiteti and in Anyanui respectively. The form of educational level that was obtained by most of the respondents was the primary – middle school in each of the communities.

4.4 Sources of Drinking Water.



	well	poly-tank	pipe	sachet	others
Anyako	1	122		97	5
Atiteti			127	5	
Anyanui	70		135	4	

Figure 4.4 1. Bar chart showing the levels of the sources of water available in each community.

Figure 4.4.1 indicate the sources of water used in Anyako as a well, poly-tanks, sachet and others. The sources within the others include water from a reservoir and rain water which is harvested by the residents. In Atiteti the water sources used are the pipes and sachet whilst in Anyanui it was wells, pipes and sachet. The highest source used in each of the communities were the poly-tanks in Anyako with 122 respondents followed by the sachet water used by 97 respondents, the pipes in Atiteti used by 127 respondents and the pipes in Anyanui which was used by 135 respondents followed by the use of the wells in Anyanui which was also used by 70 of the respondents.

4.4.1 Containers used in storing water in each community

Table 4.4. 1. Responses to type of storage containers available in indicated community.

Water Storage Containers	Number of Respondents		
	Anyako	Atiteti	Anyanui
Gallon containers	191	3	28
Barrels	17	128	73
Earthen pots	17	1	9

The storage containers that are used by majority of the respondents in each of the communities was gallon containers with 191 respondents in Anyako, 128 respondents using Barrels in Atiteti and 73 respondents using Barrels in Anyanui. The least storage container used was the earthen pot which had few respondents confirming that in each community.

4.4.2 Treatment of water in each community.

Table 4.4. 2. Responses to treatment of water in indicated community.

Water treatment	Number of Respondents		
	Anyako	Atiteti	Anyanui
Yes, to Treatment	75(33%)	0	15(7.1%)
No to Treatment	90(40%)	129(97.7%)	145(69.1%)
Have no knowledge	60(27%)	3(2.3%)	50(23.8%)

The responses to the treatment of water in each community differed. According to them they use Aqua-tab which is found in pharmacies or in town to treat their drinking water or they boil it before drinking. In Anyako majority of the respondents which was 90 replied no to treating the water followed by those who said yes with a total of 75 respondents then 60 respondents for those who had no knowledge on how to treat the water. None of the respondents in Atiteti confirmed to treating the water, whilst 129 respondents answered no to the treatment. In Anyanui the highest response was no to treating the water with 145 respondents, 15 respondents answered yes to water treatment whilst 50 of them had no idea on how to treat the water.

4.4.3 Cost of water in each community.

Table 4.4. 3 Responses to cost of water in each community

	Number of Respondents		
Cost of water	Anyako	Atiteti	Anyanui
0-5	140	132	210
6-11	60		
12-17	1		
18-23	24		

The responses to the treatment of water in each community differed, in Anyako majority of the respondents which was 90 replied no to treating the water followed by those who said yes with a total of 75 respondents then 60 respondents for those who had no knowledge on how to treat the water. None of the respondents in Atiteti confirmed to treating the water, whilst 129 respondents answered no to the treatment. In Anyanui the highest response was no to treating the water with 145 respondents, 15 respondents answered yes to water treatment whilst 50 of them had no idea on how to treat the water.

The responses to the cost of water in each community differed. In Anyako, the lack of treated water from Ghana Water Company has resulted in the purchasing of gallons of water at different prices, depending on the household. Majority buy water with price range within 0-5ghc, followed by 6-11ghc and then 18-24ghc. In both Atiteti and in Anyanui, the price of water was within 0-5ghc.

4.5 Socioeconomic Factors Association

4.5.1 Diarrhoea cases in each Community.

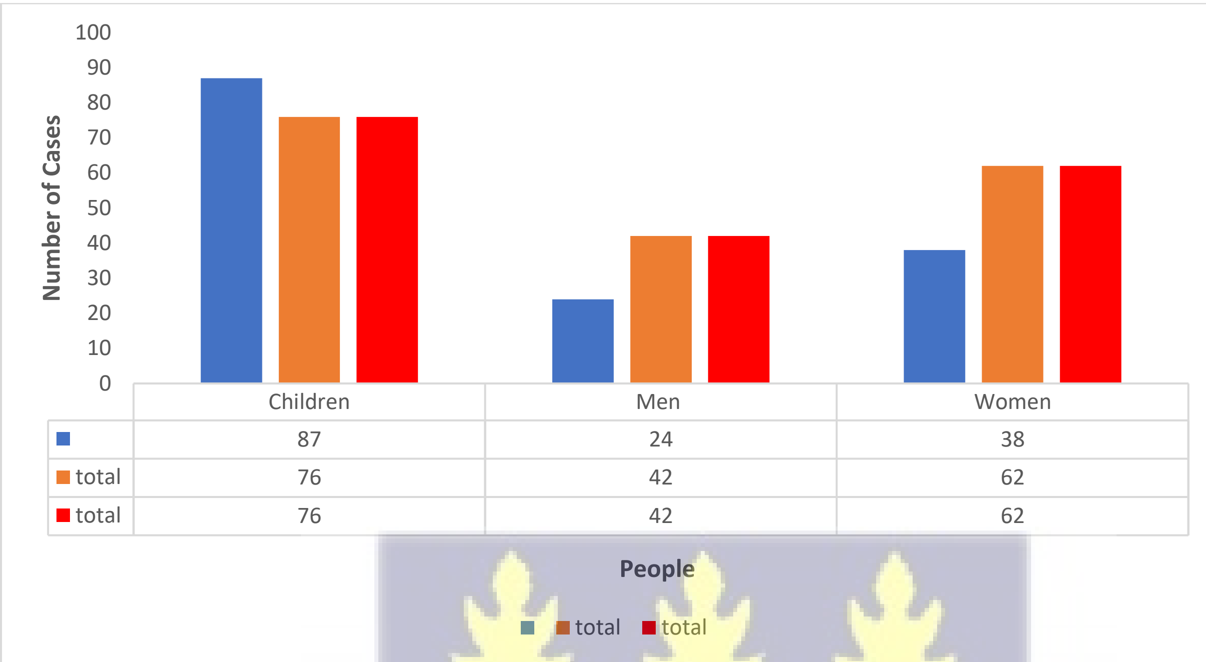


Figure 4.5. 1 Bar chart showing the levels of the Total Cases of diarrhoea in each community for Women, Men and Children.

Anyako

In Anyako the total number of diarrhoea cases recorded for men was 24, the recorded data for that of Women was 38 and 87 for the children. Number of cases are higher in children than in men and women though comparing the men and women, the men had the least diarrhoea cases.

Atiteti

In Atiteti, the total number of diarrhoea cases recorded for men was 42, the recorded data for that of women was 62 and 76 for the children. Number of cases are higher in children than in men and women though comparing the men and women, the men had the least number of cases.

Anyanui

In Anyanui, the total number of diarrhoea cases recorded for men was 42, the recorded data for that of women 62 and 76 for children. Number of cases are higher in children than in men and women though comparing the men and women, the men had the least number of cases.

Table 4.5. 1 Chi-square results between level of education and understanding health and sanitation

Chi-Square Test				
Community		Value	df	Asymptotic Significance (2-sided)
Anyako	Pearson Chi-Square	.254[a]	1	.615
	N of Valid Cases	225		
Atiteti	Pearson Chi-Square	.041[c]	1	.839
	N of Valid Cases	132		
Anyanui	Pearson Chi-Square	.695[d]	1	.405
	N of Valid Cases	210		

Details of the results are as follows:

Anyako, Atiteti and Anyanui are have p- values that are statistically non-significant hence hypothesis that there is a significant association between educational level and understanding of health and sanitation is rejected.

Table 4.5. 2 Chi-Square Test between educational level and understanding water contamination

Chi-Square Test				
Community		Value	df	Asymptotic Significance (2-sided)
Anyako	Pearson Chi-Square	4.822	3	.185
Atiteti	Pearson Chi-Square	.964	2	.618
Anyanui	Pearson Chi-Square	3.107	3	.375

Anyako, Atiteti and Anyanui are have p- values that are statistically non-significant hence hypothesis that there is a significant association between educational level and understanding of water contamination is rejected.

Type of Toilet Facilities in each community

Table 4.5. 3 Respondent's responses to toilet types used in indicated community

Toilet Facility	Number of Respondents		
	Anyako	Atiteti	Anyanui
KVIP	172	119	116
Latrine	43	8	26
Bush	10	5	18

Details of results are as follows:

Majority of the respondents in each of the communities use the KVIP toilet type with 172 respondents in Anyako. 119 respondents in Atiteti and 116 respondents in Anyanui followed by the use of the latrine type. And few of the respondents confirmed to engaging in open defecation when the public toilets are engaged or unavailable.

Location of Toilet facilities in the communities.

Table 4.5. 4 Respondent's responses to the location of the toilet facilities in indicated communities.

Location of the Toilet Facility	Number of Respondents		
	Anyako	Atiteti	Anyanui
Inside the house	3	15	2
Outside the house	20	72	49
Public Toilet	202	49	159

Details of results are as follows:

The public toilet was the highest response chosen in Anyako and Anyanui with 202 and 159 respondents respectively. The highest location in Atiteti was outside the house with 72 respondents which was followed by the public toilet with 49 respondents.

The least location of chosen was the toilet facilities which are located inside the houses.

The causes of diarrhoea

Table 4.5. 5. Respondent's responses to causes of diarrhoea in indicated community.

Causes of Diarrhoea	Number of Respondents		
	Anyako	Atiteti	Anyanui
Eating stale/spoilt food	117	101	123
Over eating	92	29	90
Malaria	16	2	

Details of results are as follows:

Respondents generally indicated eating spoilt food, over eating, and malaria as the causes of diarrhoea in each of the communities. Majority of the respondents in Anyako indicated eating spilt food followed by over eating and the least was getting malaria. In Atiteti the highest was also eating stale food with 101 respondents which was also followed by over eating. Respondents in Anyanui indicated just eating stale food and over eating but nothing with Malaria. Eating stale food was the option selected by 123 respondents.

Salty nature of the water.

In Anyako, 25% of respondents agreed their drinking water sources tasted salty while 75% disagreed. Interestingly, Anyako was the only community were some respondents agreed to the salty nature of the water

CHAPTER FIVE

DISCUSSION

Universal access to safe and good drinking water is a fundamental need and human right (Oliviera, 2017). Securing access for all would go a long way in reducing illness and death, especially among children. Water is essential to the existence of man and all living things. Water is a cross-cutting element of the Growth and Poverty Reduction Strategy (GPRS II) of the Republic of Ghana and is linked to the Sustainable Development Goals. The 3rd Goal states "Good health and well-being" and the 6th Goal states "Clean water and sanitation" (Tortajada, 2020).

5.1 The physical and chemical quality of drinking water sources in the communities.

Conductivity

The conductivity of the samples had a variation of figures each month sampled, although the mean conductivity in each of the communities had no significant differences between them. There were well sources in Anyanui that exceeded the WHO standard of drinking and this was as a result of the sediments and the soil of these low-lying areas due to high levels of soluble salts comprising of anions like sulphates, chlorides, carbonates and cations like calcium magnesium which was in accordance to a study done in 2011 by Mensah.

Salinity

The ranges of salinity recorded over the period of sampling varied over time although the mean levels of salinity in each community had no significant differences. There were a few poly-tanks in Anyako and wells in Anyanui that recorded levels exceeding the WHO standard, this was as a result of the accumulation of natural salts in the soil. This was confirmed by the respondents in the communities during the survey. In studies done in coastal areas, by Mensah (2011) and Sasikran *et al* (2012) located in the coastal areas; hence it is common to have an accumulation of naturally occurring salts and its consumption causes intestinal issues which leads to diarrhoea.

Dissolved oxygen

The range of dissolved oxygen varied in each community changing over each sampling period. There were no significant changes in the samples from the communities. The results from the present study also indicated that although the water samples from the various sources had levels which did not exceed the WHO standards, they were below the required standard. This was due to the high salinity content in the water which decreases the dissolved oxygen, and sewage leakages which occurred from toilet facilities which from observations were not far from some of the sources as well as runoff from nearby farm lands which contain phosphates and nitrates (fertilizer). According to a study in domestic waste water, surface runoff form farmlands and the nature of the land all have an impact on the dissolved oxygen content in groundwater sources (Rajendiran *et al*, 2023). An article from Lenntech (2018) stated that as temperatures increase during the day, stagnant water temperatures also rise which in turn causes dissolved oxygen to decrease. Water contained in poly-tanks like in Anyako have low dissolved oxygen due to the changes in the temperature.

Total dissolved solids

High values of total dissolved solids varied and were recorded in AKOC1, AKOC2, AKOC4, AKOC8 & AKOC9 as well as AKW1 in Anyako and ANYW5 ANYW4 & ANYW9 in Anyanui, although there were no significant differences. These high values in both communities resulted from the close proximity to the keta lagoon and the sea. In addition, the to the distance to the sea, an increase in total dissolved solids could originate from natural sources such as sewage, and agriculture run off from nearby farms (Norvivior, 2013) which from observations in the communities are also in close proximity to a few water sources in the communities.

pH

Varying results were recorded for pH in the water sources in each of the communities, and there were significant changes each sampling month in Anyako and in Atiteti. The sources ANYW1, ANYW4 & ANYW7 in Anyanui had high pH values which exceeded the WHO standard. A study undertaken by Mensah (2011) showed that the ground water sources he analysed had pH in the alkaline range. Carbonate or hydroxide compounds in the soil or bedrock around the groundwater sources which gets dissolved within the water may be the cause of the alkaline levels in the results (Eldorado, 2022).

Consumption of water with high alkalinity does not cause any harm to the body although it causes the water to have a bitter taste, but the ideal pH for good quality drinking water is between 6.5 to 8.5 (Cirino *et al*,2018).

Nitrogen Nitrate

The levels of nitrate nitrogen within the drinking water sources sampled varied differently in each community, with only samples in Anyako exceeding the WHO limit of drinking water. Nitrate nitrogen samples taken in Anyako showed significant differences between them. This difference was within samples taken from a commercial poly-tank in the community. From observations during the survey and data collection the high level of nitrate nitrogen within the drinking water source was likely as a result of accumulation at the source which is a borehole in the neighbouring town as well as the accumulation during the continuous refill of the poly-tank every week.

The low nitrate nitrogen levels in the other water sources in the communities may likely be because nitrates have a high retention time which can remain within the soil around the groundwater sources for a long period of time, continually accumulating due to agriculture runoff from nearby farmlands which is also in accordance with a study done in a coastal community by Norvivor in (2013). High levels, cause methaemoglobin within infants and babies that consume water with high levels (Klein *et al* 2013).

Phosphate

The results of phosphates from this study had levels which had varying ranges in each of the three communities. Atiteti was the only community which had all drinking water sources within the range of WHO standards. The samples in Anyako and in Anyanui differed significantly the samples in each month was different. The samples in Anyako that had differences were sources from the poly-tanks and in Anyanui from the wells. The high levels were consistent with the observation of improper disposal of laundry waste around the sources of water and the high concentration of accumulated phosphate within the soils of the groundwater sources. This is accordance to a study done in Keta by Norvivor in 2013 who recorded high levels of phosphate in wells he sampled due to the close proximity of the well to farmlands and a pit latrine. The consumption of water containing high concentrations of phosphate could lead to problems in the digestive system (Taiwo *et al*, 2011) which further leads to diarrhoea.

Total Alkalinity

The sources of drinking water in the communities each recorded levels of total alkalinity with ranges that fell within the limit of WHO standards. The mean values and the samples showed no significant differences. This could be considered as the sources having good and quality water which is safe for consuming.

Sulphate

Each month the sources were sampled, they recorded different values of sulphate. The mean sulphate levels in the samples from the various drinking water sources in the three communities had ranges that fell within the acceptable WHO standard of drinking water. There were significant differences in the samples recorded from Anyako and in Atiteti but they were still within the standard. Studies show that high levels of sulphate concentration may increase bacteria load as it decreases the pH of the water (Molinari *et al* 2014). The residents of the community may freely drink from the sources without getting illnesses such as diarrhoea, vomiting and dehydration (Norvivor, 2013; Rapant *et al*, 2017).

Calcium

The analysis of the water samples from each community recorded values that differed each month. Significantly, there were changes in the samples from Anyako although they were well within the WHO standard of drinking water. The sources in the community had safe levels of calcium which is safe for human consumption as lack of calcium in drinking water causes bone fractures, low blood clotting and rickets whereas high levels of calcium in drinking water causes cardiovascular diseases (Moshin *et al*, 2013).

Magnesium

Drinking water sources in the community when analysed recorded levels that varied each month. They were all within the WHO standard of drinking water with the exception of one poly-tank source in Anyako (AKOC9) which exceeded the limit and also showed significant differences. This high level of magnesium within the source was likely due to deposits of magnesium from the source; a borehole which was in a neighbouring town. High levels of magnesium were recorded in other drinking water sources in other studies done by Rahmanian *et al* in 2015 which was as a result of accumulated deposits of magnesium underground. High levels of magnesium give the water a bitter taste and causes a laxative effect (Norvivor, 2013).

Sodium

From the results of this study, the levels of sodium in samples sourced from the various water sources in each of the three communities indicate that, the levels are all within the required WHO standard of drinking water of 200 mg/l. The mean levels in Anyako and in Anyanui showed no significant differences between them though it wasn't the same for the samples in Atiteti which had significant differences. The water sources are of good quality as the levels are all within the standards, water with the right quantity of sodium prevents consumers from kidney issues and hypertension (Scheelbeek *et al* 2016).

Potassium

The levels of potassium recorded each sampling month in Atiteti varied although they were all within the WHO standard. In Anyako and Anyanui, there were poly-tank (AKOC9), wells sources (AKW1, ANYW1, ANYW4, ANYW5, ANYW6, ANYW7, ANYW8, & ANYW9) and a pipe (ANYP4) that had significant differences with levels that exceeded the standard. The reason for these high levels were as a result of naturally occurring accumulated potassium salts within the soil (Mensah, 2011) and from agriculture runoff from nearby farmlands which was observed during survey and the improper disposal of domestic waste water around the sources which may leach into the soil and into the groundwater.

The Microbial quality of the drinking water sources in the communities.

Total coliform

Drinking water standards by WHO requires that for water to be considered of good quality for drinking, and pose no risk to human health, there should be no coliform bacteria present in the water. According to a report in 2011 by WHO, within a 100ml sample of water, the recommended guideline limit should be 0cfu/100 ml.

The range of the total coliform count with the samples in each community ranged with 2 cfu/100 ml to 2092 cfu/100 ml in Anyako, 1 cfu/100 ml to 8 cfu/100 ml in Atiteti and from 2 to 2611 cfu/100 ml in Anyanui, the mean value of the total coliform count in the samples sourced from the drinking water sources exceeded the WHO standard in each of the communities. The samples from each of the drinking sources differed significantly in only Anyako (Anova Table 1) although the samples in Atiteti and Anyanui had high levels. Pairwise comparison showed that the differences varied. The high count of total coliform in each of the communities per observations made was likely as a result of improper disposal of waste, young children engaging in open defecation not too far from the drinking water sources, improper maintenance of the poly-tanks and immediate surroundings of the water sources. Total coliform in the water sources is not likely to cause health issues but it indicates that the source of drinking water is now vulnerable to the contamination from the environment

Faecal coliform

The presence of faecal coliform in drinking water sources meant that such sources have been exposed and contaminated with faecal matter (Abinah, 2013). Findings from this study indicated count of faecal coliform in the poly-tanks, well and the reservoir in Anyako and in all the wells and one pipe (ANYP3) in Anyanui to be high. One pipe (ATIP5) out of the six in Atiteti recorded a count of faecal coliform.

The mean faecal coliform count in the water sources in Anyako were significantly different $p < 0.05$ unlike Atiteti and Anyanui, which had no significant differences between them (Anova Table 2). Discussions and observations within the communities confirmed the reason for the presence of faecal counts in the drinking water sources as due to the challenges with regular supply of water in Anyako, hence the toilets are always choked and dirty causing some of them to mostly defecate in the open. The children washing their hands with only water instead of both soap and water, domestic sewage and non-point human and animal waste (Oram, 2020). Faecal coliform in drinking water when consumed causes intestinal problems, vomiting and diarrhoea (USEPA, 2016).

Escherichia. coli

Escherichia coli is a species of faecal coliform, the presence of *E. coli* in a water sample indicates the presence of pathogens in the water which poses as a great risk to the health of whoever consumes the water (Loyola *et al*, 2020). *E. coli* within the water sources, means that the water has been contaminated with human or animal waste and may indicate the presence of disease-causing pathogens, which when consumed may cause diarrhoea, dysentery or hepatitis (Abinah, 2013). The range of *E. coli* count within some drinking water sources in both Anyako and Anyanui was high and exceeded the standard set by WHO. The mean count of *E. coli* in Anyako showed significant differences between the samples. Although *E. coli* was observed and recorded in a few drinking water sources in Anyanui, there were no significant differences between them. The cause of high count recorded in Anyako and in Anyanui was as a result of the contaminated poly-tanks which may have had leakages in the pipes connected to the poly-tanks. The poly-tanks have metal pipes and polyvinyl chloride pipes which are connected to the base of the poly-tank, to allow the flow of water.

Observations around these drinking water sources have shown that the plastic pipes are mishandled especially by the children and is often dropped on the ground. This could be the likely cause of the increase in the *E. coli*. In Anyanui it could be as a result of faecal matter from animals and open defecation usually by the young children. The cut-out containers used in drawing water from the wells are usually left on the ground next to the well. Using these without washing first also introduces these pollutants into the water and insects easily pass through these cracks causing contamination in the water. Consuming water from the drinking water sources which recorded counts of *E. coli* pose as a risk to human health as it leads to gastrointestinal issues and diarrhoea (Hunter, 2010).

The drinking water sources in Atiteti recorded no *E. coli*.

5.2 Exploring the link between Water Quality and the Risk of Diarrhoea

According to Robert (2021), the release of pathogens into the water as a result of rainfall and related events like floods or unsanitary human activities could increase the health risk of the community in using the untreated water for drinking and other household purposes.

Water contaminated with pathogenic microorganisms is unsafe for drinking. One becomes vulnerable to water-borne diseases such as dysentery, typhoid fever, cholera and diarrhoea when the contaminated water is consumed (Mahmud *et al*, 2019). The drinking water sources and the household drinking water sources in each of the three communities differed from one another. The highest mean count of *E. coli* recorded in the household was 242 cfu/100 ml (Household 3) in Anyako, 108 cfu/100 ml (Household 9) in Atiteti and 42 cfu/100 ml (Household 2) in Anyanui. The contamination levels of *E. coli* count in the household drinking water sources (Point of Use) were more than that of the count in the community drinking water source as shown with results. The reason for the high count within the household drinking water sources in Anyako was because of the improper sanitation and personal hygiene which was backed with lack of continuous water supply in the community. In Atiteti and in Anyanui it was likely as a result of unclean nature of the containers used to either fetch and store the water in the various homes. Diarrhoea diseases are related with agents that are infectious and are transmitted through the faecal oral route (Asamoah *et al*, 2016).

Within the study communities, the children recorded a higher number of diarrhoea case and the least being the men. This was consistent with a study done by (Asamoah *et al* 2016) that children recorded higher cases in diarrhoea, this was backed with another study undertaken by Ganguly *et al*, (2015) that showed the diarrhoeal cases in India to be prevalent in children and another study done in Kenya by Kiptoo *et al* (2013) which also confirmed the results of Ahmed. Ways of improving the water at point of use rather than at point of supply has been more effective in the reduction of diarrhoea diseases which is caused by poor quality water (Asamoah *et al*, 2016). According to the results from this study, there was an indication that *E. coli* count and diarrhoea in Atiteti and in Anyanui have no correlation, whilst there was a moderately strong correlation between the two in Anyako. The months which recorded the highest count of *E. coli* within the communities were different with either a high or low number of diarrhoea cases. This showed the inconsistent increase and decrease of both the count of *E. coli* and the number of diarrhoea cases.

About 94% of the disease is as a result of our surroundings and environment as well as factors such as consuming unsafe water, poor hygiene and improper sanitation (Pruss-Ustun *et al*, 2006). From the results of the study, there was no relationship between *E. coli* counts and the number of diarrhoea cases in both Atiteti and Anyanui but Anyako.

Escherichia coli is an indicator for diseases especially diarrhoea. Water is one way or the other polluted by bacteria especially during the wet season, hence the residents in a community are vulnerable to the risk of getting diarrhoea during that period (Abia *et al*, 2015). Household point of use sources is more contaminated that that of the sources, (Mahmud *et al*, 2019). The diarrhoea cases showed an increase in each month during the sampling period, in addition the *E. coli* count results showed that, an increase in *E. coli* count was not necessarily associated with an increase in the number of diarrhoea cases in each community and the decrease in *E. coli* was not associated with the decrease in the number of diarrhoea cases. Therefore, it is possible that rotavirus is responsible for the increase in the number of diarrhoea cases and not *E. coli,* which other studies done by Nitiema *et al,* (2011) and Robert *et al,* (2021). This means though the household water recorded counts of *E. coli,* it was not necessarily the cause of the residents having diarrhoea in each of the community, therefore there was no relationship between the quality of water and the incidence of diarrhoea in the study areas.

4.3 Influence of Socio-economic factors on Water Quality and Incidence of Diarrhoea.

Diarrhoea is a disease which is linked to the environment and with certain risk factors such as unsafe drinking water, lack of proper sanitation and poor hygiene and in some cases educational status (Robert *et al* 2021). A study carried out in the northern part of Ghana, discovered that the sharing of sanitation facilities, dependence on water from vendors and frequent consumption of food prepared by street vendors were significantly associated with childhood diarrhoea (Danquah, 2016).

In each community, the number of respondents that were interviewed were mostly within ages 31-55 years with majority having had primary level of education. The sources of drinking water from this study were pipes, wells, poly-tanks, sachet water, reservoirs, and harvested rain water. Water from these sources is stored in containers in each home for drinking and cooking purposes. The results from this study indicated that majority of the respondents in each community, though clean their containers regularly, do not treat the water before drinking with the least of the respondents having no knowledge on how to treat the water before consumption. The treatment of water both from the source and household water storage are important to reduce diarrheoa outcomes (WHO, 2014; Clasen *et al*, 2015). The contamination of household storage could be from several sources, from the containers, or from the source water or it could also occur due to the unhygienic practices of the user.

The second highest response in the treatment of water were those who treat the water either by boiling or by using Aqua-tabs purchased at the local pharmacies, however, the treatment of water from the source and household water is still one of the major challenges for the people and organizations to guarantee quality and good drinking water supply (Enger *et al*, 2013). The main toilet type used by the residents in the communities is usually the public toilets or the toilets that are located outside the houses. According to the results, just a few of the respondents engage in open defecation in bushes.

Socioeconomic factors have a role in the incidence and rate of diseases through their connection with water as well as environmental sanitation (Dessalegn *et al*, 2011). Common answers such as keeping one's body clean, sweeping the house and its surroundings and cleaning the containers used in fetching and storing water came up. There was a moderate association between the level of education of the respondents understanding of health and sanitation in Anyako and in Anyanui. The respondents in both communities that had some form of education explained health and sanitation as keeping the body, the environment and water containers clean. In Atiteti the number of respondents that understood was slightly higher that the number that had no knowledge on what it meant by keeping the environment and body clean. In this case the lack of education poses as a factor which adds to the reduction in personal hygiene and clean environments leading to the contamination of water and the risk of diarrhoea. In a study by Woldu *et al* (2016) education increases the awareness of the transmission and the prevention methods of diarrhoea. It also encourages changes in behaviour at the household level. The residents believed diarrhoea to be caused by over eating, and eating stale food, drinking the water causes slight headaches and nausea but not diarrhoea.

Cost of water and distance to the health centres were also factors that lead to the risk of the incidence of diarrhoea in the communities. Through a survey, and discussions with the residents in Anyako, water is supplied every few days in a week with a household paying between 50p to 20 cedis. The high expenses on water every day causes the residents in Anyako to rely on other alternatives such as harvested rain water in reservoir, which has been kept for a while or water meant for other domestic chores such as cooking and washing. A few of the locals claimed the distance to the health centres from the town discourages them from seeking health care when there is a problem so most of the residents who partook in the interview practice home treatment to any illness they get.

Observations, within each of the communities revealed that there are some locals that rear animals by the free feeding system, thus are allowed to roam freely. In their search for food and water, these animals contaminate the environment around the sources of drinking water with their faeces. The closeness of these domestic and grazing animals in and around sources of water play a role in the severity of faecal and *E. coli* contamination of these water sources (Mensah, 2011). The cups used to fetch water from the storage containers and buckets used to fetch water from the wells were left in the open and not cleaned regularly Waste from household is stored in either buckets or gallons and disposed improperly. In Anyako the respondents dispose their waste on the shore and in the lagoon, all of which have impact on water quality and health.

Within the three communities, the drinking water from the different sources showed less changes during the sampling period in Atiteti, than that of the changes within Anyako and Anyanui. Microbial quality of drinking water is usually associated to poor hygiene and sanitation practices. Not all the drinking water sources in the communities had total coliform present and not all those that recorded total coliform had *E. coli* within them.

Diarrhoea has several ways of transmission with the common being consumption and use of untreated water and poor hygiene in the environment. Faecal pathogens and *E. coli* are the coliforms that contaminate drinking water sources and is most common in communities where there is poor sanitation and hygiene. When it comes to treated water, the contamination is said to occur after the treatment and within the distribution system. Treating water at the household level according to studies is more effective in reducing diarrhoeal diseases (Eshete *et al*, 2020). The study also shows that socio-economic factors such as personal hygiene and sanitation, education, and cost of water within each community added to the contamination of the drinking water both at the source and at the household level, eventually leading to diarrhoea.

CHAPTER SIX

CONCLUSION

The present study which was done to assess the drinking water quality was carried out in three coastal communities, Anyako, Atiteti and Anyanui, located in the Volta region of Ghana with specific objectives to access the concentrations of both physico chemical (conductivity, salinity, dissolved oxygen, total dissolve solids, pH, nitrogen nitrate, phosphate, total alkalinity, sulphate, calcium, magnesium, sodium and potassium) and microbial parameters (Total coliform, faecal coliform and *E. coli*) and to explore the relationship between microbial water quality and socio-economic influence on the incidence of diarrhoea.

The following conclusions are drawn based of the finding from the study:

- The physico chemical quality of the community drinking water sources in each of the study areas, had varying levels throughout the sampling period. Within the three communities, the parameters with good levels were dissolved oxygen, total alkalinity and sulphate and sodium. The other parameters recorded levels that were either below or exceeding the WHO standard of drinking water.
- The microbial quality of the water sources showed AKOC5, AKOS1, AKOS4 ATIP2, ATIP3, ATIP6, ANYP2, ANYP4 and ANYP5 as the only sources that had no changes in them during the period although statistically, Anyako was the only community to record significant changes within the samples from the water sources.
- *E. coli* counts were observed more in the household water sources than in the community drinking water sources, although this did not account for the high number of diarrhoea cases in each of the community. This was an indication that the high cases of diarrhoea in each of the study areas could be as a result of other predicting factors.
- The increased levels of *E. coli* count in the drinking water source at the community level and the household level which causes diarrhoea was as a result of water handling practices of the residents, personal hygiene as well as poor environmental sanitation practices and their level of education.

RECOMMENDATIONS

The following recommendations are made following the conclusion drawn from the findings of this study:

- All sources of drinking water regardless of its source must be treated. There are several cost-efficient ways to treat water at home such as by boiling, by using the chlorine tabs, and by using the slow sand filtration method. The Locals in the community should be educated on the different ways and means of treating water before use by officers from Ghana Water Company, and Water Resource Institutes.
- Buckets used to draw water from the wells should always be kept clean and changed if broken. The lids of the wells should be kept dry at all times and should not have any holes or opening which will allow water or any other foreign material to enter.
- The District Assembly should ensure that animals reared in the free-range feeding system do not graze close to the sources of water.
- The District Assembly should further ensure that toilet facilities should not be sited close to water sources. These facilities should be cleaned and maintained regularly to encourage the residents in the community to patronise it to eliminate or reduce open defecation.
- The District Assembly should seek aid from Ghana Water Company in repairing broken pipes in Anyako, to prevent getting water which has little treatment from neighbouring towns
- A properly sited and maintained Trash Bin should be provided by the Assembly, and sited over a safe distance from any source of water to ensure proper disposal of waste and safe water sources for the community.
- Communities should be educated by the Ministries of Water Resources & Sanitation, and Health, on the importance of good sanitation and health practices, as well as encouraged to visit health facilities when sick to be protect them.

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